RHONDDA CYNON TAF COUNTY BOROUGH COUNCIL

Flood and Water Management Act 2010

Section 19 Flood Investigation Report

Storm Dennis –

Flood Investigation Area RCT05

(Abercwmboi & Fernhill)

June 2022

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This report should be read in its entirety

This report has been prepared in accordance with the requirements of section 19 Flood and Water Management Act 2010. The Council assumes no responsibility or liability from any person in connection with its contents or findings.

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EXECUTIVE SUMMARY

This report has been produced through the duties placed upon Rhondda Cynon Taf County Borough Council 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 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 that occurred on 15 and 16th of February 2020 within the Rhondda Cynon Taf County Borough Council area, focusing investigation on the flooding within the villages of Abercwmboi and Fernhill in the Cynon valley (Flood Investigation Area RCT05, Figure 1).

This report was undertaken to identify the mechanism for flooding, establish which Risk Management Authorities have relevant flood risk management functions under the Flood and Water Management Act 2010 and ascertain if those Risk Management Authorities' have undertaken or were planning to undertake actions related to those functions to manage the risk of flooding.

The flooding that affected RCT on 15 and 16th of February 2020, was a result of an extreme rainfall event, designated by the Met Office as 'Storm Dennis'. The impact of the event at investigation area RCT05 resulted in internal flooding to 68 residential properties, 5 non-residential properties and extensive flooding to the highway. These impacts were identified through inspections made by RCT's Flood Risk Management Team during the days following the storm event, as well as information collated by residents, RCT's Public Health team, RCT's Highway and Streetcare Depot, Natural Resources Wales and Dŵr Cymru Welsh Water.

The evidence gathered within this report demonstrates that the cause of internal flooding at RCT05 on the 15 and 16th February 2020 was a result of significant overland runoff being generated from the steep hillsides above Abercwmboi and Fernhill draining to lower ground via a series of ordinary watercourses, many of which became overwhelmed with water and debris, contributing to the surcharging of several culvert inlets and the internal flooding of multiple properties on its course of flow.

On review of the condition and hydraulic performance of the six culvert inlets identified as sources of flooding to properties, it was confirmed that 'Culvert Inlet 1' and 'Culvert

Inlet 2', associated with the Bronallt Terrace East and Mostyn Street networks respectively, do not provide adequate standards of protection in free-flowing condition, and is further reduced with the presence of blockage. 'Culvert Inlets 4, 7 and 8', associated to the Cwm Alarch Close, Fernhill and Glenboi culvert networks were assessed as having adequate standards of protection in free-flowing conditions. Despite this, all five culvert inlets are considered to have surcharged primarily due to blockages caused by debris mobilised from the hillside during the storm event.

Upon a greenfield runoff calculation of 'Culvert Inlet 3', which is maintained by NRW as land estate manager of the WGWE, the inlet was assessed as having inadequate capacity for the expected flows from the hillside during the storm event, which resulted in its surcharge.

Surface water flooding associated to sheeting runoff from the hillsides and a collapsed section of highway drainage network were also identified as sources of flooding to properties within RCT05 during Storm Dennis.

RCT as the Lead Local Flood Authority (LLFA) and Land Drainage Authority (LDA) has been determined as the relevant Risk Management Authority (RMA) responsible for managing the ordinary watercourse and surface water flooding that occurred at RCT05 during Storm Dennis. RCT as the Highway Authority has been identified as the relevant RMA in relation to the surface water flooding observed along the highway. DCWW have also been identified as a relevant RMA in relation to the sewer flooding observed at Maple Terrace.

In response to the flooding at investigation area RCT05, the LLFA has undertaken 16 actions and have proposed to undertake a further 6. A summary of which include;

- Undertaken clearance works to the culvert inlet structures identified as sources of flooding following the storm event (assisted by the Highway Authority);
- Carried out survey, jetting and cleansing operations to an estimated 868 metres of ordinary watercourse and 749 metres of surface water drainage network length within the investigation area;
- Carried out significant upgrades to the culvert inlets identified as sources of flooding to properties;
- Led on the development of a central Control Room, to compliment the Council's Contact Centre and CCTV Centre, to provide a comprehensive and informed response to residents during storm events; and

- Initiated an interim Property Flood Resistance project offering expandable flood gates to properties deemed at high risk of ordinary watercourse and surface water flooding.

As the relevant RMA for ordinary watercourse flooding, RCT as the Lead Local Flood Authority will also look to better understand the catchment above investigation area RCT05, and the overall risk from ordinary watercourse, surface water and groundwater sources, through the development of a formal Strategic Flood Risk Assessment. The LLFA will look to work with NRW as land manager of the Welsh Government Woodland Estate to identify suitable management mechanisms to reduce the risk of scour within the upper catchments.

The event that occurred on 15 and 16th February 2020 was extreme, and it is unlikely flooding from a similar event could be prevented entirely. It is concluded that RMAs satisfactorily carried out their flood risk management functions in response to the flood event, however, further functions have been proposed by RMAs to better address preparedness and response to future flood events.

ABBREVIATIONS

BJC – Business Justification Case

CaRR – Communities at Risk Register

DCWW – Welsh Water

FRMP – Flood Risk Management Plan

FWMA – Flood and Water Management Act 2010

LDA – Land Drainage Authority

LFRMS – Local Flood Risk Management Strategy

LLFA – Lead Local Flood Authority

NRW – Natural Resources Wales

Q – Return Period (1 in X chance of an event occurring in any given year)

RCT - Rhondda Cynon Taff CBC

RCT05 – Flood Investigation Area RCT 05

RMA – Risk Management Authority

SAB – Sustainable Drainage Approval Body

SFRA – Strategic Flood Risk Assessment

SOC – Strategic Outline Business Case

SuDs – Sustainable Drainage Systems

WGWE – Welsh Government Woodland Estate

TABLES AND FIGURES

1 INTRODUCTION

1.1. PURPOSE OF INVESTIGATION

On the 15 and 16th February 2020 RCT was impacted by an extreme weather event which was designated by the Met Office as 'Storm Dennis'. Due to the extent and impact of the event, the LLFA opted to undertake a formal investigation.

The storm resulted in widespread residential and commercial flooding within the Rhondda Cynon Taf County Borough Council area. This report will focus on Flood Investigation Area RCT 05 which covers the villages of Abercwmboi and Fernhill in the Cynon valley.

The reason behind RCT's investigation is in response to the duties of the local authority in regard to Section 19; of the Flood and Water Management Act 2010, which states:

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 the response to the flood."

2. "When 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 authority"[1]

The purpose of the investigation is to determine which RMAs have relevant flood risk management functions and which functions have been exercised in response to a flood.

Specific details of Storm Dennis, such as rainfall analysis are covered within a separate overview report that covers the wider RCT area. The report is titled 'Storm Dennis February 2020 – Overview Report' and will be referred to as 'FRM – Storm Dennis – Overview Report'[2].

[1] Flood and Water Management Act 2010 – Section 19 - https://www.legislation.gov.uk/ukpga/2010/29/section/19
[2] Flood Investigation Reports | Rhondda Cynon Taf County Borough Council (rctcbc.gov.uk)

1.2. SITE LOCATION

The area investigated within this report covers the villages of Abercwmboi, Fernhill and Glenboi, situated within the electoral wards of Aberaman South to the west and Mountain Ash West to east. Both towns are situated in the north-eastern sector of Rhondda Cynon Taf CBC in the River Cynon catchment, to the southeast of Aberdare (Figure 1).

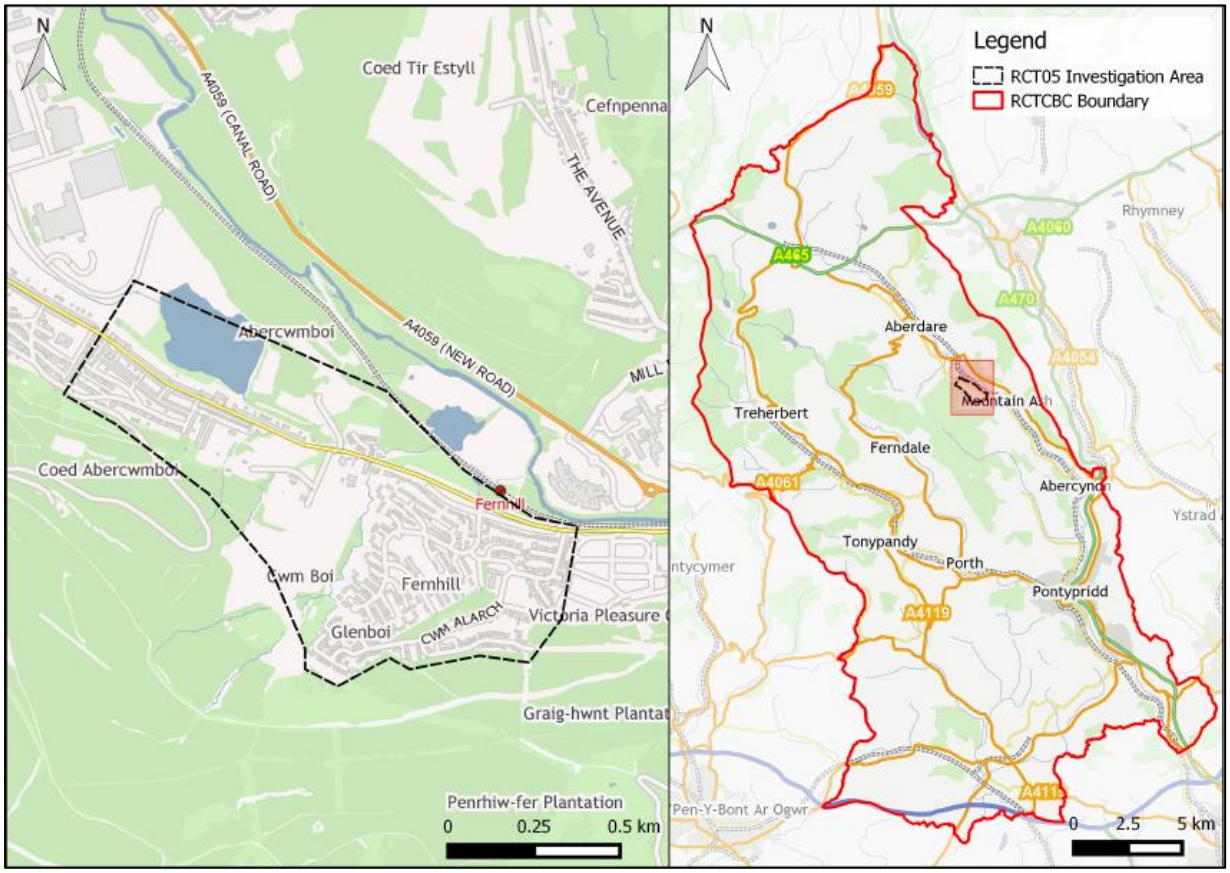

Figure 1: Flood Investigation Area RCT05 location plan

The catchment is predominantly a rural environment owing to the steep topography of the higher elevations in the southwest which are mostly forested. Residential development is confined to the valley floor of the Cynon River which flows west to east immediately north of investigation area RCT05. The highlands in the southwest are drained by the Nant Cwm Boi and a number of minor unnamed watercourses which are partially culverted beneath both towns and ultimately discharge into the Cynon River.

According to RCT's Flood Risk Management Plan (FRMP), both electoral wards are identified as being at high risk of surface water and ordinary watercourse flooding. Aberaman South is ranked 4th and Mountain Ash West is ranked 18th, respectively.

The greatest risk to people and property is sourced primarily from the potential surcharge of culvert inlets resulting in surface water accumulation in the lower reaches of the towns. Significant risk of flooding from surface water and ordinary watercourse sources is noted along sections of Glenboi, Fernhill and Bronallt Terrace, illustrated below in NRW's Flood Risk Assessment Wales (FRAW) map (Figure 2). A high to low risk of Main River flooding is noted north of the B4275 (Aberdare Road).

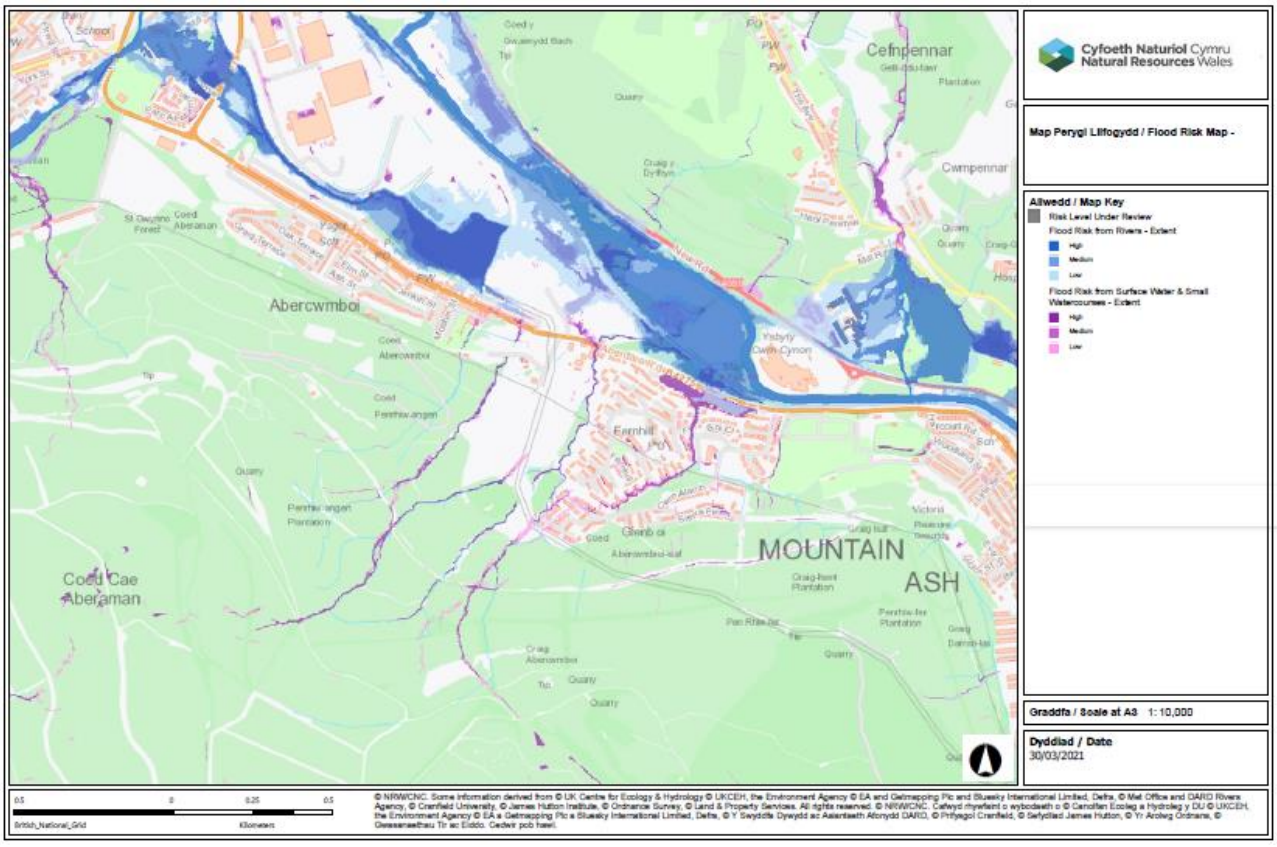

Figure 2: Natural Resources Wales' Flood Risk Assessment Wales (FRAW) map for rivers and ordinary watercourse and surface water flood risk within investigation area RCT05. Contains Natural Resources Wales information © Natural Resources Wales and database right. All rights reserved.

1.3. DRAINAGE SYSTEM

The surface water drainage system that serves investigation area RCT05 is that of the highway drainage network designed to manage the surface water within the highway

and public surface water sewer and combined sewer networks operated by Dŵr Cymru Welsh Water.

1.4. Investigation Evidence

To support the investigation a range of qualitative and quantitative evidence has been gathered from numerous sources, the summary of which is listed within Table 1.

Table 1: Investigative evidence gathered in preparation of the Storm Dennis Section 19 report

Source	Data
Residents	Photos, videos, statements, email correspondence, public engagement survey responses
Responders' statements	Local responders' statements
CCTV Surveys	Internal surveys of the local culvert networks
Met Office Data	Weather Warning information (see overview report reference (see FRM – Storm Dennis – Overview Report)
Rain Gauges	RCT and NRW operated gauge information (see FRM – Storm Dennis – Overview Report)
Natural Resources Wales	River Level and Flood Warning data
RCT Flood Risk Management Plan	Site specific information and data for each electoral ward in RCT
Communities at Risk Register	Flood risk ranking and scores for all flood types based on community data in Wales
Flood Investigation Report (Redstart's FIR)	A summary of the source-pathway-receptors, culvert capacity assessment and hydraulic modelling work undertaken by Redstart. The Flood Investigation Report was commissioned by RCT prior to writing the Section 19 report.

Evidence sourced from the 'Flood Investigation Report', commissioned by RCT, will be further referred to as 'Redstart's FIR' throughout this report.

1.5. PUBLIC ENGAGEMENT

Following the initial flooding event that occurred on the 15 and 16th February during Storm Dennis, flood risk officers from the RCT Flood Risk Management department were deployed to areas across the borough to investigate reports of internal flooding by residents. Residents were engaged with by the Flood Risk Management team to determine the initial impacts caused by the flooding event and to investigate the potential source(s) and pathway(s) of flood water during the event. Due to the volume of calls received by RCT's Out of Hour department, visits were prioritised to those areas experiencing significant internal flooding to residential properties.

To support the flood investigations, a public engagement exercise was undertaken between 4th and 25th January 2021 by Redstart on behalf of RCT. The aim of this was to engage with the local residents who were affected by the flood event to capture details on how they were impacted, the source and movement of flood water within the area, how receptors were impacted as well as drawing on local knowledge to query how local conditions could have exacerbated the event. This data is useful to help the LLFA better understand and validate our assessment of the flood event to support the investigation under Section 19 of the FWMA.

2 FLOODING HISTORY

2.1. PREVIOUS FLOOD INCIDENTS

Previous incidences of flooding to properties within investigation area RCT05 have occurred over the past twenty years, often in relation to the network of ordinary watercourses and culverted infrastructure which convey a substantial volume of water through the villages of Abercwmboi and Fernhill. Despite this, no storm event has resulted in flooding so extreme as the flooding that occurred during Storm Dennis.

Information relating to historical flood incidence prior to 2018 is limited however, in recent years the frequency and impact of property flooding has increased. The most notable flood incidences prior to Storm Dennis being Storm Bronagh on 20-21st September 2018 and Storm Callum on 12-13th October 2018 where several properties along Bronallt Terrace and the surrounding area in Abercwmboi were internally flooded due to a blocked culvert inlet. Since Storm Callum, properties at Bronallt Terrace have experienced repeat external and, in some instances, internal flooding during periods of heavy rainfall.

Properties situated below the forestry land at Abercwmboi stated within the consultation responses that they had not experienced any flooding prior to Storm Dennis.

Residents accounts captured by RCT's Flood Risk Management officers post event, as well as responses provided as part of the public engagement exercise, suggest that the residents of Sierra Pines and Cwm Alarch Close in Fernhill have experienced frequent external flooding to their properties in the last ten years, which they consider to be originating from the forestry land to the rear of properties. One resident stated that "surface water from the mountain had been increasing every year in the last decade with Storm Dennis being the most severe".

Ordinary watercourse flooding has also occurred downstream of Sierra Pines and Cwm Alarch Close, associated with the culvert inlets situated at Fernhill. Both inlets drain the hillsides above the village of Fernhill and have a history of surcharging during storm events. Surface water conveys from these upper inlets towards the low point within Glenboi highway. Surface water flooding to Glenboi highway is relatively common during storm events. Notably, external and internal flooding has impacted several properties at Glenboi during recent storms, including Storm Bronagh and Storm Callum.

2.2. FLOOD INCIDENT

The flooding that occurred on the 15th and 16th February 2020 was a result of an extreme rainfall event, designated by the Met Office as 'Storm Dennis' which affected the majority of RCT and caused widespread flooding to communities.

Specific details of Storm Dennis, such as rainfall and river level analysis are covered within a separate overview report that covers the wider RCT area, referenced 'FRM – Storm Dennis – Overview Report'[2].

The post event inspections undertaken on the days following the storm event by RCT's Flood Risk Management Team and RCT's Public Health, Protection and Community team identified 68 residential properties, 4 commercial properties and one school as internally flooded.

A summary of the source(s) and pathway(s) of flooding within investigation area RCT05 during Storm Dennis have been outlined in Table 2 and further described throughout this section. For the purpose of this investigation, the flood incident at investigation area RCT05 will be described in two parts: the incident at 'Abercwmboi' sub-catchment and the incident at 'Fernhill & Glenboi' sub-catchment. The sub-catchment areas are illustrated below Table 2, within Figure 3.

Table 2: Summary of the source(s), pathway(s) and receptor(s) affected during Storm Dennis within investigation area RCT 05

Source	Pathway	Receptor
Abercwmboi Sub-Catchment		
Intense rainfall running off the hillsides to the south of Abercwmboi draining to lower ground.	Surface water runoff travelled overland down the hillside towards the rear of properties along Maple Terrace. Overland runoff conveyed primarily towards properties on the western site of Maple Terrace where the topography slopes downwards. Overland flow also conveyed east via an undefined ordinary watercourse channel which became overwhelmed and overtopped during the storm event, resulting in water conveying towards the eastern side of Maple Terrace.	Internal flooding to 6 residential properties along the western side of Maple Terrace. The eastern flow path resulted in internal flooding to 1 residential property at Maple Terrace. This flow path is also considered to have contributed to the surcharging at Mostyn Street inlet, resulting

	In addition to this, the surface water flows overwhelmed the combined sewer network within several properties.	in internal flooding to 4 properties at Tanycoed Terrace.
A culvert inlet at the top of Mostyn Street surcharged during the storm event.	Water overflowed from the inlet at the top of Mostyn Street and down the rear lane of Tanycoed Terrace before entering the rear gardens of several properties and overwhelming private surface water drainage systems. Secondary flows from the steep hillside above Maple Terrace is also believed to have contributed to the flooding at this location.	Internal flooding to 4 residential properties along Tanycoed Terrace.
Intense rainfall resulting in surface water accumulation along the highway at John Street	Surface water was observed to have pooled outside the front of properties on John Street before entering the basement of two properties.	Internal flooding to 2 residential properties on John Street.
A culvert inlet located opposite the eastern end of terraced houses on Bronallt Terrace surcharged during the storm event after becoming blocked with debris.	The primary flow path originated from the surcharged inlet which flowed in a westerly direction towards the front of terraced properties on Bronallt Terrace and flowed towards the rear lane before out-falling into the adjacent lake/pond. Surface water runoff from the hillside above Maple Terrace also contributed secondary flows from the east of Bronallt Terrace. Both flow paths met at the lowest part of Bronallt Terrace causing surface water to pond up to 3 feet in height.	Internal flooding to 29 residential properties on Bronallt Terrace including 4 commercial properties.
Surcharged ordinary watercourse manhole within the lane to the rear of Bronallt Terrace.	Surcharging flows from the ordinary watercourse manhole contributed additional surface water flows along the lane behind properties on Bronallt Terrace.	Contributed to the internal flooding of 29 residential and 4 commercial properties on Bronallt Terrace.
Fernhill & Glenboi Sub-Catchment		
Privately owned pond structure overtopped	Water was observed to have overtopped a privately owned pond	Internal flooding at 1 property and external

due to intense rainfall at Forest View	structure in the rear garden of a property at Forest View. Water travelled towards the rear gardens of two properties.	flooding to another at Forest View.
A culverted ordinary watercourse that flows adjacent to Fernhill surcharged during the storm event.	Significant flows running down the hillside above Forest View enters a culverted watercourse at Fernhill. Surcharging flows from the top inlet flowed overland towards the rear of properties at Fernhill.	Contributed to the internal flooding of 13 residential properties situated at the southern end of Fernhill cul-de-sacs.
Intense rainfall caused surface water to accumulate outside the fronts of properties at Fernhill.	Surface water ponding outside the front of properties occurred during the event because the properties are situated at lower elevations than the footpaths. The surface water drainage system was overwhelmed in these areas.	Contributed to the internal flooding of 13 residential properties situated at the southern end of Fernhill cul-de-sacs.
A culvert inlet situated at Fernhill became blocked and surcharged during the storm event.	The culvert inlet surcharged, causing water to overtop at the inlet and upstream ordinary watercourse channel, resulting in a flow path along the steep roads of Fernhill towards Glenboi before pooling here due to local topography.	Internal flooding to 10 residential properties at Glenboi. Water ingress initially affected properties from the rear before also entering properties from the front and side entrances.
Intense rainfall running off the hillside above Sierra Pines draining to lower ground.	Overland runoff from the hillside conveyed towards the rear of properties along Sierra Pines. Surface water runoff from the hillside entered Sierra Pines and then onwards towards Cwm Alarch Close which is situated lower down the hillside.	External flooding to several properties at Sierra Pines and Cwm Alarch Close. Internal flooding to 2 residential properties at Sierra Pines located at low points in the road.
A surface water drainage culvert inlet at the eastern edge of Sierra Pines became	Runoff along the land drainage ditch towards the culvert caused the inlet to surcharge and flow towards Sierra	Contributed to the external and internal flooding of properties on the western side of

blocked with debris and overwhelmed by flows from the hillside.	Pines and onwards to Cwm Alarch Close.	Sierra Pines and Cwm Alarch Close.
Culvert inlet at Cwm Alarch Close became blocked and surcharged during the storm event	Surcharging flows from the culvert inlet conveyed along Cwm Alarch road towards Fernhill and Glenboi.	Internal flooding to Glenboi Community Primary School. Contributed surface water flows towards Glenboi.
The River Cynon overtopped its banks near Peace Park	Water overtopped the riverbanks and flooded Peace Park and onwards to Fernhill railway station. The River Cynon was observed to have reached the threshold level of Aberdare Road but did not overtop.	Flooding to Peace Park, Fernhill railway station and sections of the railway track.

On review of Table 2, the principal source of flooding at investigation area RCT05 originated from intense rainfall running off the steep hillsides to the south of Abercwmboi and Fernhill draining to lower ground. This runoff was routed towards the investigation area via several ordinary watercourses, many of which became overwhelmed during Storm Dennis and caused flooding associated to blocked culvert inlets and sheeting runoff directly from the hillsides.

Figure 3 depicts the topographic watershed for the Cynon River valley (bold pink line) based on LIDAR data, with rainfall falling to the north and east of the watershed draining to the Cynon River catchment. The catchment above investigation area RCT05 can be sub-divided into further sub-catchments to illustrate the area of land that would expect to drain towards the investigation area (hatched areas in Figure 3). The flood incident at RCT05 will be further described in two parts: the incident at Abercwmboi (red hatched area, Figure 3) and the incident at Fernhill & Glenboi (blue hatched area, Figure 3).

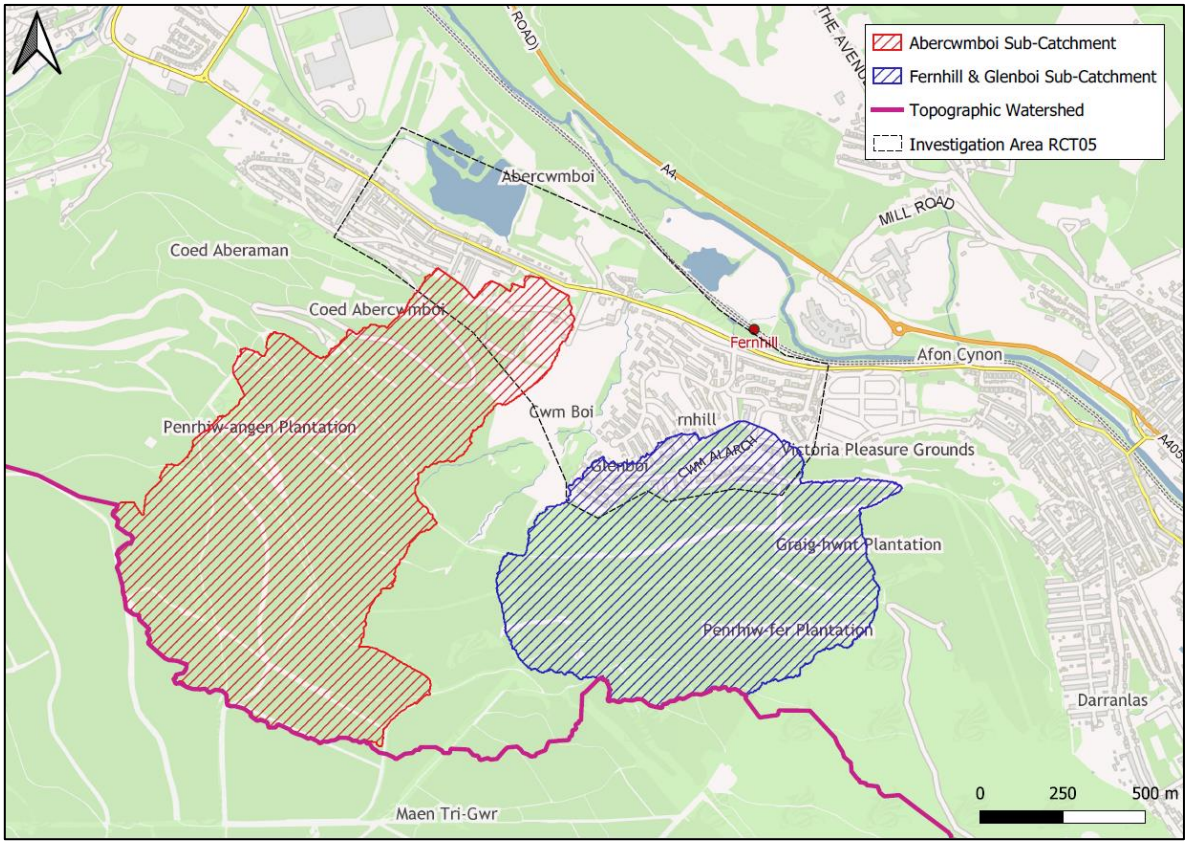

Figure 3: Rainfall Topographic Watershed and Sub-catchments above investigation area RCT05

2.2.1. ABERCWMBOI SUB-CATCHMENT

The steep hillsides above Abercwmboi are drained by a network of unnamed ordinary watercourses which form the 'Abercwmboi' sub-catchment to the west of RCT05. Figure 4 shows the pathways of flooding within the 'Abercwmboi' sub-catchment during Storm Dennis. The infrastructure known to have surcharged and contributed to the flooding are also illustrated in Figure 4.

Figure 4: Observed flow paths within 'Abercwmboi' sub-catchment during Storm Dennis (15-16th February 2020)

During the early hours of Sunday 16th February, RCT received a large volume of calls from residents at Bronallt Terrace referencing significant flooding emanating from a culvert inlet located at the eastern end of Bronallt Terrace. The location of the inlet, named 'Culvert Inlet 1', is provided in Figure 4.

Storm event inspections undertaken by RCT's Flood Risk Management team on 16th February identified 'Culvert Inlet 1' as having surcharged at the inlet due to a blockage caused by debris accumulation on the inlet's debris screen. This resulted in water overtopping the inlet structure and flowing in a westerly direction along the highway

towards a series of terraced properties along Bronallt Terrace. Figure 5 shows evidence of 'Culvert Inlet 1' continuing to surcharge on the morning of the 16th of February 2020. Properties situated at the eastern edge of Bronallt Terrace avoided the worst of the flooding as the street kerb is slightly raised.

Figure 5: 'Culvert Inlet 1' surcharging at the inlet causing water to flow onto the highway and towards properties at Bronallt Terrace (captured by RCT's Flood Risk Management team on 16/02/2020)

The site inspection also identified a manhole located in the rear lane behind Bronallt Terrace, downstream of 'Culvert Inlet 1', to have surcharged (labelled 'Manhole 1' in Figure 4). It was confirmed by RCT's on-site inspector that 'Manhole 1' surcharged prior to the inlet, resulting in initial flooding to the rear of the affected properties at Bronallt Terrace. Water sourced by 'Manhole 1' flowed down the rear lane before out-falling into the pond behind Bronallt Terrace.

According to RCT's on-site inspector, 'Culvert Inlet 1' continued to surcharge until the accumulated debris was removed by a Council appointed contractor on 16th February 2020. Prior to this, a manhole within the highway was opened to manage the flow of water. The flood water dissipated within a few hours following the removal of the blockage at 'Culvert Inlet 1'.

RCT's Flood Risk Management team and Public Health, Protection and Community team identified 29 residential properties and 4 commercial properties as internally

flooded along Bronallt Terrace, primarily sourced by ‘Culvert Inlet 1’ surcharging at the inlet.

Further post event surveys carried out through questionnaires and discussions with the local community indicated that water was also observed to flow along Bronallt Terrace in the opposite direction of ‘Culvert Inlet 1’s’ flow path, suggesting that a second source of flooding was present. Residents claim a second culvert inlet, located at the top of Mostyn Street (‘Culvert Inlet 2’, Figure 4), also surcharged during the storm event, causing water to flow down the steep streets towards Bronallt Terrace. This water originated from the steep hillsides to the south of Maple Terrace.

Surface water flowed in an easterly direction along Bronallt Terrace, meeting water flowing west from the surcharged ‘Culvert Inlet 1’. Anecdotal reports from residents’ state both flow paths met in the middle of the street, causing water to rise up to approximately 1 metre in depth (Figure 6). The capacity of the highway drainage infrastructure within Bronallt Terrace was exceeded by the volume of water, exacerbating surface water flooding to properties along the street.

Figure 6: Flooding at Bronallt Terrace (captured by RCT's Flood Risk Management team on 16/02/2020)

The steep topography above Maple Terrace resulted in fast flowing overland runoff travelling down the hillside towards the rear of properties along Maple Terrace. Based on the topography in this area, surface water from the hillside is considered to have continued its pathway downhill, contributing to the surface water flooding at John Street and Bronallt Terrace.

Several blocked gullies along John Street were reported by residents during the storm event however, one isolated incidence of internal flooding was confirmed, whereby surface water accumulated on the highway and entered the basements of two properties at John Street.

Upon a site inspection of land to the rear of Maple Terrace, it was evident that significant overland flows originating from the steep hillside had caused some minor scouring on the hillslopes and vegetation appeared to have been flattened by overland flows. On review of the hillside, an open ditch to the rear of properties along Maple Terrace was identified (Figure 7). The open ditch generally slopes towards the east of Maple Terrace before being culverted beneath the highway at Mostyn Street ('Culvert Inlet 2', Figure 4).

Figure 7: Open ditch that flows to the rear of Maple Terrace (captured by RCT's Flood Risk Management team on 12/03/20)

It is considered that significant overland flows from the hillside to the south of Abercwmboi caused the open ditch to overflow and water to flow towards either end of Maple Terrace where the topography slopes downwards. This resulted in internal

flooding to six properties on the western edge of Maple Terrace, and one property located at the eastern edge of Maple Terrace, with water ingress from the rear.

According to resident's accounts received as part of the public engagement exercise, the drainage systems within their properties could not cope with the volume of surface water entering their rear gardens from the hillside combined with the intense rainfall, which resulted in the surcharging of residents' surface water and sewer drainage systems.

Additional reports of internal residential flooding were confirmed at Tanycoed Terrace, originating from 'Culvert Inlet 2'. 'Culvert Inlet 2' is located behind a retaining wall at the top of Mostyn Street. Anecdotal evidence reports that the debris screen at 'Culvert Inlet 2' became blocked with silt and stone carried by overland flows from the hillside, which caused water to build up behind the retaining wall and flow west towards the rear lane behind Tanycoed Terrace, resulting in internal flooding to at least four residential properties.

No properties at Mostyn Street were reported to have flooded during the storm event. This is because, in the event of a blockage at 'Culvert Inlet 2', water will flow alongside the retaining wall towards the rear lane of Tanycoed Terrace. Water ingress through the weep holes within the retaining wall was observed, contributing surface water flows to Bronallt Terrace further downstream.

RCT carried out emergency clearance works to the inlet and replaced the rusted debris screen with a temporary mesh cage (Figure 8).

Figure 8: Mostyn Street culvert inlet (Culvert Inlet 2) following clearance works to remove the blockage (captured by RCT's Flood Risk Management team on 12/03/2020)

2.2.2. FERNHILL & GLENBOI SUB-CATCHMENT

The steep hillsides above Fernhill are drained by a network of unnamed ordinary watercourses which form the 'Fernhill & Glenboi' sub-catchment to the east of RCT05. Figure 9 shows the pathways of flooding within the 'Fernhill & Glenboi' sub-catchment during Storm Dennis. The infrastructure known to have surcharged and contributed to the flooding are also illustrated in Figure 9.

Figure 9: Observed flow paths within 'Fernhill & Glenboi' sub-catchment during Storm Dennis (16th February 2020)

Flow pathways in this sub-catchment capture overtopping surface runoff from the hillsides above Fernhill which overwhelmed several watercourses and contributed to the surcharging of four culvert inlets.

Significant overland flows originating from the forested hillside to the southeast of Fernhill, to the rear of Sierra Pines, was reported by residents as a significant flow path in this area. This pathway contributed to the surcharging of culvert inlets at Sierra Pines ('Culvert Inlet 3', Figure 9) and Cwm Alarch Close ('Culvert Inlet 4', Figure 9), contributing to the flow of surface water towards Glenboi highway.

Overland runoff from the hillside above Fernhill initially caused external flooding to the rear of several properties on the southern side of Sierra Pines and onwards to impact the highway via the sides of the properties. Internal flooding to two properties located in a localised low spot of topography at Sierra Pines was also confirmed. According to some residents, surface water flows into the rear gardens of properties persisted for almost a week after Storm Dennis.

Surface water runoff from the hillside above Sierra Pines flows into a roadside channel which is taken by a culvert pipe towards Cwm Alarch Close ('Culvert Inlet 3', Figure 9). During the storm event, water was observed to have overtopped the roadside channel and flow towards Sierra Pines. Water was prevented from flowing further down Sierra Pines by sandbags placed by residents near the forestry entrance. Instead, water was diverted towards the open watercourse on the eastern edge of Sierra Pines, causing the watercourse to overtop and flow overland towards Cwm Alarch Close, exacerbating surface water flows downstream within the investigation area.

'Culvert Inlet 4' is sourced by flows coming from Sierra Pines and Cwm Alarch Close. The inlet surcharged during the storm event, causing water to overtop and flow downstream towards Glenboi (Figure 10). On its flow path, Glenboi Primary School was internally flooded due to it being located at a low point (Figure 11)

Figure 10: Image of 'Culvert Inlet 4' surcharging during Storm Dennis on 16th February 2020 (image provided by resident)

Figure 11: Image showing flooding to Glenboi Community Primary School, located opposite 'Culvert Inlet 4', during Storm Dennis on 16th February 2020 (image provided by resident)

To the southwest of the 'Fernhill & Glenboi' sub-catchment, internal flooding to one property at Forest View was confirmed. It was reported that intense rainfall during the storm event caused a large privately owned pond structure, situated in the rear garden of the impacted property, to overtop and flow towards the rear of the property. The neighbouring property was also impacted externally from the rear.

The primary pathway down the hillside above Forest View continues downhill before entering a channel and culvert beneath Forest View ('Culvert Inlet 6', Figure 9), out falling and re-entering the culvert network at 'Culvert Inlet 7' and exiting to a channel between Fernhill and Cwm Alarch Close before being culverted underneath the highway at 'Culvert Inlet 8'. Multiple calls were received on Sunday 16th February 2020 to report internal flooding to several residential properties at Fernhill caused by this pathway.

The watercourse that runs alongside the affected properties at Fernhill is culverted before entering a section of open watercourse and finally flowing into 'Culvert Inlet 8'. It was reported by residents that the culvert system surcharged at 'Culvert Inlet 7' which caused water to overtop and flow overland in the direction of 'Culvert Inlet 8'.

Residents reported water overtopping their rear retaining walls, indicating that the source of flooding was originating from the culverted watercourse. Surface water drainage systems in the area are also assumed to have been overwhelmed by intense rainfall. The properties affected are situated at lower elevations than the footpaths which would have allowed water to accumulate outside the properties' front thresholds.

It was identified that 'Culvert Inlet 8' also surcharged during the storm event (Figure 12). Flow from this inlet travelled overland down the steep roads within Fernhill towards Glenboi where water was able to pond due to local topography, namely as Aberdare Road sits several meters higher than Glenboi Road, thereby preventing the conveyance of surface water to the downstream networks.

Figure 12: 'Culvert Inlet 8' surcharging during Storm Dennis on 16th February 2020 (image provided by resident)

Approximately 3 feet of internal and external flooding to 10 residential properties at Glenboi occurred during the event, with initial ingress from the front of properties before entering the rear gardens and side entrances. Evidence of surface water accumulation at Glenboi during Storm Dennis is shown in Figures 13 and 14.

The Fire Service and RCT's Highway and Streetcare Depot deployed surface water pumps to manage the depth of flooding within the Glenboi estate during emergency response operations.

Figure 13: Flooding to properties at Glenboi during Storm Dennis on 16th February 2020 (image provided by resident)

Figure 14: Flooding to properties at Glenboi during Storm Dennis on 16th February 2020 (image captured by RCT's Flood Risk Management team)

2.3. RAINFALL ANALYSIS

See RCT's 'Overview Report' of Storm Dennis, reference 'FRM – Storm Dennis – Overview Report'[22], for a detailed analysis of the rainfall and ordinary watercourse response.

3 POSSIBLE CAUSES

3.1. CULVERT CONDITIONS

Within investigation area RCT05 there are several unnamed watercourses which drain the hillsides above Fernhill and Abercwmboi and discharge into the River Cynon. Many of these watercourses are culverted beneath RCT05's urban settlement (previously described in Section 1.2).

Several culvert inlets were inspected by RCT's Flood Risk Management team and the Council's Highway and Streetcare Depot following the flood event to assess their condition and help determine whether they served as a contributing factor to the flooding at RCT05. CCTV survey inspections of the culvert networks were undertaken to ascertain both the operational condition of the network, and its structural integrity along sections of the network.

It should be noted that all surveys reported in this section were undertaken post flood event. It's not possible to say what debris identified in the survey was mobilised and deposited as a result of the storm event and what had been deposited by previous events. As such, the following should be considered to be reflective of the asset condition at the end of the storm event and may not necessarily be reflective of the condition of the assets prior to the onset of the storm event.

For the purpose of this investigation, the culvert conditions within investigation area RCT05 will be described in two parts: the 'Abercwmboi' sub-catchment and the 'Fernhill & Glenboi' sub-catchment.

3.1.1. ABERCWMBOI SUB-CATCHMENT

Figure 15 outlines the three culverted ordinary watercourse networks surveyed within the 'Abercwmboi' sub-catchment and highlights the culvert inlets associated to those networks. 'Culvert Inlets 1 and 2' and 'Manhole 1' were known to have surcharged during the storm event.

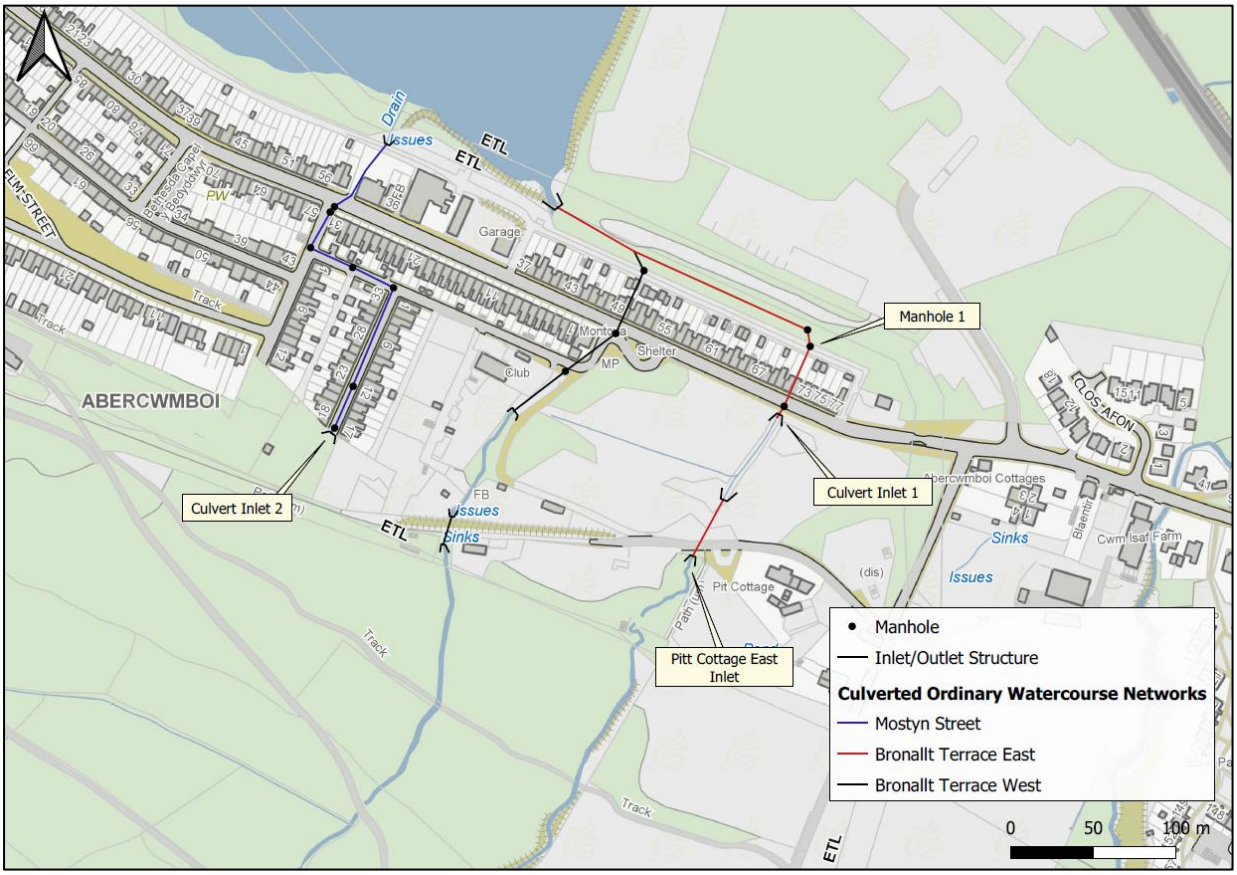

Figure 15: Surveyed culverted ordinary watercourse networks within the 'Abercwmboi' sub-catchment

3.1.1.1. BRONALLT TERRACE EAST CULVERT NETWORK

'Culvert Inlet 1', associated to the 'Bronallt Terrace East' culvert network (Figure 15), was identified as a source of flooding to properties along Bronallt Terrace during Storm Dennis. The culvert inlet is identified as the responsibility of RCT as the Highway Authority.

The inlet became blocked with debris during the storm event which reduced the culvert's ability to manage the flow of water, resulting in surcharge (Figure 16). Approximately six tonnes of debris, mostly consisting of stonewash, was removed from the inlet during the storm event (shown in Figure 17) by RCT's Highways and Streetcare Depot, which succeeded in alleviating the flooding.

Figure 16: 'Culvert Inlet 1' surcharging during Storm Dennis on 16th February 2020 (captured by RCT's Flood Risk Management team)

Figure 17: Debris removed from 'Culvert Inlet 1' which was identified as surcharging during Storm Dennis on 16th February 2020 (captured by RCT's Flood Risk Management team)

The culvert network downstream of the inlet was surveyed by a Council appointed contractor following the storm event. Immediately downstream of the inlet the network was shown to be in poor operational condition, with up to 30% loss in cross-sectional area caused by debris which may have entered the culvert network during the storm

event, however it is considered that the blockage at the inlet avoided the majority of debris from entering the culvert system.

The ‘Bronallt Terrace East’ culvert network deviates approximately 45 degrees at the location of ‘Manhole 1’ (Figure 15) which surcharged prior to the inlet during the storm event. The survey identified debris downstream of ‘Manhole 1’ however the survey was abandoned due to the downstream network falling on Coal Authority land, restricting access. It is assumed that debris was also apparent further downstream within the culvert network which led to a reduction in hydraulic capacity within the network and contributed to ‘Manhole 1’ becoming hydraulically overwhelmed during the storm event. The blockage and associated surcharge of ‘Culvert Inlet 1’ is assumed to have significantly reduced the flow of water entering the network during the event.

Despite the poor operational condition of the ‘Bronallt Terrace East’ culvert network, the blockage at ‘Culvert Inlet 1’ is considered the primary cause of surcharge and resultant flooding during the storm event.

3.1.1.2. MOSTYN STREET CULVERT NETWORK

‘Culvert Inlet 2’ associated to the ‘Mostyn Street’ culvert network was identified as a source of flooding to four properties at Tanycoed Terrace during Storm Dennis. The inlet is identified as the responsibility of RCT as the Highway Authority.

The inlet was identified as blocked with woody debris, scour material and other debris, inclusive of bricks, during post event inspections. Several tonnes of material, including the damaged inlet grill, was removed from ‘Culvert Inlet 2’ by RCT’s Highways and Streetcare Depot post event (Figure 18).

Figure 18: Debris and former inlet debris screen removed from 'Culvert Inlet 2' by RCT's Highways and Streetcare Depot following Storm Dennis (image captured by RCT's FRM officer on 12/03/2020)

The culvert network was initially surveyed post event (18/05/2020) and shown to be in mostly good condition however, some debris was identified in the network. The identified debris consisted of a large stone and house bricks. This debris matches with the type of debris identified at the inlet, suggesting that some debris was able to enter the culvert network during the storm event. No flooding was attributed to the blockages identified within the culvert network during Storm Dennis however, the items of debris were removed by a Council appointed contractor during cleansing operations.

It is assumed that the inlet blockage avoided any surcharging in the 'Mostyn Street' culvert network during the storm event because water was unable to enter the network due to its reduced capacity. The primary cause of flooding has been determined as significant runoff from the steep hillside and the associated mobilisation of debris which blocked 'Culvert Inlet 2', resulting in exceedance ordinary watercourse flows towards Tanycoed Terrace.

3.1.2. FERNHILL & GLENBOI SUB-CATCHMENT

Figure 19 outlines the four culvert networks surveyed within the 'Fernhill & Glenboi' sub-catchment and highlights the culvert inlets associated to those networks. 'Culvert Inlets 3, 4, 7 and 8' were known to have surcharged during the storm event.

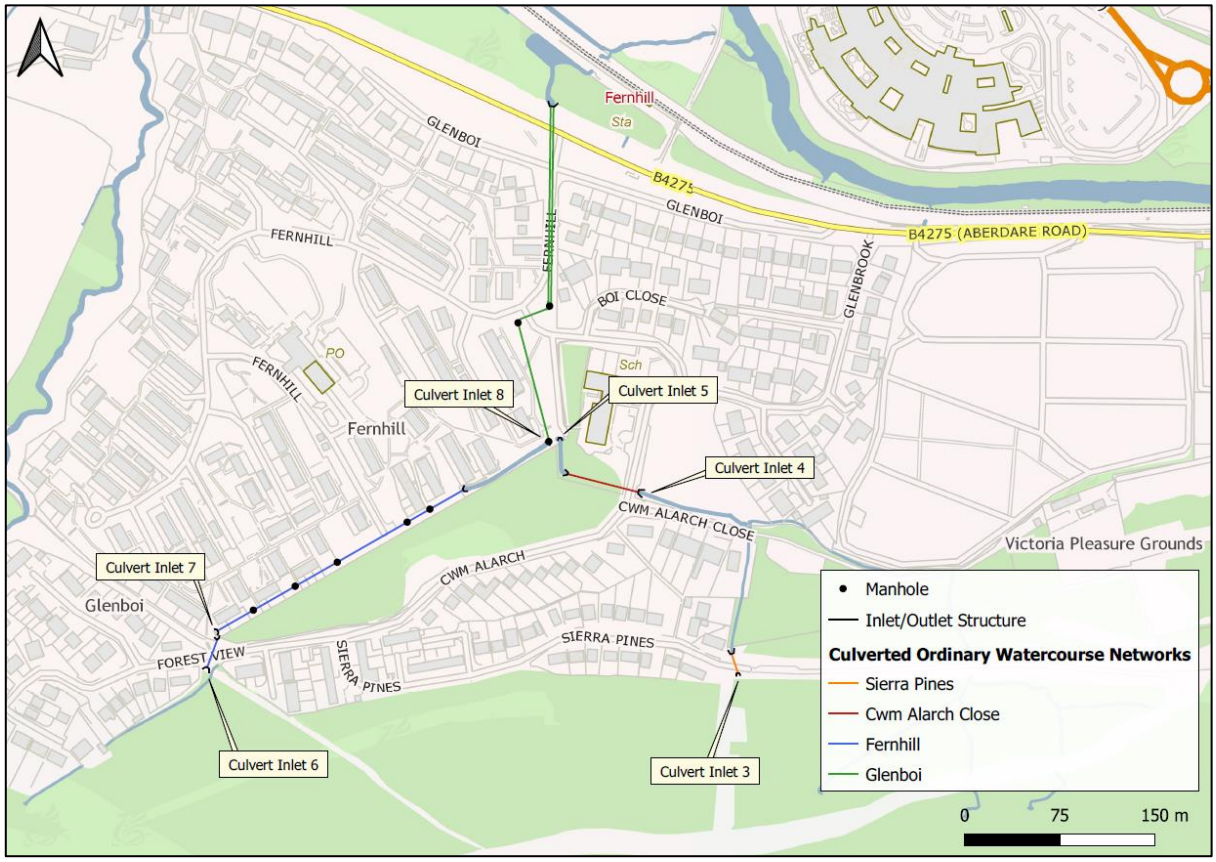

Figure 19: Surveyed culverted ordinary watercourse networks within the 'Fernhill & Glenboi' sub-catchment

3.1.2.1. SIERRA PINES CULVERT NETWORK

To the southeast of investigation area RCT05, 'Culvert Inlet 3' associated to the 'Sierra Pines' culvert network was observed to have surcharged during the storm event after becoming hydraulically overloaded. The resultant flow path contributed to the internal flooding of two properties at Sierra Pines, in addition to contributing to the surface water flows conveying towards the lower reaches of Fernhill and Glenboi.

The inlet and culvert network are identified as the responsibility of NRW on behalf of the Welsh Government as land manager of the WGWE.

‘Culvert Inlet 3’ comprises of a 300mm dia plastic pipe which changes to a 300mm dia concrete pipe at a certain point within the network (Figure 20). The outlet concrete structure was identified as damaged following the mobilisation of debris from the hillside which is likely to have contributed to its surcharge. The condition of the network is not however considered the primary cause of flooding. The volume of water entering the network is considered to have overwhelmed ‘Culvert Inlet 3’, causing the inlet and upstream drainage ditch to back up and overflow onto Sierra Pines.

Figure 20: 'Culvert Inlet 3' (left) and outlet (right) at Sierra Pines captured post storm event (images provided by NRW)

3.1.2.2. CWM ALARCH CLOSE CULVERT NETWORK

'Culvert Inlet 4' associated to the 'Cwm Alarch Close' culvert network was identified as the source of flooding to Glenboi Primary School, in addition to contributing flows towards the lower reaches of Fernhill and Glenboi. The inlet is identified as the responsibility of RCT as the Highway Authority.

The 'Cwm Alarch Close' culvert network was surveyed post storm event and assessed as being in poor structural condition. The poor condition of the culvert network, however, is not considered to have been the primary cause of surcharge.

Figure 21 shows the condition of 'Culvert Inlet 4' prior to the storm event (captured on 13th February 2020) whilst Figure 22 shows the condition of the inlet and channel after the storm event (captured on 21st February 2020). There is evidence of heavy siltation within the channel and debris deposited on the embankment and debris screen. Based on the available evidence, it is considered that the inlets' capacity was severely reduced during the storm event due to debris that had been washed down from the hillsides above RCT05 causing a blockage to the inlets' debris screen. This resulted in water overtopping the inlet structure and flowing overland along the highway towards Glenboi (Figure 10).

The surcharging at 'Culvert Inlet 4' is also considered to have avoided the downstream culvert ('Culvert Inlet 5', Figure 19) from surcharging by reducing the volume of water entering the culvert network.

Figure 21: 'Culvert Inlet 4' captured before Storm Dennis by RCT's Flood Risk Management team on 13th February 2020

Figure 22: 'Culvert Inlet 4' captured after Storm Dennis by RCT's Flood Risk Management team on 21st February 2020

3.1.2.3. FERNHILL CULVERT NETWORK

The surcharging of 'Culvert Inlet 7', associated to the 'Fernhill' culvert network, was confirmed by residents to have surcharged during the storm event, causing a flow path behind properties at Fernhill which contributed to the internal flooding of 13 residential properties. 'Culvert Inlet 7' is identified as the responsibility of RCT as the Highway Authority.

The 'Fernhill' culvert network was surveyed following the storm event and assessed as being in acceptable condition, both upstream and downstream of 'Culvert Inlet 7' suggesting that the inlet structure was overwhelmed as a result of intense rainfall and flows entering from the steep hillsides above Forest View.

During the storm event, 'Culvert Inlet 6', upstream of the 'Fernhill Culvert Network', did not have a debris screen present on the culvert structure. It is considered that debris was able to enter the culvert network at 'Culvert Inlet 6' and convey towards 'Culvert Inlet 7', reducing its hydraulic capacity and contributing to its surcharge during the storm event.

3.1.2.4. GLENBOI CULVERT NETWORK

'Culvert Inlet 8' associated to the 'Glenboi' culvert network was identified as the primary source of flooding to 10 residential properties at Glenboi during the storm event. The inlet is identified as the responsibility of RCT as the Highway Authority.

Figure 23, captured during the storm event, shows 'Culvert Inlet 8' as blocked with debris which reduced the inlet's capacity to manage the flow of water and resulted in water overtopping the inlet and conveying towards Glenboi. In response to the debris identified at the inlet structure, RCT's Highway and Streetcare Depot undertook emergency clearance works following the storm event.

The 'Glenboi' culvert network was assessed as being in very poor condition, with multiple items of debris pulled out of the network following the storm event during the CCTV surveying and cleansing operation. Figure 24 shows the material that was removed from the network. This debris mostly consisted of large objects indicative of fly-tipping. It is considered that the poor operational condition of the network reduced the culvert's ability to manage the flow of water by at least 50%, causing the system to back up and contributing to the surcharging of water at the inlet.

Figure 23: 'Culvert Inlet 8' blocked with debris and surcharging during Storm Dennis on 16th February 2020 (image provided by resident)

Figure 24: Debris removed from the 'Glenboi' culvert network following Storm Dennis during CCTV surveying and cleansing operations on 26/08/2020

Based on the available evidence, this investigation has concluded that the condition of several culvert networks within RCT05 have been assessed as being in poor condition, with several Grade 4 and 5 structural and operational defects identified. Despite this, the internal condition of the culvert networks, albeit the 'Glenboi' culvert network, is not considered to be the primary cause of flooding to properties within the investigation area during Storm Dennis. The primary cause of flooding has been determined as the significant volume of water entering the watercourses from the hillsides, and the associated mobilisation of debris downstream, which caused several culvert inlets to become blocked, resulting in the observed flow pathways that occurred during Storm Dennis.

3.2. Open Watercourse Conditions

Several sections of natural ditches and open watercourses which drain the steep hillsides above RCT05 are identified to flow through the investigation area and discharge into the River Cynon to the north of RCT05 (Figure 25).

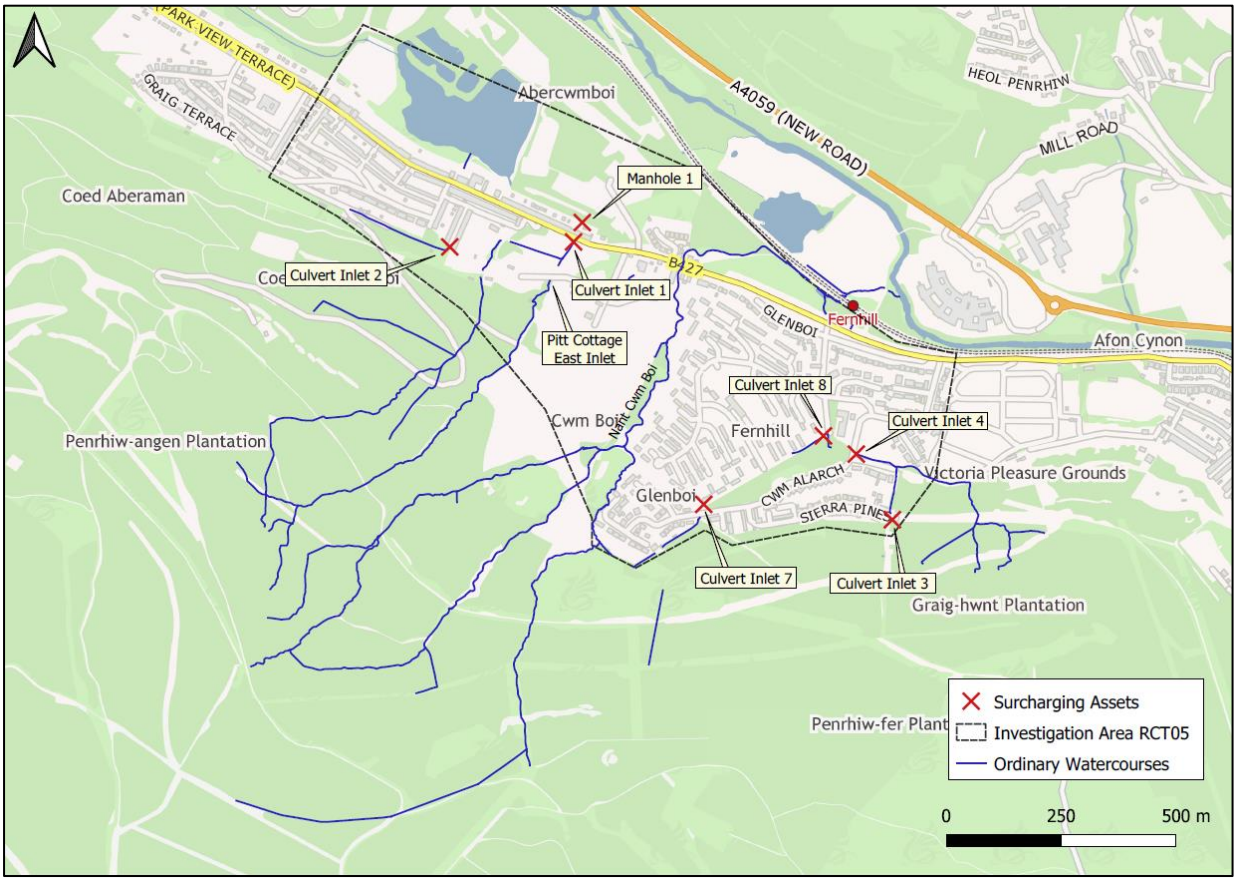

Figure 25: Map of Ordinary watercourses which flow through investigation area RCT05

The primary watercourse the Nant Cwm Boi and its tributaries were not identified as a source of flooding during Storm Dennis. The unnamed watercourses which drain the hillsides in the southeast and southwest of RCT05 however were identified as contributing to the flooding that occurred at Abercwmboi and Fernhill on 16th February 2020.

Following the flood event, RCT's Flood Risk Management officers carried out a site walk-over assessment of the ordinary watercourses and upper catchment areas upstream of the culvert inlets identified as sources of flooding (highlighted in Figure 24) to assess the condition of the watercourses for any signs of overtopping, evidence of scour and any land movement of the hillside.

3.2.1. UNNAMED ORDINARY WATERCOURSE - CULVERT INLET 1

To the west of the Nant Cwm Boi ordinary watercourse, an unnamed watercourse drains the hillside above Abercwmboi and is partially culverted beneath the village at 'Pitt Cottage East Inlet' and 'Culvert Inlet 1' (labelled in Figure 24) before outfalling into the Abercwmboi Pond. The unnamed ordinary watercourse was inspected by RCT's Flood Risk Management officers on 18th February 2020.

According to the on-site officer, the watercourse upstream of 'Pitt Cottage East Inlet', associated to the 'Bronallt Terrace East' culvert network (Figure 15) was identified as having significant scour material, consisting mainly of stonewash, within the channel. Figure 27 shows substantial scour material trapped behind the upper debris screens and on the surrounding embankment area. Figure 26 is provided to illustrate the condition of the upper catchment debris screens operating debris free prior to Storm Dennis.

The images below highlight the extreme flows within the unnamed watercourse during the storm event which were able to mobilise and convey a significant volume of scour material downstream towards the 'Pitt Cottage East Inlet'.

Figure 26: Open watercourse and upper catchment debris screens upstream of 'Pitt Cottages East Inlet' prior to Storm Dennis (captured by RCT's Flood Risk Management team on 06/02/2020)

Figure 27: Open watercourse and upper catchment debris screens upstream of 'Pitt Cottages East Inlet' post Storm Dennis (captured by RCT's Flood Risk Management team on 18th February 2020)

Based on a comparison of the type of debris depicted within the watercourse in Figure 27 and the debris removed from 'Culvert Inlet 1' during emergency clearance works (Figure 17), it is considered that debris entered the 'Bronallt Terrace East' culvert network during the storm event and contributed to the surcharge of 'Culvert Inlet 1'.

Photographic evidence does however show that the upper debris screen and 'Pitt Cottage East' inlet structure succeeded in minimising the volume of scour material entering the culvert network downstream and onwards towards 'Culvert Inlet 1' but could not avoid all materials entering the network due to the strong flows.

The open channel upstream of 'Culvert Inlet 1' is a steep and smooth modified channel. Upon inspection of the channel post event, no significant scouring was identified, which confirms that the majority of the debris at 'Culvert Inlet 1 was primarily mobilised from the upper catchment via 'unnamed ordinary watercourse 1'. A small area of scour within the channel (Figure 28) was observed during post event inspections and is considered to have contributed to the larger block stones identified within the removed debris (Figure 17).

Figure 28: Image depicting a small area of scour within the unnamed open watercourse upstream of 'Culvert Inlet 1' (captured by RCT's Flood Risk Management team post Storm Dennis)

3.2.2. UNNAMED ORDINARY WATERCOURSE – CULVERT INLET 2

A walkover assessment of the catchment above Mostyn Street and Maple Terrace was undertaken following the storm event by RCT's Flood Risk Management team. The assessment identified an undefined land drainage ditch flowing in an easterly direction along the lane behind Maple Terrace (illustrated in Figure 27) towards 'Culvert Inlet 2'.

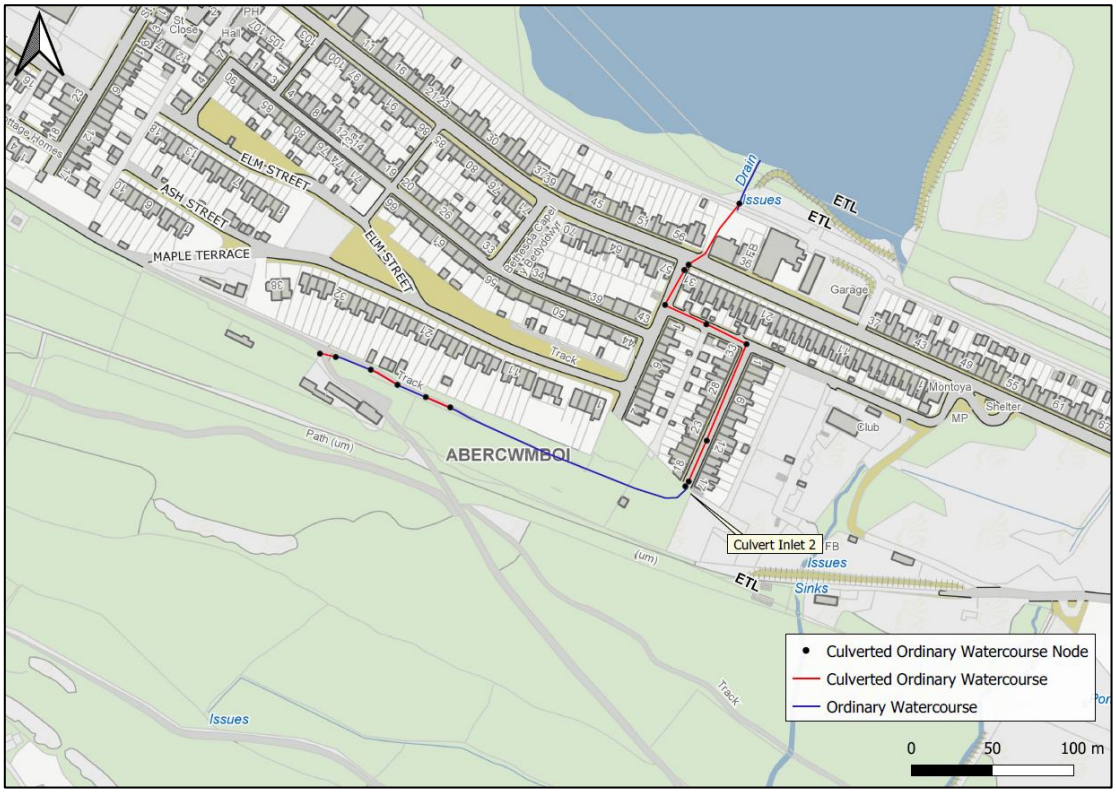

Figure 29: Open watercourse identified to the rear of Maple Terrace which enters the 'Mostyn Street' culvert network at 'Culvert Inlet 2'

The ditch appeared to be culverted in sections, however the pipework was observed to be in poor condition. Evidence of mobilised debris, inclusive of woody debris, and cracked pipework within the open ditch is illustrated in Figure 28. The debris identified is assumed to have been mobilised during the storm event by overland flows travelling down the hillside. This debris was also identified as the cause of blockage to 'Culvert Inlet 2' and associated flooding at Tanycoed Terrace.

Based on the available evidence within this investigation it is considered that the poor condition of the open ditch contributed to the flooding at Mostyn Street, Tanycoed Terrace and Maple Terrace, however, the primary cause of flooding has been

determined as significant overland flows travelling down the hillside during the storm event which overwhelmed the open ditch and resulted in water overtopping the channel and flowing towards the rear of Maple Terrace.

Figure 30: Cracked pipework within the open ditch and various pieces of debris within the channel and surrounding area (captured by RCT's Flood Risk Management team on 12/03/20)

3.2.3. UNNAMED ORDINARY WATERCOURSE(S) – CULVERT INLET 3 & 4

'Culvert Inlet 3' drains the forested hillsides to the south of Fernhill via several undefined and unnamed ordinary watercourse and land drainage channels. 'Culvert Inlet 3' is fed via a land drainage channel which runs adjacent to the forestry access road (Figure 31).

'Culvert Inlet 3' was observed to have overtopped during the storm event after becoming hydraulically overwhelmed, resulting in flooding to properties at Sierra Pines as well as contributing to the surcharging of 'Culvert Inlet 4'. The condition of the open land drainage channel was not identified as the cause of flooding. The volume of water entering the watercourses from the hillside has been determined as the likely cause of surcharge at 'Culvert Inlet 3'.

The catchment above Sierra Pines which feeds into 'Culvert Inlet 3' has been discussed in Section 3.5.

Figure 31: Land drainage channel adjacent to the St Gwynno forestry access road which feeds into 'Culvert Inlet 3'

‘Culvert Inlet 3’ outfalls into an unnamed open watercourse which flows towards ‘Culvert Inlet 4’ at Cwm Alarch Close. This section of watercourse was observed by residents as overtopping during the storm event, contributing additional runoff towards Fernhill and Glenboi. This has been attributed to the significant flows entering the watercourse from the hillside.

On review of the channel immediately upstream of ‘Culvert Inlet 4’, it was observed as heavily eroded with evidence of out-of-bank flows having occurred (Figure 32). The condition of the channel is not considered the primary cause of flooding at ‘Culvert Inlet 4’. A combination of accumulated debris at the inlet screen in addition to the significant flows entering the network is considered the cause of surcharge at ‘Culvert Inlet 4’.

Figure 32: Condition of the open watercourse upstream of 'Culvert Inlet 4' captured post Storm Dennis (captured by RCT's Flood Risk Management team on 21/02/2020)

3.2.4. UNNAMED ORDINARY WATERCOURSE(S) – CULVERT INLET 7 & 8

The open channel upstream of ‘Culvert Inlet 8’ at Fernhill was identified as heavily overgrown but not considered to have been the primary cause of flooding at this location. Evidence of debris and litter surrounding ‘Culvert Inlet 8’ (Figure 33) suggests these materials were mobilised from the surrounding embankment area during the storm event which accumulated at the inlet’s debris screen, reducing its hydraulic capacity and leading to surcharge.

Figure 33: Open watercourse upstream of 'Culvert Inlet 8' captured post Storm Dennis (captured by RCT's Flood Risk Management team on 25/02/2020)

The outfall pond which discharges the ‘Glenboi’ culvert network was also identified as heavily silted following the storm event (Figure 34). This is considered to have reduced the culvert network’s ability to discharge flows, however this has not been determined as the primary cause of flooding to properties at Glenboi. Based on the volume of debris identified at the outfall it is considered that the high sediment loading originated from the main River Cynon which is considered to have influenced the outfall control.

Figure 34: Photo of silt accumulation at the Glenboi culvert network outfall pond (captured by RCT during Storm Dennis on 16/02/2020)

The open watercourses within investigation area RCT05 became hydraulically overwhelmed following intense rainfall generating significant overland flows down the steep hillsides above Abercwmboi and Fernhill. On review of the evidence presented within this investigation, the condition of the open watercourses is not considered to be the primary cause of flooding to properties; however, it is assumed to have contributed to the flooding in some instances, particularly in relation to the mobilisation of debris towards several culvert inlets and onwards to impact the highway drainage infrastructure at RCT05.

3.3. MAIN RIVER

The designated main River Cynon flows west to east to the north of Abercwmboi and Fernhill (Figure 1). The River Cynon itself falls outside of the investigation area.

The hydrograph in Figure 34 illustrates the rapid rise in levels on the River Cynon in response to rainfall, captured at NRW's Aberdare monitoring station which is located upstream of investigation area RCT05. The River Cynon at Aberdare reached its highest peak ever recorded at 03:00am 16th February 2020, reaching 2.13 metres.

The green bar displayed on the hydrograph shows the typical level of the River Cynon at Aberdare station, ranging between 0.1 and 0.55 metres. At its peak, the River Cynon at Aberdare was almost three times higher than its average level, stressing the extreme and unprecedented levels that RCT's rivers rose to during the storm's peak intensity. River levels in the Cynon at Aberdare subsided relatively quickly following the peak, returning to its typical levels the following day on the 17th of February 2020.

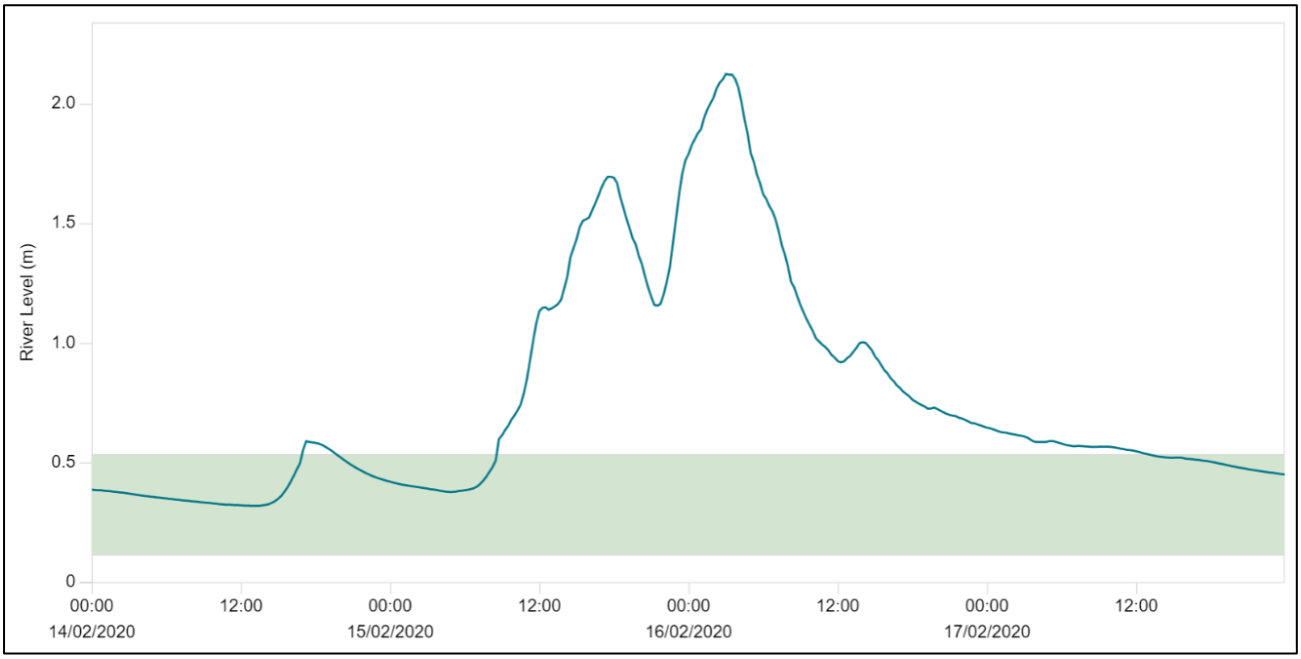

Figure 35: The River Cynon level at Aberdare station between the 14th and 17th February 2020 (Natural Resources Wales)

Anecdotal reports and photographs provided by residents show evidence that the River Cynon overtopped its banks and flooded its eastern floodplains, just north of investigation area RCT05 at Fernhill. Evidence of main river flooding at Peace Park and Fernhill railway track on 16th February 2020 is shown in Figure 35.

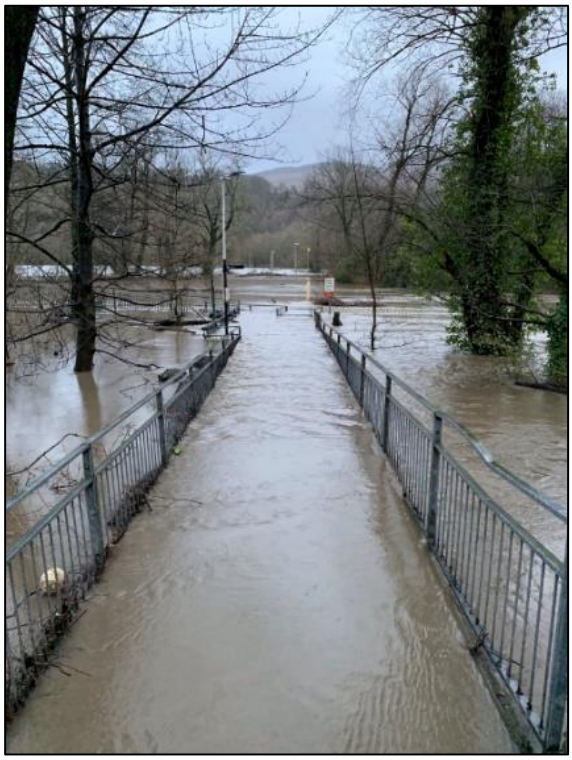

Figure 36: Flooding from the River Cynon at Peace Park and Fernhill railway station on 16th February 2020 (image provided by resident)

According to one resident, the River Cynon reached up to the threshold to the B4275 (Aberdare Road) but did not overtop. This is further reinforced by evidence of fluvial deposits at the Glenboi culvert network outfall (Figure 34) which indicate the level to which the River Cynon rose too. Whilst heavily siltation at the outfall would have restricted the discharge of water from the ordinary watercourses, the River Cynon is not considered to have contributed to the recorded flooding within RCT05 due to the surcharging of several culvert inlets upstream causing overland flow pathways towards the lower reaches of the catchment.

There is no other evidence from this investigation that the main River Cynon significantly contributed to the recorded flooding of properties at RCT05 during Storm Dennis.

3.4. HIGHWAY DRAINAGE CONDITIONS

Following Storm Dennis, investigation area RCT05 was left with widespread deposits of silt and mud which was reported to have been washed off the hillsides and carried by the surcharging water through the villages of Abercwmboi and Fernhill. These deposits are assumed to have entered the highway drainage system, leading to blockages and a reduction in the hydraulic capacity of the surface water network. This was particurarly apparent within the lower reaches of RCT05 at John Street, Bronallt Terrace and Glenboi, where heavily silted surface water accumulation on the highway exacerbated the flooding issues in these locations.

The surface water drainage network along sections of John Street and Glenboi was surveyed and mapped following extensive jetting and cleansing of the network by the Council's Highway and Streetcare Depot following Storm Dennis. CCTV surveys of the highway drainage conditions at both streets confirm significant amounts of settled debris were present along the network, indicating that the network was significantly impacted by the mobilisation of debris and silt carried by overland and ordinary watercourse flows. The result was a significant cleansing operation utilising specialised contractors that utilised High Pressure Water Jetting to clear the debris from within the highway drainage network.

A partial collapse of the highway drainage network at John Street has been determined as the cause of flooding to two properties at John Street, whereby surface water was able to accumulate on the road and ingress into the basements of both properties. In response to the defective highway drainage network at John Street, RCT's Highway and Streetcare Depot carried out repairs to reinstate the surface water drainage network at this location.

Highway drainage is not designed to manage overland flows from private areas, parks or open space. In this instance, the capacity of the highway drainage was exceeded by the substantial ordinary watercourse and surface water flows entering the drainage network across RCT05. As a result, the highway drainage was unable to remove surface water from the highway, resulting in surface water ponding and ultimately exacerbating the flooding to properties within RCT05.

Given the severity of the storm, the maintenance condition of the highway surface water drainage system is not considered to have significantly impacted on the flooding experienced within RCT05.

3.5. SURFACE WATER

Surface water was identified as a significant source of flooding within investigation area RCT05. This surface water was observed to have originated from the hillsides above Abercwmboi and Fernhill following intense rainfall on the catchment. The area of land that drains towards the investigation area forms part of the WGWE which is owned by the Welsh Government and managed by NRW (illustrated in Figure 36).

Figure 37: Welsh Government Woodland Estate (WGWE) boundary within the upper catchment above investigation area RCT05

On the hillside above Sierra Pines, residents claim that water was observed to flow overland down the steep hillside towards properties. Residents also claim that surface water runoff originating from the hillside continued to impact properties in the days following Storm Dennis.

A site walk-over assessment of the upper catchment above Sierra Pines was undertaken by RCT's Flood Risk Management team post event to inspect the drainage arrangements of the hillside. The ordinary watercourse culvert structures identified on the hillside were mapped following the site visit and are presented in Figure 38.

Information provided by NRW post event was also utilised to verify the extent of culvert structures within the area.

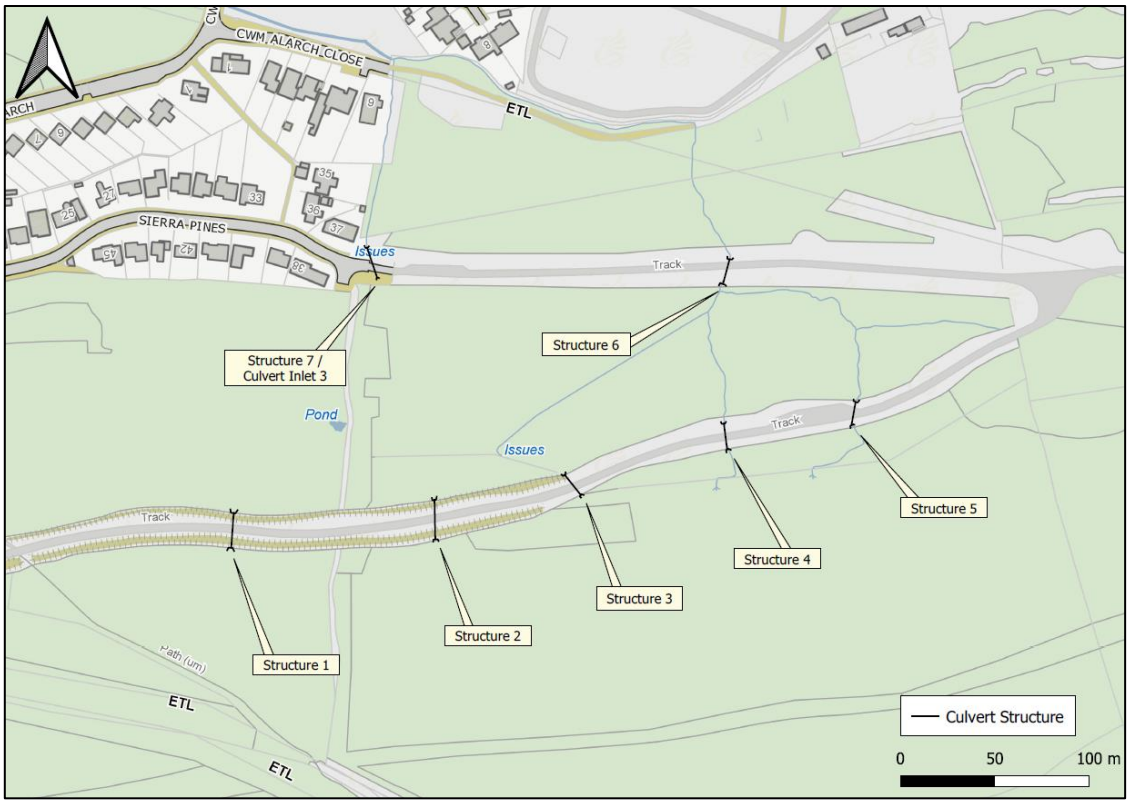

Figure 38: Location plan of the ordinary watercourse surface water drainage arrangements (culvert structures) on the hillside above Sierra Pines that was present during Storm Dennis

On review of the culvert structures on the hillside, RCT as the Land Drainage Authority reviewed its records associated to consents under Section 23 of the Land Drainage Act 1991 and identified that several structures did not have consent. The unconsented structures were observed to be redirecting ordinary watercourse and surface water flows from the hillside above the track towards 'Structure 7 / Culvert Inlet 3' via undefined channels. Figure 39 depicts the undefined channel below 'Structure 3' which is considered to have contributed to the discharge of flows towards 'Structure 7 / Culvert Inlet 3'.

These uncontrolled surface water flows are considered to have increased the catchment area draining towards 'Structure 7 / Culvert Inlet 3', contributing to its surcharge during the storm event. The redirection of flows via undefined channels below 'Structure 1' is also considered to have exacerbated the overland flows observed to the rear of properties at Sierra Pines.

Figure 39: Undefined channel below 'Structure 3' which is considered to have directed flow towards ‘Structure 7 / Culvert Inlet 3’ (image captured by RCT’s Flood Risk Management team post storm event)

On review of the catchment above Maple Terrace, photographic evidence indicates overland surface water flows occurred during the storm event. Evidence of flattened grass and mobilised debris, inclusive of woody debris, is provided in Figure 40, indicating significant overland flows did occur across this area of hillside and contributed to the internal flooding of 7 properties at Maple Terrace, in addition to flooding at Tanycoed Terrace, John Street and Bronallt Terrace.

Figure 40: Evidence of flattened grass and mobilised debris indicative of overland flows down the hillside behind Maple Terrace during Storm Dennis (captured by RCT's Flood Risk Management team on 12/03/2020)

Surface water was also identified as a contributing source of flooding to several properties by way of private surface water drainage infrastructure becoming overwhelmed by the sheer volume of rainfall and runoff entering the networks. Residents at Maple Terrace reported the surcharging of private surface water drainage, in addition to the combined sewer network, within their properties as a result of the significant overland flows entering the rear of their properties from the hillside. Residents at Fernhill also reported the surcharging of private drainage assets outside the fronts of their properties as a result of intense rainfall overwhelming the drainage infrastructure.

The surcharging of private surface water drainage systems has been determined as a contributing source of flooding to those properties affected at Maple Terrace and Fernhill, but not the primary cause of flooding which has been attributed to significant overland flows travelling down the steep hillsides above RCT05 which resulted in open channels and culvert inlets becoming hydraulically overwhelmed during the storm event.

3.6. WOODLAND LOSS AND FORESTRY WORKS

Areas of woodland to the north of Abercwmboi and Fernhill have been felled in recent years. The areas in which tree felling has occurred forms part of the WGWE. Figures 41 and 42 illustrate the woodland loss observed between 2013 and 2020 in areas of Abercwmboi and Fernhill's upper catchments, respectively, using historic aerial imagery from Google Earth.

Figure 41: Google Earth imagery of area above Abercwmboi showing change in tree cover between 2013 and 2020

Figure 42: Google Earth imagery of area above Fernhill showing change in tree cover between 2013 and 2020

Forests and woodlands can have an impact on flooding in multiple ways; trees reduce sediment runoff and forests and woodlands typically produce less runoff than other land uses such as farms and grasslands; the removal of canopy cover increases the rate and volume of runoff of surface water due to the reduction in rainfall interception; and furthermore, felling activity can involve large mechanical plants to fell and transport the material causing disturbances and alterations to local landscape. The choice of forest management can thereby have an impact on the water use of a stand of trees and clear-felling is “the most dramatic intervention” in terms of its impact on

the reduction of water use from trees, as stated within NRW's Land Estate Management Review[3].

Areas of forestry in the upper catchments of Abercwmboi and Fernhill have been felled in recent years which several responses from the public engagement exercise believe to have exacerbated the flooding during Storm Dennis. This was particularly highlighted by residents at Sierra Pines who expressed their concerns that "surface water from the mountain (hillside to the rear of Sierra Pines) had been increasing every year in the last decade, with Storm Dennis being the most severe".

NRW state that "woodlands are usually benign or helpful when reducing flood risk" but when considering extreme flood events such as Storm Dennis, there is some uncertainty surrounding the limited available evidence to conclude the impact of woodland and forests on extreme flood flows at a wider landscape level. They do, however, state that "there is evidence that changes to how we (NRW) design, manage and run land management operations on the WGWE could have a positive impact on a more local scale in some high risk areas", especially "where the WGWE is a high % of the total catchment of smaller rivers, streams; and areas prone to flooding upstream from main rivers". Whilst the total % cover by the WGWE is 21% in RCT, the WGWE represents approximately 56% of the total catchment area of Aberaman South and Mountain Ash West Electoral Wards.

It is difficult to determine the exact impact of woodland felling on flood flow routes, however, woodland loss within the investigation area has been observed over the last decade and is considered to have contributed to the overland routing of runoff from the steep hillsides above investigation area RCT05 which resulted in the surcharging of watercourses and contributed to the blockages of culvert inlet structures.

[3] February 2020 Floods in Wales: Natural Resources Wales Land Estate Management Review (cyfoethnaturiol.cymru)

3.7. DCWW APPARATUS

Despite residents at Maple Terrace suggesting possible sewer flooding contributed to the flooding of properties during the public engagement exercise, no incidences of flooding at RCT05 were reported to DCWW during Storm Dennis.

The intensity of rainfall and subsequent overland flows running down the hillside towards the rear gardens of properties at Maple Terrace is considered to have overwhelmed parts of DCWW's combined drainage infrastructure during the storm event, which contributed to the internal flooding of six properties.

As outlined in 'FRM – Storm Dennis – Overview Report'[2], DCWW sewers have a current deign standard of Q30, as per the 'Sewers for Adoption 7th Edition'[4] guidance document. Given that the design standard was markedly exceeded during Storm Dennis, the maintenance condition of DCWW apparatus is not considered to have significantly impacted the flooding experienced.

[4] WRC., 2012. Sewers for Adoption: 7th edition

3.8. PUMPING STATIONS

Water is typically removed from Glenboi highway by surface water pumps, with water flowing through a culvert and discharging into a flood storage area between Aberdare Road and Fernhill railway station and onwards to the River Cynon. The surface water pumping station falls under the ownership and responsibility of RCT.

The design capacity of the pumping station located at Glenboi to remove surface water from the road, underneath the B4275 to the storage area on the other side, was reportedly overwhelmed during the storm event, exacerbating the surface water issues that was already causing flooding to properties and the highway.

The pumping station was noted as working during Storm Dennis however the intensity of rainfall, combined with additional flows conveying from the surcharging culverts within the upper areas of the Fernhill estate towards the low point at Glenboi, exceeded the capacity of the pumps which became overwhelmed. It should be noted that the pumping station is only intended to manage highway drainage for the Glenboi area and not overland and ordinary watercourse flows.

In response to the flooding at Glenboi highway, the Fire Service and RCT's Highways and Streetcare Depot aided in the emergency response operation by deploying pumps to manage the depth of flooding within the estate (Figure 43).

Figure 43: Image depicts the flooding at Glenboi and the Fire Service response during Storm Dennis (image captured by RCT's Flood Risk Management team on 16th February 2020)

3.9. ACCESS STRUCTURES

No access structures were identified during the asset investigations within the area, as such ‘access structures’ have not been considered within this report.

3.10. System at Capacity

The evidence gathered within this report has identified six culvert inlet structures as sources of flooding within RCT05. For the purpose of this investigation, the culvert capacity assessments of the ordinary watercourse infrastructure within RCT05 will be described in two parts: the ordinary watercourse infrastructure identified as sources of flooding within the urban communities of Abercwmboi, Fernhill and Glenboi; and the ordinary watercourse infrastructure identified as a source of flooding within the WGWE.

3.10.1. Ordinary Watercourse Infrastructure – Urban Communities

Culvert networks within the investigation area (Figures 15 and 19) were surveyed post event to ascertain the internal condition of the networks, the results of which fed into a review of the hydraulic performance of the network to ascertain its current standard of protection using Causeway Flow modelling. The results of the culvert inlet capacity assessments for the culvert inlets identified as sources of flooding within the urban communities of Abercwmboi, Fernhill and Glenboi are summarised in the Table below (refer to Figures 15 and 19 for culvert labels).

Table 3: Summary of the culvert capacity assessment results which indicate the current standard of protection of the culverted networks in free flowing and blockage conditions within RCT05's urban communities

Culvert Name	Standard of Protection (SOP) – Free Flowing	Standard of Protection (SOP) – Blockage Conditions
Culvert Inlet 1	Q50 (2% AEP)	<Q2 (50% AEP)
Culvert Inlet 2	<Q2 (50% AEP)	<Q2 (50% AEP)
Culvert Inlet 4	>Q1000 (0.1% AEP)	<Q10 (10% AEP)
Culvert Inlet 7	>Q500 (0.2% AEP)	Q2 (50% AEP)
Culvert Inlet 8	>Q1000 (0.1% AEP)	<Q10 (10% AEP)

The results from the culvert capacity assessments and hydraulic modelling undertaken as part of Redstart's FIR, infer that both 'Culvert Inlet 1' and 'Culvert Inlet 2' do not provide adequate standards of protection (SOP) up to and including the Q100 (1% AEP) event plus climate change allowance, as stipulated by CIRIA C786. The

standards of protection provided by both inlets are further reduced to below Q2 with the presence of blockage.

On review of the culvert capacity assessments for 'Culvert Inlet 1 & 2', it is inferred that both inlets would have potentially surcharged during the storm event as a result of becoming hydraulically overwhelmed, however, based on the available evidence presented within this report, it has been confirmed that the primary cause of surcharge at both inlets during Storm Dennis was due to blockages to the inlet structure caused by debris which significantly reduced the culvert networks' capacities.

The capacities of 'Culvert Inlet's 4, 7 and 8' have been assessed as having a SOP greater than the current design standard, as defined by CIRIA C786, when considering the free-flowing scenario. In 'medium' (67%) blockage conditions[5], the capacity of 'Culvert Inlet's 4, 7 and 8' are significantly reduced to below Q10 for 'Culvert Inlet 4 and 8', and below Q2 for 'Culvert Inlet 7'. This correlates with the evidence provided in this investigation that scoured material and debris from the hillsides above RCT05 caused significant blockages to these inlets, reducing their hydraulic capacity to manage the flow of water.

3.10.2. Ordinary Watercourse Infrastructure - WGWE

The online calculation tool from HR Wallingford, 'Greenfield runoff rate estimation tool'[6], was used to generate the runoff flow calculation for the hillside above Sierra Pines. The watershed area considered to have discharged into 'Culvert Inlet 3' was measured using GIS software, utilising contour and topographical features. The watershed area for 'Culvert Inlet 3' (Figure 38) during the storm event was approximated as 24 Ha. The area includes the hillside immediately above 'Culvert Inlet 3' in addition to the area of hillside flowing to 'Structures 1, 2 and 3' (Figure 38).

The results from the greenfield estimation tool for 'Culvert Inlet 3', which was identified as a source of flooding during Storm Dennis, are presented in Table 4, along with the culvert capacity determination based upon the diameter, type and gradient of the culvert structure.

[5] Natural Resources Wales Guidance Note (Ref No GN43)
[6] Greenfield runoff rate estimation | UK SuDS

Table 4: Runoff flow calculation for Culvert Inlet 3 for Q100 return period using the Greenfield runoff rate estimation tool and the IH124 approach

Culvert Name	Watershed Area (Ha)	Culvert Capacity (l/s)	Q100 + 40% (l/s)
Culvert Inlet 3	24	395.5	603.23

The estimated greenfield runoff rate for the 1 in 100-year annual probability event (Q100), plus 40% climate change allowance, generates a runoff flow of 603.23 l/s. The generated runoff flow is greater than the culvert capacity of 'Culvert Inlet 3' during the storm event.

Based on the results presented in Table 4, it is considered that the existing structure is under capacity and cannot accommodate the expected flows from the hillside during the storm event. This correlates with the observed surcharging of the inlet during Storm Dennis which contributed to the flooding of properties at Sierra Pines and Cwm Alarch Close.

3.11. Summary of Possible Causes

The above sections have identified and described the possible causes of flooding within investigation area RCT05 during Storm Dennis which occurred on the 15 and 16th February 2020. A summary of the identified source(s) and possible cause(s) of flooding (issue) has been outlined below in Table 5.

Table 5: Summary of source(s) and possible cause(s) of flooding in investigation area RCT05 during Storm Dennis

Ref No	Asset (Source)	Issue	Asset Owner	Type of Flooding
1	Welsh Government Woodland Estate to the south of the investigation area	Areas of the WGWE (forestry land owned by Welsh Government and maintained by NRW) above Abercwmboi and Fernhill have been felled in recent years which may have contributed to increased sediment and debris runoff from the hillsides exacerbating the siltation and blockage of drains and gullies. Additionally, the rate and runoff from the felled areas is expected to have increased following the removal of the canopy cover as well as potential alterations to the surface water drainage arrangements from the WGWE following forestry operations.	Welsh Government (managed by Natural Resources Wales)	Ordinary Watercourse and Surface Water
2	Culvert Inlet 1 (Bronallt Terrace East culvert network)	The culvert inlet surcharged during the storm event after becoming blocked with debris which caused water to overtop at the inlet and flow towards Bronallt Terrace.	RCT Highway Authority	Ordinary Watercourse
3	Manhole 1 (Bronallt Terrace East culvert network)	The ordinary watercourse manhole located in the rear lane behind Bronallt Terrace surcharged prior to 'Culvert Inlet 1' after becoming hydraulically	RCT Highway Authority	Ordinary Watercourse

		overloaded during the storm event.		
4	Culvert Inlet 2 (Mostyn Street culvert network)	The culvert inlet surcharged during the storm event after becoming blocked with debris which caused water to overtop at the inlet and flow towards properties at Tanycoed Terrace, in addition to conveying down Mostyn Street and contributing surface water flows towards the lower reaches of Abercwmboi.	RCT Highway Authority	Ordinary Watercourse
5	Open watercourse channel to the rear of Maple Terrace	The undefined open watercourse channel became hydraulically overwhelmed by surface water flows travelling down the hillside during the storm event. This resulted in significant overland flows travelling towards the rear of properties along Maple Terrace in addition to 'Culvert Inlet 2'.	RCT	Ordinary Watercourse and Surface Water
6	Highway surface water drainage network at John Street	A section of defected surface water drainage network along John Street caused surface water flooding to two properties basements.	RCT Highway Authority	Surface Water
7	Culvert Inlet 3 (Sierra Pines culvert network)	A culvert inlet associated to the surface water and ordinary watercourse drainage of the hillside behind Sierra Pines became hydraulically overwhelmed during the storm event, causing water to flow towards Sierra Pines and Cwm Alarch Close	Welsh Government (managed by Natural Resources Wales)	Ordinary Watercourse and Surface Water
8	Culvert Inlet 4 (Cwm Alarch Close culvert network)	The culvert inlet surcharged during the storm event after becoming blocked with debris which caused water to overtop at the inlet and flow towards Glenboi Primary School and onwards to the lower reaches of Fernhill and Glenboi.	RCT Highway Authority	Ordinary Watercourse

9	Culvert Inlet 7 (Fernhill culvert network)	The culvert inlet surcharged during the storm event after becoming hydraulically overwhelmed and blocked with debris which caused water to overtop at the inlet and flow towards 'Culvert Inlet 8'.	RCT	Ordinary Watercourse
10	Culvert Inlet 8 (Glenboi culvert network)	The culvert inlet surcharged during the storm event after becoming hydraulically overwhelmed and blocked with debris which caused water to overtop at the inlet and flow towards Glenboi highway.	RCT Highway Authority	Ordinary Watercourse
11	Surface water drainage network across RCT05	Ponding surface water was reported by residents across several streets, including John Street, Bronallt Terrace and Glenboi. Both private and highway surface water drainage networks within RCT05, particularly in the lower reaches, became over capacitated and unable to convey the substantial surface water exceedance flows during Storm Dennis. Overland flow transporting silt and debris also contributed to the blockage of highway drainage infrastructure, limiting the capacity of the network further.	Private Landowner(s) & RCT Highway Authority	Surface Water
12	DCWW combined sewer network to the rear of Maple Terrace	Residents at Maple Terrace reported surcharging of the combined sewer network to the rear of their properties as a result of intense rainfall and subsequent overland flows from the hillside overwhelming the system.	DCWW	Sewer

4. Risk Management Authority Actions

A Welsh Risk Management Authority is defined in Section 6 of the Flood and Water Management Act 2010 as NRW; a LLFA, a district council for an area where there is no unitary authority, or a highway authority wholly in Wales; an internal drainage board for an internal drainage district that is wholly or mainly in Wales; a water company that exercises functions in relation to an area in Wales. As the LLFA, RCT has the responsibility to coordinate the management of flood risk and the interaction of Risk Management Authorities across Rhondda Cynon Taf.

An overview of the relevant Risk Management Authority in relation to flood type is provided in Table 6. For further details of the roles and responsibilities of individual Risk Management Authorities in managing flooding, refer to the Welsh Government's National Strategy for Flood and Coastal Erosion Risk Management, Section 4 'Roles & Responsibilities'[7], and RCT's 'FRM – Storm Dennis - Overview Report'[2].

Table 6: Risk Management Authority with relevant functions to manage the risk for different flood types

Type of Flooding	Relevant Risk Management Authority
Flooding from Main River, reservoirs and the sea (including coastal erosion).	Natural Resources Wales
Flooding from ordinary watercourses, surface water and groundwater	Lead Local Flood Authority
Flooding from water and sewage systems	Water Companies (Dŵr Cymru Welsh Water)
Flooding from the highway	Highway Authority
Flooding from the highway (motorways and major trunk roads)	Welsh Government Trunk Road Agency

Risk Management Authorities have direct flood risk management functions under the Flood and Water Management Act 2010, as well as the Water Resources Act 1991, Land Drainage Act 1991 and the Highways Act 1980. Through the investigation of the flooding that impacted investigation area RCT05, the flood risk management functions exercised or proposed to be exercised by relevant RMAs was recorded pursuant to Section 19 of the Flood and Water Management Act 2010, which states;

[7] National Strategy for Flood and Coastal Erosion Risk Management in Wales (English) (gov.wales)

"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 the response to the flood."

Through the investigation process, the source(s) and possible cause(s) of flooding in RCT05 during Storm Dennis have been previously identified and summarised within Table 5. The Risk Management Authority(ies) responsible for managing that flooding have been listed within Table 7 below, along with a series of recommendations presented by the LLFA.

Table 7: Recommendations provided by the LLFA to be considered by the relevant Risk Management Authority identified in response to the source(s) of flooding in RCT05 (as per Table 5)

Ref No	Asset (Source)	Asset Owner	Type of Flooding	Relevant Risk Management Authority	Recommendations	
1	Welsh Government Woodland Estate to the south of the investigation area	Welsh Government (managed by Natural Resources Wales)	Surface Water	Lead Local Flood Authority and Land Drainage Authority	R1A	NRW to review their Forest Resource Plans and Coupe Management Plans with regard to water management, particurarly surface water management. Aligned with recommendation FRP1, 2 and 3 within NRW's Land Estate Management Review.
					R1B	NRW to review their Llanwynno Forest Resource Plan which encompasses the forestry above investigation area RCT05, in collaboration with the

						LLFA, to identify and reflect the key challenges facing the communities of Abercwmboi and Fernhill. Aligned with recommendation FRP1 within NRW's Land Estate Management Review.
					R1C	NRW to 'develop Water Management Plans at a scale most appropriate for water management' and embed their Water Management Plans into their forest management operations to ensure the impacts of flood risk downstream are fully realised. Aligned with recommendation FRP2 within NRW's Land Estate Management Review.
					R1D	NRW to 'improve engagement of local communities in Forest Resource Planning and forest operations' to help develop greater confidence in the WGWE and NRW's contribution to reducing flood risk. Aligned with recommendation FRP4 within NRW's Land Estate Management Review.

2	Culvert Inlet 1 (Bronallt Terrace East culvert network)	RCT Highway Authority	Ordinary Watercourse	Lead Local Flood Authority and Land Drainage Authority	R2A	The LLFA and LDA to identify drainage asset ownership and responsibility.
					R2B	The LLFA and LDA to investigate the standard of protection and the condition of the culvert structure and network as a whole.
					R2C	Jet and cleanse the ordinary watercourse network.
					R2D	Install a new and upgraded culvert inlet structure to accommodate the expected flows as per CIRIA C786 guidance.
					R2E	The LLFA to develop a BJC to identify suitable management methods to reduce the risk of ordinary watercourse and surface water flooding in the Abercwmboi sub-catchment.
					R2F	The LLFA to install remote telemetry monitoring at Culvert Inlet 1 to monitor the risk of blockage.
3	Manhole 1 (Bronallt Terrace East culvert network)	RCT Highway Authority	Ordinary Watercourse and Surface Water	Lead Local Flood Authority, Land Drainage Authority and Highway Authority	R3A	The LLFA and LDA to identify drainage asset ownership and responsibility.
					R3B	The LLFA and LDA to investigate the standard of protection and the condition of the culvert structure

						and network as a whole.
					R3C	Jet and cleanse the ordinary watercourse network.
					R3D	The LLFA to develop a BJC to identify suitable management methods to reduce the risk of ordinary watercourse and surface water flooding in the Abercwmboi sub-catchment.
4	Culvert Inlet 2 (Mostyn Street culvert network)	RCT Highway Authority	Ordinary Watercourse	Lead Local Flood Authority and Land Drainage Authority	R4A	The LLFA and LDA to identify drainage asset ownership and responsibility.
					R4B	The LLFA and LDA to investigate the standard of protection and the condition of the culvert structure and network as a whole.
					R4C	Jet and cleanse the ordinary watercourse network.
					R4D	Install a new and upgraded culvert inlet structure to accommodate the expected flows as per CIRIA C786 guidance.
					R4E	The LLFA to develop a BJC to identify suitable management methods to reduce the risk of ordinary watercourse and surface water flooding in the Abercwmboi sub-catchment.

5	Open watercourse channel to the rear of Maple Terrace	RCT	Ordinary Watercourse and Surface Water	Lead Local Flood Authority and Land Drainage Authority	R5A	The LLFA and LDA to identify drainage asset ownership and responsibility.
					R5B	The LLFA to work with the Highway Authority to clear and re-instate the ordinary watercourse channel above Maple Terrace
					R5C	The LLFA to develop a BJC to identify suitable management methods to reduce the risk of ordinary watercourse and surface water flooding in the Abercwmboi sub-catchment.
6	Highway surface water drainage network at John Street	RCT Highway Authority	Surface Water	Highway Authority and Lead Local Flood Authority	R6A	The LLFA and LDA to identify drainage asset ownership and responsibility.
					R6B	The LLFA, LDA and Highway Authority to investigate the standard of protection and the condition of the surface water drainage network at John Street
7	Culvert Inlet 3 (Sierra Pines culvert network)	Welsh Government (managed by Natural Resources Wales)	Ordinary Watercourse and Surface Water	Lead Local Flood Authority and Land Drainage Authority	R7A	The LLFA and LDA to identify drainage asset ownership and responsibility.
					R7B	The LLFA, LDA and NRW to investigate the standard of protection and the condition of the culvert structure and network as a whole.
					R7C	The LLFA to work alongside NRW as

						land estate manager of the WGWE to identify suitable management methods to reduce the risk of ordinary watercourse and surface water flooding in the Fernhill & Glenboi sub-catchment.
8	Culvert Inlet 4 (Cwm Alarch Close culvert network)	RCT Highway Authority	Ordinary Watercourse	Lead Local Flood Authority and Land Drainage Authority	R8A	The LLFA and LDA to identify drainage asset ownership and responsibility.
					R8B	The LLFA and LDA to investigate the standard of protection and the condition of the culvert structure and network as a whole.
					R8C	Jet and cleanse the ordinary watercourse network.
					R8D	The LLFA and LDA to work with upstream riparian landowners to identify suitable management methods to reduce the risk of scour within the ordinary watercourse.
9	Culvert Inlet 7 (Fernhill culvert network)	RCT	Ordinary Watercourse	Lead Local Flood Authority and Land Drainage Authority	R9A	The LLFA and LDA to identify drainage asset ownership and responsibility.
					R9B	The LLFA and LDA to investigate the standard of protection and the condition of the culvert structure and network as a whole.

					R9C	Jet and cleanse the ordinary watercourse network.
					R9D	The LLFA and LDA to work with upstream riparian landowners to identify suitable management methods to reduce the risk of scour within the ordinary watercourse.
10	Culvert Inlet 8 (Glenboi culvert network)	RCT Highway Authority	Ordinary Watercourse	Lead Local Flood Authority and Land Drainage Authority	R10A	The LLFA and LDA to identify drainage asset ownership and responsibility.
					R10B	The LLFA and LDA to investigate the standard of protection and the condition of the culvert structure and network as a whole.
					R10C	Jet and cleanse the ordinary watercourse network.
					R10D	Install a new and upgraded culvert inlet structure to accommodate the expected flows as per CIRIA C786 guidance.
					R10E	The LLFA to install remote telemetry monitoring at Culvert Inlet 8 to monitor the risk of blockage.
					R10F	The LLFA and LDA to work with upstream riparian landowners to identify suitable management methods to reduce the risk of scour within the ordinary watercourse.

11	Surface water drainage network across RCT05	Private Landowner(s) & RCT Highway Authority	Surface Water	Highway Authority and Lead Local Flood Authority	R11A	The Highway Authority to jet and cleanse the highway drainage network and action repairs accordingly.
					R11B	The LLFA to work alongside the Highway Authority to evaluate surface water management options to alleviate the risk of flooding to areas of high risk.
12	DCWW combined sewer network to the rear of Maple Terrace	DCWW	Sewer	DCWW	R12A	DCWW to evaluate the standard of service and the condition of the combined sewer network servicing Maple Terrace.
					R12B	DCWW to work with the LLFA and the Highway Authority to identify suitable management methods to reduce the risk of flooding from all sources in Abercwmboi.

4.1. LEAD LOCAL FLOOD AUTHORITY

In review of Ref 1 - 11 in Table 7, the LLFA has been determined as the relevant Risk Management Authority in relation to the ordinary watercourse and surface water flooding which occurred at investigation area RCT05 during Storm Dennis.

The LLFA exercised the following functions in response to the flooding at investigation area RCT05;

- Officers investigated the initial flooding and have produced this report in line with Section 19 of the Flood and Water Management Act 2010.
- Officers contacted residents affected by flooding to offer support and advice to assist in the recovery following the five events.
- A public engagement exercise carried out by Redstart, on behalf of RCTCBC as the LLFA, was undertaken in order to gain further local insight and anecdotal evidence to support the flood investigation.
- The LLFA and LDA have exercised their permissive powers under Section 64 of the Land Drainage Act 1991 to investigate the culvert structures, network conditions, ordinary watercourse conditions and surface water drainage arrangements to determine their impacts on the flooding within the investigation area. **(R2B, R3B, R4B, R6B, R7B, R8B, R9B, R10B)**
- An estimated 868 metres of ordinary watercourse culvert network and 749 metres of surface water drainage network length within investigation area RCT05 has been surveyed following the storm event to ascertain both the operational condition and structural integrity along sections of the network. **(R2B, R3B, R4B, R7B, R8B, R9B, R10B)**
- An estimated 229 tonnes of material and debris was removed from the culvert and surface water drainage networks within Abercwmboi and Fernhill during jetting and cleansing operations. **(R2C, R3C, R4C, R8C, R9C, R10C)**
- The LLFA and LDA have undertaken clearance works to the culvert inlet structures and network systems which fall under the responsibility of the Authority. **(R2C, R3C, R4C, R8C, R9C, R10C)**
- The LLFA commissioned Redstart to investigate the standard of protection of the existing culvert networks in Abercwmboi and Fernhill to determine their hydraulic capacity following the identification of several structural and operational defects within sections of the network. **(R2B, R3B, R4B, R8B, R9B, R10B)**

- In review of Ref 6 and 11, the LLFA and Highway Authority have led on the mapping of the ordinary watercourse and highway drainage infrastructure and networks at Glenboi and John Street to identify connectivity and identify where systems can be modified to reduce flood risk. **(R6B, R11A)**
- In review of Ref 2, 4 and 10, RCT as the LLFA and LDA has led on the delivery of new headwall and inlet arrangements for Culvert Inlets 1 and 2 within the 'Abercwmboi' sub-catchment and Culvert Inlet 8 within the 'Fernhill & Glenboi' sub-catchment which were identified as sources of flooding during Storm Dennis. **(R2D, R4D, R10D)**
- In response to the debris identified within the Fernhill and Glenboi culvert networks, inlet upgrade works have been carried out at 'Culvert Inlet 6' in addition to the installation of two debris screens upstream of the inlet to minimise the impact of debris blockages within the culverted ordinary watercourse infrastructure.
- In response of Ref 2 - 4, The LLFA have developed a BJC for the Abercwmboi sub-catchment area. The proposed works include the installation of an upper catchment attenuation pond to increase the capacity of the downstream culvert networks and to act as a point of maintenance for debris control, thereby reducing the risk of culvert blockages within the urban community. Construction is programmed to start March 2022 **(R2E, R3D, R4D)**
- The LLFA has exercised its powers, under Section 13 of the FWMA, to request information and co-operation from the relevant risk management authorities (NRW and DCWW) in relation to their responsibilities as RMAs and NRW as land estate manager of the Welsh Government Woodland Estate in response to Storm Dennis.
- The LLFA has set up a central Control Room, to compliment the Council's Contact Centre and CCTV centre which is based at the Council's offices, to provide a comprehensive and informed response to the residents of RCT as appropriate during storm events.
- The LLFA have initiated an interim Property Flood Resistance project offering expandable flood gates to those properties deemed at high risk of flooding from local sources.
- The LLFA and LDA have initiated remote telemetry monitoring devices at key culvert structures to enable operators to ensure the drainage systems in RCT05 are operating effectively. **(R2F, R10E)**

The LLFA propose to exercise the following functions in response to the flooding at investigation area RCT05;

- Following the surveying of culvert networks in investigation area RCT05, the LLFA propose to input and update all relevant asset data. **(R2A, R3A, R4A, R5A, R6A, R7A, R8A, R9A, R10A)**
- The LLFA and LDA intend to clarify drainage asset owners and management responsibilities to make them aware of their personal risk. To ensure landowners manage the risk in compliance with the relevant legislation, a team of Flood Enforcement Officers including legal support is to be appointed.
- The LLFA will be commencing a Flood Alleviation Scheme in the area of Glenboi highway. The works will facilitate an enhanced highway surface water pumping station, designed to accommodate overland flows from surface water and ordinary watercourses which enter into the low point within Glenboi Road. **(R8D, R9D, R10F, R11B)**
- As part of RCT's comprehensive review of the County Borough's most at risk communities, the LLFA are proposing to undertake a formal Strategic Flood Risk Assessment (SFRA) of the Cynon catchment area to better understand the overall risk from ordinary watercourse and surface water flooding in order to target investment to areas of highest risk. The SFRAs also aim to encourage whole catchment measures, including working with natural processes, to alleviate flood risk in those areas of highest risk. **(R2E, R3D, R4E, R5C, R6B, R7C, R8D, R9D, R10F, R11B)**
- The LLFA and LDA propose to undertake Geomorphological assessments of the upper catchments in Abercwmboi and Fernhill to determine the risk of culvert blockages as a result of scour and debris potential. In addition to this the LLFA and LDA will engage with Riparian landowners and NRW as land managers of the WGWE to identify suitable management methods to reduce the risk of scour within the ordinary watercourses. **(R2E, R3D, R4E, R5C, R6B, R7C, R8D, R9D, R10F)**
- In response to Ref 4 in Table 7, the LLFA have applied for Welsh Government funding to undertake upgrade and rehabilitation works to increase the standard of protection and condition of the Mostyn Street culvert network. **(R4D, R4E)**

4.2. NATURAL RESOURCES WALES

Natural Resources Wales were not directly identified as a relevant Risk Management Authority in relation to the flooding at investigation area RCT05 because the flood type was identified as being largely ordinary watercourse and surface water flooding which is the responsibility of the LLFA to manage. However, the Authority, as the LLFA and LDA, has engaged with NRW in relation to Storm Dennis, specifically regarding their role and responsibility as the woodland and forestry land estate manager.

NRW, as both the Risk Management Authority and as a significant land estate manager within RCT, have exercised the following functions in response to the flooding at investigation area RCT05;

- Following the flooding events of February 2020, NRW published a review of its incident response to Storm Ciara and Dennis in October 2020[8]. The review contains several recommendations for improvements to their ways of working and services which NRW are in the process of implementing through an internal delivery program.
- As part of NRW's incident response review, and in relation to their role as landowners, NRW have published a Land Estate Management Review[3] following the February 2020 flooding. The report details further recommendations put forward by NRW to improve their current approach to Forest Management. **(R1A, R1B, R1C, R1D)**
- NRW have completed or are in the process of completing a review of their Forest Resource Plans and Coupe Management Plans. **(R1A)**
- NRW are in the progress of completing a review of their Llanwynno Forest Resource Plan which encompasses the forestry above RCT05. **(R1B)**
- On review of the ordinary watercourse and surface water drainage arrangements of the hillside above Sierra Pines, NRW have removed the unconsented structures (Structure 1, 2 and 3 in Figure 38) to ensure the flow of water from the hillside is appropriately drained via defined channels. NRW have also upgraded Structures 4, 5, 6 and 7 (Figure 38) to improve the hydraulic capacity of the inlets and to reduce the risk of blockages caused by debris. The LLFA have worked with NRW to ensure the culvert structures are appropriately regulated and the relevant consents are in place. **(R7B)**
- In response to the observed main river flooding which impacted the railway track at RCT05, NRW have utilised post event data and information to review

[8] Natural Resources Wales / Our response to Storm Ciara and Storm Dennis

the Resultant Thresholds for the River Cynon at Aberaman and Mountain Ash Flood Warning Areas. This is critical for assessing the performance, timeliness and accuracy of the warning service after a flood.

- NRW have commissioned a Cynon Flood Modelling Study which is programmed for completion by the end of March 2022.

NRW propose to exercise the following functions in response to the flooding at RCT05;

- As land manager of the WGWE, NRW are developing Flood Risk Guidance for Forest Operations which will explore the mechanisms in which they can provide better advise on the water management of the Welsh Government Woodland Estate. **(R1C)**
- Building upon their role as land manager of the WGWE, NRW are developing a Local Approach to Woodland and Trees which aims to provide NRW with the necessary guidance to ensure that woodland creation can address priority issues including improvements to both air and water quality, rebuilding ecosystem resilience and contribute to reducing flood risk. **(R1C)**
- Following the completion of NRW's Cynon Flood Modelling Study, NRW propose to undertake an initial economic assessment of the viability of potential flood risk management options.
- Following the completion of NRW's Cynon Flood Modelling Study, NRW propose further threshold work and flood warning area amendments.
- NRW will undertake a review of the modelled outputs and adopt changes to their maintenance program within the investigation area if required.

4.3. WATER COMPANY

In review of Ref 12 in Table 7, DCWW has been identified as the relevant Risk Management Authority in relation to the sewer flooding associated with the surcharging of the combined sewer network at Maple Terrace.

DCWW have exercised the following functions in response to the flooding at RCT05;

- DCWW carried out their own investigations in response to incidences of flooding that were reported by residents directly to DCWW.
- DCWW have investigated the performance of their network and telemetry systems during the storm event to ensure their assets were operating with no issues.

DCWW do not propose to exercise further functions in response to the flooding at investigation area RCT05.

4.4. HIGHWAY AUTHORITY

During the investigation into the flooding at investigation area RCT05 during Storm Dennis, the Highway was identified as flooding as a result of ordinary watercourse flooding associated to blocked and overwhelmed culvert inlets, and surface water runoff flowing down the steep hillsides above Abercwmboi and Fernhill. Mud and debris mobilised and deposited by the overland flows caused blockages to the majority of highway drainage infrastructure in the lower reaches of RCT05, exacerbating surface water flooding to the highway and properties.

Ref 6 and 11 of Table 7 identifies the Highway Authority as the relevant Risk Management Authority in relation to the surface water flooding that occurred along the highway in the lower reaches of RCT05.

RCT as the Highway Authority have exercised the following functions in response to the flooding at RCT05;

- The Highway Authority assisted with the emergency response during the event by supplying equipment and sandbags, some to individual properties and using sandbags to redirect flood water away from properties.
- The Highway Authority exercised their functions under Section 100 of the Highways Act 1980, to arrange for all gullies and open drains in the highway to be inspected and cleansed following the influx of flood water to ensure the safety of the highway post event. **(R11A)**
- The Highway Authority also carried out repairs to the carriageway, road gullies and gully connections which became damaged by debris during Storm Dennis. **(R11A)**
- The Highway Authority has undertaken emergency clearance works to the culvert infrastructure identified as sources of flooding. **(R2C, R3C, R4C, R8C, R9C, R10C)**
- In review of Ref 5, the LLFA and Highway Authority have carried out maintenance works to reinstate the ordinary watercourse ditch to the rear of Maple Terrace to alleviate the risk of future flooding associated to the overtopping of the ditches. **(R5B)**
- RCT as the LLFA and Highway Authority carried out CCTV surveys of the highway surface water drainage infrastructure at John Street and Glenboi highway to identify damages caused by the blockages and also to determine overall connectivity of the drainage network. **(R6B)**

- The Highway Authority have increased their resource capacity by establishing a dedicated ‘Pluvial Drainage Team’ to focus entirely on the refurbishment and maintenance of RCT’s existing and enhanced highway drainage infrastructure.

RCT as the Highway Authority propose to undertake the following functions in relation to the event at investigation area RCT05;

- In response to the defective highway drainage network identified at John Street, Abercwmboi, the LLFA, alongside the Highway Authority, have applied for Welsh Government funding to upgrade the highway drainage infrastructure at John Street via the upgrading of the highway carrier line and associated inflow gully structures. **(R11B)**

USEFUL LINKS/CONTACTS

Blue Pages – property Resilience - http://bluepages.org.uk/

Flood Re – Flooded Property Insurance Scheme - https://www.floodre.co.uk/

Natural Resources Wales – Check Flood Warnings - https://naturalresources.wales/flooding/check-flood-warnings/?lang=en

Natural Resources Wales - Long Term Flood Risk - https://naturalresources.wales/evidence-and-data/maps/long-term-flood-risk/?lang=en

Rhondda Cynon Taf CBC - Local Flood Risk Management Plan - https://www.rctcbc.gov.uk/EN/Resident/ParkingRoadsandTravel/Roadspavementsandpaths/FloodAlleviation/Floodriskregulations2009.aspx

Rhondda Cynon Taf CBC - Local Flood Risk Management Strategy - https://www.rctcbc.gov.uk/EN/Resident/ParkingRoadsandTravel/Roadspavementsandpaths/FloodAlleviation/LocalFloodRiskManagementStrategy.aspx

Rhondda Cynon Taf CBC – Sustainable Drainage – https://www.rctcbc.gov.uk/EN/Resident/ParkingRoadsandTravel/Roadspavementsandpaths/SustainableDrainage/SustainableDrainage.aspx

Welsh Government - National Strategy for Flood and Coastal Erosion Risk Management - https://gov.wales/sites/default/files/publications/2019-03/national-strategy-for-flood-and-coastal-erosion-risk-management-in-wales.pdf

Welsh Water – How to Contact Us – https://www.welshwater.com/en/Contact-Us.aspx