Technical Note:

Torcoed Quarry: Discharge Activity Permit Application

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APPENDICES

1 Introduction

1.1 Background

Stantec UK Ltd (Stantec) has been engaged by Tarmac Trading Limited (Tarmac) to prepare and submit an application for a Discharge Activity Environmental Permit ("Discharge Permit") at Torcoed Quarry ("the Site"), in Carmarthenshire, South Wales as shown in Figure 1.1. The discharge permit is required in order to augment the flow volumes at Garn Ffrwd Spring (the Spring) by discharging water to a sinkhole located adjacent to the quarry (the Quarry Sink) when flow at the Spring drops below 8 l/s.

The current conceptual site model is described by Stantec (formerly ESI Ltd) as part of an SLR (2015) Environmental Statement for the Site in which Stantec undertook the hydrogeological conceptual site model (Chapter 8).

1.2 Collection and review of monitoring data

As required by the Torcoed Water Management Plan (WMP) (Appendix A), monitoring data are collected from a large number of locations at, and around the Site, typically on a monthly basis. Review of these data is presented to the planning authority and NRW annually via the Annual Reports. These reviews include an assessment of any observed effects of the quarry dewatering on the water environment, breaches of trigger levels, and recommendations for mitigation. The most recent annual report is included in Appendix B.

1.3 Application forms

This Technical Note provides the overarching document containing all necessary information and referencing the supporting documents for the Discharge Permit application for submission to Natural Resources Wales (NRW). It is accompanied by the appropriate application forms as follows (submitted online):

- Part B6 – Application for an environmental permit – new bespoke water discharge activity and groundwater (point source) activity

Tarmac Director details are provided in Appendix C.

The application forms are sign by Delia Boulis of Tarmac (Permitting and Compliance Manager), who is authorised to do so as shown in the Letter of Signing Authority presented in Appendix D.

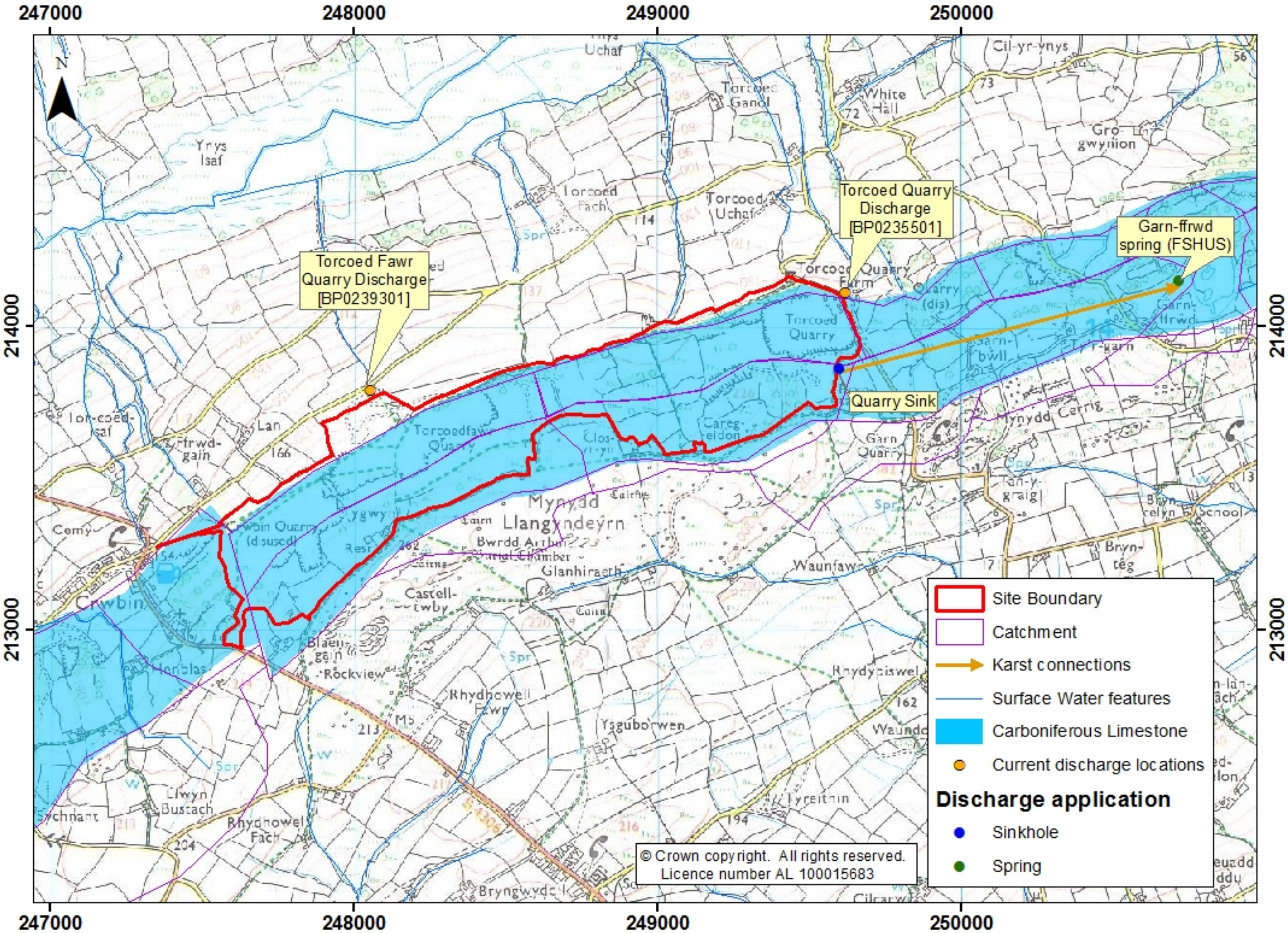
1.4 Application fee

Payment of the application fee has been processed via BACs transfer.

The application fee will be £912, as per:

- I. Schedule 4 – charges for specified water activities, section 2. Charge rates (NRW, 2022).

Figure 1.1 Monitoring locations plan



2 Current Water Management

2.1 Conceptual model and predicted impacts

The conceptual site model has been summarised below but is explained in more detail in the Environmental Statement (ES) included in Appendix E.

The local geology comprises Old Red Sandstone, overlain by Carboniferous Limestone, overlain by Millstone Grit and Coal Measures. The strata dip uniformly to the south-south east at approximately 18 – 23 degrees. Old Red Sandstone crops out to the north of the quarry, which has worked the Carboniferous Limestone. The Mynydd-Llangyndeyrn ridge comprises Millstone Grit, with younger strata overlying to the south-south east.

The Carboniferous Limestone is subdivided into the Lower Limestone Shales, the Main Limestone, and the Upper Limestone Shale. The main limestone itself can be sub divided into two contrasting aquifer systems: the relatively 'clean' lower limestones (Penderyn Oolite and Cilyrychen Limestone) which are the main economic mineral for the quarries, and the overlying, much shalier Mynydd-y-Garegg Limestone. Evidence from groundwater levels and tracer tests suggests that there is relatively little hydraulic connection between these two aquifer systems.

Superficial deposits in the area are generally thin or absent with variable cover of Boulder Clay across the area with some glacial sand and gravel and peat in places. Generally the cover of superficial material has little effect on the local hydrogeology other than to help to route recharge into particular locations.

Several north-north west faults are mapped in the area. However these do not appear to completely disrupt the geological sequence at any point and there is no evidence that these act as barriers to groundwater flow.

Groundwater flow in the Carboniferous Limestone is predominantly through karstic features (secondary permeability). Several sinkholes are observed in the Carboniferous Limestone and these have been traced to springs issuing from the Carboniferous Limestone. The main outflows from the Carboniferous Limestone system are the Felindre springs, about 1.8 km to the west of the proposed Crwbin quarry excavation, and Garn Ffrwd spring (i.e. the Spring), about 1 km to the east of Torcoed quarry. Other significant springs in the vicinity of Crwbin quarry include Crwbin spring, about 200 m to the west of Crwbin quarry, and Ffrwd-Gain spring, about 120 m to the north of Crwbin quarry.

The predominance of along-strike flow in the Mynydd-y-Garegg Limestone and the shaley nature of the formation, means that the zone of influence of Crwbin quarry is largely constrained to the underlying limestones (Penderyn Oolite and Cilyrychen Limestone) at present.

The influence of the karst system on groundwater levels is seen as flashy responses to rainfall with little evidence of groundwater storage, and also gives rise to the 'dual water table' effect observed in water levels recorded in borehole BH95/5. The Old Red Sandstone is a more diffusive aquifer (higher storage and lower permeability) than the Carboniferous Limestone and this is reflected in the nature of the hydrographs.

Groundwater elevations indicate that the groundwater in the Main Limestone and the Old Red Sandstone are not in hydraulic continuity due to the presence of the intervening Lower Limestone Shales which effectively isolate the two groundwater systems.

Testing indicated that the Garn Ffrwd Spring (the Spring) is a major outlet for streams sinking on the ridge to the east. The Quarry Sink is included in the list of sinkholes identified as feeding the Spring. The catchment of the Spring is considered to extend up to 1.35 km to the west of Garn Bwll sink, and to include a substantial discharge contribution from the Millstone Grit and Mynydd-y-Garegg Limestones. These results suggest the presence of strike-oriented conduits between the sinks to the Spring. Tracer tests indicated that these are isolated from the Cilyrychen Limestone as tracer was generally not detected in the quarries, although the Tyn-y-banc sink was considered to have an overflow connection with Torcoed Fawr Quarry.

A screening exercise for the sump and discharge location concluded that the sump is representative of groundwater even though it contains surface water as well. This screening exercise compared data against UK Drinking Water Standards and shows that the sump contains no significant hazardous pollutants as outlined below in Section 2.4.4 with no risk to groundwater.

2.2 Garn-Ffrwd fisheries augmentation agreement

Tarmac entered into an agreement with the owner of the Garn-Ffrwd fisheries in 2007 to augment flows at the Spring when they drop below a prescribed level (8 l/s or 691 m^3/d) or the Target Rate. Spring flows will therefore, when required, be supported by pumping to the Quarry Sink, which as discussed above has been shown to be connected to the Spring. An augmentation test was carried out in December 2003, which demonstrated the feasibility of this approach for mitigation. The methodology for the test, including monitoring requirements, was agreed with the Environment Agency (now NRW) beforehand and no adverse effects on the quality of the spring flow were noted during the test.

In order to ensure that there is sufficient water available for augmentation, Tarmac has agreed to maintain a sump with a capacity of 10,000 m^3 in the floor of Torcoed Quarry. The development plans have incorporated a sinking to the 115 mAOD level which will provide a suitable area to provide this storage.

The analysis indicates that it would not be possible to maintain the target flows (even with a much larger sump) under extreme drought conditions and this is acknowledged in the agreement between Tarmac and the Garn-Ffrwd fisheries owner. Hence, should the volume in the Sump fall below 10,000 m^3, the minimum flow rate that needs to be maintained at the Spring shall be varied as detailed in Table 2.1.

Table 2.1 Minimum flow rates based on sump level

Sump water capacity levels (percentage full)	Minimum flow rate (litres per second)
100% - 51%	8 l/s
50% - 25%	7 l/s
24% – 15%	6 l/s
14% - 0%	5.5 l/s until complete utilisation

The outline of the scheme is detailed in Appendix F and is summarised below:

- In the event that the owner of the Garn-Ffrwd fisheries believes that the flow from the Spring has fallen below the Target Rate, they may notify Tarmac and request that Tarmac supplement the flow of water at the Spring.
- Upon receipt of a request from the owner, Tarmac shall have the option to establish, by conducting its own testing, that the flow from the Spring has fallen below the Target Rate.
- If Tarmac, acting reasonably, does not accept the owner’s assertion that the flow from the Spring has fallen below the Target Rate, Tarmac shall have no obligation to supplement such flow.
- Following receipt of a written request from the owner, Tarmac undertakes to pump Suitable Water (defined as such quantities of water as may naturally occur at the Quarry that might reasonably be expected to comply with the Discharge Consent (which this application is applying for) and that are reasonably capable of being directed to the Sump for storage) from the Sump to the Quarry Sink for

such period until either the natural flow of the Spring recovers to greater than or equal to the Target Rate or until there is no Suitable Water in the Sump.

2.3 Findings of the 2003 augmentation trial

The results of the 2003 augmentation trial are detailed in a letter from ESI (now Stantec) to Tarmac on 20th April 2004 included in Appendix G.

The Spring flow showed a very rapid response to changes in augmentation rate (within 30 to 70 minutes). This response is faster than noted in tracer tests at the same sink (peak recovery after around 1 day). This is probably due to the tracer tests being carried out during low flow conditions but also reflects the difference between the time taken for a hydraulic response to occur and the time taken for the bulk of the tracer to be transported through the system.

In the short term, the change in spring flow varied from 30 to 80% of the change in augmentation discharge. However, the results over longer timescales over the course of the test the change in flow in the Spring was generally very close to the augmentation rate.

The most probable reason for the difference between short and long term responses is that not all of the augmentation flow will go via the fastest routes. Thus, whilst most of the response in the Spring flow rate to a change in discharge rate is fairly immediate, some of the response will take longer to break through. This suggests that the 'efficiency' of the augmentation scheme will be higher in the long term than in the short term. The Quarry Sink discharge point is clearly within the capture zone of the Spring and thus any water discharged at that point will ultimately reach the Spring.

The trial augmentation test showed that the flow at the Spring can be successfully augmented by discharge of water at the Quarry Sink. The quality of water at the Spring complied with all relevant water quality standards throughout the course of the test.

Due to the background variation in flow at the Spring during the course of the test (caused by rainfall during the test), it was not possible to quantify the efficiency of the discharge (i.e. how much of the discharge actually reached the Spring during the course of the test). However, the Quarry Sink is clearly within the source zone of the Spring and there is no reason to believe that water discharged at this point would travel in any other direction.

2.4 Surface water and groundwater baseline conditions

2.4.1 Rainfall

The annual reports include a yearly review of rainfall at the Site and the surrounding area as shown in Appendix B for the most recent report. A long-term average (LTA) annual rainfall of 1,696 mm/year has been calculated from annual total rainfalls between 2000 and 2021. There was 1,320 mm of rainfall in total during 2021, which is 78% of the LTA and the third lowest since 2000.

Monthly rainfall, expressed as percentage of LTA, is presented in Table 2.2. This shows that:

- There was below average rainfall in 2021, especially during spring months with the lowest April rainfall recorded since 2000. Rainfall was lower than average in February (62% of monthly LTA) and over the spring months of March (39% of monthly LTA) and April (9% of monthly LTA) followed by a wetter May (168% of monthly LTA).
- While total recorded summer rainfall was lower in comparison to 2019 and 2020, the degree of water scarcity over the summer months was not as pronounced as the 2018 drought. The water scarcity in summer 2021 was prolonged and pronounced enough to cause a sustained decline in groundwater levels as is evident in the groundwater hydrographs over this time.

- November 2021 recorded its lowest monthly rainfall (32% of monthly LTA) since 2000.

Table 2.2 Monthly total rainfall as a percentage of the LTA for each month (last 20 years)

Month	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Jan	105%	112%	115%	69%	54%	113%	108%	154%	44%	100%	77%	136%	238%	149%	196%	41%	96%	54%	70%	95%
Feb	209%	75%	94%	50%	60%	151%	67%	34%	43%	147%	64%	69%	234%	99%	139%	72%	72%	80%	183%	62%
Mar	78%	73%	104%	81%	192%	107%	142%	82%	134%	39%	44%	86%	95%	110%	119%	91%	158%	119%	81%	39%
Apr	75%	83%	115%	145%	66%	65%	84%	109%	57%	47%	171%	85%	169%	36%	105%	121%	148%	82%	46%	9%
May	164%	111%	48%	74%	165%	149%	82%	85%	51%	91%	100%	166%	132%	134%	137%	44%	58%	27%	17%	163%
Jun	58%	90%	74%	113%	34%	171%	84%	68%	28%	163%	261%	79%	80%	97%	150%	95%	20%	121%	164%	61%
Jul	81%	137%	43%	83%	72%	168%	127%	211%	174%	122%	149%	58%	77%	115%	88%	36%	55%	28%	95%	79%
Aug	64%	17%	137%	54%	59%	87%	178%	107%	108%	74%	164%	129%	106%	150%	77%	113%	105%	100%	121%	59%
Sep	20%	30%	103%	123%	75%	71%	100%	57%	176%	155%	108%	77%	23%	92%	158%	107%	105%	171%	78%	110%
Oct	83%	40%	138%	95%	103%	40%	139%	92%	103%	92%	97%	155%	137%	54%	20%	81%	76%	94%	88%	114%
Nov	157%	98%	41%	100%	118%	44%	94%	168%	103%	66%	122%	89%	140%	182%	46%	57%	129%	81%	76%	33%
Dec	114%	74%	67%	46%	128%	82%	59%	89%	25%	119%	169%	167%	95%	229%	54%	67%	92%	95%	133%	83%
Annual Sum as % of annual LTA	104%	77%	91%	82%	95%	98%	106%	108%	85%	101%	125%	114%	131%	128%	100%	74%	93%	87%	98%	78%

Notes:

1 - Months shaded brown have less than 70% LTA rainfall for the respective month (85% for annual sum values given the lower variability of annual data).

2 - Months shaded blue have more than 130% LTA rainfall for the respective month (115% for annual sum values given the lower variability of annual data).

3 – LTA% is calculated from available rainfall data from 2000. Only the last 20 years of data are shown in the table.

2.4.2 Current Discharge Permit

Quarry discharge flows are measured at Torcoed Quarry Discharge and historically at Torcoed Fawr Quarry Discharge. Torcoed Fawr Discharge is currently not used as a discharge point and is no longer monitored (following the vandalisation of the equipment in 2019). Torcoed Quarry Discharge is monitored by water level measurements adjacent to a thin plate weir (the same was also true of the Torcoed Fawr Discharge). The water level at the weir is then converted to a flow rate.

Details of the consented discharge limits are summarised in Table 2.3. The discharge licence for the Site is presented in Appendix H.

Table 2.3 Quarry discharge limits

Discharge	Location	Consent number	Discharge permit limit since 20 Feb 2009 (l/s)
Torcoed	Northeast corner of Torcoed Quarry	BP0235501	73
Torcoed Fawr	Northwest of Torcoed Fawr quarry	BP0239301	61

2.4.3 Current site water management

The water will be treated before being discharged through settlement of solids at the sump which is currently in place in the existing site water management plan.

The environmental management system for this discharge is detailed in Appendix I.

2.4.4 Water quality

Water quality is monitored at the quarry discharge points and Garn Ffrwd spring (the Spring) on a monthly basis as defined in the current 2018 WMP (Stantec, 2017) for total suspended solids (TSS) and pH. These have limits of 60 mg/l for TSS and from pH 7 to 9. No significant issues have been recorded in terms of exceedances of these limits as summarised in the annual reports with only three exceedances of each limit since monitoring began in 2016.

Spot sampling of a wider range of determinands has also been carried out at the Site since 2016. These have been compared against Environmental Quality Standards for Fresh Water (EQS FW) below in Table 2.4 (the Spring) and Table 2.5 (the discharge locations) and against UK Drinking Water Standards (UKDWS) in Table 2.6 (the Spring) and Table 2.7 (the discharge locations). This shows that the only samples greater than the respective EQS values are for iron with one sample at each location greater than the 1 mg/l EQS FW. Similarly, compared to UKDWS only iron was recorded once above the 0.2 mg/l standard at FSHUS and the discharge locations. One sample of manganese was also recorded at the discharge locations above the 0.05 mg/l standard. Therefore, these results show that there are no sources of contamination in the Spring or the discharge locations.

Temperature was recorded during the 2003 trial at the location of augmentation into the Quarry Sink and at the fisheries. These were between 6 – 7.2°C at the Quarry Sink and between 9.8 – 10°C at the fisheries which shows it is likely that the passage of the augmentation water through the underground conduit has brought the water into equilibrium with normal underground temperatures. Therefore, the maximum temperature of the discharge will be ambient.

Table 2.4 Statistical summary for FSHUS against EQS FW (2016 – 2022)

Determinand	No. of Results	Unit	Min	Max	Mean	Median	Standard Deviation	5th Percentile	95th Percentile	# > LOD	% > LOD	EQS FW No. Exceeding	EQS FW % Exceeding	EQS FW Action Level
Field / lab parameters														
Conductivity- Electrical (Field)	35	µS/cm	300	850	451	420	127	-	-	35	100	0	0	-
Conductivity- Electrical 20deg	4	µS/cm	310	363	333	329	26.8	310	361	4	100	0	0	-
pH	37	pH	7.1	8.24	7.59	7.56	0.237	7.33	8.06	37	100	0	0	-
pH (Field)	36	pH	6.85	8.23	7.58	7.62	0.397	7.04	8.21	36	100	0	0	-
Major ions														
Alkalinity	10	mg/l	154	220	194	195	20.8	166	220	10	100	0	0	-
Calcium	12	mg/l	52	81.8	71	72.5	8.52	57.5	79.9	12	100	0	0	-
Chloride	12	mg/l	11	15.7	13.9	14.3	1.38	11.6	15.5	12	100	0	0	250
Magnesium	12	mg/l	1.4	2.28	2.03	2.05	0.24	1.64	2.26	12	100	0	0	-
Potassium	3	mg/l	0.835	2.77	1.74	1.6	0.975	0.912	2.65	3	100	0	0	-
Sodium	12	mg/l	6.3	9.48	7.84	7.84	0.846	6.66	9.17	12	100	0	0	-
Sulphate as SO4	12	mg/l	<2	15.1	10.4	11.6	4.67	n.d.	14.9	11	91.7	0	0	400
Minor ions														
Iron	12	mg/l	<0.019	28	2.35	0.0152	8.08	n.d.	12.6	6	50	1	8.33	1
Manganese	12	mg/l	<0.003	0.0115	0.00318	0.00211	0.00286	n.d.	0.00803	10	83.3	0	0	-
Nitrogen species														
Ammoniacal Nitrogen as N	12	mg/l	<0.2	0.05	n.d.	n.d.	n.d.	n.d.	0.1	1	8.33	0	0	-
Nitrate as NO3	13	mg/l	0.103	15	5.61	5.03	3.41	2.31	11	13	100	0	0	-
Nitrite as NO2	12	mg/l	<0.05	<0.05	n.d.	n.d.	n.d.	n.d.	n.d.	0	0	0	0	-
Nitrogen	2	mg/l	1.06	3.59	2.33	2.33	1.79	1.19	3.46	2	100	0	0	-
Other parameters														
Alkalinity (Bicarbonate)	4	mg/l	159	160	160	160	0.5	159	160	4	100	0	0	-
Ammonium	1	mg/l	<0.3	<0.3	n.d.	n.d.	n.d.	n.d.	n.d.	0	0	0	0	-
Orthophosphate	10	mg/l	<0.05	0.155	0.0567	0.0393	0.0457	n.d.	0.133	8	80	0	0	-
Total suspended solids	27	mg/l	<2	17.8	2.49	1	4.13	n.d.	11.9	14	51.9	0	0	-

Note: if significant number of results that are detected exceed action limit row is coloured as follows: 10 - 25% pale red, 25 - 50% darker red, >50% dark red. n.d. statistic not determinable. Mean statistics for non-detects are calculated at half the limit of detection.

If significant number of results exceed action limit where some are non-detects the '% Exceeding' column is coloured as follows: 10 - 25% pale blue, 25 - 50% darker blue, >50% dark blue. n.d. statistic not determinable.

Table 2.5 Statistical summary for discharge locations against EQS FW (2016 – 2022)

												EQS FW		
Determinand	**No. of Results**	**Unit**	**Min**	**Max**	**Mean**	**Median**	**Standard Deviation**	**5th Percentile**	**95th Percentile**	**# > LOD**	**% > LOD**	**No. Exceeding**	**% Exceeding**	**Action Level**
Field / lab parameters														
Conductivity- Electrical (Field)	42	µS/cm	380	1000	758	780	163	-	-	42	100	0	0	-
Conductivity- Electrical 20deg	14	µS/cm	201	775	557	591	176	250	759	14	100	0	0	-
pH	53	pH	7.1	8.09	7.82	7.89	0.193	7.5	8.05	53	100	0	0	-
pH (Field)	43	pH	0.84	8.81	7.87	7.85	1.17	7.54	8.76	43	100	0	0	-
Temperature (Field)	5	DegC	10	16	12.2	10.3	2.87	10	15.7	5	100	0	0	-
Major ions														
Alkalinity	14	mg/l	95	9950	1489	133	2850	102	6940	14	100	0	0	-
Calcium	17	mg/l	32.4	180	114	129	38.5	43.7	151	17	100	0	0	-
Chloride	15	mg/l	3.1	17.4	10.7	10.2	4.21	4.71	16.8	15	100	0	0	250
Magnesium	17	mg/l	1.67	10.7	6.33	7.76	2.78	1.81	9.18	17	100	0	0	-
Potassium	17	mg/l	1.47	2.55	1.89	1.9	0.294	1.5	2.41	17	100	0	0	-
Sodium	17	mg/l	2.53	9.96	7.12	7.45	1.69	4	9.06	17	100	0	0	-
Sulphate as SO4	15	mg/l	19.1	291	185	247	112	20.6	285	15	100	0	0	400
Minor ions														
Iron	17	mg/l	<0.019	7	0.423	n.d.	1.69	n.d.	1.42	4	23.5	1	5.88	1
Manganese	17	mg/l	<0.003	0.0559	0.00743	0.00228	0.0135	n.d.	0.0253	14	82.4	0	0	-
Nitrogen species														
Ammoniacal Nitrogen as N	17	mg/l	<0.2	1.13	0.208	n.d.	0.265	n.d.	0.643	4	23.5	0	0	-
Nitrate as NO3	15	mg/l	0.84	17.8	7.17	8.06	5.25	1	14.7	15	100	0	0	-
Nitrite as NO2	17	mg/l	<0.05	0.292	0.0592	n.d.	0.0681	n.d.	0.172	4	23.5	0	0	-
Nitrogen	14	mg/l	<1	4.51	2.23	2.26	1.43	n.d.	4.35	11	78.6	0	0	-
Other parameters														
Alkalinity (Bicarbonate)	16	mg/l	95	9950	1238	139	2603	103	5757	16	100	0	0	-
Ammonium	1	mg/l	0.458	0.458	0.458	0.458	-	0.458	0.458	1	100	0	0	-
Orthophosphate	14	mg/l	<0.02	<0.05	n.d.	n.d.	n.d.	n.d.	n.d.	0	0	0	0	-
Phosphate as PO4	8	mg/l	<0.05	<0.05	n.d.	n.d.	n.d.	n.d.	n.d.	0	0	0	0	-
Total suspended solids	46	mg/l	<2	2810	76.2	2.6	415	n.d.	230	30	65.2	0	0	-

Note: if significant number of results that are detected exceed action limit row is coloured as follows: 10 - 25% pale red, 25 - 50% darker red, >50% dark red. n.d. statistic not determinable. Mean statistics for non-detects are calculated at half the limit of detection.

If significant number of results exceed action limit where some are non-detects the '% Exceeding' column is coloured as follows: 10 - 25% pale blue, 25 - 50% darker blue, >50% dark blue. n.d. statistic not determinable.

Table 2.6 Statistical summary for FSHUS against UK DWS (2016 – 2022)

Determinand	No. of Results	Unit	Min	Max	Mean	Median	Standard Deviation	5th Percentile	95th Percentile	# > LOD	% > LOD	UKDWS No. Exceeding	UKDWS % Exceeding	UKDWS Action Level
Field / lab parameters														
Conductivity- Electrical (Field)	35	µS/cm	300	850	451	420	127	-	-	35	100	0	0	-
Conductivity- Electrical 20deg	4	µS/cm	310	363	333	329	26.8	310	361	4	100	0	0	-
pH	37	pH	7.1	8.24	7.59	7.56	0.237	7.33	8.06	37	100	0	0	-
pH (Field)	37	pH	6.8	8.23	7.56	7.59	0.412	7.4	7.45	37	100	0	0	-
Major ions														
Alkalinity	10	mg/l	154	220	194	195	20.8	166	220	10	100	0	0	-
Calcium	12	mg/l	52	81.8	71	72.5	8.52	57.5	79.9	12	100	0	0	-
Chloride	12	mg/l	11	15.7	13.9	14.3	1.38	11.6	15.5	12	100	0	0	250
Magnesium	12	mg/l	1.4	2.28	2.03	2.05	0.24	1.64	2.26	12	100	0	0	50
Potassium	3	mg/l	0.835	2.77	1.74	1.6	0.975	0.912	2.65	3	100	0	0	-
Sodium	12	mg/l	6.3	9.48	7.84	7.84	0.846	6.66	9.17	12	100	0	0	200
Sulphate as SO4	12	mg/l	<2	15.1	10.4	11.6	4.67	n.d.	14.9	11	91.7	0	0	250
Minor ions														
Iron	12	mg/l	<0.019	28	2.35	0.0152	8.08	n.d.	12.6	6	50	1	8.33	0.2
Manganese	12	mg/l	<0.003	0.0115	0.00318	0.00211	0.00286	n.d.	0.00803	10	83.3	0	0	0.05
Nitrogen species														
Ammoniacal Nitrogen as N	12	mg/l	<0.2	0.05	n.d.	n.d.	n.d.	n.d.	0.1	1	8.33	0	0	0.39
Nitrate as NO3	13	mg/l	0.103	15	5.61	5.03	3.41	2.31	11	13	100	0	0	50
Nitrite as NO2	12	mg/l	<0.05	<0.05	n.d.	n.d.	n.d.	n.d.	n.d.	0	0	0	0	0.1
Nitrogen	2	mg/l	1.06	3.59	2.33	2.33	1.79	1.19	3.46	2	100	0	0	-
Other parameters														
Alkalinity (Bicarbonate)	4	mg/l	159	160	160	160	0.5	159	160	4	100	0	0	-
Ammonium	1	mg/l	<0.3	<0.3	n.d.	n.d.	n.d.	n.d.	n.d.	0	0	0	0	0.5
Orthophosphate	10	mg/l	<0.05	0.155	0.0567	0.0393	0.0457	n.d.	0.133	8	80	0	0	-
Total suspended solids	27	mg/l	<2	17.8	2.49	1	4.13	n.d.	11.9	14	51.9	0	0	-

Note: if significant number of results that are detected exceed action limit row is coloured as follows: 10 - 25% pale red, 25 - 50% darker red, >50% dark red. n.d. statistic not determinable. Mean statistics for non-detects are calculated at half the limit of detection.

If significant number of results exceed action limit where some are non-detects the '% Exceeding' column is coloured as follows: 10 - 25% pale blue, 25 - 50% darker blue, >50% dark blue. n.d. statistic not determinable.

Table 2.7 Statistical summary for discharge locations against UK DWS (2016 – 2022)

Determinand	No. of Results	Unit	Min	Max	Mean	Median	Standard Deviation	5th Percentile	95th Percentile	# > LOD	% > LOD	UKDWS No. Exceeding	UKDWS % Exceeding	UKDWS Action Level
Field / lab parameters														
Conductivity- Electrical (Field)	42	µS/cm	380	1000	758	780	163	-	-	42	100	0	0	-
Conductivity- Electrical 20deg	14	µS/cm	201	775	557	591	176	250	759	14	100	0	0	-
pH	53	pH	7.1	8.09	7.82	7.89	0.193	7.5	8.05	53	100	0	0	-
pH (Field)	44	pH	0.84	8.81	7.85	7.85	1.16	7.88	8.03	44	100	0	0	-
Temperature (Field)	5	DegC	10	16	12.2	10.3	2.87	-	-	5	100	0	0	-
Major ions														
Alkalinity	14	mg/l	95	9950	1489	133	2850	102	6940	14	100	0	0	-
Calcium	17	mg/l	32.4	180	114	129	38.5	43.7	151	17	100	0	0	-
Chloride	15	mg/l	3.1	17.4	10.7	10.2	4.21	4.71	16.8	15	100	0	0	-
Magnesium	17	mg/l	1.67	10.7	6.33	7.76	2.78	1.81	9.18	17	100	0	0	50
Potassium	17	mg/l	1.47	2.55	1.89	1.9	0.294	1.5	2.41	17	100	0	0	-
Sodium	17	mg/l	2.53	9.96	7.12	7.45	1.69	4	9.06	17	100	0	0	200
Sulphate as SO4	15	mg/l	19.1	291	185	247	112	20.6	285	15	100	0	0	-
Minor ions														
Iron	17	mg/l	<0.019	7	0.423	n.d.	1.69	n.d.	5.95	4	23.5	1	5.88	0.2
Manganese	17	mg/l	<0.003	0.0559	0.00743	0.00228	0.0135	n.d.	0.0329	14	82.4	1	5.88	0.05
Nitrogen species														
Ammoniacal Nitrogen as N	17	mg/l	<0.2	1.13	0.208	n.d.	0.265	n.d.	1.04	4	23.5	0	0	-
Nitrate as NO3	15	mg/l	0.84	17.8	7.17	8.06	5.25	1	14.7	15	100	0	0	-
Nitrite as NO2	17	mg/l	<0.05	0.292	0.0592	n.d.	0.0681	n.d.	0.27	4	23.5	0	0	-
Nitrogen	14	mg/l	<1	4.51	2.23	2.26	1.43	n.d.	4.4	11	78.6	0	0	-
Other parameters														
Alkalinity (Bicarbonate)	16	mg/l	95	9950	1238	139	2603	103	5757	16	100	0	0	-
Ammonium	1	mg/l	0.458	0.458	0.458	0.458	-	0.458	0.458	1	100	0	0	-
Orthophosphate	14	mg/l	<0.02	<0.05	n.d.	n.d.	n.d.	n.d.	n.d.	0	0	0	0	-
Phosphate as PO4	8	mg/l	<0.05	<0.05	n.d.	n.d.	n.d.	n.d.	n.d.	0	0	0	0	-
Total suspended solids	46	mg/l	<2	2810	76.2	2.6	415	n.d.	239	30	65.2	0	0	-

Note: if significant number of results that are detected exceed action limit row is coloured as follows: 10 - 25% pale red, 25 - 50% darker red, >50% dark red. n.d. statistic not determinable. Mean statistics for non-detects are calculated at half the limit of detection.

If significant number of results exceed action limit where some are non-detects the '% Exceeding' column is coloured as follows: 10 - 25% pale blue, 25 - 50% darker blue, >50% dark blue. n.d. statistic not determinable.

2.4.5 Flow regimes associated with the Spring and Quarry Sink

The general pattern of flows in the Garn Ffrwd Spring (the Spring) is a rapid response to rainfall with an initial peaky response followed by a slower baseflow response. Table 2.8 compares the available average monthly flow data at the Spring with average monthly rainfall from 2007 to 2021 and Table 2.9 shows the number of days when average flows were below 8 l/s (the level below which augmentation of Garn Ffrwd Fisheries would be required if requested).

During 2021 the recorded mean daily flow at the Spring was below the point of augmentation on 44 days; the minimum daily flow of 4.49 l/s was recorded at the end of August, following a pronounced dry period. A succession of low flow days is evident in the data throughout July and August, coinciding with the dry weather over this period.

Mean daily summer flows below 8 l/s are not uncommon at Garn Ffrwd Spring as can be identified from the historical data displayed in the annual reports. The summer flows over 2021 were notably low but were in fact lower still on numerous previous years (such as 2006, 2010, 2014 and 2020).

Table 2.8 Comparison of average monthly flow at Garn Ffrwd Spring and total rainfall

Year	Total rainfall/average flow	Unit	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
2007	Total rainfall	mm	200	202	113	59	163	171	210	127	86	82	79	166
	Average flow	l/s	44	35	22	12	14	12	30	17	8	9	9	26
2008	Total rainfall	mm	191	89	151	76	89	84	160	260	122	283	168	119
	Average flow	l/s	40	20	15		10	6	11	34	18	32	5	
2009	Total rainfall	mm	273	46	87	99	92	68	265	157	69	188	302	180
	Average flow	l/s				14	13	12	22	27	36	27	41	31
2010	Total rainfall	mm	178	196	41	43	99	163	152	108	187	188	119	241
	Average flow	l/s	26	22	22	10	3		16	15	23	41	47	18
2011	Total rainfall	mm	158	162	37	39	89	146	137	97	168	168	106	215
	Average flow	l/s	31	28	14	17	12	13		12	22	22	25	40
2012	Total rainfall	mm	136	86	47	155	109	260	187	241	131	198	219	342
	Average flow	l/s	30	26										
2013	Total rainfall	mm	241	92	91	77	181	79	73	190	93	316	161	338
	Average flow	l/s												
2014	Total rainfall	mm	422	312	101	154	144	80	96	155	28	279	252	193
	Average flow	l/s					10	7*	4	3	5	8	27	
2015	Total rainfall	mm	12	132	116	33	146	96	144	220	112	110	327	465
	Average flow	l/s		19	15	14	15	8	17	15	15	45		
2016	Total rainfall	mm	348	212	140	81	142	117	67	108	192	40	83	109
	Average flow	l/s	58	32	20	15	13	11	14	15	19	12	13	13
2017	Total rainfall	mm	72	96	97	110	47	95	45	162	221	99	135	219
	Average flow	l/s	11	16		8	12	26	10	18	26	30	24	40
2018	Total rainfall	mm	171	96	168	135	63	20	69	154	127	155	232	186

Year	Total rainfall/average flow	Unit	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
	Average flow	l/s	41	30	26	23	14	7	6	9	15	18	33	36
2019	Total rainfall	mm	95	107	126	74	29	121	35	147	208	191	145	193
	Average flow	l/s	13	29	40	15	9	14	9			47	35	42
2020	Total rainfall	mm	123	245	86	42	18	164	119	178	94	179	137	270
	Average flow	l/s	28	40	26	7	4	8	16	19	16	30	44	54
2021	Total rainfall	mm	168	82	42	9	178	61	99	86	134	233	60	168
	Average flow	l/s	43	47			32	17	13	7	13	39	19	33

** Potentially suspect data – initial period following reinstallation of logger and no manual data to validate*

Table 2.9 Number of days when average flows at Garn Ffrwd Spring dropped below 8 l/s

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2007	0	0	0	0	0	0	0	0	16	17	17	0	50
2008	0	0	0		1	29	13	3	5	2	8		61
2009				0	0	0	0	0	0	2	0	0	2
2010	0	0	0	20	20		0	2	0	0	0	0	42
2011	0	0	1	0	0	0		0	0	0	0	0	1
2012	0												0
2013													0
2014						21*	30*						51
2015				0	0	0	15	9					24
2016	0	0	0	0	0	9	0	0	0	4	8		21
2017	8				15	0	10	0	0	0	0	0	33
2018	0	0	0	0	4			22	18	17	1	0	62
2019	4	0	0	0	0	1	0	0	0	0	0	0	5
2020	0	0	0	23	31	23	5	8	0	0	0	0	90
2021	0	0			0	0	0	21	23	0	0	0	44
Average from 2007 to 2021	1.2	0	0.1	4.8	6.5	8.3	7.3	5.4	5.6	4.2	3.4	0	32

Note: Some years contain incomplete data sets; see Figure 2.10 for summary of data gaps in the reporting period. Blank cells indicate no data available

** Potentially suspect data – initial period following reinstallation of logger and no manual data to validate*

3 Calculations

Based on the maximum rate of 8 l/s being pumped continuously for 24 hours, the maximum volume of discharge in a day will be 691.2 m^3.

The maximum instantaneous rate of discharge is 8 l/s which is the augmented flow rate when the sump is at full capacity.

4 Conclusions

Augmentation is a requirement when flow at the Spring drops below 8 l/s and therefore a discharge activity permit is needed. As shown in Section 2.4.4, the water quality of both the discharge water (Quarry Sump) and fisheries spring (the Spring which is representative of groundwater) is good. Therefore, the risk to groundwater and surface water from the proposed discharge is low.

The methodology for the 2003 augmentation test, including monitoring requirements, was agreed with the Environment Agency (now NRW) beforehand and no adverse effects on the quality of the spring flow were noted during the test. We have assumed that this historical work is sufficient to satisfy NRW that the environmental risks are acceptable.

It should be noted that the Spring flow rate at which augmentation will commence (8 l/s) was agreed for practical purposes and does not indicate that the occurrence of flows below that rate means that the quarry has had an impact on the spring flows. Indeed, the water balance calculations presented in the ES (Appendix E) suggest that flows below 8 l/s have occurred regularly at the Spring during dry weather in the past (prior to any quarry impacts occurring).

References

NRW (2022). Natural Resources Wales Environmental Permitting Charging Scheme 2022/23. *https://naturalresources.wales/about-us/what-we-do/how-we-regulate-you/our-charges/?lang=en.*

Stantec (2017). Water Management Plan (WMP): Torcoed/Torcoed Fawr/Crwbin Quarry.

Appendices

Appendix A of Application

Torcoed Water Management Plan

Report Reference: 331201249TN1
Report Status: Final

Technical Note:

Water Management Plan (WMP): Torcoed/Torcoed Fawr/Crwbin Quarry

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Prepared for Tarmac Services Ltd.

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Contents

1 Background

Tarmac Services Ltd. (Tarmac) was originally granted revised planning permission for the combined operation of Torcoed and Torcoed Fawr Quarries on 30 August 2007. Planning Condition 7 of this permission states that:

> *A Water Management Plan shall be submitted for the approval of the LPA within 6 months of the date of this planning permission [i.e. by 1 March 2008]. No deepening of the quarry below 143 mAOD shall take place until the expiry of 6 months from the date of submission or the Local Planning Authority's written approval of the Water Management Plan whichever is the sooner.*

The Environmental Statement (ES) that supported the application for the revised planning permissions at the quarries included a series of recommendations for monitoring and mitigation that it was proposed would form the basis of the WMP for the site (ESI, 2006). The finalised WMP was submitted in May 2008 (ESI, 2008) and has formed the structure for monitoring since then.

Planning permission for the consolidation of Torcoed quarry, Torcoed Fawr quarry and Crwbin quarry into a single operational unit was granted on the 29th August 2017 (application reference W/33265) with Condition 9 of this permission stating:

> *A Revised Water Management Plan for the Torcoed/Torcoed Fawr/Crwbin Quarry Complex shall be submitted for the approval of the Local Planning Authority within 6 months of the date of this permission. The Water Management Plan shall be implemented as approved.*

This document constitutes the revised WMP for the consolidated site and has been based upon the conclusions of the Hydrology and Hydrogeology Chapter 8 (undertaken by ESI) of the Environmental Statement (ES) submitted for this application (SLR, 2015). The draft WMP, updated here, was presented in Appendix 8.7 of the aforementioned ES.

This document specifies requirements for three key activities. These activities are:

- Monitoring (Section 2)
- Mitigation measures (Section 3)
- Annual review (Section 4)

It is intended that the WMP should be subject to regular review and modification as necessary in the light of ongoing data collection.

2 Monitoring

The monitoring network is presented in Tables 1 and 2 and on Figure 1 attached.

2.1 Potential receptors

Sites at which the Hydrogeological Impact Assessments in ESI (2015) indicated that a potentially significant impact was possible, and mitigation may be required, are:

- Well at Ysgubor-fach (W20) – and associated private water supply (PWS4).
- Private water supply at Ffrwd-gain (PWS3) thought to be abstraction from stream.
- Garn-ffrwd fish farm spring (S09).
- Crwbin Spring (S53)

The previous Hydrogeological Impact Assessments (ESI 2006, 2010, 2011) identified a potentially significant impact from the development on Garn-ffrwd fish farm spring (S09). Tarmac has entered into an agreement with the owner of the Garn-ffrwd fish farm to augment flows at the spring when they drop below a prescribed level (8 l/s or 690 m^3/d). This agreement requires monitoring of Garn Ffrwd spring, construction of a 10,000 m^3 sump within the quarry and development of a system to discharge water into the sink hole to the east of the site in order to augment flows at the spring. As the legal agreement is in place, this site is therefore not addressed in this WMP.

2.2 Key changes to 2008 WMP monitoring locations

Monitoring wells

A number of new monitoring wells were installed in 2013 at locations around the quarry to increase the monitoring network. Two of these locations were to act as monitoring wells as required under the 2008 WMP.

These new locations are as follows:

- BH3B/13 (limestone installation) – drilled as a substitute for 07/02 (never installed) which was required under the 2008 WMP
- BH7/13 (limestone installation) – drilled to as a substitute for 07/03 (never installed) which was required under the 2008 WMP
- BH8B/13 (limestone installation) - drilled to replace 97/01 which was blocked.
- BH6/13 (limestone installation) – replaces BH95/7 which was destroyed.
- Location 07/01 (limestone installation), as required under the 2008 WMP, was not accessible for drilling. Location BH1/13 in Crwbin quarry is currently monitored and is deemed a suitable replacement for 07/01.
- BH5/13 (sandstone installation) - installed to provide a replacement sandstone installation to BH95/4 which was destroyed by blasting.
- BH8A/13 (sandstone installation) was drilled as a requirement for an additional sandstone installation in the vicinity of the northern ridge as specified in Environment Agency (now Natural Resources Wales) letter reference SH/2011/112252/01-L01 dated 6 December 2011.

Ty'r Garn well & Ty'r Garn pool (S40)

Previous data requests to NRW had indicated that a deregulated abstraction "licence" is present for a well at the location previously known as "Ty'r Garn Well". This is a licence which was authorised for abstraction of less than 20 m^3 per day. However, following a number of local enquires and site walkovers this feature cannot be located and it is thought that it is no longer in existence or used. Previous monitoring has been undertaken at Ty'r Garn pool (S40) only rather than a well. S40 is a hollow with a seep at the bottom and it is considered that monitoring at this location does not provide any useful data. It has therefore been removed from the WMP.

Stream flows

The significance of any impact to S25-A is not considered to significant. Therefore, monitoring at this location is not included in the monitoring schedule. However, W20 is considered to be a suitable indicator of a potential impact on flows in this stream.

Further investigation at S25-B has indicated that there is no spring at this location, with it simply being a point on Crwbin Stream which emerges from Crwbin Spring (S53). As flow monitoring is undertaken at Crwbin Spring, flow monitoring at location S25-B has been removed from the WMP.

2.3 Monitoring requirements

The monitoring network is presented in Tables 1 and 2 and is summarised below:

- Monitoring will be undertaken at a total of eleven monitoring wells using data loggers set at 15 minute intervals and/or monthly dipping (see Table 1)
- Manual monitoring of spring flows will be carried at monthly intervals at Crwbin Spring (S53)[1];
- Monthly dips will be undertaken at three off site wells - Garn Bwll (W03), Garn Farm (W11) and Ysgubor-fach (W20);
- Monitoring of flows at Garn-ffrwd spring and the quarry discharges will be undertaken with data loggers set at 15 minute intervals;
- Rainfall will be measured by a data logger linked to a tipping bucket rain gauge;
- Water quality (suspended solids and pH) will be monitored at monthly intervals at the quarry discharges and Garn Ffrwd spring.

The monitoring scheme is considered to be appropriate for determining whether any impacts have been caused at the potentially vulnerable receptors by future dewatering as, not only will these receptors be monitored, but there are also other monitoring points between the quarry and the receptors which will provide supporting information.

[1] Subject to access permissions

Table 1: Monitoring scheme at Torcoed Quarry

Monitoring point	Monitoring methodology and frequency	Remark
Monitoring wells in Old Red Sandstone		
BH95/3	Dipping at monthly intervals	Currently monitored.
BH5/13	Data loggers supported by dipping at monthly intervals	Currently monitored. If appropriate, the monitoring may be reduced to monthly manual readings after an appropriate period of monitoring (two to three years).
BH8A/13		
Monitoring wells in Penderyn Oolite and Cilyrychen Limestone		
BH6/13	Dipping at monthly intervals	Currently monitored.
BH1/13	Data loggers supported by dipping at monthly intervals	Currently monitored. If appropriate, the monitoring may be reduced to monthly manual readings after an appropriate period of monitoring (two to three years).
BH3B/13		
BH4A/13		
BH8B/13		
BH9/13		
Monitoring wells in Mynydd-y-Garegg Limestone		
BH17	Dipping at monthly intervals	Currently monitored.
BH7/13	Data loggers supported by dipping at monthly intervals	Currently monitored. If appropriate, the monitoring may be reduced to monthly manual readings after an appropriate period of monitoring (two to three years).
Quarry discharge flows		
Torcoed discharge	Data loggers supported by monthly manual measurements	Currently monitored.
Torcoed Fawr discharge		
Flow measurements		
Garn-Ffrwd (S09)	Data loggers supported by monthly manual measurements	Currently monitored
Crwbin Spring (S53)	Manual measurement on a monthly basis	
Wells		
Garn Bwll (W03) Ysgubor-fach (W20)	Dipping at monthly intervals	Currently monitored. W03 to act as indicator of drawdown effects to the east.
Garn Farm (W11)	Dipping at monthly intervals	Included to validate conceptual model.
Rainfall measurements		
Rainfall gauge	Data loggers with monthly downloads	Currently monitored

Table 2: Water quality monitoring scheme at Torcoed Quarry

Name and feature	Monitoring methodology and frequency
FSHUS (S09) - Garn-ffrwd spring	Water quality (suspended solids and pH) will be monitored at monthly intervals
Quarry discharge points*	

** Torcoed discharge and Torcoed Fawr discharge. Samples only taken when adequate flow is present.*

3 Mitigation Measures

3.1 General approach

The objective of the mitigation measures defined in this WMP is to develop a robust and practical system that protects the receptors that were identified in the ES (ESI, 2015) as being potentially at risk as a result of the quarry operation. The methodology also aims to protect the quarry operator from excessive/unnecessary costs from excessive or impractical mitigation requirements.

The general approach for mitigation at this site is as follows:

- Carry out baseline monitoring to define the 'natural' range of conditions at the site. For each relevant receptor define a target level.
- Derogation is considered to have occurred when the monitoring data fall below the target level.
- Once derogation has been identified, appropriate mitigation measures will be implemented.

Note that the definition of target levels based on historic data series assumes that future climatic conditions are similar to those in the baseline period. If future climate conditions are significantly different to current conditions, the selection of target levels should be reconsidered.

The mitigation measures discussed in this section fall into three categories as follows:

- Maintenance of water levels
- Maintenance of stream flows
- Protection of water quality

3.2 Maintenance of water levels

The relevant receptors (shown in Figure 1) are:

- Ysgubor-fach (W20) is sourced from the Old Red Sandstone which is not considered to be at risk from the proposed development of the quarry. However, the presence of the Crwbin Fault may allow some water to enter the Old Red Sandstone from the Carboniferous Limestone in this area and there is thus some potential for impact. These impacts are therefore considered to be of low probability but potentially significant.
- Private water supply at Ffrwd-gain (PWS3) is thought to be an abstraction from the stream. The potential impact is deemed to be moderate. Monitoring of W20 will be used as an indicator of possible impact on this location.

Note Garn Bwll (W03) will be monitored to act as an additional indicator of drawdown effects to the east but the degree of impact is considered to be minor and no mitigation is considered necessary.

3.2.1 Target levels

Water levels at W20 have been monitored since November 2008 as summarised in Table 3.

Table 3 Water levels statistics (mBDAT) at well locations

	Ysgubor-fach (W20)
Min	0.04

Average	0.11
Max	0.19
Target	0.44

Note: water level statistics cover data from start of data collection (see above) to September 2017

The target levels for this site is set at 0.25 m lower than the lowest recorded value (i.e. max value in Table 3) as shown in Table 3.

If water levels at W20 drop below the Target Level over two consecutive months, the quarry operator will notify the MPA of this occurrence in writing within four weeks of recording the data, and provide details of any proposed additional monitoring or other investigations to identify the cause of the fall. The investigations will include an assessment of the actual vulnerability of any potentially vulnerable receptors on the groundwater pathway affected if this has not already been carried out.

If water levels at W20 drop below the target levels for two consecutive monthly readings, it will be assumed that derogation has occurred unless:

- It can be shown to the satisfaction of the Mineral Planning Authority that the low water level has been caused by a mechanism other than dewatering at the quarry (e.g. background climate factors); or
- It can be shown to the satisfaction of the Mineral Planning Authority that the fall in water levels has not had a significant impact on the utility of the water supply.

3.3 Mitigation

In the event of derogation occurring, options for mitigation will be explored in the following order:

- Lowering of pumps;
- Deepening of boreholes/wells;
- Provision of alternative supplies (mains water in the event of complete derogation) or short term supplementary supplies if derogation is temporary.

The quarry operator will notify the MPA in writing of any occurrence of derogation within four weeks of noting the occurrence of such derogation outlining the proposed mitigation measures. The quarry operator will make reasonable endeavors to implement any mitigation measures within 12 weeks of noting the occurrence of derogation.

3.4 Maintenance of spring flows

Garn-Ffrwd (S09) – This spring may be affected by the development of the quarry, it is subject of a separate legal agreement and therefore is not addressed in this WMP. In the ES it was identified that some residual pumping to Garn-Ffrwd spring will be required following cessation of quarrying. Tarmac's obligation under this agreement only ceases once flows and quality at the spring have been restored to the owner's reasonable satisfaction.

Crwbin Spring (S53) – ESI (2015) estimate the flows from this receptor are expected to reduce by 50% and 100% during the proposed development. The Crwbin Spring is not subject to any specific ecological designations and it represents one of many minor watercourses joining the Gwendraeth Fach in this area. As such, the degree of impact caused by the development is unlikely to be ecologically significant. Mitigation measures for this receptor are not considered to be feasible given the location of the spring (on the far side of a road and housing) and the long term nature of the effect.

3.5 Water quality

The quality standard to be met by any new discharge for augmentation purposes will be set by a discharge consent to be issued by Natural Resources Wales. If necessary, settling lagoons or other appropriate quality control systems will be implemented to ensure compliance with the conditions of the discharge consent.

4 Annual review

The data collected will be forwarded to Carmarthenshire County Council (CCC), as the MPA, on an annual basis.

The annual report will present the following data:

- groundwater levels;
- groundwater quality;
- dewatering rates;
- stream flow;
- water quality;
- augmentation volumes to date.

The content of the WMP will be reviewed and agreed by CCC, Natural Resources Wales and Tarmac every two years. The aim of these reviews will be to ensure that the WMP continues to safeguard the water resources and conservation interest of the catchment without imposing unnecessary or impractical constraints on the development. Any party will have the right to call interim meetings to discuss specific issues that may arise.

5 References

ESI Ltd. (2006). Torcoed and Torcoed Fawr Quarries: Hydrogeological Impact Assessment

ESI Ltd. (2008). Water Management Plan (WMP): Torcoed/Torcoed Fawr Quarry

ESI Ltd., (2010). Crwbin Quarry: Hydrogeological Impact Assessment Report. Ref 6257R4.

ESI Ltd., (2011). Crwbin Quarry: Torcoed Quarry Hydrogeological Impact Assessment : Northern Extension. Report Ref 60449R1.

SLR., (2015) Torcoed, Torcoed Fawr and Crwbin quarries Carmarthenshire. South west extension and consolidation application. Environmental Statement Volume 1.

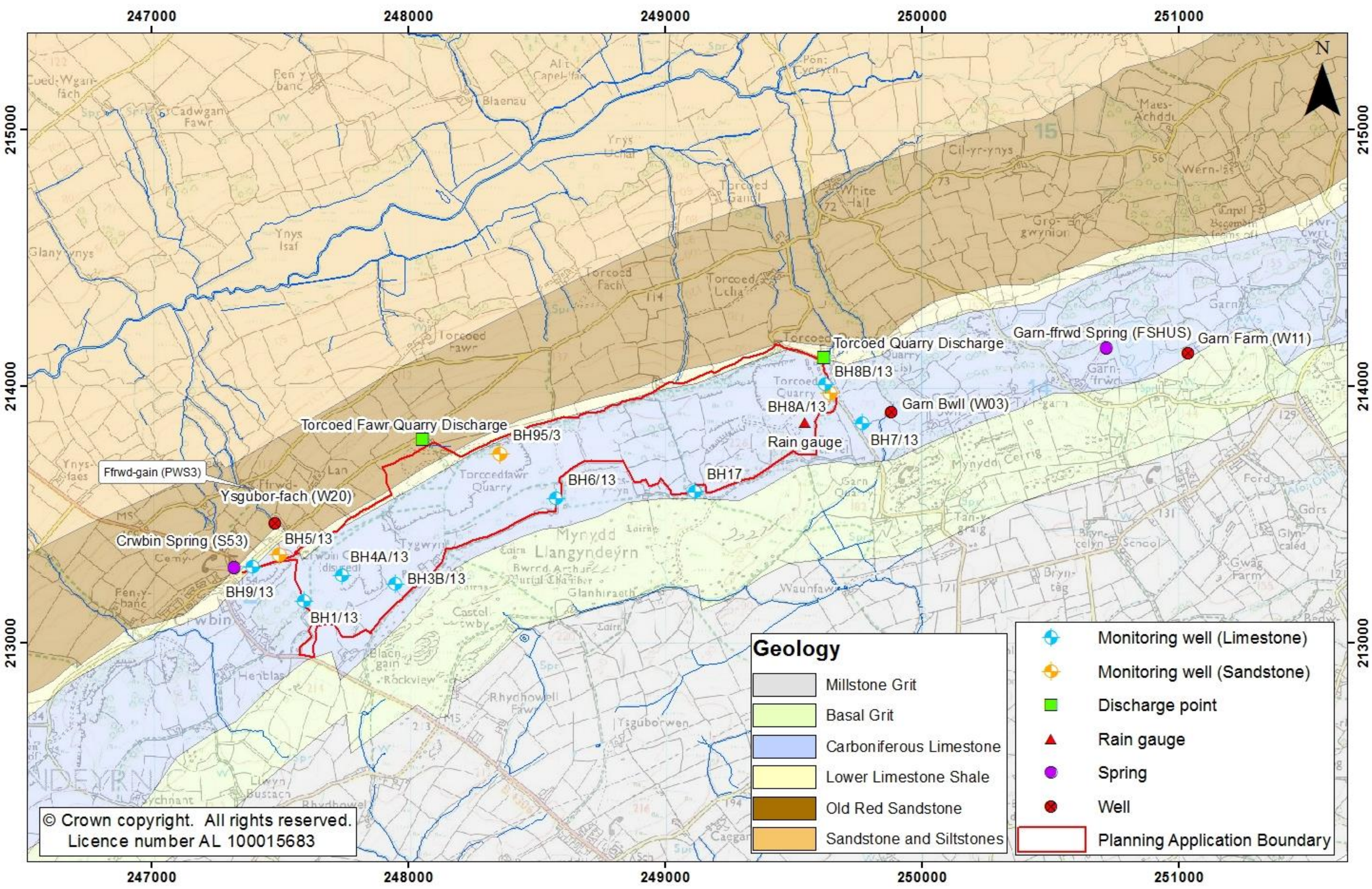

Figure 1 Monitoring locations

Appendix B of Application

Torcoed Quarry 2021 Annual Hydrometric Monitoring Report

Report Reference: 331201249TN1
Report Status: Final

Stantec

Torcoed Quarry 2021 Annual Hydrometric Monitoring Report

31 May 2022

Torcoed Quarry 2021 Annual Hydrometric Monitoring Report

Prepared for

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Report reference:

330201675R1D1, July 2022

Report status:

Draft

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Torcoed Quarry 2021 Annual Hydrometric Monitoring Report

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	Name	Signature
Author	Vladimir Kohut	
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Revision record:

Issue	Date	Status	Comment	Author	Checker	Reviewer
1	05/05/2022	Draft	Draft for Tarmac comment	VXK	RAH	RAG

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APPENDICES

1 Introduction

1.1 Planning context

Tarmac Trading Ltd (Tarmac) operates Torcoed Limestone Quarry (the Site) in Carmarthenshire, South Wales. The Site now includes three separate former quarries – Crwbin Quarry in the west (not currently being worked), the original Torcoed Quarry in the east, and Torcoed Fawr Quarry in between the two. These areas are labelled in Figure 2.1.

Tarmac was granted revised planning permission for the combined operation of Torcoed and Torcoed Fawr Quarries on 30 August 2007. A Water Management Plan (WMP) was finalised in May 2008 which set out the monitoring requirements for the Site.

Planning permission to consolidate Torcoed, Torcoed Fawr and Crwbin quarries into one active site (planning application reference W/33265) was granted in August 2017. An updated WMP was submitted in February 2018 to Natural Resources Wales (NRW) as a condition of the planning permission. Approval of the updated WMP was confirmed in November 2018; which now supersedes the previous, 2008 WMP. The current WMP is included in Appendix A and sets out all hydrometric monitoring currently required at the Site.

The reporting of hydrometric monitoring at the Site is carried out as prescribed in the currently approved 2018 WMP. This Annual Monitoring Report covers data collected in 2021, from 1st January to 31st December (the Reporting Period).

Stantec UK Ltd (Stantec) (formerly as ESI[1]) has been commissioned by Tarmac to operate the data management and reporting functions of the monitoring program since 2001. The data are reviewed at monthly intervals and advice is given to Tarmac where data quality issues occur.

1.2 Report structure

The structure of this report is as follows:

- Section 2 discusses the performance of the individual monitoring sites and reviews the data collected;
- Section 3 presents a discussion of the results; and
- Section 4 summarises the conclusions.

[1] ESI became part of Stantec in 2018

2 Annual Hydrometric Monitoring Review

2.1 Quarry operations in the Reporting Period

Over the Reporting Period, quarrying activity has been concentrated in the "Ty Gwyn" area of the Torcoed Fawr excavation. Extraction has progressed southwards on the 205, 190 and 175 mAOD benches while tipping of shales has been taking place in the "CRH Ramp Tip" in the centre of Torcoed Fawr. No excavation has taken place in the Crwbin, McAlpine or Torcoed areas of the quarry.

During the Reporting Period, a dual monitoring borehole (BH1A/21 and BH1B/21) and a single monitoring borehole (BH2/21) were installed to assess basal heap in the Brownstones Formation that forms part of the Lower Old Red Sandstone Group. Manual groundwater dips at these locations have been collected from July 2021 and groundwater level loggers were installed in November. These boreholes are not included in the current WMP and are not discussed in this report.

In 2022, it is proposed to continue progressing the Ty Gwyn faces southward and begin forming the restoration tip in the area separating Torcoed and Torcoed Fawr quarries. Pending a further geotechnical review, it is proposed to expand the final bench at 118 mAOD to the full available area in Torcoed Quarry as per the approved design, before earthmoving the old quarry tips to infill the void and allow extraction to progress east under the now-removed asphalt plant.

There were no changes to the quarry pumping arrangements over the Reporting Period. Water is pumped from the groundwater-fed sump and is discharged into Torcoed Quarry Discharge Point on the northeast boundary of the Site.

2.2 Performance of the monitoring network

This section describes the performance of the individual monitoring sites and reviews the data collected. Figure 2.1 shows hydrometric monitoring locations. The hydrogeological and hydrological behaviour of the system is assessed. This report assumes that the reader is familiar with the current conceptual site model as described by Stantec (formerly ESI) as part of an SLR (2015) Environmental Statement for the Site in which Stantec presented the hydrogeological conceptual site model (Chapter 8).

Automated water level, rainfall and discharge data are collected using pressure transducers and tipping bucket gauges (for rainfall) connected to data loggers. The logger data are downloaded monthly, and a manual level is collected to provide a check on the accuracy of the water level loggers. Where there is a discrepancy between the logger and the manual reading this is noted and investigated, if required.

The performance of each monitoring site is summarised in Table 2.1 below. Table 2.1 includes information on:

- what monitoring at each location is required as part of the current 2018 WMP;

- the recent data record obtained and the completeness of the data record. Any gaps in the data record are noted in this table with the reason for data gaps summarised; and
- the status of loggers at each monitoring point and any remedial actions which may be required.

It is noted that due to the loss of key personnel at Tarmac in March 2013, some significant data gaps are present in the dataset throughout 2013 to 2015 as hydrometric monitoring duties were handed over to a third party and difficulties were experienced during the process of getting acquainted with the Site and its requirements. Monitoring duties were taken on by Stantec in February 2016. Tarmac briefly took over the monitoring duties at the Site between November 2018 and January 2019 inclusive, with Stantec taking on the role again from February 2019 until January 2020. Data collection is now undertaken by BCL Hydro.

Figure 2.2 graphically summarises the data coverage over the Reporting Period. Coverage over the Reporting Period is fairly complete although there were some manual readings missed due to missing keys and locations being obstructed or inaccessible. Some water levels logger data are unavailable due to malfunctioning of the loggers.

Figure 2.1 Monitoring locations plan

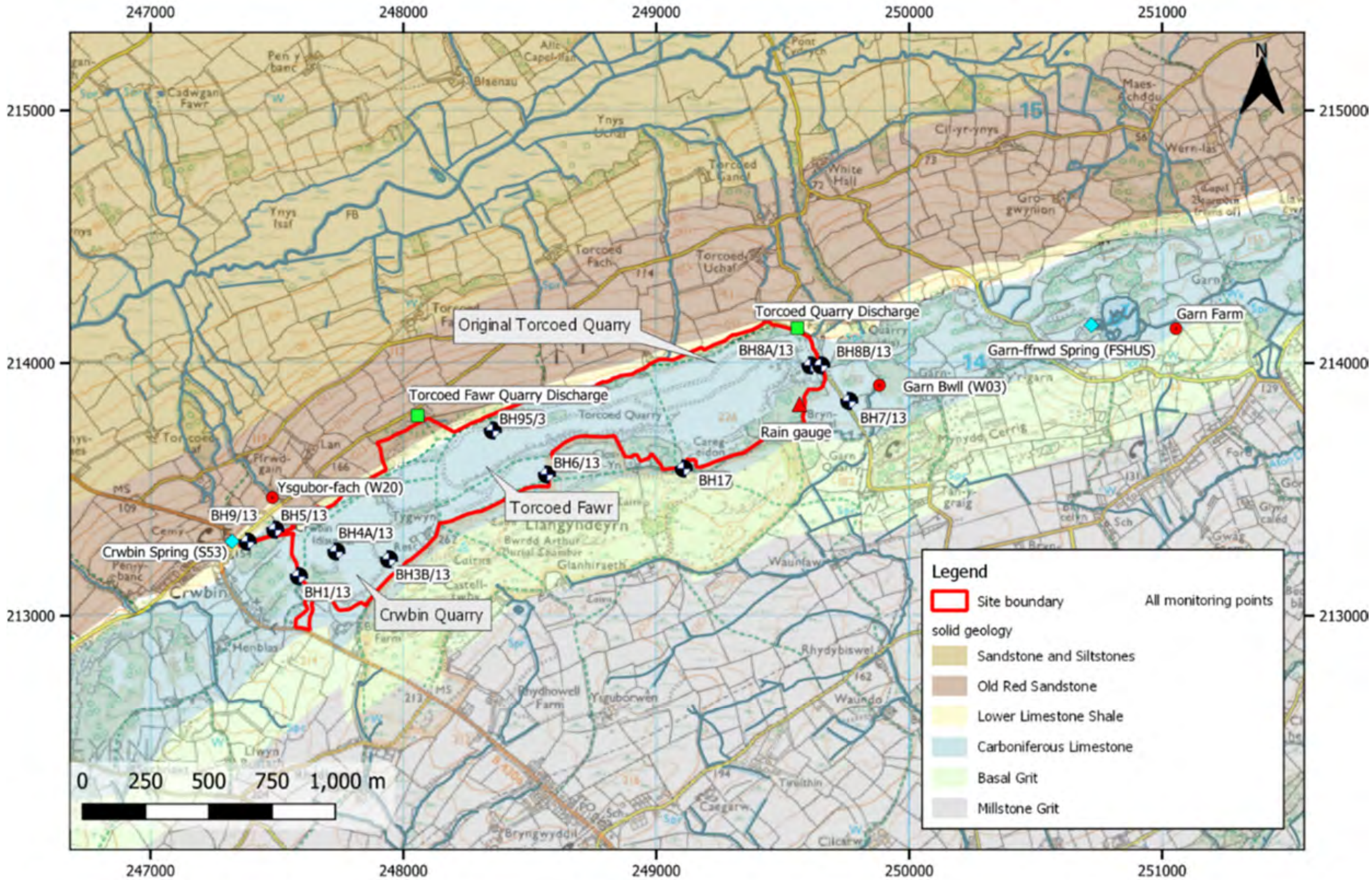


Figure 2.2 Reporting Period data coverage summary 2021

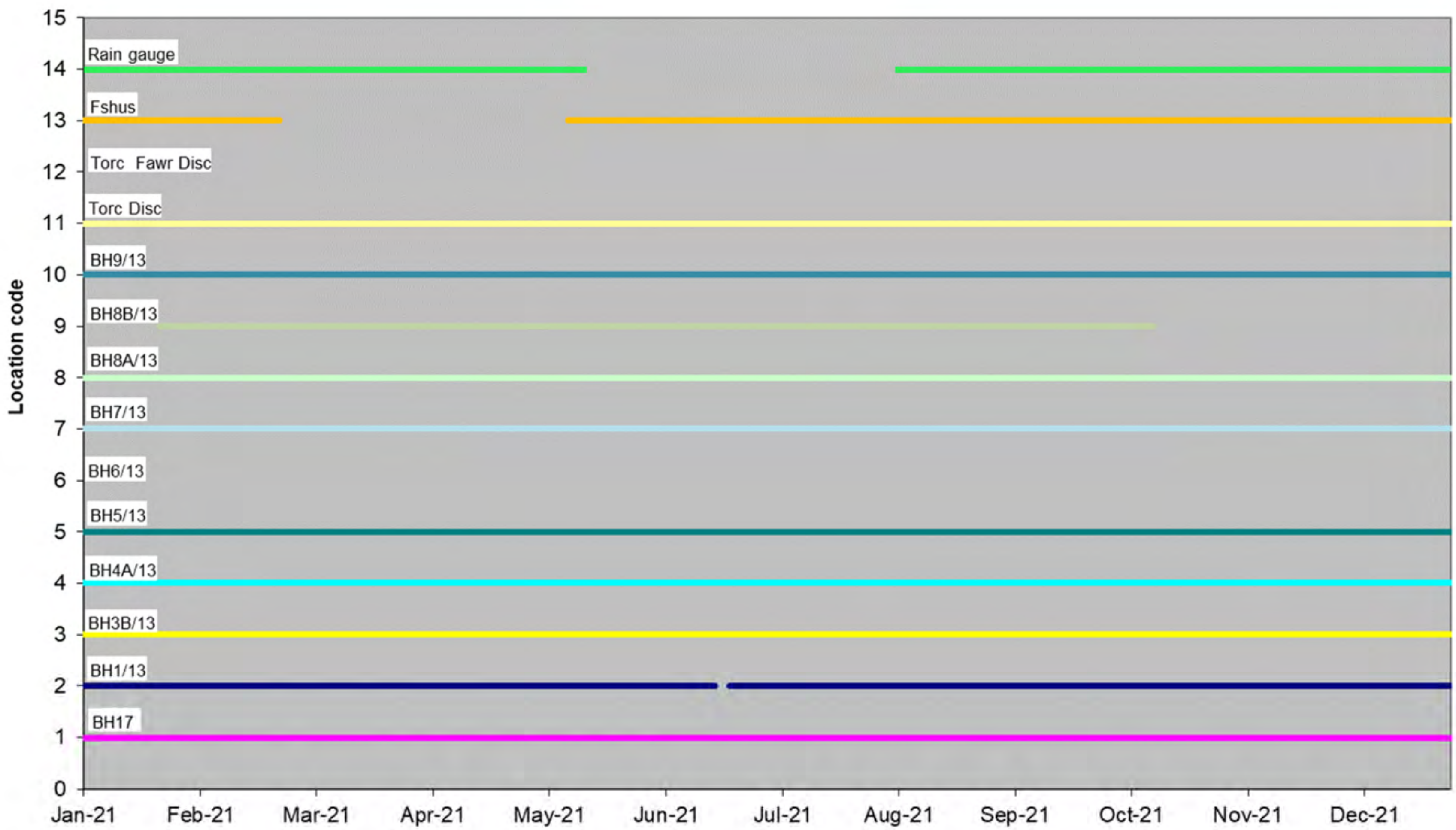


Table 2.1 Summary of 2021 performance of hydrometric monitoring issues

Location ID	Location	Type of monitoring required in WMP	No. of days data available in Reporting Period	% of days data available in Reporting Period	Data gap periods	Reason for gaps in data record	Logger currently fully functional?	Action needed?
Boreholes (Limestone)								
BH17	S of Torcoed Quarry	Logger & manual dips	Logger:365 Manual:12	Logger:100 Manual:100	None	-	Yes	No
BH1/13	Crwbin Quarry	Logger & manual dips	Logger:362 Manual: 11	Logger:92 Manual:92	June and May	Unknown 3 day data loss in June, missing keys in May	Yes	No
BH3B/13	SW of Torcoed Fawr quarry	Logger & manual dips	Logger:365 Manual:12	Logger:100 Manual:100	None	-	Yes	No
BH4A/13	Crwbin Quarry	Logger & manual dips	Logger:365 Manual:10	Logger:100 Manual:92	May and October	Missing key and key snapped inside the lock	Yes	No
BH7/13	E of Torcoed Quarry	Logger & manual dips	Logger:365 Manual:12	Logger:100 Manual:100	None	-	Yes	No
BH8B/13	NE corner of Torcoed Quarry	Logger & manual dips	Logger:322 Manual:8	Logger:88 Manual:75	01-22/01,14/10-31/12 Manual data missing - January, February, October.	Logger malfunction and BH obstructed by parked car	Yes	No
BH9/13	W of Crwbin Quarry	Logger & manual dips	Logger:365 Manual: 12	Logger:100 Manual:100	None	-	Yes	No
Boreholes (Old Red Sandstone)								
BH5/13	Crwbin Quarry	Logger & manual dips	Logger:365 Manual:12	Logger:100 Manual:100	None	-	Yes	No
BH6/13	S of Torcoed Fawr	Logger & manual dips	Logger:0 Manual:0	Logger:0 Manual:0	No data over 2021	Location has been quarried out	No	No
BH8A/13	NE corner of Torcoed Quarry	Logger & manual dips	Logger:365 Manual:12	Logger:100 Manual:100	None	-	Yes	No

Location ID	Location	Type of monitoring required in WMP	No. of days data available in Reporting Period	% of days data available in Reporting Period	Data gap periods	Reason for gaps in data record	Logger currently fully functional?	Action needed?
BH95/3	N of Torcoed Fawr quarry	Manual dips	Manual:8	Manual:67	January, February, May and June	No access due to Site vehicle and staff unavailability	N/A	No
Quarry discharge								
Torcoed Discharge	NE corner of Torcoed Quarry	Logger & manual dips	Logger:365 Manual:12	Logger:100 Manual:100	None	-	Yes	No
Torcoed Fawr Discharge	Northwest of Torcoed Fawr quarry	Logger & manual dips	Logger:0 Manual: 0	Logger: 0 Manual: 0	Whole Review Period	Location no longer used as discharge point	No	No
Spring/stream flows								
FSHUS (S09)	Garn-ffrwd Spring (Fisheries)	Logger & manual readings	Logger:258 Manual:12	Logger:71 Manual:100	23/02 - 09/05	Logger malfunction, replacement installed	Yes	No
Crwbin Spring (S53)	W of Torcoed Fawr Quarry	Monthly manual gauging	12	100	None	-	N/A	No.
Rainfall								
Rain gauge	SW of Torcoed Quarry	Data logger	284	78	16/05 - 04/08	Rain gauge blocked by debris. Was cleaned and returned to fully operational	Yes	No
Well levels								
Garn Bwll (W03)	E of Torcoed Quarry	Month dips	12	100	None	-	N/A	No

Location ID	Location	Type of monitoring required in WMP	No. of days data available in Reporting Period	% of days data available in Reporting Period	Data gap periods	Reason for gaps in data record	Logger currently fully functional?	Action needed?
Garn Farm (W11)	E of Torcoed Quarry	Month dips	12	100	None	-	N/A	No
Ysgubor Fach (W20)	W of Torcoed Fawr Quarry	Month dips	12	100	None	-	N/A	No

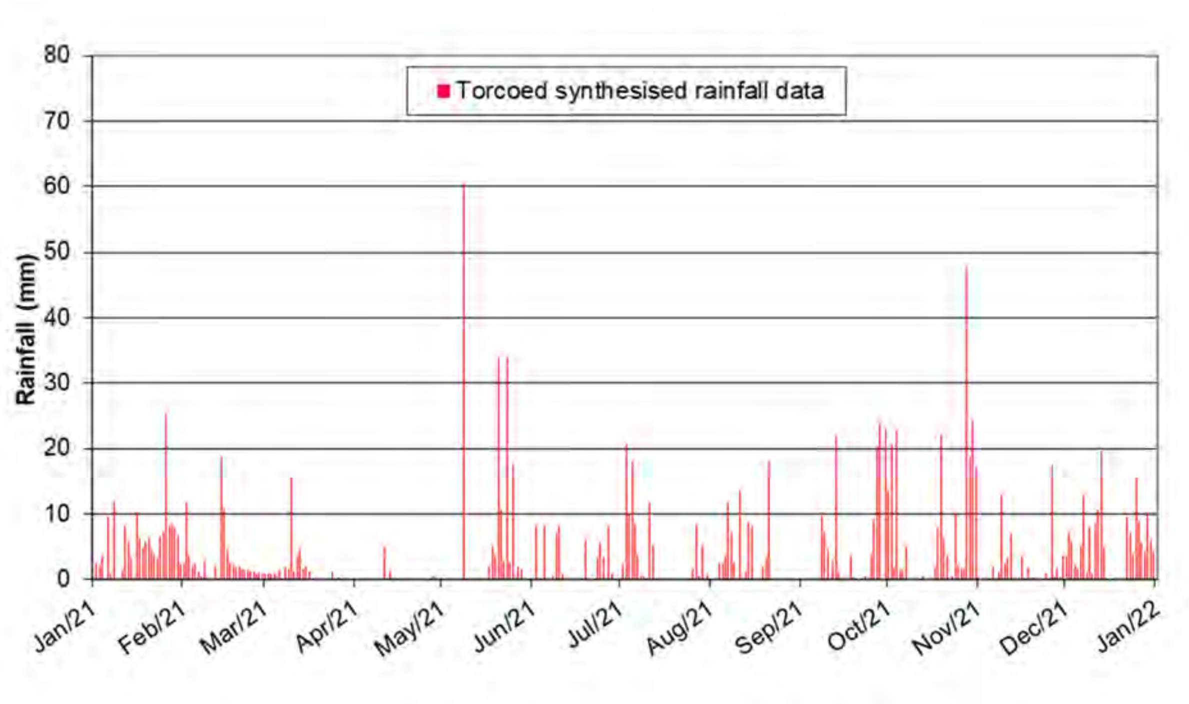
2.3 Rainfall data

The rainfall logger at the Site (the "Torcoed rain gauge") was replaced on the 9th August 2016 after which time rainfall data has been successfully collected at the Site. Prior to this, a number of unsuccessful attempts to replace and repair the logger resulted in a data gap spanning a number of years.

Using the methodology described in Appendix C, historical rainfall data have been synthesised for the period of missing data using rainfall data from the Gorslas, Margam Park and Hirwaun rain gauges operated by NRW. A correlation has been calculated based on the ratio of the long-term average (LTA) rainfall measured at Torcoed and at these external gauges. Multiplication of external rainfall data by this correlation factor enables artificial data of a correct magnitude to be synthesised for periods of missing Torcoed data. Synthesised data are also routinely used in place of the Torcoed rain gauge data (where Torcoed data are missing) or where significant variance (defined in Appendix C) between Torcoed data and the external gauges exists, using an algorithm. This allows for a routine quality check of this crucial data set. Data resulting from this process (combined Torcoed and adjusted third-party data) are presented in Figure 2.3 and Figure 2.4.

Rainfall data from the Torcoed rain gauge are missing from 5th May – 4th August 2021 due to the logger blockage. The rainfall logger data from Hirwaun rain gauge and Gorslas rain gauge are complete over the Reporting Period (Figure 2.3). The rainfall data from Margam rain gauge are missing from 2nd – 31st December due to the next monitoring visit being carried out too long after the end of the Reporting Period. Missing data will be requested from Natural Resources Wales (NRW) during 2022.

Figure 2.3 Daily rainfall dataset over 2021



An LTA annual rainfall of 1,696 mm/year has been calculated from annual total rainfalls between 2000 and 2021. There was 1,320 mm of rainfall in total during the Reporting Period (2021), which is 78% of the LTA. Figure 2.4 shows monthly totals between 2000 and 2021 (inclusive) as well as the cumulative departure from the mean (CDM) over this period.

Table 2.2 compares monthly rainfall totals from the Reporting Period with previous Reporting Periods and the monthly LTAs. This shows there was below average rainfall in 2021, especially during spring months with the lowest April rainfall recorded since 2000.

Rainfall was lower than average in February (62% of monthly LTA) and over the spring months of March (39% of monthly LTA) and April (9% of monthly LTA) followed by a wetter May (168% of monthly LTA). While total recorded summer rainfall was lower in comparison to 2019 and 2020, the degree of water scarcity over the summer months was not as pronounced as the 2018 drought as shown in Figure 2.4. The water scarcity in summer 2021 was prolonged and pronounced enough to cause a sustained decline in groundwater levels as is evident in the groundwater hydrographs over this time.

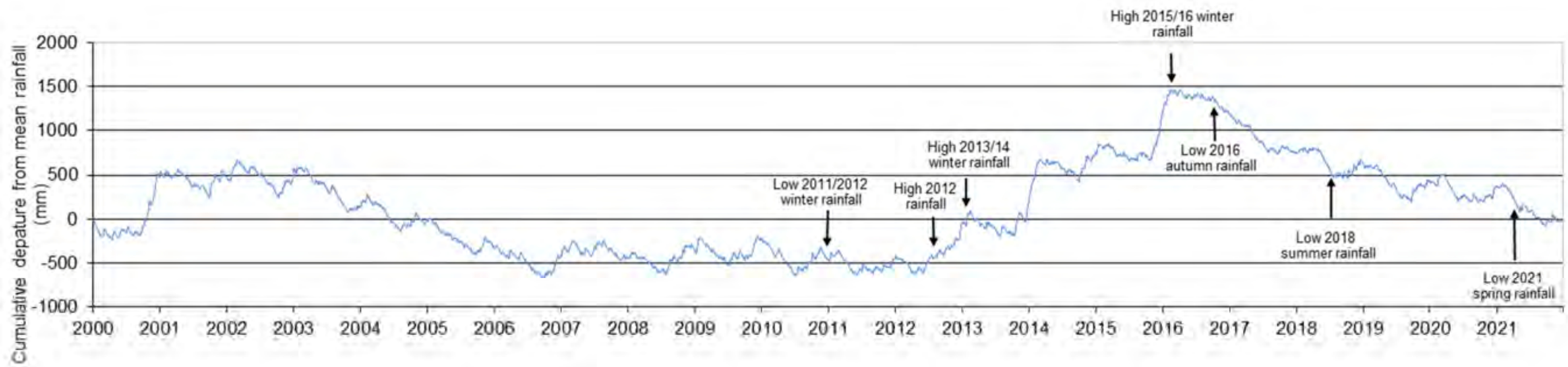
Over the autumn months of September and October, rainfall data was relatively close (±4%) to the LTA for each respective month with the exception of November 2021 which recorded its lowest monthly rainfall (32% of monthly LTA) since 2000. As described above, the total rainfall over the whole year was below (78% of) the LTA, the third lowest since 2000.

The results in Table 2.2 and Figure 2.4 show some patterns that are useful to note when interpreting other hydrometric data for this period. Key periods include:

- The severe drought in 2003;

- Wet summers of 2007 to 2012;
- High autumn/winter rainfall in 2013/2014;
- High annual total 2012, 2014 and 2015;
- High winter rainfall in 2015/2016;
- Low autumn/winter rainfall in 2016 continuing into 2017;
- Low winter rainfall in 2017/2018;
- Dry summer in 2018; and
- Low spring/summer rainfall 2021.

Figure 2.4 Cumulative departure from mean rainfall and monthly sum rainfall at Torcoed Quarry



Note: CDM calculated using 1961 - 2021 mean daily rainfall value

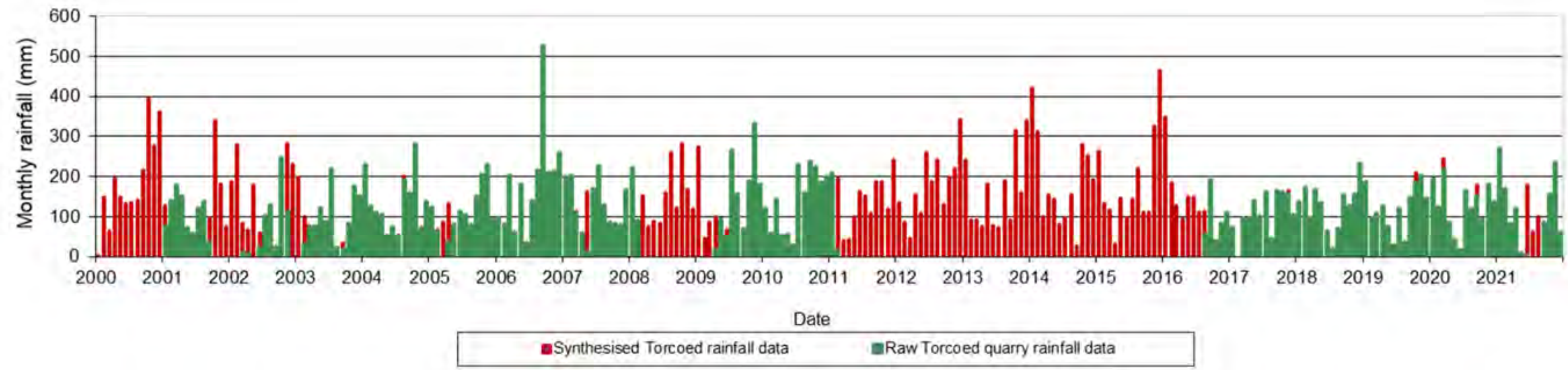


Table 2.2 Monthly total rainfall as a percentage of the LTA for each month (last 20 years)

Month	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Jan	105%	112%	115%	69%	54%	113%	108%	154%	44%	100%	77%	136%	238%	149%	196%	41%	96%	54%	70%	95%
Feb	209%	75%	94%	50%	60%	151%	67%	34%	43%	147%	64%	69%	234%	99%	139%	72%	72%	80%	183%	62%
Mar	78%	73%	104%	81%	192%	107%	142%	82%	134%	39%	44%	86%	95%	110%	119%	91%	158%	119%	81%	39%
Apr	75%	83%	115%	145%	66%	65%	84%	109%	57%	47%	171%	85%	169%	36%	105%	121%	148%	82%	46%	9%
May	164%	111%	48%	74%	165%	149%	82%	85%	51%	91%	100%	166%	132%	134%	137%	44%	58%	27%	17%	163%
Jun	58%	90%	74%	113%	34%	171%	84%	68%	28%	163%	261%	79%	80%	97%	150%	95%	20%	121%	164%	61%
Jul	81%	137%	43%	83%	72%	168%	127%	211%	174%	122%	149%	58%	77%	115%	88%	36%	55%	28%	95%	79%
Aug	64%	17%	137%	54%	59%	87%	178%	107%	108%	74%	164%	129%	106%	150%	77%	113%	105%	100%	121%	59%
Sep	20%	30%	103%	123%	75%	71%	100%	57%	176%	155%	108%	77%	23%	92%	158%	107%	105%	171%	78%	110%
Oct	83%	40%	138%	95%	103%	40%	139%	92%	103%	92%	97%	155%	137%	54%	20%	81%	76%	94%	88%	114%
Nov	157%	98%	41%	100%	118%	44%	94%	168%	103%	66%	122%	89%	140%	182%	46%	57%	129%	81%	76%	33%
Dec	114%	74%	67%	46%	128%	82%	59%	89%	25%	119%	169%	167%	95%	229%	54%	67%	92%	95%	133%	83%
Annual Sum as % of annual LTA	104%	77%	91%	82%	95%	98%	106%	108%	85%	101%	125%	114%	131%	128%	100%	74%	93%	87%	98%	78%

Notes:

1 - Months shaded brown have less than 70% LTA rainfall for the respective month (85% for annual sum values given the lower variability of annual data).

2 - Months shaded blue have more than 130% LTA rainfall for the respective month (115% for annual sum values given the lower variability of annual data).

3 – LTA% is calculated from available rainfall data from 2000. Only the last 20 years of data are shown in the table.

2.4 Quarry discharge

Quarry discharge flows are measured at Torcoed Quarry Discharge and historically at Torcoed Fawr Quarry Discharge (Figure 2.1). Torcoed Fawr Discharge is no longer used as a discharge point and is no longer monitored (following the vandalisation of the equipment in 2019) as noted in Section 2.2. Torcoed Quarry Discharge is monitored by water level measurements adjacent to a thin plate weir (the same was also true of the Torcoed Fawr Discharge). The water level at the weir is then converted to a flow rate.

Details of the consented discharge limits are summarised in Table 2.3. The discharge licence for the Site is presented in Appendix E.

Table 2.3 Quarry discharge limits

Discharge	Consent number	Discharge permit limit since 20 Feb 2009 (l/s)
Torcoed	BP0235501	73
Torcoed Fawr	BP0239301	61

Data quality comments relating to the two discharge monitoring locations are given in Section 2.2.

2.4.1 Torcoed Quarry Discharge

Figure 2.5 shows the mean daily flow measured at the Torcoed Quarry Discharge point (location shown in Figure 2.1) over the Reporting Period.

Over the Reporting Period, the discharge hydrograph is spikey, with the average daily flows ranging from 0.00 l/s to c. 191.70 l/s, with the annual maximum of 191.70 l/s occurring in February 2021. The average daily flow data exceeded the 73 l/s discharge consent limit on only two occasions during the Reporting Period; from 20th to 21st February 2021.

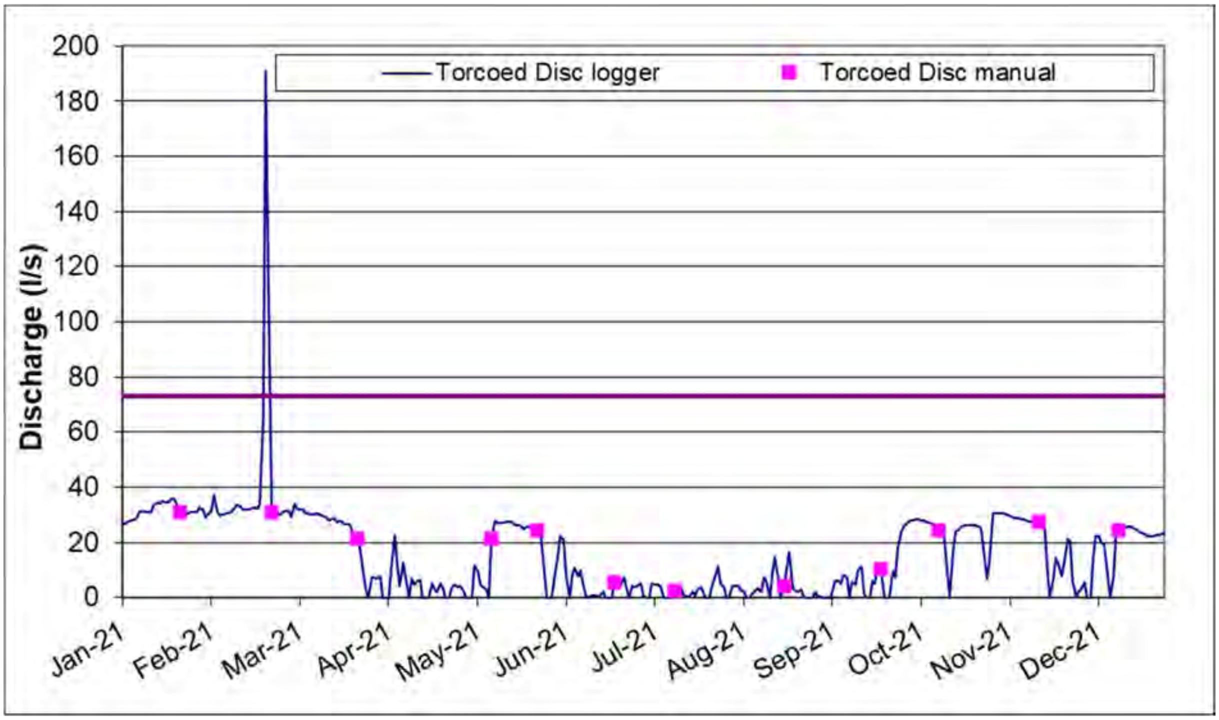
The Torcoed pump has a maximum capacity of 40 l/s so the values beyond this in the data series on 20th to 21st February 2021 are likely to be spurious or due to runoff entering the channel during periods of high rainfall. Stage level logger data show a rapid change in water levels (equivalent to an exceedance of the discharge consent) from 7:15 PM on the 19th February to 21st February 12:15 PM. The Torcoed pump operates only during working hours (6 AM – 5 PM) so it is highly unlikely that these elevated levels were caused by the quarry discharges. High rainfall events prior and during to this period were most likely contributing factors to the sudden changes in recorded levels. There was a similar spike in flow rate recorded on 20th February 2021 at the nearby Garn-ffrwd Spring (Fisheries) (see Section 2.6 and Figure 2.10).

Rainfall data recorded at the Torcoed rain gauge did not show any significant increase during the Reporting Period (average 1.8 mm/day), however nearby gauging stations at Gorslas (6.9 km away) and Hirwaun (44.7 km away) recorded 59.4 mm/day and 100.8 mm/day, respectively. It is therefore possible that a high rainfall event that occurred at the Site and resulted in this episode of extremely high flow was missed from the Torcoed rain gauge data record. The issues that caused this could be related to the rain gauge malfunction that caused a data gap between 16th May to 4th August.

The average daily flow during the Reporting Period, excluding the elevated flows on 19th , 20th and 21st February, was 15.65 l/s.

Manual recordings are complete throughout the monitoring period. The manual and logger level data correlate fairly well over this time, although there is some discrepancy between the flows calculated from instantaneous (manual) data and daily average values (as may be expected). There was no missing logger data during 2021. Due to increasing drift between manual and automated stage data a replacement data logger has been installed in April 2021.

Figure 2.5 Mean daily flow at Torcoed Quarry Discharge point



2.4.2 Torcoed Fawr Quarry Discharge

Over the Reporting Period, no discharge measurements were recorded at Torcoed Fawr Quarry. As outlined above, the monitoring equipment at this location was vandalised in September 2019 and no replacement logger has been installed to date, given that the point is not used for discharge at present and is not intended to be used in the foreseeable future.

2.5 Groundwater elevations

Groundwater level logger records and corresponding manual data during the Reporting Period are shown in Figure 2.6 and Figure 2.7, with logger data presented as daily average readings. Groundwater levels in Carboniferous Limestone and Old Red Sandstone boreholes are shown on separate plots. Key statistics are summarised in Table 2.4.

Figure 2.8 plots the long-term groundwater level data covering the period 2014 to 2021 with CDM rainfall. It should be noted that groundwater data from 2000 is available at BH17 and BH95/3 (available in Appendix F), although, monitoring at BH95/3 has been reduced only to monthly manual dips from 2019.

Data quality issues are noted in Section 2.2 with the number of days for which data are available in the period shown in Table 2.1. The following data gaps (relative to the 2018 WMP requirements) are noted:

- BH95/3 is missing manual dips in January, February, May and June due to no quarry vehicle and staff being available during monitoring visit.
- Manual dips are missing at: BH1/13 (May) due to missing keys, BH4A/13 (March and October) due to missing key and broken padlock, BH8B/13 (January, February and October) due to obstruction of the borehole.
- BH8B/13 data are missing between 1st and 22nd January and 14th October and 31st December owing to a temporary logger malfunction. Data is missing also between 8th and 31st December 2020 due to obstruction of the borehole. Note, although outside the Reporting Period, this issue was resolved in January 2022.

Where the data are available, a very good correlation is generally observed between automatic logger data and manual readings.

Flat/stable (low variability) data were observed at location BH3B/13 over March to September 2021 similar to data observed over parts of 2018, 2019 and 2020.

Groundwater data recorded at each borehole over the Reporting Period are discussed in Section 2.5.1 and 2.5.2.

Table 2.4 Groundwater level statistics for the Reporting Period (01 Jan 21 to 31 Dec 21)

Location	No. of days data available	Mean groundwater level measured (mAOD)	Minimum groundwater level measured (mAOD)	Maximum groundwater level measured (mAOD)	Seasonal variation of groundwater levels (m)
Carboniferous Limestone					
BH17	365	196.91	191.55	200.27	8.72
BH1/13	362	169.19	165.18	175.03	9.85
BH3B/13	365	191.53	190.49	199.35	8.86
BH4A/13	365	172.70	170.56	174.89	4.33
BH7/13	365	146.10	144.79	149.19	4.40
BH8B/13	266	151.82	147.30	155.02	7.72
BH9/13	365	159.91	157.50	163.51	6.01
Old Red Sandstone					
BH5/13	365	154.15	152.24	159.10	6.86
BH8A/13	365	150.04	146.26	153.83	7.57
BH 95/3*	8	162.34	157.54	167.03	9.49

*Note: * = Statistics based on available data - where no logger data are available, manual data only were used.*

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2.5.1 Groundwater levels in the Carboniferous Limestone

Borehole BH 17

Borehole BH17, between Torcoed and Torcoed Fawr Quarries Quarry, is installed within the Carboniferous Limestone to an approximate depth of 86 mbgl. The base of the borehole is at approximately 118 mAOD. It is understood this borehole is an open hole within the limestone.

Monitoring data generally show that the groundwater response to individual rainfall events is relatively small at this location, although the overall annual range is relatively large due to long-term gradual changes in levels. Gradual changes in water level correlate well with CDM, particularly since 2018.

The range in 2021 was more similar to those previously seen than compared with the larger range observed during the 2018 drought. In 2021, the minimum groundwater level was 191.55 mAOD in September and the maximum groundwater level was 200.27 mAOD in January.

Borehole BH 1/13

This borehole is installed within the Carboniferous Limestone, in the old Crwbin Quarry to an approximate depth of 36 mbgl and screened from 150 – 156 mAOD. Logger data are available at this location since 2019.

Groundwater levels exhibit a larger range at this location compared to groundwater levels recorded in other boreholes in Limestone strata, with responses to rainfall events being rapid and pronounced. The range of the Reporting Period was 9.85 m, the minimum recorded level was 165.18 mAOD in August. The maximum recorded level was 175.03 mAOD in January. Gradual changes in groundwater levels generally correlates well with the CDM rainfall since 2019.

Borehole BH 3B/13

Borehole BH3B/13 to the south-east of Crwbin Quarry is within the Carboniferous Limestone and is approximately 54 m deep. The base of the borehole is at approximately 188 mAOD.

Groundwater levels exhibit a larger range at this location compared to groundwater levels recorded in other boreholes in Limestone strata, with responses to rainfall events being rapid and pronounced. Gradual changes in groundwater levels generally correlates well with CDM over long-term. The range over 2021 (8.86 m) is higher than that recorded over 2020 (7.75 m). During 2021, the minimum recorded level was 190.49 mAOD in August. The maximum recorded level was 199.35 mAOD in January. Although 2021 levels at BH3B/13 were similar to those observed since 2019, a decline in water levels is apparent compared to 2017 and 2018 when levels were mainly between 200 – 210 mAOD.

Some “flat spots” in the data are noted at this location over summer period, where the level does not drop below c. 190.75 mAOD. This has occurred since 2019. Prior to 2019 water levels were higher, but they declined during 2018 to the present levels. This decline may relate to quarrying activities in Torcoed Fawr or due to the long-term decrease in rainfall shown in the CDM and the very dry spring/summers from 2018 to 2021.

Borehole BH 4A/13

This borehole is installed within the Carboniferous Limestone, in the old Crwbin Quarry to an approximate depth of 98 mbgl and is screened between 99 and 105 mAOD.

The variability at this location is quite limited, with an annual range of 4.33 m over 2021. Responses to rainfall events are very muted at this location. In 2021, the minimum water level was in May at 170.56 mAOD and the maximum water level was in January at 174.89 mAOD.

Borehole BH 7/13

Borehole BH 7/13, to the southeast of the Torcoed Quarry plant area, is 45 metres deep and is screened from approximately 119 mAOD to 125 mAOD in the Carboniferous Limestone.

Monitoring data show that the groundwater level range is relatively small (4.40 m). Responses to rainfall events are very muted at this location. In 2021, the minimum water level was in August at 144.79 mAOD and the maximum water level was in January at 149.19 mAOD.

Borehole BH 8B/13

Logger data are available at this location since 2014. The borehole is screened from approximately 122 mAOD to 128 mAOD in the Carboniferous Limestone.

Groundwater elevations at this location are in general very stable; responses to rainfall events are minor and the overall range over the Reporting Period is relatively low, however, during the Reporting Period the range was 7.72 m, higher than recorded over 2020 (4.55 m). During 2021, the minimum recorded level was 147.30 mAOD in early September following a dry period, the lowest recorded level since 2014. The maximum recorded value was 155.02 mAOD in January. A similar trend was observed in nearby BH8A.

Borehole BH 9/13

BH 9/13 was installed in the western extent of Crwbin in 2013. It is screened from approximately 126 mAOD to 132 mAOD in the Carboniferous Limestone.

The groundwater hydrograph at this location is relatively stable, with a modest response to individual rainfall events. The range of the Reporting Period was 6.01 m, between 157.50 mAOD and 163.51 mAOD.

2.5.2 Groundwater levels in the Old Red Sandstone

Borehole BH 5/13

BH5/13 is located at the western end of the old Crwbin Quarry. The borehole is screened between approximately 137 mAOD and 143 mAOD in the Old Red Sandstone.

Water levels at BH5/13 were relatively stable over the Reporting Period particularly over the spring to summer months. The variation in manual readings is less pronounced than the trend in the BH95/3 manual readings over this and in past periods.

Borehole BH 8A/13

BH8A/13 is installed within the Old Red Sandstone to an approximate depth of 77 mbgl and is screened from 74 to 80 mAOD. A logger was installed in BH8A/13 in February 2015.

Water levels at this location are more similar in elevation and variability to those recorded in BH5/13 compared with BH95/3, although the locations are not spatially proximal. BH8A/13 is located in the east of the Site and BH5/13 is located in the west of the site in the Crwbin Quarry area. BH95/3 is located in the centre of the Site in the Torcoed Fawr area. The hydrograph since the data series begins is fairly smooth with a low long term annual variability. No particular long terms or short term trends are apparent.

The range during 2021 (7.57 m) was higher than that recorded in 2020 (5.33 m). In 2021, the minimum recorded level was 146.26 mAOD in early September, the second lowest levels since 2015. The maximum recorded level was 153.83 mAOD in January.

Borehole BH 95/3

Borehole BH95/3 is located to the north of Torcoed Fawr Quarry and is installed within the Old Red Sandstone to an approximate depth of 45 mbgl with borehole base at 135 mAOD. The screened interval is not known. Monthly manual readings are taken at this location.

Previously the hydrograph was, in general, quite smooth, with gradual responses to groundwater recharge. The manual data during 2021 show high variability in groundwater elevation at 9.49m, which is much higher than the 2020 annual range of 3.24 m. The groundwater levels at this location as also higher than in other two sandstone locations (BH5A/3 and BH8A/13). This is consistent with historical data.

Over the Reporting Period only eight manual readings were obtained, potentially missing some of the high groundwater levels during January and February. As such, annual groundwater variability at this location might be even greater.

Figure 2.6 Groundwater levels at Carboniferous Limestone boreholes during 2021

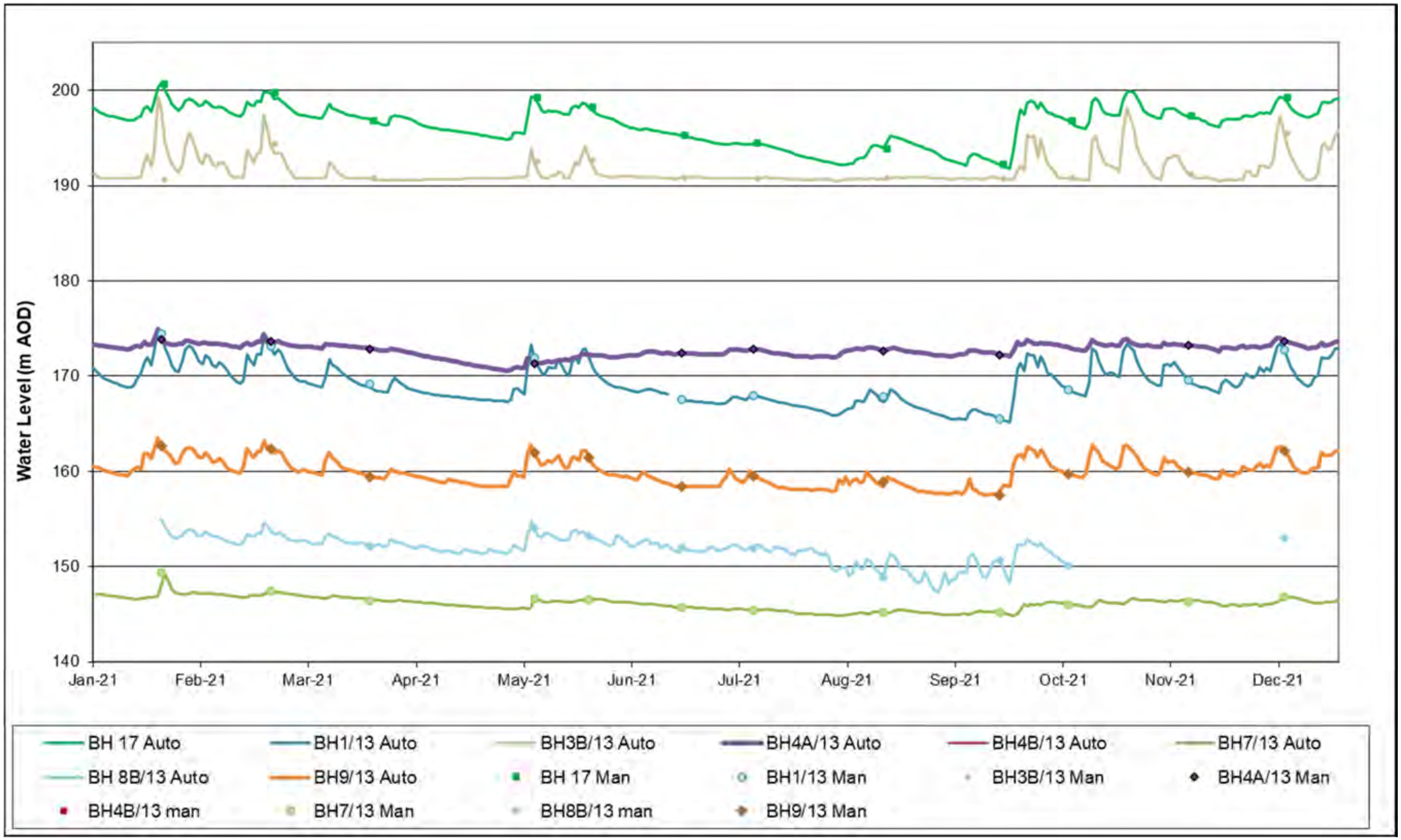
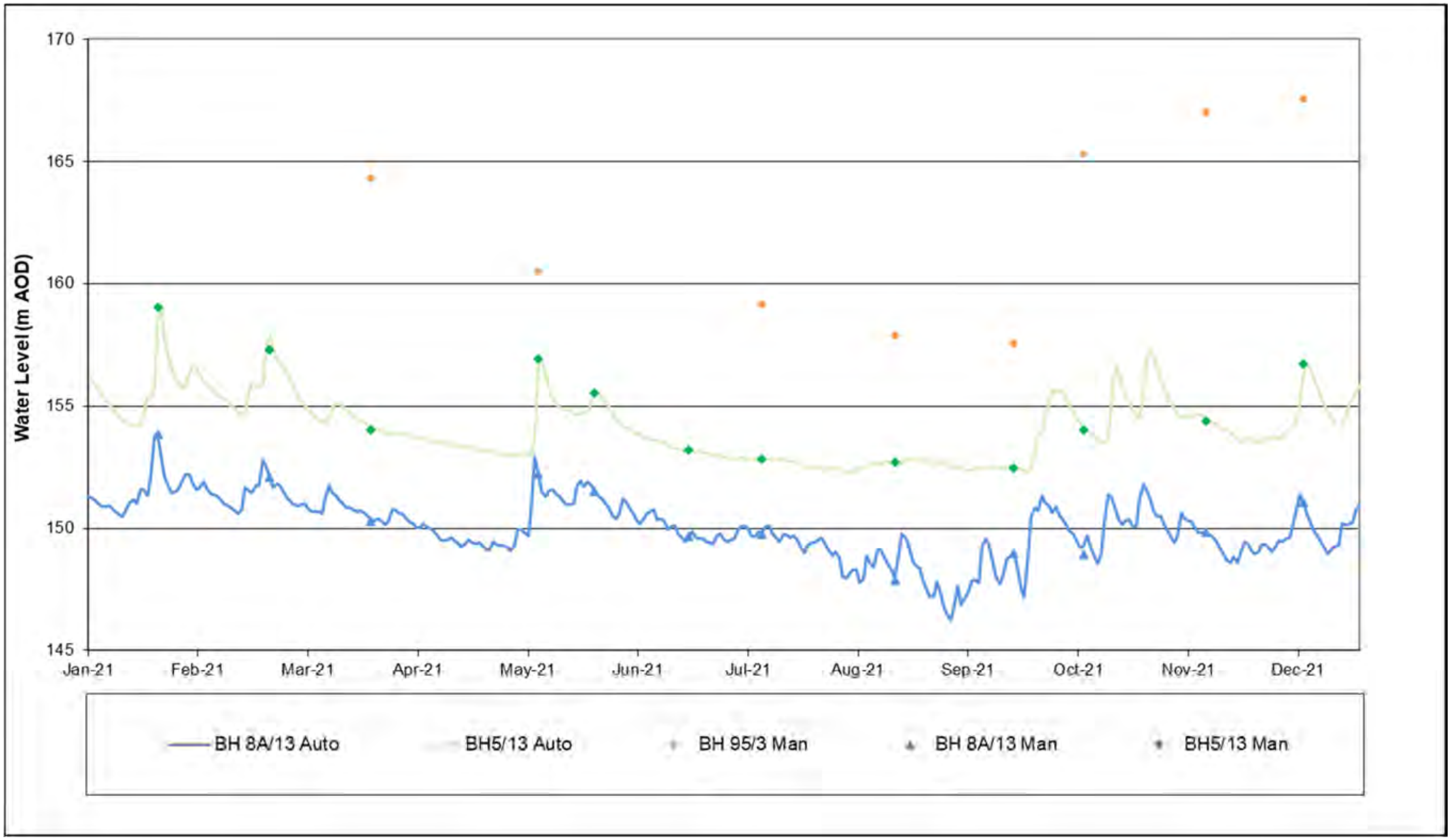


Figure 2.7 Groundwater levels at Old Red Sandstone boreholes during 2021



N.B. The logger in BH 95/3 was removed from the monitoring requirements in February 2019

Figure 2.8 Long-term groundwater hydrograph for Limestone boreholes

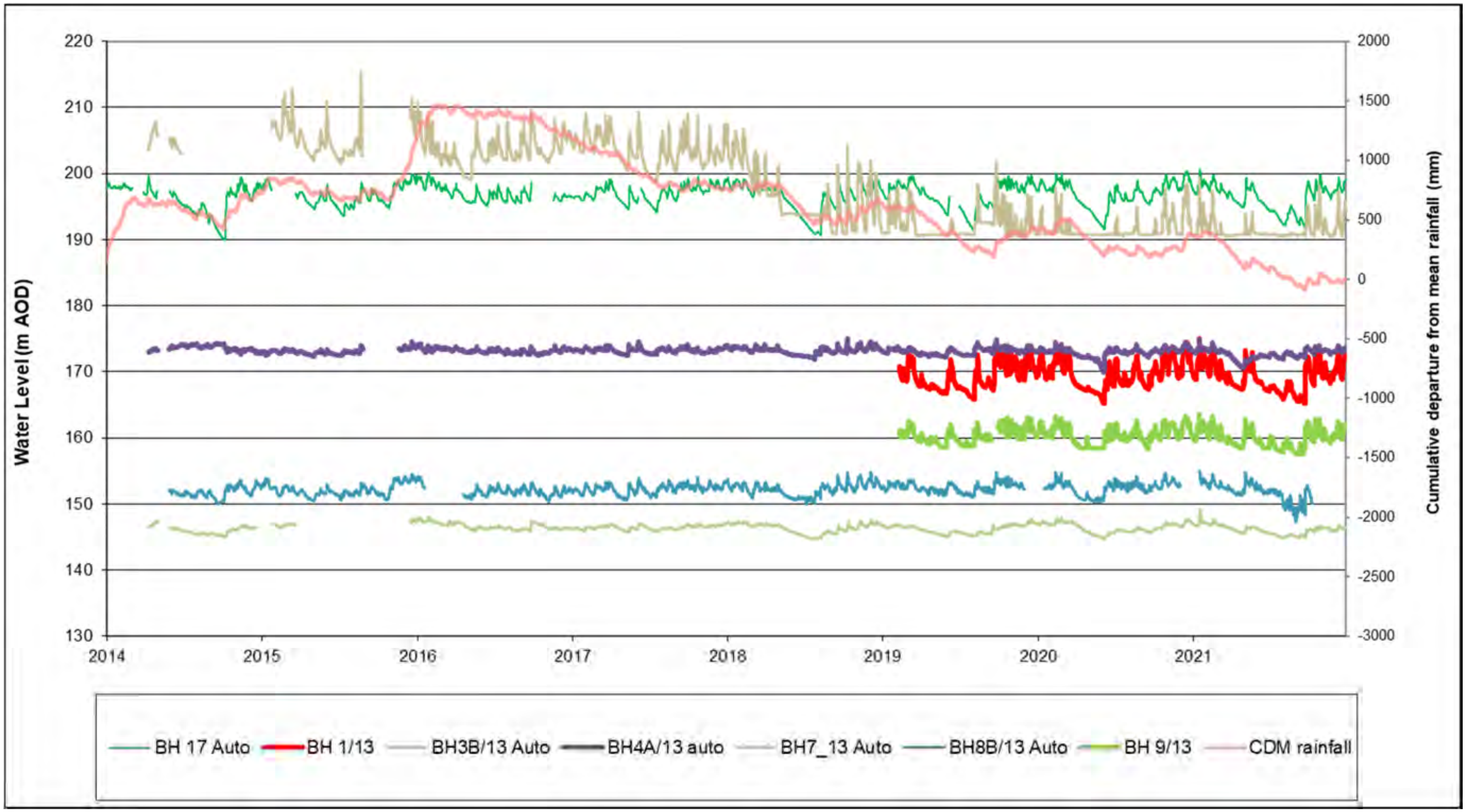
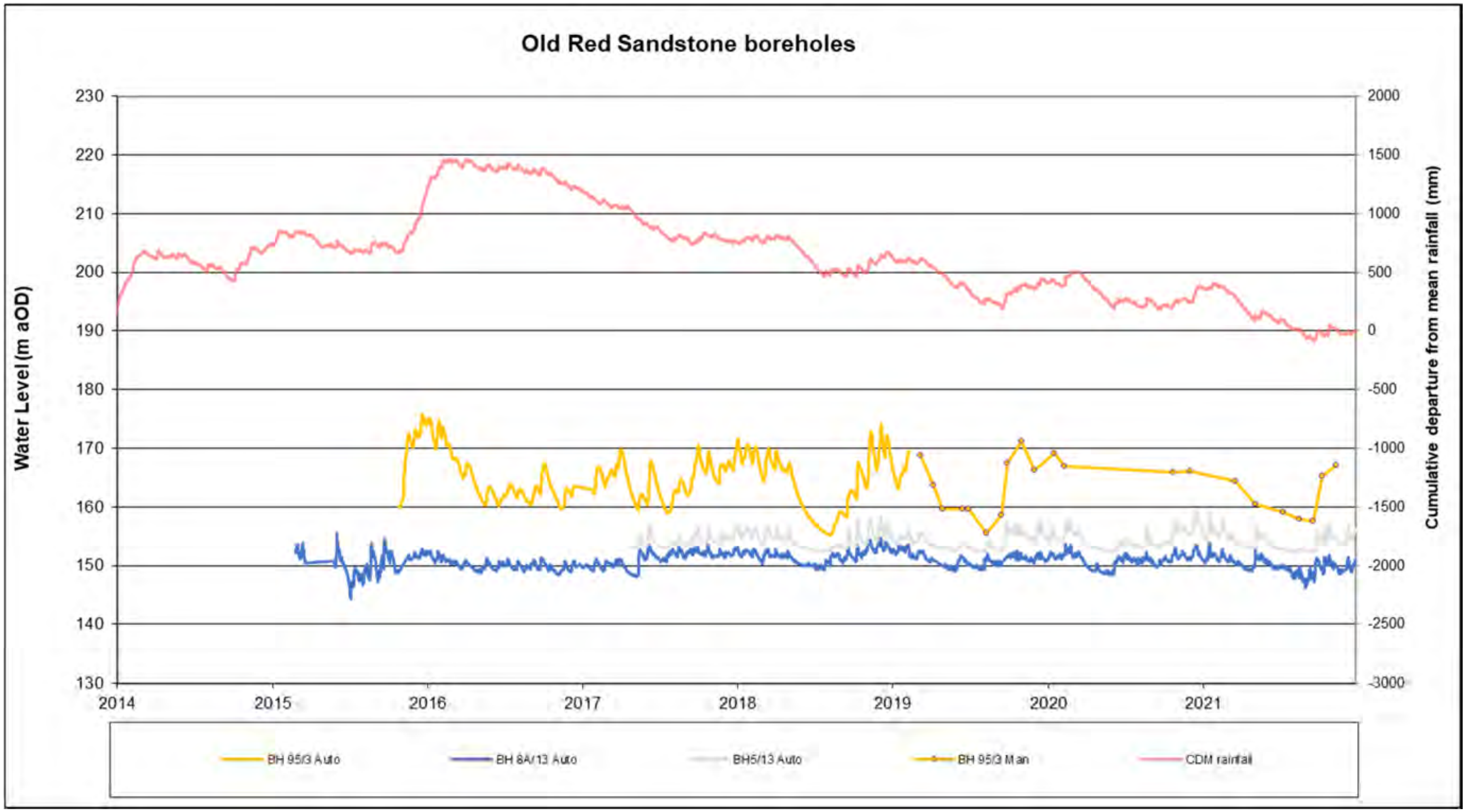


Figure 2.9 Long-term groundwater hydrograph for Old Red Sandstone boreholes



2.6 Surface water flows

Surface water flows are currently monitored at the inlet to Garn Ffrwd Fishery Lake (FSHUS), the location of which is shown in Figure 2.1. There is a complete record of monthly manual recordings over the Reporting Period and these correlate well with the automated readings.

The Garn Ffrwd Fishery Inlet data are presented graphically in the following figures:

- Figure 2.10 shows flow at Garn Ffrwd Spring during the Reporting Period with the lower limit at which augmentation may be required and CDM rainfall.
- Figure 2.11 shows long term flow at Garn Ffrwd Spring with monthly and daily rainfall as well as CDM rainfall and monthly rainfall expressed as a percentage of LTA rainfall.

In May 2007, Tarmac entered into an agreement with the owner of the fish farm that is fed by Garn Ffrwd spring. This agreement requires the owner to notify Tarmac of times at which flow at the spring is below 8 l/s and additional flow is required. At these times, Tarmac has agreed to augment the spring by discharging to a nearby sinkhole that feeds the spring. A summary of flows at the spring over the Reporting Period in comparison to the 8 l/s augmentation limit is given in Section 3.4.

Figure 2.10 Flow at Garn Ffrwd Spring during the Reporting Period

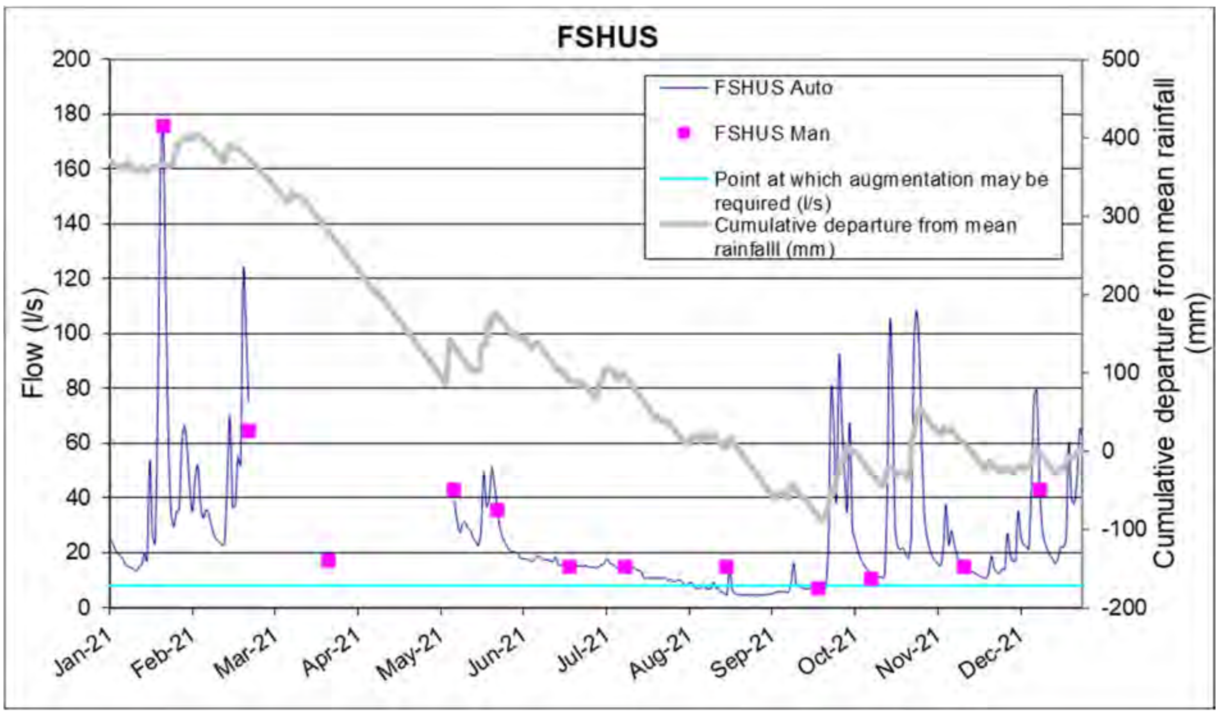


Figure 2.11 Long term flow at Garn Ffrwd Spring with monthly and daily rainfall

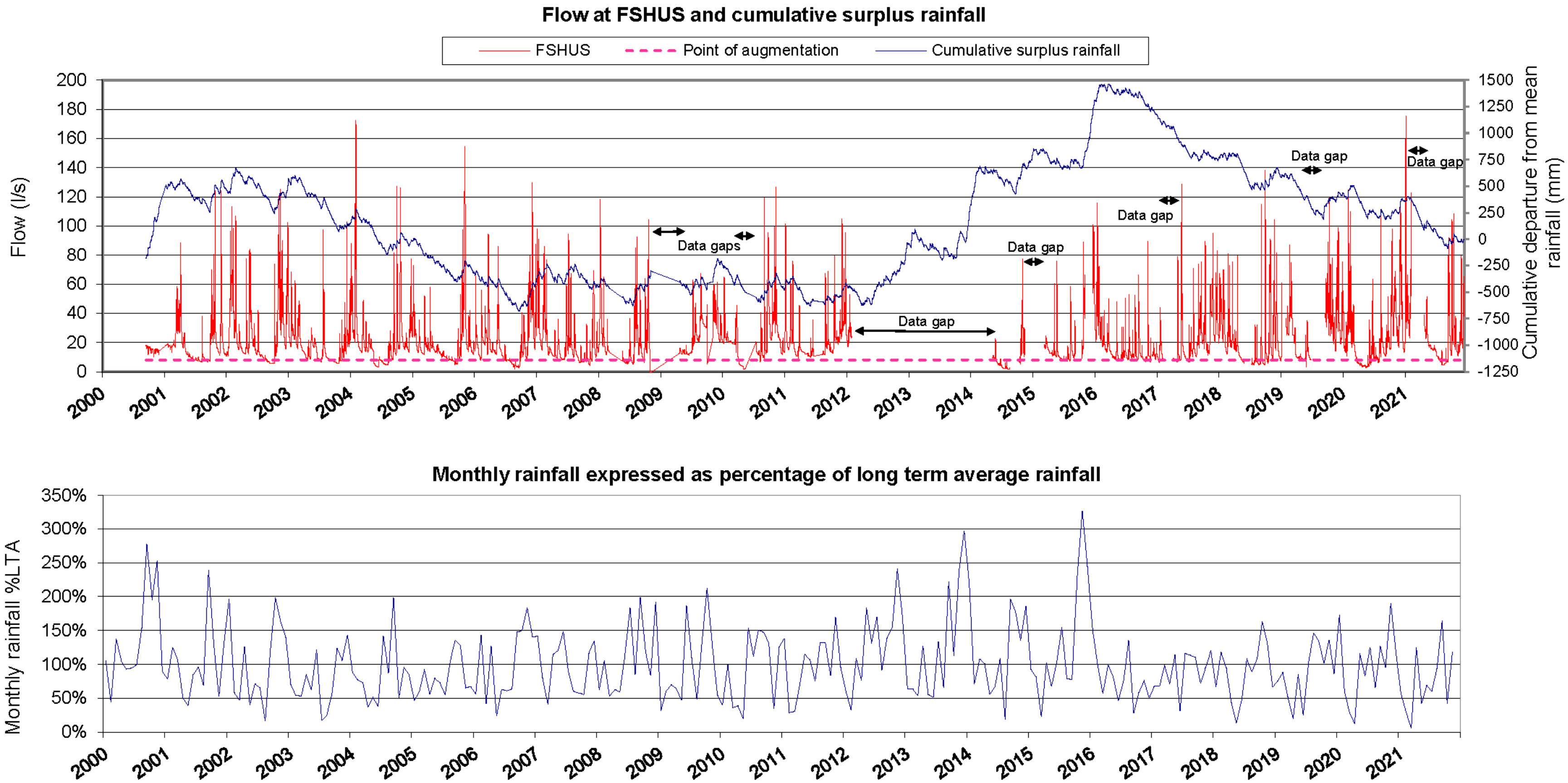


Table 2.5 summarises the maximum and minimum flow at Garn Ffrwd Fishery Inlet recorded from the available data over the Reporting Period.

Table 2.5 Maximum and minimum flow at Garn Ffrwd Fishery Inlet

Discharge	Dates of measurement	Flow (l/s)
Minimum discharge measured	31/08/2021	4.49
Maximum discharge measured	21/01/2021	175.42

The flow hydrograph of the spring typically displays large peaks in flow followed by short steep recessions, with peaks corresponding well to rainfall events.

Determination of the relative significance of quarry-related activities and meteorological effects has been improved by a detailed assessment of the patterns of rainfall and evapotranspiration in 2006, undertaken during detailed studies carried out by ESI (now Stantec) as part of the Environmental Statement for the Site (SLR, 2015). This indicates that the spring is largely sourced from the Mynydd-y-Garegg limestone to the south of the quarries.

Over the Reporting Period, the mean daily flow at the Garn Ffrwd Fisheries location was recorded below the point of potential augmentation on 44 days; the minimum daily flow of 4.49 l/s was recorded at the end of August following a dry period. A succession of low flow days was observed throughout July, August and September owing to the dry weather at this time and is also reflected in the groundwater hydrographs. How these data compare with long term historical data is discussed in Section 3.3.

2.7 Water quality

The current 2018 WMP requires water quality to be monitored at the quarry discharge points and Garn Ffrwd spring on a monthly basis. Samples are analysed for total suspended solids (TSS) and pH. Data collected over 2021 are presented in Appendix D.

No data were collected at the Torcoed Fawr Discharge point over the Reporting Period as this location was not in use over this time. Samples were collected 12 times from the Torcoed Quarry Discharge point and Garn Ffrwd spring over the Reporting Period.

Water quality data collected over the Reporting Period are presented in Table 2.6. The Torcoed Quarry Discharge Licence has limits on the quality of discharge from pH 7 to 9 and TSS below 60 mg/l. The pH of the discharge was always within these limits, and apart from in September 2021, the TSS at Torcoed Quarry Discharge over the Reporting Period complied with the Discharge Licence limit. During September, TSS was 61 mg/l, slightly over the limit of the discharge consent. The sample was obtained after high rainfall, which may have disturbed silt on the stream bed contributing to the high TSS. The following sample in October was below the detection limit (<5 mg/l).

TSS at Garn Ffrwd spring were generally low, often below the detection limit (<5 mg/l). However, the highest value recorded in January 2021 was 178 mg/l as the sample was collected after several days of intense rainfall, which is likely to have contributed to high sediment load. In addition to this, the sample holding time was exceeded prior to testing, therefore the validity of the test results may be compromised.

Table 2.6 Laboratory water quality data during Reporting Period

Determinant	Units	Minimum	Mean	Maximum
Fisheries (Garn Ffrwd Spring) – 12 samples				
pH	pH	7.4	7.6	8.2
Total suspended solids	mg/l	<5	15.33	178
Torcoed Quarry Discharge – 12 samples				
pH	pH	7.4	7.65	7.9
Total suspended solids	mg/l	<5	7.75	61

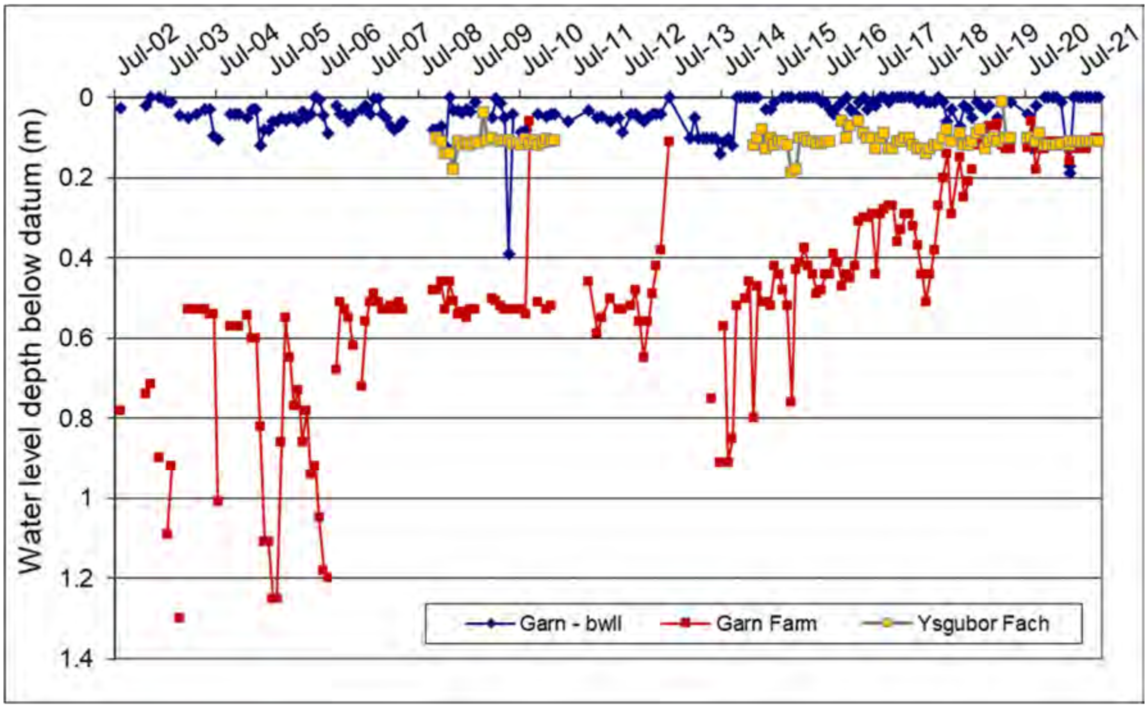
Note: Where the value is below the Limit of Detection (LOD), half of the LOD value is used in the statistics.

2.8 Other monitoring locations

Manual dips are taken at monthly intervals from wells at Ysgubor Fach (W20), Garn Bwll (W03), and Garn Farm (W11) (see Figure 2.1). There is no evidence of a reduction in water levels at these locations. Water levels below the datum (ground level) are presented in Figure 2.12. Levels at Garn Farm had risen from 2014 to 2018 but from 2018 to 2021 they appear to have stabilised. The cause of this is not known. During the Reporting Period, there was little variation in water levels at these locations apart from in May when sudden drops were recorded at Garn Farm and Garn Bwll. However, the cause of these drops is not known.

A trigger level of 0.44 m below ground level (mbgl) is set at Ysgubor Fach to initiate a further investigation into low flows at this location. Levels did not drop below this during the Reporting Period with the lowest level recorded at 0.12 mbgl in from January to May.

Figure 2.12 External hydrometric monitoring locations



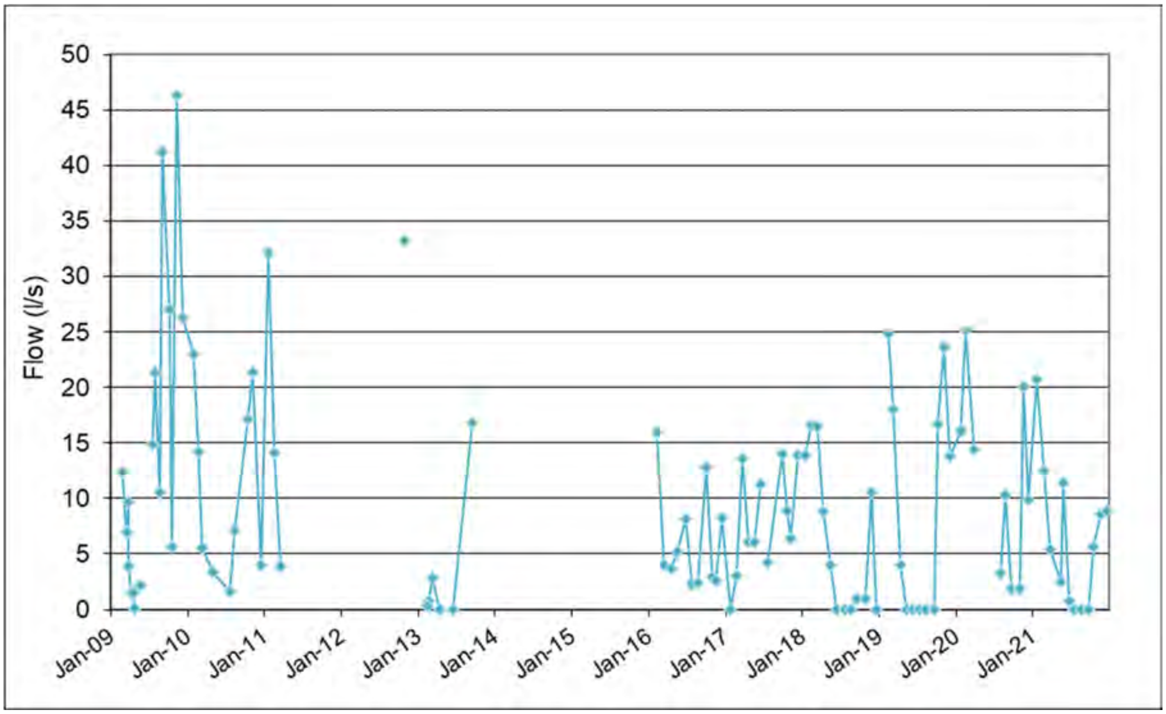
Between January 2012 and January 2015, no manual dips were recorded at Ysgubor Fach (W20); the cause of this is thought to be a result of a change in monitoring staff which meant that the well could not be located over this period. Data are currently being collected at this location, as required. A review of the long term data series does not indicate any trends in water levels at this location.

To the west of Torcoed Quarry, monthly flow measurements are recorded at Crwbin Spring (S53) (see Figure 2.1). This commenced in November 2008 as part of the previous 2008 WMP. Data are presented in Figure 2.13.

The flow data collected pre-2013 at Crwbin Spring has different characteristics from that collected from 2016 by Stantec and from February 2020 by BCL. The reason for this is not known although it was noted in July 2017 that a proportion of the flow from the spring was bypassing the engineered feature in which spring flow is currently measured and surfacing at a property further downstream. It is not known for exactly how long this process has been occurring, but the occupant of the property stated, in summer 2017, that the development was not a recent one.

Flows during the winter months at the start of 2021 were high and comparative to previous years. During recent years, very low flows (not flowing on occasion) have been recorded in the summer months, as shown in Figure 2.13. However, as outlined above, flows to the spring may be bypassing the channel where measurements are taken.

Figure 2.13 Flow measured at Crwbin Spring



3 Discussions

In this section, the conceptual model of the area is revisited in light of recent work and the latest data from the hydrometric network.

3.1 Conceptual model

This section summarises the hydrogeological conceptual model of the area around Torcoed Quarry. The conceptual model is supported by the extensive data sets available from the hydrometric monitoring system operated by Tarmac and by the works by Smart (2001) and Smart and Halton (2002).

The local geology comprises Old Red Sandstone, overlain by Carboniferous Limestone, overlain by Millstone Grit and Coal Measures. The strata dip uniformly to the south-south-east at approximately 18 – 23 degrees. Old Red Sandstone outcrops to the north of the quarry, which works the Carboniferous Limestone. The Mynydd-Llangyndeyrn ridge comprises Millstone Grit, with younger strata overlying to the south-southeast.

The Carboniferous Limestone is subdivided into the Lower Limestone Shales, the Main Limestone, and the Upper Limestone Shale. The Main Limestone itself can be subdivided into two contrasting aquifer systems: the relatively 'clean' lower limestones (Penderyn Oolite and Cilyrychen Limestone) which are the main economic mineral for the quarries, and the overlying, shalier, Mynydd-y-Garegg Limestone. Evidence from groundwater levels and tracer tests suggests that there is relatively little hydraulic connection between these two aquifer systems.

There is a variable cover of Glacial Till across the area with some glacial sand and gravel in places. Generally, the superficial cover has little effect on the local hydrogeology other than to help to route recharge into particular locations.

Several north-northwest trending faults are mapped in the area of the quarries. However, these do not appear to completely disrupt the geological sequence at any point.

Groundwater flow in the Carboniferous Limestone is predominantly through karstic features (secondary permeability). Several sinkholes are present in the Carboniferous Limestone and these have been traced to springs issuing from the Carboniferous Limestone. The largest spring in the vicinity of the quarries is Garn Ffrwd Spring, which lies to the east of the quarries and supports a fishery. The studies presented here indicate that this spring is primarily sourced from the Mynydd-y-Garegg Limestone and runoff from the Millstone Grit via karstic conduits.

The predominance of along-strike flow in the Mynydd-y-Garegg Limestone and the shaley nature of the formation results in the zone of influence of the quarries being largely constrained to the underlying limestones (Penderyn Oolite and Cilyrychen Limestone) at present.

The influence of the karst system on groundwater levels is seen as flashy responses to rainfall with little evidence of groundwater storage, and also gives rise to the 'dual water table' effect observed in water levels recorded in historically monitored boreholes at the Site. The Old Red Sandstone is more dominated by porous media flow (higher storage and lower permeability) than the Carboniferous Limestone and this is reflected in the nature of the hydrographs.

Groundwater elevations indicate that the groundwater in the Main Limestone and the Old Red Sandstone are not in hydraulic continuity due to the presence of the intervening Lower Limestone Shales which effectively isolate the two groundwater systems (Smart, 2001).

Hydrochemical analysis previously undertaken indicates that whilst all the groundwaters are of broadly similar character (limestone dominated), the water chemistry of the Garn Ffrwd Spring is more similar to that in the Mynydd-y-Garegg and Millstone Grit waters than the Cilyrychen Limestone and Quarry sump waters.

3.2 Water balance

The calculation of a water balance for an area provides important quantitative support for a conceptual model by demonstrating that it has included all the important flow processes. ESI (2015) presented detailed daily water balance calculations for the Site.

As part of the EIA for the quarries, ESI detailed daily water balance calculations in for Garn Fffrwd Spring and the quarries for the period for which there are accurate flow data against which to calibrate the model. This formed Appendix 8.5 of SLR (2015). In summary, the water balances of the study area indicated that:

- The spring flows recorded at Garn Ffrwd Spring can be entirely accounted for by the groundwater flow from the Mynydd-y-Garegg Limestone and discharge/runoff from the Millstone Grit to the south. This is consistent with the results of tracer tests and hydrochemistry in this area. It is possible that the spring did receive some discharge from the Cilyrychen Limestone that was worked at the quarries in the past. However, it is more likely that any such groundwater flow would have made its way to the springs at Garn Bwll (W03). Any discharge from this route would have ceased when the quarries were first significantly dewatered.
- The discharges from Torcoed and Torcoed Fawr Quarries can be accounted for by recharge on the Cilyrychen Limestone in the immediate vicinity of the quarries. The indications from these calculations are that the groundwater catchments of the combined quarries extend from Crwbin Quarry in the west to Garn Bwll (W03) in the east.
- The sensitivity of the calculations to the main assumptions and parameters has been tested and it is concluded that the results are robust to a level of accuracy that is within the range of accuracy with which the outflows of the system can be measured (+/- 5% to 10%).

3.3 Comparison of Reporting Period data with previous data

Figure 2.4 (Rainfall), Figure 2.8 (Groundwater) and Figure 2.11 (flow at Garn Ffrwd Spring) include the Reporting Period data in the context of the entire data record, to enable comparison between seasons and identification of long-term changes in behaviour. No long-term trends in the pattern of water level responses have been observed in any of the hydrographs, and the range of water level variation has been broadly maintained for each monitoring location.

Levels at BH3B/13 appear lower in 2018 - 2021 compared with data pre-2018, although the data series is relatively short and the trend does follow a decline in CDM rainfall over this time. Water levels at this location have exhibited some "flat spots" over the past three years (Figure 2.8). It is possible that water levels are being drawn down in this area.

Groundwater levels at BH8A/13 and BH8B/13 appear to have been lower during the summer months in comparison to previous years (see Figure 2.8 and Figure 2.9). Similar groundwater levels at BH8A/13 were observed during the summer 2015. BH8B/13 had the lowest recorded groundwater levels since 2014. Groundwater trends at both locations follow CDM in summer to September quite well, and the drop is levels is therefore likely to be due to a reduction in rainfall during this period.

3.4 Low flows and potential derogation at Garn Ffrwd Spring

The general pattern of flows in the Garn Ffrwd Spring is a rapid response to rainfall with an initial peaky response followed by a slower baseflow response. Figure 2.11 shows the complete data record for the Garn Ffrwd Spring and compares it with the CDM rainfall record for this time, illustrating the broad correlation between baseflow trends and CDM rainfall. Monthly rainfall expressed as a percentage of the long-term average rainfall for the complete data record is also displayed in Figure 2.11 for comparison. Table 3.1 compares the available average monthly flow data at the Garn Ffrwd Spring with average monthly rainfall from 2007 to 2021 and Table 3.2 shows the number of days when average flows were below 8 l/s (the level below which augmentation of Garn Ffrwd Fish Farm would be required if requested by the fisheries). It should be noted that complete dataset from 2000 is available in Appendix G.

Comparing the rainfall record and spring flow in Table 3.1 and Figure 2.11 reveals that during the summer months of each year of the data record, rainfall events are visible as small peaks on the spring hydrograph. However, these events are only seen in the hydrograph if rainfall occurs over several days and if the rainfall is greater than a certain depth (approximately 10 mm).

Figure 2.11 shows that the minimum flow recorded in 2008, 2009, 2010 and 2011 is greater than that observed in most previous years due to the high summer rainfall (although there is some missing summer flow data in both 2010 and 2011 and the minimum base flow may not have been captured in the dataset).

As mentioned in Section 2.2, logger flow data at Garn Ffrwd Spring are not complete (71%) over the Reporting Period. Flow data is missing from 22nd February to 10th May and some of the base low flow may not have been captured, considering April rainfall levels were the lowest since 2000. Over the Reporting Period the recorded mean daily flow at this location was below the point of augmentation on 44 days; the minimum daily flow of 4.49 l/s was recorded at the end of August, following a pronounced dry period. A succession of low flow days is evident in the data throughout July and August, coinciding with the dry weather over this period and this trend is also observed in the groundwater hydrographs.

Mean daily summer flows below 8 l/s are not uncommon at Garn Ffrwd Spring as can be identified from the historical data (Figure 2.11). The summer flows over 2021 were notably low but were in fact lower still on numerous previous years (such as 2006, 2010, 2014 and 2020).

Table 3.1 Comparison of average monthly flow at Garn Ffrwd Spring and total rainfall

Year	Total rainfall/average flow	Unit	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
2007	Total rainfall	mm	200	202	113	59	163	171	210	127	86	82	79	166
	Average flow	l/s	44	35	22	12	14	12	30	17	8	9	9	26
2008	Total rainfall	mm	191	89	151	76	89	84	160	260	122	283	168	119
	Average flow	l/s	40	20	15		10	6	11	34	18	32	5	
2009	Total rainfall	mm	273	46	87	99	92	68	265	157	69	188	302	180
	Average flow	l/s				14	13	12	22	27	36	27	41	31
2010	Total rainfall	mm	178	196	41	43	99	163	152	108	187	188	119	241
	Average flow	l/s	26	22	22	10	3		16	15	23	41	47	18
2011	Total rainfall	mm	158	162	37	39	89	146	137	97	168	168	106	215
	Average flow	l/s	31	28	14	17	12	13		12	22	22	25	40
2012	Total rainfall	mm	136	86	47	155	109	260	187	241	131	198	219	342
	Average flow	l/s	30	26										
2013	Total rainfall	mm	241	92	91	77	181	79	73	190	93	316	161	338
	Average flow	l/s												
2014	Total rainfall	mm	422	312	101	154	144	80	96	155	28	279	252	193
	Average flow	l/s					10	7*	4	3	5	8	27	
2015	Total rainfall	mm	12	132	116	33	146	96	144	220	112	110	327	465
	Average flow	l/s		19	15	14	15	8	17	15	15	45		
2016	Total rainfall	mm	348	212	140	81	142	117	67	108	192	40	83	109
	Average flow	l/s	58	32	20	15	13	11	14	15	19	12	13	13
2017	Total rainfall	mm	72	96	97	110	47	95	45	162	221	99	135	219
	Average flow	l/s	11	16		8	12	26	10	18	26	30	24	40
2018	Total rainfall	mm	171	96	168	135	63	20	69	154	127	155	232	186
	Average flow	l/s	41	30	26	23	14	7	6	9	15	18	33	36

Year	Total rainfall/average flow	Unit	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
2019	Total rainfall	mm	95	107	126	74	29	121	35	147	208	191	145	193
	Average flow	l/s	13	29	40	15	9	14	9			47	35	42
2020	Total rainfall	mm	123	245	86	42	18	164	119	178	94	179	137	270
	Average flow	l/s	28	40	26	7	4	8	16	19	16	30	44	54
2021	Total rainfall	mm	168	82	42	9	178	61	99	86	134	233	60	168
	Average flow	l/s	43	47			32	17	13	7	13	39	19	33

** Potentially suspect data – initial period following reinstallation of logger and no manual data to validate*

Table 3.2 Number of days when average flows at Garn Ffrwd Spring dropped below 8 l/s

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2007	0	0	0	0	0	0	0	0	16	17	17	0	50
2008	0	0	0		1	29	13	3	5	2	8		61
2009				0	0	0	0	0	0	2	0	0	2
2010	0	0	0	20	20		0	2	0	0	0	0	42
2011	0	0	1	0	0	0		0	0	0	0	0	1
2012	0												0
2013													0
2014						21*	30*						51
2015				0	0	0	15	9					24
2016	0	0	0	0	0	9	0	0	0	4	8		21
2017	8				15	0	10	0	0	0	0	0	33
2018	0	0	0	0	4			22	18	17	1	0	62
2019	4	0	0	0	0	1	0	0	0	0	0	0	5
2020	0	0	0	23	31	23	5	8	0	0	0	0	90
2021	0	0			0	0	0	21	23	0	0	0	44
Average from 2007 to 2021	1.2	0	0.1	4.8	6.5	8.3	7.3	5.4	5.6	4.2	3.4	0	32

Note: Some years contain incomplete data sets; see Figure 2.10 for summary of data gaps in the reporting period. Blank cells indicate no data available

** Potentially suspect data – initial period following reinstallation of logger and no manual data to validate*

4 Conclusions

For Torcoed Quarry a baseline hydrometric monitoring data set is available from January 2001. The full baseline monitoring dataset commences from March 2001 and is generally of very high quality although some notable data gaps are present over 2012 to 2015 during which time responsibilities for collecting data were reallocated following the loss of key personnel at Tarmac. This report presents data for 2021 as required by the current 2018 WMP and historical data are available from the previous annual reports for the Site.

The historical issues with the monitoring network have since been resolved and at the time of this report, all requirements of the current 2018 WMP are being met with the exception of the now destroyed BH6/13. The data coverage presented by the remainder of the network is considered to be sufficient to understand groundwater levels across the area of interest and flag any trends observed.

The rainfall over the Reporting Period was below the average (78% of the annual LTA), the third driest since 2000. In general, groundwater levels and flows were within the normal range observed in recent years. Water levels at BH3B/13 have remained low in 2021 following an apparent decline in 2018. This may be a sign of drawdown in this area. Water levels at BH8A/13 and BH8B/13 during the summer seemed low in comparison to previous years. However, there is no evidence of long-term trends of falling groundwater levels in any of the other boreholes.

There were 44 days with a recorded mean flow below 8 l/s at the Garn Ffrwd Spring (the level below which augmentation of Garn Ffrwd Fish Farm may be required). The overall number of days with below 8 l/s flow is above the average, although the prolonged dry spell in July and August is likely to be responsible and also caused a lengthy decline in groundwater hydrographs over this period.

Where data loss has occurred, the resulting data gaps are not considered to be significant with regards to interpreting the hydrogeological behaviour of the quarry and its environs. The good correlation between behaviour at different locations increases confidence in the quality of the data.

References

ESI (2015). Water balance for the area around Torcoed Quarry. Report reference 60449TN1.

SLR (2015). Torcoed, Torcoed Fawr and Crwbin Quarries Southwestern Extension and Consolidation Application. Environmental Statement. Chapter 8 *"Hydrology and Hydrogeology" completed* by ESI Ltd.

Smart, P. L. (2001). Torcoed and Torcoed Fawr Quarries and Assessment of the Potential Effects of the Jones Land Development on the Garn-ffrwd Spring. School of Geographic Sciences, University of Bristol.

Smart, P. L. and Halton P. (2002). Water tracing at Torcoed Quarry, Dyfed. University report.

Appendices

Appendix A

Water management plan

Applied Environmental Insight
esi consulting

Technical Note:

Water Management Plan (WMP): Torcoed/Torcoed Fawr/Crwbin Quarry

Published by ESI Limited
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CONFIDENTIAL

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Prepared for Tarmac Services Ltd.

Document reference: 60449TN3rev1,January 2018

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Contents

1 Background

Tarmac Services Ltd. (Tarmac) was originally granted revised planning permission for the combined operation of Torcoed and Torcoed Fawr Quarries on 30 August 2007. Planning Condition 7 of this permission states that:

> *A Water Management Plan shall be submitted for the approval of the LPA within 6 months of the date of this planning permission [i.e. by 1 March 2008]. No deepening of the quarry below 143 mAOD shall take place until the expiry of 6 months from the date of submission or the Local Planning Authority's written approval of the Water Management Plan whichever is the sooner.*

The Environmental Statement (ES) that supported the application for the revised planning permissions at the quarries included a series of recommendations for monitoring and mitigation that it was proposed would form the basis of the WMP for the site (ESI, 2006). The finalised WMP was submitted in May 2008 (ESI, 2008) and has formed the structure for monitoring since then.

Planning permission for the consolidation of Torcoed quarry, Torcoed Fawr quarry and Crwbin quarry into a single operational unit was granted on the 29th August 2017 (application reference W/33265) with Condition 9 of this permission stating:

> *A Revised Water Management Plan for the Torcoed/Torcoed Fawr/Crwbin Quarry Complex shall be submitted for the approval of the Local Planning Authority within 6 months of the date of this permission. The Water Management Plan shall be implemented as approved.*

This document constitutes the revised WMP for the consolidated site and has been based upon the conclusions of the Hydrology and Hydrogeology Chapter 8 (undertaken by ESI) of the Environmental Statement (ES) submitted for this application (SLR, 2015). The draft WMP, updated here, was presented in Appendix 8.7 of the aforementioned ES.

This document specifies requirements for three key activities. These activities are:

- Monitoring (Section 2)
- Mitigation measures (Section 3)
- Annual review (Section 4)

It is intended that the WMP should be subject to regular review and modification as necessary in the light of ongoing data collection.

2 Monitoring

The monitoring network is presented in Tables 1 and 2 and on Figure 1 attached.

2.1 Potential receptors

Sites at which the Hydrogeological Impact Assessments in ESI (2015) indicated that a potentially significant impact was possible, and mitigation may be required, are:

- Well at Ysgubor-fach (W20) – and associated private water supply (PWS4).
- Private water supply at Ffrwd-gain (PWS3) thought to be abstraction from stream.
- Garn-ffrwd fish farm spring (S09).
- Crwbin Spring (S53)

The previous Hydrogeological Impact Assessments (ESI 2006, 2010, 2011) identified a potentially significant impact from the development on Garn-ffrwd fish farm spring (S09). Tarmac has entered into an agreement with the owner of the Garn-ffrwd fish farm to augment flows at the spring when they drop below a prescribed level (8 l/s or 690 m^3/d). This agreement requires monitoring of Garn Ffrwd spring, construction of a 10,000 m^3 sump within the quarry and development of a system to discharge water into the sink hole to the east of the site in order to augment flows at the spring. As the legal agreement is in place, this site is therefore not addressed in this WMP.

2.2 Key changes to 2008 WMP monitoring locations

Monitoring wells

A number of new monitoring wells were installed in 2013 at locations around the quarry to increase the monitoring network. Two of these locations were to act as monitoring wells as required under the 2008 WMP.

These new locations are as follows:

- BH3B/13 (limestone installation) – drilled as a substitute for 07/02 (never installed) which was required under the 2008 WMP
- BH7/13 (limestone installation) – drilled to as a substitute for 07/03 (never installed) which was required under the 2008 WMP
- BH8B/13 (limestone installation) - drilled to replace 97/01 which was blocked.
- BH6/13 (limestone installation) – replaces BH95/7 which was destroyed.
- Location 07/01 (limestone installation), as required under the 2008 WMP, was not accessible for drilling. Location BH1/13 in Crwbin quarry is currently monitored and is deemed a suitable replacement for 07/01.
- BH5/13 (sandstone installation) - installed to provide a replacement sandstone installation to BH95/4 which was destroyed by blasting.
- BH8A/13 (sandstone installation) was drilled as a requirement for an additional sandstone installation in the vicinity of the northern ridge as specified in Environment Agency (now Natural Resources Wales) letter reference SH/2011/112252/01-L01 dated 6 December 2011.

Ty'r Garn well & Ty'r Garn pool (S40)

Previous data requests to NRW had indicated that a deregulated abstraction "licence" is present for a well at the location previously known as "Ty'r Garn Well". This is a licence which was authorised for abstraction of less than 20 m^3 per day. However, following a number of local enquires and site walkovers this feature cannot be located and it is thought that it is no longer in existence or used. Previous monitoring has been undertaken at Ty'r Garn pool (S40) only rather than a well. S40 is a hollow with a seep at the bottom and it is considered that monitoring at this location does not provide any useful data. It has therefore been removed from the WMP.

Stream flows

The significance of any impact to S25-A is not considered to significant. Therefore, monitoring at this location is not included in the monitoring schedule. However, W20 is considered to be a suitable indicator of a potential impact on flows in this stream.

Further investigation at S25-B has indicated that there is no spring at this location, with it simply being a point on Crwbin Stream which emerges from Crwbin Spring (S53). As flow monitoring is undertaken at Crwbin Spring, flow monitoring at location S25-B has been removed from the WMP.

2.3 Monitoring requirements

The monitoring network is presented in Tables 1 and 2 and is summarised below:

- Monitoring will be undertaken at a total of eleven monitoring wells using data loggers set at 15 minute intervals and/or monthly dipping (see Table 1)
- Manual monitoring of spring flows will be carried at monthly intervals at Crwbin Spring (S53)[1];
- Monthly dips will be undertaken at three off site wells - Garn Bwll (W03), Garn Farm (W11) and Ysgubor-fach (W20);
- Monitoring of flows at Garn-ffrwd spring and the quarry discharges will be undertaken with data loggers set at 15 minute intervals;
- Rainfall will be measured by a data logger linked to a tipping bucket rain gauge;
- Water quality (suspended solids and pH) will be monitored at monthly intervals at the quarry discharges and Garn Ffrwd spring.

The monitoring scheme is considered to be appropriate for determining whether any impacts have been caused at the potentially vulnerable receptors by future dewatering as, not only will these receptors be monitored, but there are also other monitoring points between the quarry and the receptors which will provide supporting information.

[1] Subject to access permissions

Table 1: Monitoring scheme at Torcoed Quarry

Monitoring point	Monitoring methodology and frequency	Remark
Monitoring wells in Old Red Sandstone		
BH95/3	Dipping at monthly intervals	Currently monitored.
BH5/13	Data loggers supported by dipping at monthly intervals	Currently monitored. If appropriate, the monitoring may be reduced to monthly manual readings after an appropriate period of monitoring (two to three years).
BH8A/13		
Monitoring wells in Penderyn Oolite and Cilyrychen Limestone		
BH6/13	Dipping at monthly intervals	Currently monitored.
BH1/13	Data loggers supported by dipping at monthly intervals	Currently monitored. If appropriate, the monitoring may be reduced to monthly manual readings after an appropriate period of monitoring (two to three years).
BH3B/13		
BH4A/13		
BH8B/13		
BH9/13		
Monitoring wells in Mynydd-y-Garegg Limestone		
BH17	Dipping at monthly intervals	Currently monitored.
BH7/13	Data loggers supported by dipping at monthly intervals	Currently monitored. If appropriate, the monitoring may be reduced to monthly manual readings after an appropriate period of monitoring (two to three years).
Quarry discharge flows		
Torcoed discharge	Data loggers supported by monthly manual measurements	Currently monitored.
Torcoed Fawr discharge		
Flow measurements		
Garn-Ffrwd (S09)	Data loggers supported by monthly manual measurements	Currently monitored
Crwbin Spring (S53)	Manual measurement on a monthly basis	
Wells		
Garn Bwll (W03) Ysgubor-fach (W20)	Dipping at monthly intervals	Currently monitored. W03 to act as indicator of drawdown effects to the east.
Garn Farm (W11)	Dipping at monthly intervals	Included to validate conceptual model.
Rainfall measurements		
Rainfall gauge	Data loggers with monthly downloads	Currently monitored

Table 2: Water quality monitoring scheme at Torcoed Quarry

Name and feature	Monitoring methodology and frequency
FSHUS (S09) - Garn-ffrwd spring	Water quality (suspended solids and pH) will be monitored at monthly intervals
Quarry discharge points*	

** Torcoed discharge and Torcoed Fawr discharge. Samples only taken when adequate flow is present.*

3 Mitigation Measures

3.1 General approach

The objective of the mitigation measures defined in this WMP is to develop a robust and practical system that protects the receptors that were identified in the ES (ESI, 2015) as being potentially at risk as a result of the quarry operation. The methodology also aims to protect the quarry operator from excessive/unnecessary costs from excessive or impractical mitigation requirements.

The general approach for mitigation at this site is as follows:

- Carry out baseline monitoring to define the 'natural' range of conditions at the site. For each relevant receptor define a target level.
- Derogation is considered to have occurred when the monitoring data fall below the target level.
- Once derogation has been identified, appropriate mitigation measures will be implemented.

Note that the definition of target levels based on historic data series assumes that future climatic conditions are similar to those in the baseline period. If future climate conditions are significantly different to current conditions, the selection of target levels should be reconsidered.

The mitigation measures discussed in this section fall into three categories as follows:

- Maintenance of water levels
- Maintenance of stream flows
- Protection of water quality

3.2 Maintenance of water levels

The relevant receptors (shown in Figure 1) are:

- Ysgubor-fach (W20) is sourced from the Old Red Sandstone which is not considered to be at risk from the proposed development of the quarry. However, the presence of the Crwbin Fault may allow some water to enter the Old Red Sandstone from the Carboniferous Limestone in this area and there is thus some potential for impact. These impacts are therefore considered to be of low probability but potentially significant.
- Private water supply at Ffrwd-gain (PWS3) is thought to be an abstraction from the stream. The potential impact is deemed to be moderate. Monitoring of W20 will be used as an indicator of possible impact on this location.

Note Garn Bwll (W03) will be monitored to act as an additional indicator of drawdown effects to the east but the degree of impact is considered to be minor and no mitigation is considered necessary.

3.2.1 Target levels

Water levels at W20 have been monitored since November 2008 as summarised in Table 3.

Table 3 Water levels statistics (mBDAT) at well locations

	Ysgubor-fach (W20)
Min	0.04

Average	0.11
Max	0.19
Target	0.44

Note: water level statistics cover data from start of data collection (see above) to September 2017

The target levels for this site is set at 0.25 m lower than the lowest recorded value (i.e. max value in Table 3) as shown in Table 3.

If water levels at W20 drop below the Target Level over two consecutive months, the quarry operator will notify the MPA of this occurrence in writing within four weeks of recording the data, and provide details of any proposed additional monitoring or other investigations to identify the cause of the fall. The investigations will include an assessment of the actual vulnerability of any potentially vulnerable receptors on the groundwater pathway affected if this has not already been carried out.

If water levels at W20 drop below the target levels for two consecutive monthly readings, it will be assumed that derogation has occurred unless:

- It can be shown to the satisfaction of the Mineral Planning Authority that the low water level has been caused by a mechanism other than dewatering at the quarry (e.g. background climate factors); or
- It can be shown to the satisfaction of the Mineral Planning Authority that the fall in water levels has not had a significant impact on the utility of the water supply.

3.3 Mitigation

In the event of derogation occurring, options for mitigation will be explored in the following order:

- Lowering of pumps;
- Deepening of boreholes/wells;
- Provision of alternative supplies (mains water in the event of complete derogation) or short term supplementary supplies if derogation is temporary.

The quarry operator will notify the MPA in writing of any occurrence of derogation within four weeks of noting the occurrence of such derogation outlining the proposed mitigation measures. The quarry operator will make reasonable endeavors to implement any mitigation measures within 12 weeks of noting the occurrence of derogation.

3.4 Maintenance of spring flows

Garn-Ffrwd (S09) – This spring may be affected by the development of the quarry, it is subject of a separate legal agreement and therefore is not addressed in this WMP. In the ES it was identified that some residual pumping to Garn-Ffrwd spring will be required following cessation of quarrying. Tarmac's obligation under this agreement only ceases once flows and quality at the spring have been restored to the owner's reasonable satisfaction.

Crwbin Spring (S53) – ESI (2015) estimate the flows from this receptor are expected to reduce by 50% and 100% during the proposed development. The Crwbin Spring is not subject to any specific ecological designations and it represents one of many minor watercourses joining the Gwendraeth Fach in this area. As such, the degree of impact caused by the development is unlikely to be ecologically significant. Mitigation measures for this receptor are not considered to be feasible given the location of the spring (on the far side of a road and housing) and the long term nature of the effect.

3.5 Water quality

The quality standard to be met by any new discharge for augmentation purposes will be set by a discharge consent to be issued by Natural Resources Wales. If necessary, settling lagoons or other appropriate quality control systems will be implemented to ensure compliance with the conditions of the discharge consent.

4 Annual review

The data collected will be forwarded to Carmarthenshire County Council (CCC), as the MPA, on an annual basis.

The annual report will present the following data:

- groundwater levels;
- groundwater quality;
- dewatering rates;
- stream flow;
- water quality;
- augmentation volumes to date.

The content of the WMP will be reviewed and agreed by CCC, Natural Resources Wales and Tarmac every two years. The aim of these reviews will be to ensure that the WMP continues to safeguard the water resources and conservation interest of the catchment without imposing unnecessary or impractical constraints on the development. Any party will have the right to call interim meetings to discuss specific issues that may arise.

5 References

ESI Ltd. (2006). Torcoed and Torcoed Fawr Quarries: Hydrogeological Impact Assessment

ESI Ltd. (2008). Water Management Plan (WMP): Torcoed/Torcoed Fawr Quarry

ESI Ltd., (2010). Crwbin Quarry: Hydrogeological Impact Assessment Report. Ref 6257R4.

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SLR., (2015) Torcoed, Torcoed Fawr and Crwbin quarries Carmarthenshire. South west extension and consolidation application. Environmental Statement Volume 1.

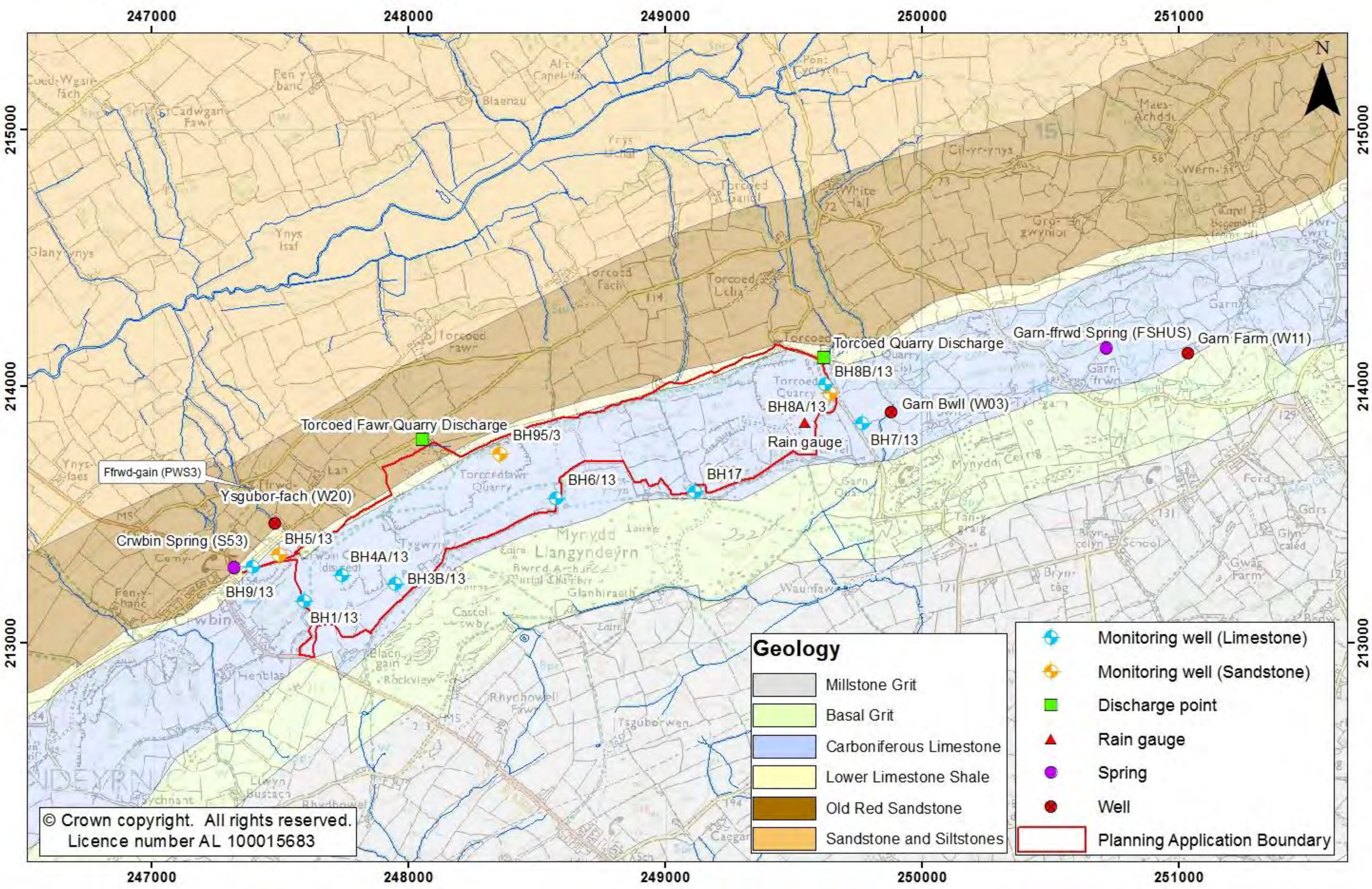
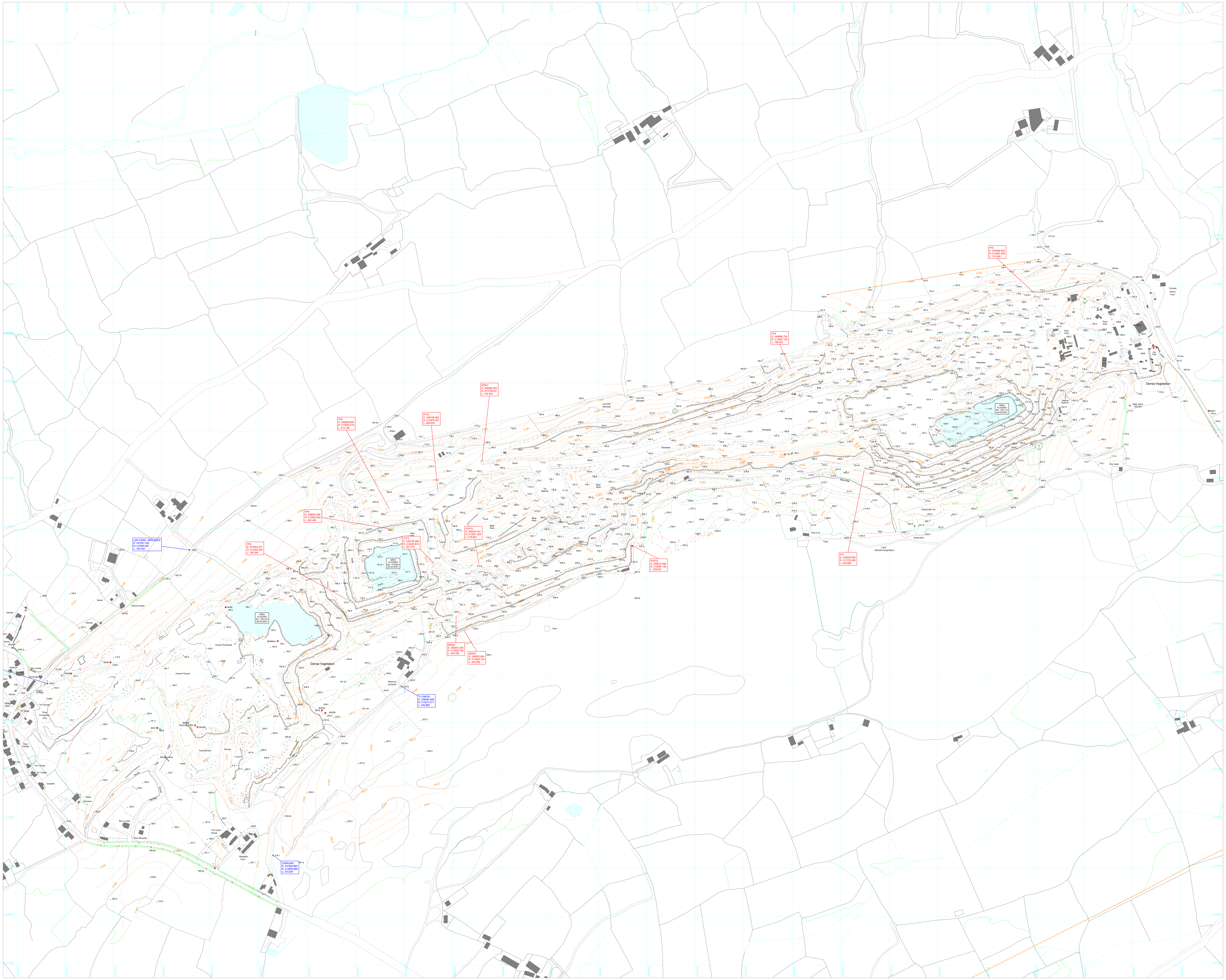


Figure 1 Monitoring locations

Appendix B

Quarry surveys



NOTE: Certain information on this plan has been
digitised and therefore its accuracy cannot be
guaranteed. Do not scale off plant/building locations.

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A CRH COMPANY

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T045 - TORCOED

TOPOGRAPHIC PLAN
2nd MARCH 2021

LSS Models Used To Create Plot

T045 TORCOED 2021-03-02 QU

Drawn By SJB	LIS Drawing Number T045-00218
Scale 1 : 2500	Drawing Name T045 2021-03-02 QU_A0L.pdf

Appendix C

QA checks and rainfall data synthesis

APPENDIX D: QA CHECKS ON RAINFALL AND DATA SYNTHESIS

D.1 Monitoring sites

Tarmac monitors rainfall onsite and comparison of the data from this gauge with nearby Natural Resources Wales rainfall gauges provides a useful indication of the reliability of the data; any deviations flag up periods during which one of the data sets is likely to be unreliable.

Daily rainfall data has been provided for three NRW gauges: the details of these sites are (Table A.1).

Table D.1 Station information for NRW locations

Station name	Gorslas DL	Margam	Hirwaun
Station number	498582	493959	494988
NGR	SN	SN	SN
Easting	56360	80920	93623
Northing	14652	85490	06731

D.2 QA Procedure

Rainfall data were compared between all four sites to assess which showed the highest degree of agreement. Table D.2 gives basic statistics for each site. As well as the total long term average (LTA) values, LTA values are also given for periods where there is “good” agreement between the relevant station and the Quarry rain gauge. The purpose of this was to derive robust multipliers to allow conversion between data from the various sites. An explanation of how “good” data were identified is given below.

Table D.2 Basic statistics and the level of agreement between sites over comparison period (01/01/2000 to 28/01/2015)

Station name	Quarry	Gorslas DL	Margam	Hirwaun
Start date	21/01/2001	01/01/2000	01/01/2000	20/11/2000
End date	01/02/2011	31/01/2016	27/11/2015	31/01/2016
Count	2655	17196	8308	4891
LTA mm	4.84	4.47	3.09	5.51
LTA mm ‘Good v Quarry’		3.70	2.90	3.90
LTA Quarry when ‘Good’		4.29	4.23	4.07
Conversion -> Quarry		1.16	1.46	1.04

A logical test is used to determine whether two data sets exhibit a high degree of agreement on a given day using the basic logic was as follows:

> *If the daily totals agree to +/- 2.0mm for totals <10mm and +/-20% for totals >10mm then define relationship between data on that data as “good”.*

The flow chart below shows the progression of the logical test (Illustration A.1).

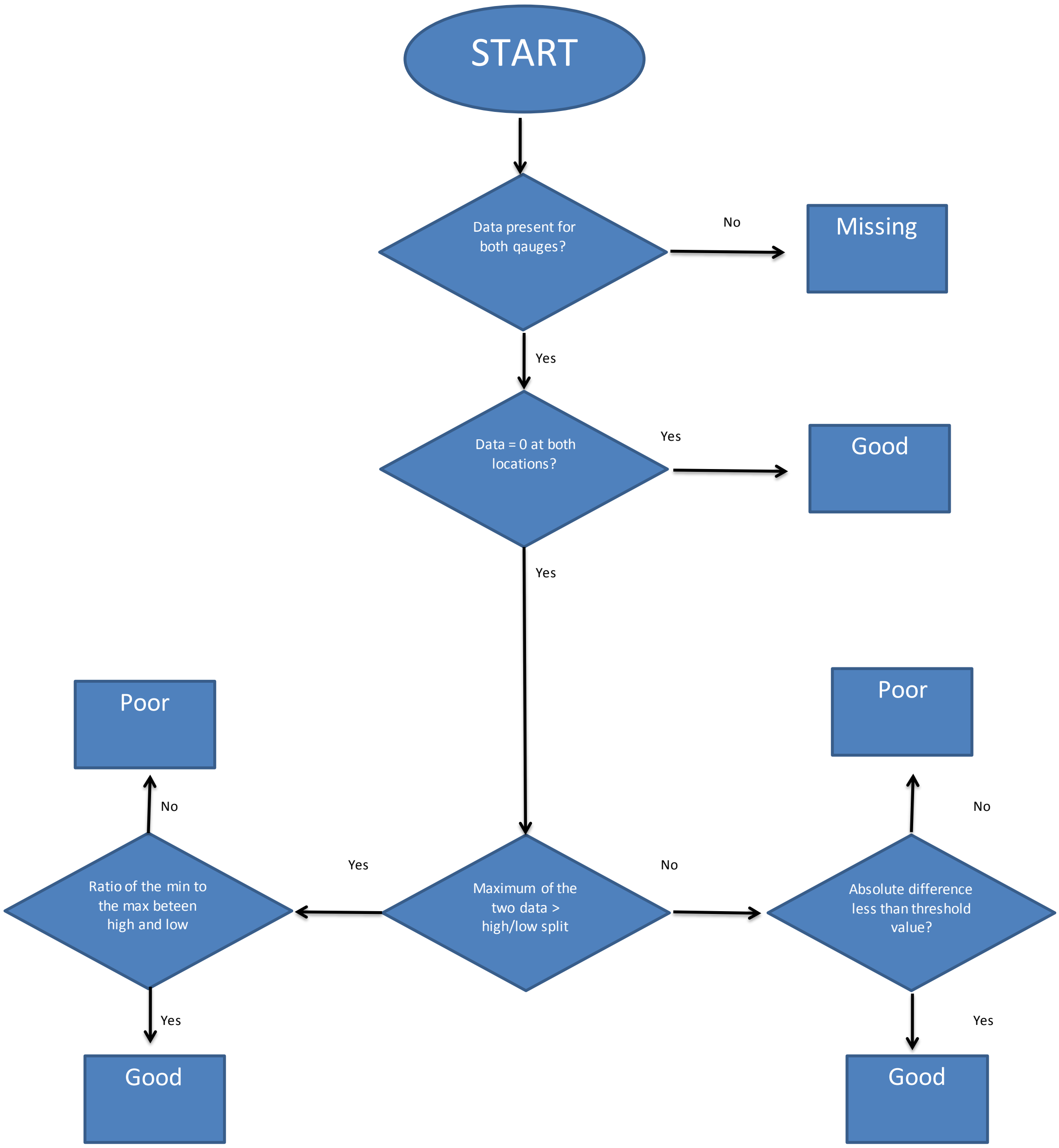


Illustration D.1 Logical tests to establish level of agreement between data sets

The resultant number of days in each category for each data set is shown in Table D.3 below. The selected output data set(s) from the process above are used to produce the final synthesised rainfall data set.

Table D.3 Count of relationships between rainfall datasets (Data to 28 Jan 2015)

Relationship	Gorslas v Quarry Quality	Margam v Quarry Quality	Quarry v Hirwaun Quality	Margam v Gorslas Quality	Gorslas v Hirwaun Quality	Margam v Hirwaun Quality
Good	2601	2601	2113	5971	4408	4749
Poor	54	46	101	133	136	141
Missing	17464	17472	17905	14015	15575	15229

The logical statement described above was used to establish the strength of the relationship between each data set on each day. Following on from this, a second logical statement was developed to establish which data set(s) should be used for a given day. This is shown in the flow chart below (Illustration D.2). The importance of each data set was established based upon the proximity to the site, and the similarity of the data sets to the Quarry data; Quarry data were taken to be the most representative data for the site.

Manual override data were used over periods where data from all sites were missing or the contributing data was thought to be spurious. In these circumstances, Margam or hirwaun, long term averages or interpolated values are entered to ensure a continuous data set is synthesised. The manual override is only used sparingly.

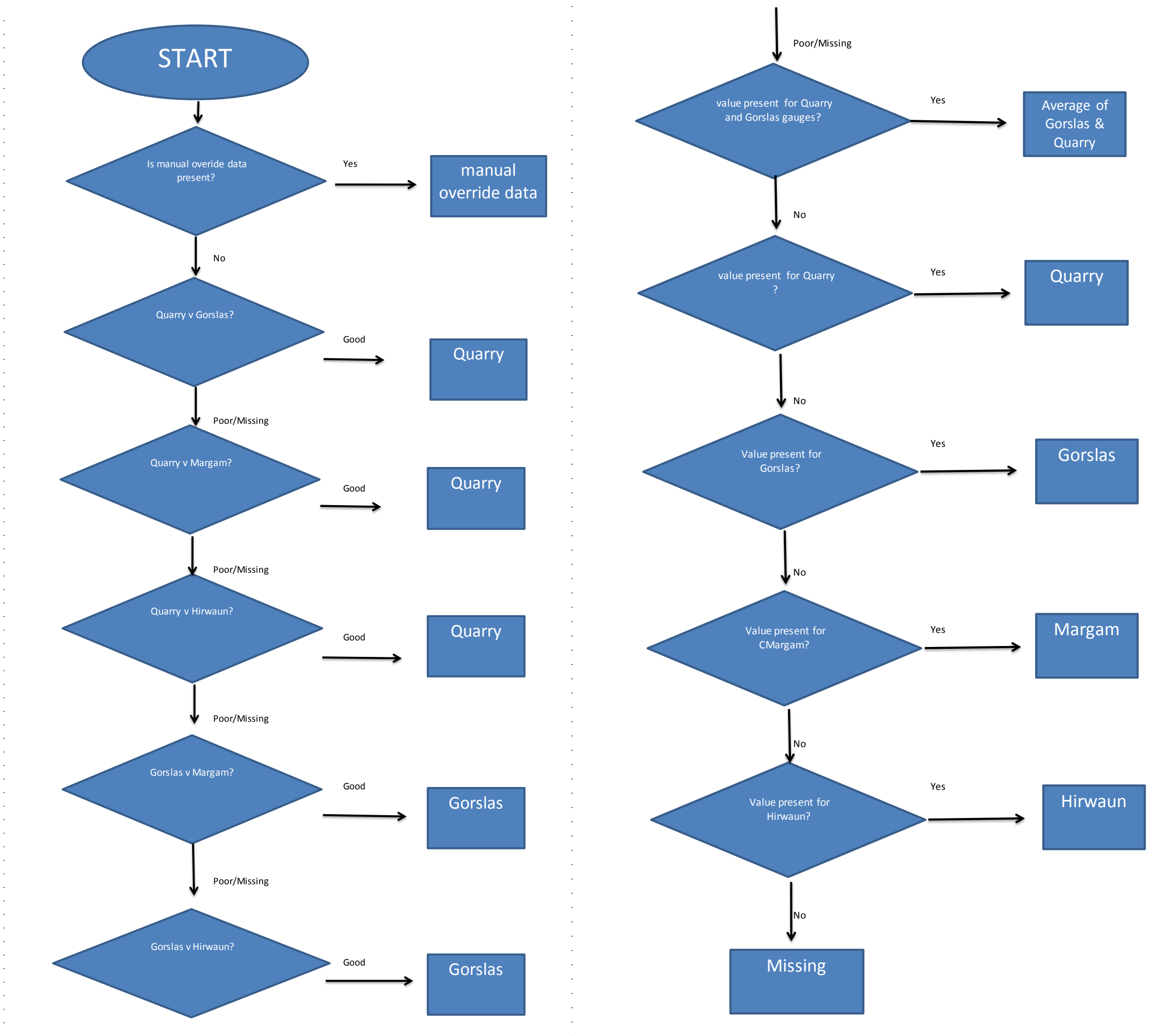


Illustration D.2 Logical tests to establish most suitable rainfall data

Each constituent value is multiplied by a correction factor to adjust the magnitude of the contributing rainfall data to match that of the Quarry rainfall data. The value of this coefficient was established by taking the ration of the two LTA of “good” data values of the relevant data sets (Table D.2).

Appendix D

Chemistry data

Stantec

Customer: Tarmac

Client Reference / Location: **Torcoed Quarry**

Customer Sample ID					**TORC DIS**	**TORC DISC**	**TORC DIS**	**TORC DIS**	**TORC DIS**	**TORC DIS**	**TORC DIS**	**TORC DIS**	**TORC DIS**	**TORC DIS**	**TORC DIS**	**TORC DIS**
Laboratory					SOCOTEC	SOCOTEC	SOCOTEC	SOCOTEC	SOCOTEC	SOCOTEC	SOCOTEC	SOCOTEC	SOCOTEC	SOCOTEC	SOCOTEC	SOCOTEC
Sample Type					LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID
Sampled Date					21/01/2021	22/02/2021	24/03/2021	11/05/2021	26/05/2021	22/06/2021	13/07/2021	23/08/2021	23/09/2021	13/10/2021	17/11/2021	15/12/2021
Sample Received Date					26/01/2021	24/02/2021	26/03/2021	15/05/2021	28/05/2021	24/06/2021	17/07/2021	25/08/2021	27/09/2021	09/11/2021	22/11/2021	04/01/2022
Report Date					01/02/2022	03/03/2021	07/04/2021	21/05/2021	04/06/2021	30/06/2021	22/07/2021	02/09/2021	04/10/2021	12/11/2021	02/12/2021	07/01/2022
Report Number					21011460	21021709	21031918	21051027	21052049	21061849	21071264	21081627	21091938	21110618	21111637	21121638
Lab Sample Number					21011460-002	21021709-002	21031918-002	21051027-002	21052049-002	21061849-002	21071264-002	21081627-002	21091938-002	21110618-002	21111637-002	21121638-002
Deviating Sample Report					Holding time	-	-	-	-	-	-	-	-	Holding time	Holding time	Holding time
Analysis	**Test**	**Method**	**Units**	**LOD**												
Inorganics																
	pH	WSLM2&3;PH CONDW	pH Units	<1	7.7	7.7	7.8	7.9	7.5	7.7	7.6	7.7	7.6	7.4	7.4	7.8
	Total Suspended solids	WSLM10	mg/l	<5	17	5	<5	5	5	<5	<5	<5	61	<5	<5	<5

Customer Sample ID					**FSHUS**	**FSHUS**	**FSHUS**	**FSHUS**	**FSHUS**	**FSHUS**	**FSHUS**	**FSHUS**	**FSHUS**	**FSHUS**	**FSHUS**	**FSHUS**
Laboratory					SOCOTEC	SOCOTEC	SOCOTEC	SOCOTEC	SOCOTEC	SOCOTEC	SOCOTEC	SOCOTEC	SOCOTEC	SOCOTEC	SOCOTEC	SOCOTEC
Sample Type					LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID
Sampled Date					21/01/2021	22/02/2021	24/03/2021	11/05/2021	26/05/2021	22/06/2021	13/07/2021	23/08/2021	23/09/2021	13/10/2021	17/11/2021	15/12/2021
Sample Received Date					2301/2020	24/02/2021	26/03/2021	15/05/2021	28/05/2021	24/06/2021	17/07/2021	25/08/2021	27/09/2021	09/11/2021	22/11/2021	04/01/2022
Report Date					28/01/2020	03/03/2021	07/04/2021	21/05/2021	04/06/2021	30/06/2021	22/07/2021	02/09/2021	04/10/2021	12/11/2021	02/12/2021	07/01/2022
Report Number					21011460	21021709	21031918	21051027	21052049	21061849	21071264	21081627	21091938	21110618	21111637	21121638
Lab Sample Number					21011460-001	21021709-001	21031918-001	21051027-001	21052049-001	21061849-001	21071264-001	21081627-001	21091938-001	21110618-001	21111637-001	21121638-001
Deviating Sample Report					Holding time	-	-	-	-	-	-	-	-	Holding time	Holding time	Holding time
Analysis	**Test**	**Method**	**Units**	**LOD**												
Inorganics																
	pH	WSLM2&3;PH CONDW	pH Units	<1	7.6	7.6	7.5	8.2	7.6	7.5	7.4	7.5	7.6	7.4	7.4	7.9
	Total Suspended solids	WSLM10	mg/l	<5	178	6	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5

Appendix E

Discharge permit

creating a better place

Environment Agency

RECEIVED
24 FEB 2009

Mr Andrew Tait
ESI Ltd
New Zealand House
160 Abbey Foregate
Shrewsbury
SY2 6FD

Our ref: BP0235501/ BP0239301

Your ref:

Date: 23 February 2008

Dear Mr Tait

Application to discharge trade effluent consisting of Quarry Dewatering by Tarmac Limited from premises at Torcoed Quarry, Porthyrhyd, Carmarthen, Dyfed, SA32 8PY. Application no: BP0235501/ BP0239301

Water Resources Act 1991 (as amended by the Environment Act 1995) Schedule 10

I enclose our formal notice of Variation of consent to discharge trade effluent consisting of Quarry Dewatering by Tarmac Limited from premises at Torcoed Quarry, Porthyrhyd, Carmarthen, Dyfed, SA32 8PY.

The changes to conditions in the consent may result in a change to the annual charge. If this is the case, we will send your client a revised bill. Information on our charges is available through our website at www.environment-agency.gov.uk/charges. If you do not have access to the internet, a hard copy is available from me on request.

If your client considers that the conditions of the Variation of consent are unreasonable, they have a right of appeal to:

National Assembly for Wales
Water Branch
Climate Change and Water Division
Department for Environment, Sustainability and Housing
Cathays Park
Cardiff CF10 3NQ

The appeal must be given in writing within three months of the date of issue of the Variation of consent and must include a statement of the grounds for the appeal. A copy of the appeal should also be sent to us at the address below.

Details of this Consent, and associated application, are placed on our Public Register which is open for inspection by the public.

WQ Permitting Support Centre, P.O. Box 4209, Sheffield, S9 9BS
Customer services line: 08708 506 506
Email: enquiries@environment-agency.gov.uk
www.environment-agency.gov.uk

Change of Consent Holder

If in the future the name of the Consent Holder is due to change, both your client and the new holder must inform us in writing before the change. We can then transfer the rights and charges to the new holder and send a certificate to confirm the transfer of consent.

If you have any queries please contact me.

Yours sincerely

M. Platts

Michaela Platts
Permitting Support Advisor

Direct dial: 0114 280 0683
Direct fax: 0114 262 6697
Direct e-mail: psc-waterquality@environment-agency.gov.uk

Enc

Variation of Consent to Discharge

Water Resources Act 1991 (as amended by the Environment Act 1995)

Consent Holder	**Tarmac Limited** **Millfields Road** **Ettingshall** **Wolverhampton** **WV4 6JP**
Consent to Discharge from	**Torcoed Quarry** **Porthyrhyd** **Camarthen** **Dyfed** **SA32 8PY**
Company Registration Number	**00453791**
Consent Number	**BP0235501**

Environment Agency
Permitting Support Centre, PO Box 4209, Sheffield, S9 9BS
Customer services line: 08708 506 506
Email: enquiries@environment-agency.gov.uk
www.environment-agency.gov.uk

Consent to Discharge

Water Resources Act 1991
Section 88, Schedule 10
(as amended by the
Environment Act 1995)

Environment Agency

Variation of Consent to Discharge

Consent Number
BP0235501

To:
Tarmac Limited ("the Consent Holder")
Millfields Road
Ettingshall
Wolverhampton
WV4 6JP

Company Registration Number: **00453791**

The Environment Agency ("the Agency") in pursuance of its powers under the Water Resources Act 1991(as amended by the Environment Act 1995) hereby consents to the making of a discharge:

Of:
Trade effluent consisting of site drainage and dewatering effluent ("the Discharge")

With respect to Consent No. BP0235501 issued on the 15th February 1995

From:
Settlement tanks serving Torcoed Quarry

At:
Torcoed Quarry, Porthyrhyd, Carmarthen, Dyfed

To:
An unnamed tributary of Gwendraeth Fach

Subject to the conditions set out in this notice of Consent to Discharge.

Subject to the provisions of Paragraphs 7 and 8 of Schedule 10 of the Water Resources Act 1991(as amended by the Environment Act 1995), no notice shall be served by the Agency, altering this consent, without the agreement of the Consent Holder, during a period of 4 years from the date this notice is issued.

This Consent is issued on:	20 February 2009
This Consent takes effect on:	20 February 2009

Signed

Carl Sweeney

Permitting Team Leader

1 Conditions of Consent for trade effluent consisting of site drainage and dewatering effluent

1.1 Nature

1.1.1 The Discharge shall consist solely of trade effluent consisting of site drainage and dewatering effluent from an area of approximately 229,000 square metres.

1.2 Place of Discharge

1.2.1

The Discharge shall be made in the manner and at the place specified as:

a discharging to an unnamed tributary of the Gwendraeth Fach;

b at National Grid Reference SN 49620 14110;

c shown marked "Discharge and Sample Point" on the Site Plan attached to this consent.

1.3 Sampling Point Requirements

1.3.1 The outlet to controlled waters shall be constructed and maintained so that a representative sample of the Discharge may be obtained at National Grid Reference SN 49620 14110 as shown marked "Discharge and Sample Point" on the Site plan attached to this consent.

1.4 Rate

1.4.1 The volume of the Discharge shall not exceed 73 litres per second.

1.5 Volume

1.5.1 The volume of the Discharge shall not exceed 6304 cubic metres per day.

1.6 Flow Measurement

1.6.1 The consent holder shall install, operate and maintain a means of flow measuring to a specification and at a location required by the Environment Agency. The flow measurement installation shall enable the instantaneous flow from the settlement tanks to be recorded. The Consent Holder shall calibrate, operate and maintain the flow measurement and recording system to a standard specified by their quality management system, that has been approved by an independent expert. The flow and maintenance records shall be provided to the Environment Agency as and when requested.

1.7 Composition

1.7.1 The Discharge shall not contain more than 60 milligrammes per litre of suspended solids (measured after drying at 105°C).

1.7.2 As far as is reasonably practicable, the site and its facilities shall be operated so as to prevent the Discharge from containing any significant trace of visible oil or grease.

1.7.3 The pH of the Discharge shall not be less than 6 or greater than 9.

1.8 **Works Operation**

1.8.1 The settlement tanks shall be operated and the effluent shall be treated in a manner which, so far as reasonably practicable, minimises the polluting effects of the discharge made from the settlement tanks on controlled waters.

This condition does not require -

a any higher standard to be achieved in relation to any characteristic of the discharge which is specifically regulated by 1.7.1, 1.7.2 and 1.7.3 than is required by those conditions.

b any alteration of the works or a change in the type of treatment used.

1.9 **Maintenance**

a The settlement tanks shall be operated and maintained in accordance with good operational practice such that the settlement tanks shall be desludged at sufficient frequency and in such a manner to prevent excessive carryover of suspended solids.

1.10 **Recording and Reporting**

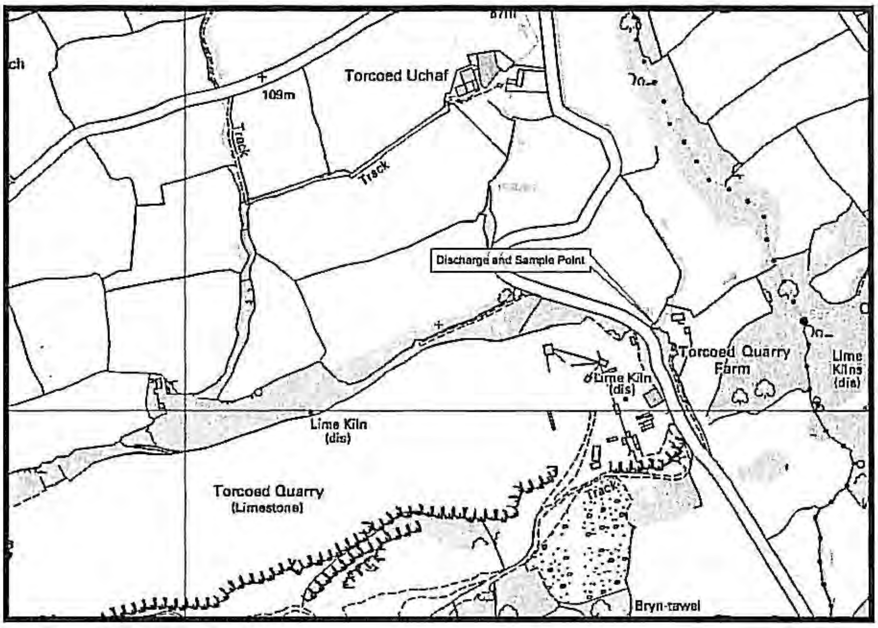
1.10.1

a The Consent Holder shall establish and operate a documented maintenance programme and record all non-routine actions undertaken that may have adversely affected effluent quality. Copies of the programme shall be made available for inspection by the Agency's officers at all reasonable times.

b On request the Consent Holder shall supply the Agency with a written report on the maintenance and all non-routine actions that may have adversely affected effluent quality

c The Consent Holder shall as soon as reasonably practicable report to the Agency all non-routine actions that may have adversely affected effluent quality.

2 Site Plan


Torcoed Uchaf
109m
Track
Discharge and Sample Point
Torcoed Quarry Farm
Lime Kilns (dis)
Lime Kiln (dis)
Lime Kiln (dis)
Torcoed Quarry (Limestone)
Track
Bryn-tawel

Environment Agency

Variation of Consent to Discharge

Water Resources Act 1991 (as amended by the Environment Act 1995)

Consent Holder(s)	**Tarmac Limited** **Millfields Road** **Ettingshall** **Wolverhampton** **WV4 6JP**
Consent to Discharge from	**Torcoed Fawr Quarry** **Porthyrhyd** **Camarthen** **Dyfed** **SA32 8PY**
Company Registration Number	**00453791**
Consent Number	**BP0239301**

Environment Agency
Permitting Support Centre, PO Box 4209, Sheffield, S9 9BS
Customer services line: 08708 506 506
Email: enquiries@environment-agency.gov.uk
www.environment-agency.gov.uk

Consent to Discharge

Water Resources Act 1991
Section 88, Schedule 10
(as amended by the
Environment Act 1995)

Environment Agency

Variation of Consent to Discharge

Consent Number
BP0239301

To:
Tarmac Limited ("the Consent Holder")
Millfields Road
Ettingshall
Wolverhampton
WV4 6JP

Company Registration Number: **00453791**

The Environment Agency ("the Agency") in pursuance of its powers under the Water Resources Act 1991(as amended by the Environment Act 1995) hereby consents to the making of a discharge:

Of:
Trade effluent consisting of site drainage and dewatering effluent ("the Discharge")

With respect to Consent No. BP0239301 issued on the 4th March 1994

From:
Settlement tanks serving Torcoed Fwar Quarry

At:
Torcoed Fawr Quarry, Porthyrhyd, Carmarthen, Dyfed

To:
An unnamed tributary of Gwendraeth Fach

Subject to the conditions set out in this notice of Consent to Discharge.

Subject to the provisions of Paragraphs 7 and 8 of Schedule 10 of the Water Resources Act 1991(as amended by the Environment Act 1995), no notice shall be served by the Agency, altering this consent, without the agreement of the Consent Holder, during a period of 4 years from the date this notice is issued.

This Consent is issued on: 20 February 2009

This Consent takes effect on: 20 February 2009

Signed

Carl Sweeney

Permitting Team Leader

1 Conditions of Consent for trade effluent consisting of site drainage and dewatering effluent

1.1 Nature

1.1.1 The Discharge shall consist solely of trade effluent consisting of site drainage and dewatering effluent from an area approximately 262,000 square metres.

1.2 Place of Discharge

1.2.1

The Discharge shall be made in the manner and at the place specified as:

a discharging to an unnamed tributary of the Gwendraeth Fach;

b at National Grid Reference SN 48060 13810;

c shown marked "Discharge and Sample Point" on Site Plan attached to this consent.

1.3 Sampling Point Requirements

1.3.1 The outlet to controlled waters shall be constructed and maintained so that a representative sample of the Discharge may be obtained at National Grid Reference SN 48060 13810 as shown marked "Discharge and Sample Point" on the Site plan attached to this consent.

1.4 Rate

1.4.1 The volume of the Discharge shall not exceed 61 litres per second.

1.5 Volume

1.5.1 The volume of the Discharge shall not exceed 5247 cubic metres per day.

1.6 Flow Measurement

1.6.1 The consent holder shall install, operate and maintain a means of flow measuring to a specification and at a location required by the Environment Agency. The flow measurement installation shall enable the instantaneous flow from the settlement tanks to be recorded. The Consent Holder shall calibrate, operate and maintain the flow measurement and recording system to a standard specified by their quality management system, that has been approved by an independent expert. The flow and maintenance records shall be provided to the Environment Agency as and when requested.

1.7 Composition

1.7.1 The Discharge shall not contain more than 60 milligrammes per litre of suspended solids (measured after drying at 105°C).

1.7.2 As far as is reasonably practicable, the site and its facilities shall be operated so as to prevent the Discharge from containing any significant trace of visible oil or grease.

1.7.3 The pH of the Discharge shall not be less than 6 or greater than 9.

1.8 **Works Operation**

1.8.1 The settlement tanks shall be operated and the effluent shall be treated in a manner which, so far as reasonably practicable, minimises the polluting effects of the discharge made from the settlement tanks on controlled waters. This condition does not require -

a any higher standard to be achieved in relation to any characteristic of the discharge which is specifically regulated by 1.7.1, 1.7.2 and 1.7.3 than is required by those conditions.

b any alteration of the works or a change in the type of treatment used.

1.9 **Maintenance**

a The settlement tanks shall be operated and maintained in accordance with good operational practice such that the settlement tanks shall be desludged at sufficient frequency and in such a manner to prevent excessive carryover of suspended solids.

1.10 **Recording and Reporting**

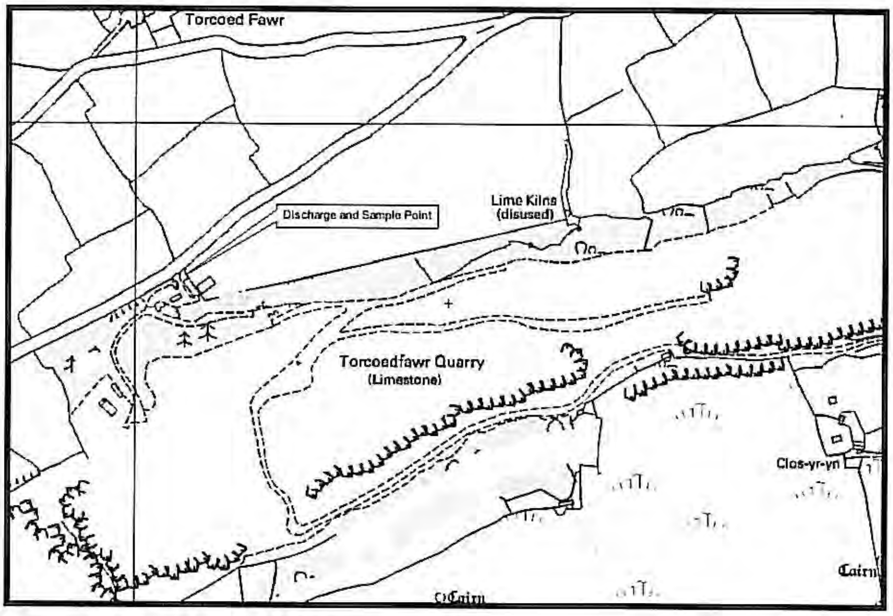
1.10.1

a The Consent Holder shall establish and operate a documented maintenance programme and record all non-routine actions undertaken that may have adversely affected effluent quality. Copies of the programme shall be made available for inspection by the Agency's officers at all reasonable times.

b On request the Consent Holder shall supply the Agency with a written report on the maintenance and all non-routine actions that may have adversely affected effluent quality

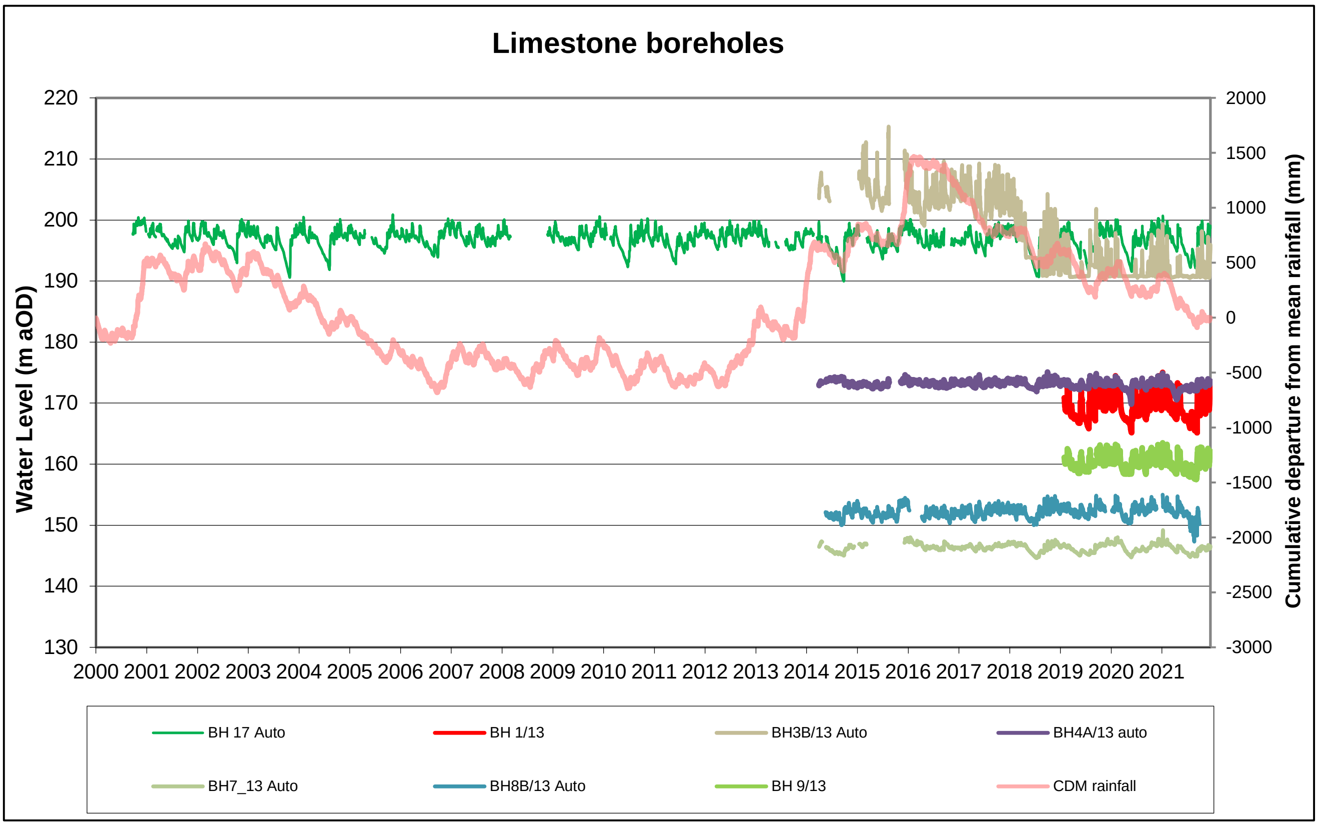
c The Consent Holder shall as soon as reasonably practicable report to the Agency all non-routine actions that may have adversely affected effluent quality.

2 Site Plan


Torcoed Fawr
Discharge and Sample Point
Lime Kilns (disused)
Torcoedfawr Quarry (Limestone)
Clos-yr-yn
Cairn

Appendix F

Long-term groundwater hydrographs



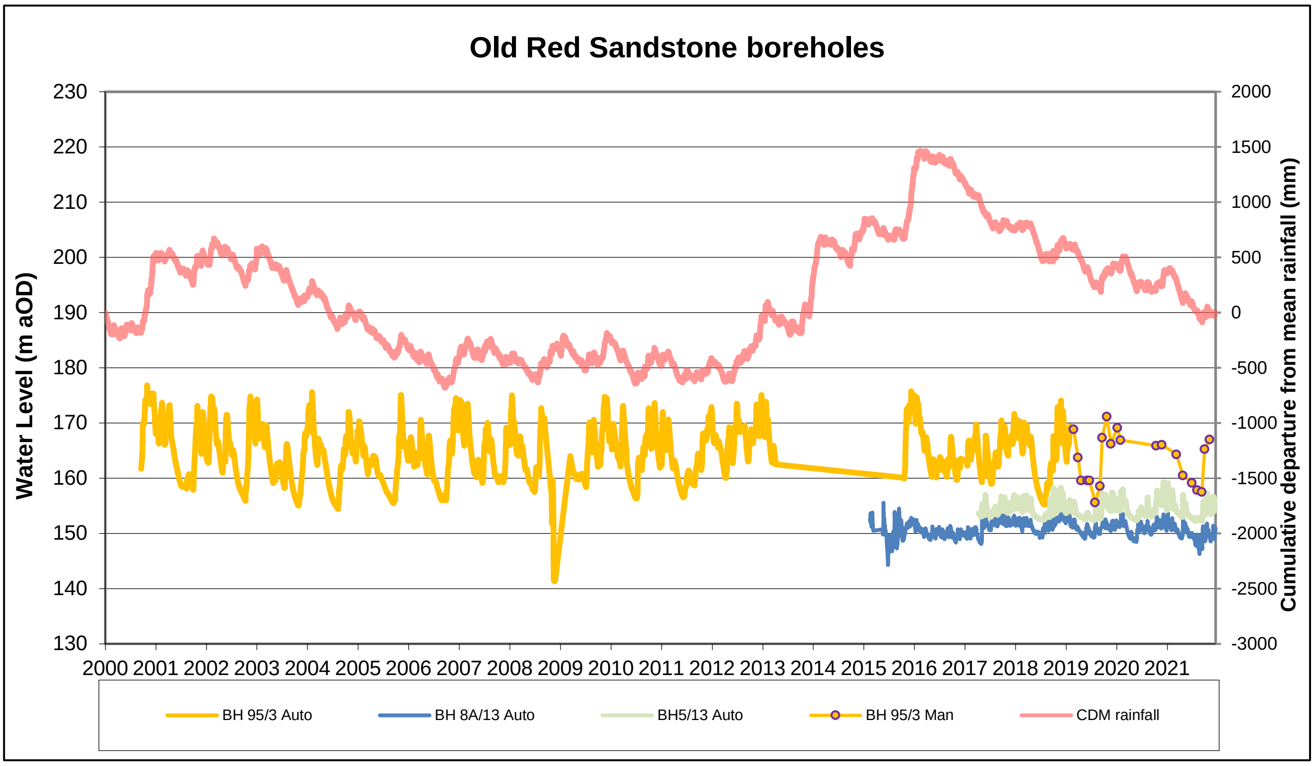


Figure 2.8 & 2.9

Long term hydrographs in Limestone and Old Red Sandstone Boreholes

Date	Drawn
Feb 22	VXK
Scale	Checked
dns	RAH
Original	Revision
A4	1

File Reference
\\Gb1029-ppfss01\workgroup\3302\active\330201038\reports\R12 2021 Annual Report\Figures\[Fig 2.6 & 2.7 & 2.8 & 2.9 GW.xls]Figure 2.7

Stantec

Appendix G

Long-term comparison of average monthly flow at Garn Ffrwd Spring and total rainfall

Table 1 Comparison of average monthly flow at Garn Ffrwd Spring and total rainfall

	Month	***Unit***	***Jan***	***Feb***	***Mar***	***April***	***May***	***June***	***July***	***Aug***	***Sept***	***Oct***	***Nov***	***Dec***
2000	Total rainfall	mm	2	150	63	196	150	132	135	141	218	394	278	360
	Average flow	l/s									17	15	14	
2001	Total rainfall	mm	128	112	178	151	72	56	121	137	99	340	181	75
	Average flow	l/s	18	18	32	31	13	9	8	10	8	40	21	26
2002	Total rainfall	mm	187	279	83	68	178	58	102	93	24	170	282	231
	Average flow	l/s	30	52	20	16	31	19	14	9	6	15	62	37
2003	Total rainfall	mm	198	100	77	76	121	89	172	25	36	82	176	151
	Average flow	l/s	34	26	24	11	17	15	15	13	7	7	15	28
2004	Total rainfall	mm	204	126	110	105	52	74	54	201	124	282	73	137
	Average flow	l/s	41	45	21	19	12	6	6	11	16	42	20	25
2005	Total rainfall	mm	122	67	86	131	80	113	104	79	149	193	180	93
	Average flow	l/s	29	17	18	19	15	13	10	8	8	25	49	18
2006	Total rainfall	mm	96	80	203	60	180	34	90	87	91	210	213	260
	Average flow	l/s	21	18	33	18	24	12	8	5	4	17	29	44
2007	Total rainfall	mm	200	202	113	59	163	171	210	127	86	82	79	166
	Average flow	l/s	44	35	22	12	14	12	30	17	8	9	9	26
2008	Total rainfall	mm	191	89	151	76	89	84	160	260	122	283	168	119
	Average flow	l/s	40	20	15		10	6	11	34	18	32	5	
2009	Total rainfall	mm	273	46	87	99	92	68	265	157	69	188	302	180
	Average flow	l/s				14	13	12	22	27	36	27	41	31
2010	Total rainfall	mm	178	196	41	43	99	163	152	108	187	188	119	241
	Average flow	l/s	26	22	22	10	3		16	15	23	41	47	18

2011	Total rainfall	mm	158	162	37	39	89	146	137	97	168	168	106	215
	Average flow	l/s	31	28	14	17	12	13		12	22	22	25	40
2012	Total rainfall	mm	136	86	47	155	109	260	187	241	131	198	219	342
	Average flow	l/s	30	26										
2013	Total rainfall	mm	241	92	91	77	181	79	73	190	93	316	161	338
	Average flow	l/s												
2014	Total rainfall	mm	422	312	101	154	144	80	96	155	28	279	252	193
	Average flow	l/s					10	7*	4	3	5	8	27	
2015	Total rainfall	mm	12	132	116	33	146	96	144	220	112	110	327	465
	Average flow	l/s		19	15	14	15	8	17	15	15	45		
2016	Total rainfall	mm	348	212	140	81	142	117	67	108	192	40	83	109
	Average flow	l/s	58	32	20	15	13	11	14	15	19	12	13	13
2017	Total rainfall	mm	72	96	97	110	47	95	45	162	221	99	135	219
	Average flow	l/s	11	16		8	12	26	10	18	26	30	24	40
2018	Total rainfall	mm	171	96	168	135	63	20	69	154	127	155	232	186
	Average flow	l/s	41	30	26	23	14	7	6	9	15	18	33	36
2019	Total rainfall	mm	95	107	126	74	29	121	35	147	208	191	145	193
	Average flow	l/s	13	29	40	15	9	14	9			47	35	42
2020	Total rainfall	mm	123	245	86	42	18	164	119	178	94	179	137	270
	Average flow	l/s	28	40	26	7	4	8	16	19	16	30	44	54
2021	Total rainfall	mm	168	82	42	9	178	61	99	86	134	233	60	168
	Average flow	l/s	43	47	0	0	32	17	13	7	13	39	19	33

** Potentially suspect data – initial period following reinstallation of logger and no manual data to validate*

Blank cells indicate no data available

Appendix C of Application

Tarmac director details

Report Reference: 331201249TN1
Report Status: Final

Date of birth information for Directors and Secretaries.

Company Name: Tarmac Trading Limited

Companies House Link: https://find-and-update.company-information.service.gov.uk/company/00453791/officers

Date: 11 May 2022

Name		Date of Birth
1	Shaun Davidson	18/08/1968
2	Robin John Doody	12/02/1975
3	Johanna O'Driscoll	09/01/1976
4	Peter Buckley	11/06/1965
5	Mark Thomas Wood	21/01/1973
6	Bevan John Browne	29/03/1980
7	Katie Elizabeth Smart	15/04/1977

Appendix D of Application

Letter of signing authority

TARMAC
A CRH COMPANY

To whom it may concern

06 August 2021

Dear Sirs,

Authority to Execute Permit Applications

I, the undersigned, being the Secretary of the Corporate Secretary hereby confirm that:

Sharon Palmer	National Environmental Permitting Manager
Lisa Sumner	Permitting and Compliance Manager
Tom Flint	Technical Manager
Delia Boulis	Permitting and Compliance Manager

are each authorised to execute, acting independently, all permit applications, variations, or surrenders on behalf of the Companies in respect of all local authorities.

For the avoidance of doubt, this letter of authority replaces any previous letters of authority provided to your agency in relation to the Companies listed in Appendix 1.

Petershill Secretaries Limited is the corporate secretary of Tarmac Secretaries (UK) Limited. The Companies House link evidencing this is https://beta.companieshouse.gov.uk/company/00532256/officers

Yours faithfully

DocuSigned by:
Andrew Yau
430E5A7ADFD1417...

Andrew Yau
For and on behalf of Petershill Secretaries Limited
Company Secretary of Tarmac Secretaries (UK) Limited

TARMAC
A CRH COMPANY

Appendix 1 – the Companies

Company Name	Company Number
Brett Tarmac Limited	03336448
Cambrian Stone Limited	01579754
East Coast Slag Products Limited	00330538
GRS Rail Services Limited	02632166
Solent Aggregates Limited	02730599
Tarmac Aggregates Limited	00297905
Tarmac Building Products Limited	04026569
Tarmac Caledonian Limited	SC176011
Tarmac Cement and Lime Limited	00066558
Tarmac Central Limited	03140503
Tarmac Limited	05560273
Tarmac Northern Limited	03140596
Tarmac Roadstone Limited	00368254
Tarmac Topmix Limited	03132032
Tarmac Trading Limited	00453791
Tarmac Western Limited	01640664

DocuSign

Certificate Of Completion

Envelope Id: BB4962471CD54799A7D6D7CF1A6BC458		Status: Completed
Subject: Please DocuSign: Letter of Authority (May 2021).pdf		
Source Envelope:		
Document Pages: 2	Signatures: 1	Envelope Originator:
Certificate Pages: 5	Initials: 0	Company Secretariat
AutoNav: Enabled		42 Fitzwilliam Square
EnvelopeId Stamping: Enabled		Dublin, Dublin 2 D02 R279
Time Zone: (UTC-08:00) Pacific Time (US & Canada)		Company.Secretariat@tarmac.com
		IP Address: 137.83.209.151

Record Tracking

Status: Original Aug-09-2021 | 07:35	Holder: Company Secretariat Company.Secretariat@tarmac.com	Location: DocuSign

Signer Events	Signature	Timestamp
Andrew Yau andrew.yau@pwc.com Security Level: Email, Account Authentication (None)	DocuSigned by: Andrew Yau 430E5A7ADFD1417... Signature Adoption: Pre-selected Style Using IP Address: 137.83.209.1	Sent: Aug-09-2021 | 07:39 Viewed: Aug-09-2021 | 07:40 Signed: Aug-09-2021 | 07:40

Electronic Record and Signature Disclosure:
Accepted: Aug-09-2021 | 07:40
ID: 3e707ce1-10c9-4099-a981-bcf161b28a4d

In Person Signer Events	Signature	Timestamp

Editor Delivery Events	Status	Timestamp

Agent Delivery Events	Status	Timestamp

Intermediary Delivery Events	Status	Timestamp

Certified Delivery Events	Status	Timestamp

Carbon Copy Events	Status	Timestamp
Lee Grogan lee.grogan@pwc.com Security Level: Email, Account Authentication (None) **Electronic Record and Signature Disclosure:** Not Offered via DocuSign	COPIED	Sent: Aug-09-2021 | 07:39 Viewed: Aug-09-2021 | 07:45

Witness Events	Signature	Timestamp

Notary Events	Signature	Timestamp

Envelope Summary Events	Status	Timestamps
Envelope Sent	Hashed/Encrypted	Aug-09-2021 | 07:39
Certified Delivered	Security Checked	Aug-09-2021 | 07:40
Signing Complete	Security Checked	Aug-09-2021 | 07:40
Completed	Security Checked	Aug-09-2021 | 07:40

Payment Events	Status	Timestamps

Electronic Record and Signature Disclosure

ELECTRONIC RECORD AND SIGNATURE DISCLOSURE

From time to time, CRH Group Procurement Services Ltd. (we, us or Company) may be required by law to provide to you certain written notices or disclosures. Described below are the terms and conditions for providing to you such notices and disclosures electronically through the DocuSign system. Please read the information below carefully and thoroughly, and if you can access this information electronically to your satisfaction and agree to this Electronic Record and Signature Disclosure (ERSD), please confirm your agreement by selecting the check-box next to 'I agree to use electronic records and signatures' before clicking 'CONTINUE' within the DocuSign system.

Getting paper copies

At any time, you may request from us a paper copy of any record provided or made available electronically to you by us. You will have the ability to download and print documents we send to you through the DocuSign system during and immediately after the signing session and, if you elect to create a DocuSign account, you may access the documents for a limited period of time (usually 30 days) after such documents are first sent to you. After such time, if you wish for us to send you paper copies of any such documents from our office to you, you will be charged a $0.00 per-page fee. You may request delivery of such paper copies from us by following the procedure described below.

Withdrawing your consent

If you decide to receive notices and disclosures from us electronically, you may at any time change your mind and tell us that thereafter you want to receive required notices and disclosures only in paper format. How you must inform us of your decision to receive future notices and disclosure in paper format and withdraw your consent to receive notices and disclosures electronically is described below.

Consequences of changing your mind

If you elect to receive required notices and disclosures only in paper format, it will slow the speed at which we can complete certain steps in transactions with you and delivering services to you because we will need first to send the required notices or disclosures to you in paper format, and then wait until we receive back from you your acknowledgment of your receipt of such paper notices or disclosures. Further, you will no longer be able to use the DocuSign system to receive required notices and consents electronically from us or to sign electronically documents from us.

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Appendix E of Application

Environmental Statement

Report Reference: 331201249TN1
Report Status: Final

8.0 HYDROLOGY AND HYDROGEOLOGY

8.1 Introduction

This chapter of the ES presents the results of a study of the hydrology and hydrogeology for Torcoed, Torcoed Fawr and Crwbin quarries ("the Site") and their environs (see **Figure 8-1** for location and Site boundary within Appendix 8.8 of ES Volume 2). This chapter relates to the potential hydrological and hydrogeological effects of an updated quarry development scheme for the consolidation of Torcoed quarry, Torcoed Fawr quarry and Crwbin quarry into a single operational unit. The study has been undertaken by ESI Ltd which is an independent consultancy which specialises in hydrogeology and water resource impact assessment.

As discussed below, ESI have extensive experience of the hydrological and hydrogeological context of the quarries.

8.2 Scope

The scope of the work undertaken as part of the study is as follows:

- Description of development proposals in terms of the potential effects on hydrology and hydrogeology;
- Summary of the baseline conditions at the site and development of a conceptual model for the site;
- Identification of potential receptors for any impacts based upon the conceptual model and the presence of source-pathway-receptor linkages;
- Assessment of the potential impacts (expressed as both an evaluation of the degree of effect of quarry dewatering, and an assessment of the significance of any resulting impacts);
- Proposed monitoring and mitigation measures where potential impacts are identified; and
- Preparation of an updated Water Management Plan (WMP) for the overall Site (see section 8.20 and Appendix 8-7).

8.2.1 Background

This impact assessment supports the submission of the application scheme for consolidation of the Site.

The study draws upon previous assessments undertaken by ESI principally including:

- ESI Ltd, (2006) -: Hydrogeological Impact Assessment for consolidation of Torcoed and Torcoed Fawr quarries planning permissions into one single planning permission. The consolidation application (reference W/13603) was approved in September 2007, subject to a number of conditions.
- ESI Ltd., (2010) - Crwbin Hydrogeological Impact Asssessment to discharge planning conditions which had been imposed on Crwbin Quarry via an Environment Act 'ROMP Review' of conditions issued in September 1998 (reference C/00031/97). The schemes were approved by Carmarthenshire County Council on 28th March 2013 (reference W/23799) and allow working to a maximum depth to 175 mAOD
- ESI Ltd., (2011a) - Torcoed Quarry Hydrogeological Impact Assessment for update of the approved quarry development scheme for the northern area of Torcoed Quarry (approved by condition 2 of the consolidation permission (reference W/13607). Planning permission for the updated quarry development scheme was approved in March 2014 (reference W/25453) (decision notice re-issued in September 2014 with an updated hours of working condition – ref W/30564).

Additionally, a hydrogeological assessment for Crwbin Quarry was carried out by RMC in 2000 (RMC, 2000).

This chapter of the ES builds upon the established knowledge of the area and updates the conceptual model with the most recent data. An impact assessment is carried out in this chapter which draws upon the updated conceptual model and the proposed development at the Site.

The impact assessment also considers the possible effects of the proposed development on the current Water Management Plan for Torcoed/Torcoed Fawr quarries and the water agreement in respect of Garn ffrwd fisheries[5].

The chapter includes a number of appendices, reproduced as **Appendix 8** within ES Volume 2 which present supporting material in more detail.

8.2.2 Study area

Crwbin quarry (NGR: 247800, 213500) is located approximately 8 km to the west of Cross Hands, some 10 km to the south east of Carmarthen and about 2 km to the north of Pontyberem in the County of Dyfed. Crwbin village is located a short distance to the west (**Figure 8-1** within Appendix 8.8 of ES Volume 2). Torcoed and Torcoed Fawr quarries (NGR: 249500 214000) are located directly to the east of Crwbin quarry. The original ground level around these quarries was from 170 to 200 m AOD.

The quarries are excavated into the northern flanks of the Mynydd-Llangyndeyrn ridge which runs from north east to south west. To the south, the ground rises to 262 m AOD at the high point of the ridge. North and south of the ridge the terrain slopes steeply to two east west flowing rivers; Gwendraeth Fach located 1.2 km to the north at an elevation of approximately 45 m AOD and Gwendraeth Fawr located 2.6 km to the south also at an elevation of about 45 mAOD. These rivers combine to form an estuary at Kidwelly, some 10 km to the south west.

8.2.3 Consultation

NRW and Carmarthenshire County Council have been consulted to obtain data for the site and wider study area. Carmarthenshire County Council has also provided a formal ‘scoping opinion’ on the issues to be addressed as part of the EIA, including hydrology and hydrogeology. The requirements have been incorporated into the HIA as set out in this chapter.

5 Tarmac has an agreement with the owner of the fisheries to mitigate the flows at Garn-ffrwd spring should they drop below a prescribed level.

8.3 Proposed Development

8.3.1 Current Conditions

Extent of working

A plan of the current extent of the three quarries is shown on **Figure 8.1**. Torcoed and Torcoed Fawr quarries are currently worked as a single unit with all output via the main plant entrance at Torcoed (to the east). Although planning permission is in place to work Crwbin quarry to 175 m AOD, there is currently no active working in this area and it is understood that this area has been inactive for at least 10 years. The lowest part of the quarry floor is flooded part of the year at approximately 180 mAOD.

The lowest worked benches of Crwbin quarry, Torcoed Fawr quarry and Torcoed quarry are currently at levels of c. 180 m AOD, 155 m AOD and 130 m AOD respectively with consented working depths of 175 m AOD in Crwbin and 130 m AOD in Torcoed Fawr quarry and Torcoed quarry. There is a ridge of in-situ rock between Crwbin and Toroced Fawr quarries at c. 220 mAOD and between Torcoed and Torcoed Fawr quarries at c. 160 mAOD.

Dewatering and discharge consents

The site has two discharge consents from the northern boundary of Torcoed and Torcoed Fawr quarries at NGR SN 4956 1412 and NGR SN 4764 1368 respectively. Quarry discharge flows have been measured at the discharge points via water level measurements in thin plate weirs since 2001. Details of the consented limits of discharge are summarised in Table 8-1.

The combined average daily rates of discharge from the two discharge points have been approximately 2,500 m^3/d (29 l/s) for the period Jan 2009 to April 2013.

Detailed water balance calculations carried out by ESI (2006), and updated in this report, suggest that the rates at which the quarries are pumped are compatible with seasonal fluctuations in recharge over relatively small catchment areas.

Table 8-1 Quarry discharge consent flow limits

Discharge	Consent number	Discharge consent limit in m^3/day (l/s)
Torcoed	BP0235501	6307 (73)
Torcoed Fawr	BP0239301	5270 (61)

Garn-ffrwd spring augmentation

Tarmac has an agreement with the owner of Garn-ffrwd Fish Farm to mitigate the flows at Garn-ffrwd spring should they drop below a prescribed level (8 l/s or 690 m^3/d) with outline details provided in Appendix 8-6. This is designed to ensure that there are no adverse effects on water levels in the lakes at the Fish Farm which are fewd by the spring. The means of mitigation will be by pumping to a sinkhole between Torcoed Quarry and the spring (NGR 2495 2138) that has been shown to be connected to the spring. An augmentation test was carried out in December 2003 which demonstrated the feasibility of this approach to mitigation. The methodology for the test, including monitoring requirements, was agreed with the Environment Agency beforehand and no adverse effects on the quality of the spring flow were noted during the test. In order to ensure that there is sufficient water available for augmentation, Tarmac has agreed to maintain a sump with a volume of 10 000 m^3 in the floor of Torcoed Quarry. This storage is not currently in place but it is proposed to develop this by creating a large sump at a level of 115 m AOD (see phased development palns produced in ES Chapter 3.0). The quarry has not been requested to augment the flow by the fish farm to date.

8.3.2 Quarry Development

The sequence of development (Phase 1 to 8) are shown in Figures 3.2 – 3.6 within ES Chapter 3.0 and at a larger scale as application plan ref numbers 98107(k).D.007 – D.011 and D.016 within the Planning Application Statement. A summary of the current and proposed workings at the Site is provided as follows:

- Torcoed Quarry has been developed to the currently approved base level of 130 m AOD. It is proposed to deepen the current quarry floor in a defined area from the consented level of 130 m AOD to 115 m AOD and to extend the excavated area some 200 m to the east within c. 80m of the eastern boundary. No additional significant quarrying to the south is proposed.

- Torcoed Fawr Quarry has been developed to a current base level of 155 m AOD. It is not proposed to deepen in this area below the consented minimum level of 130 m AOD, but the lateral extent of working to that level will increase. No additional significant quarrying to the south is proposed. A ridge is to be maintained separating Torcoed and Torcoed quarries with an "overflow" level of c. 160 m AOD.

- Crwbin Quarry has been developed to a base level of c. 180 m AOD. It is proposed to deepen in this area from the consented minimum elevation of 175 m AOD to 130 m AOD and extend c. 120 m to south east compared to current permission. No extension to the west is proposed beyond the existing permitted site boundaries, but a historical quarry area to the south east is proposed to be incorporated into the development area.

8.3.3 Quarry Decommissioning

The restoration plan is produced as Figure 4.1 within ES Chapter 4.0 and at a larger sacale as application plan ref 98107(k).D.001 within the Planning Application Statement. The quarries will ultimately be restored to two open bodies of water, separated by a ridge of rock left in place between Toroced and Torcoed Fawr quarries, with restoration of the faces and benches above the anticipated rest water level. The position to which water levels will ultimately recover is difficult to determine with absolute precsion, but the low point in the lip to the east of Torcoed Quarry is at around 160 m AOD with a controlled outfall to Garn Bwll stream (S07/S41) and/or Torcoed Quarry Farm stream (S19) proposed. This therefore forms a maximum level for the restored eastern lake. It is anticipated that the western lake (Torcoed Fawr/Crwbin lake) will recover to c. 165 m AOD. The effect that this will have on the local hydrology and hydrogeology has been assessed as part of this impact assessment.

8.4 Baseline Conditions

8.4.1 Previous studies

ESI has undertaken the data management and reporting functions of the site monitoring programme since 2001. As part of this, factual reporting, review and interpretation of the performance of the monitoring network, and a review and interpretation of the data is undertaken annually and submitted to the Planning Authority. The most recent of these annual reports presents the 2014 monitoring data (ESI, 2015a).

A number of relevant hydrogeological impact assessments undertaken between 2000 and 2010 for planning applications at the site are summarised above in Section 8.2.1.

8.4.2 Geology

Structure

The geological setting of the Site and surrounding area has been described in detail by Smart (2001) and subsequent ESI impact assessments and is summarised in **Figure 8-2 (Appendix 8.8** of ES Volume 2), as taken from British Geological Survey (BGS) (1967 and 1977). The quarries work the Carboniferous Limestone. This is overlain to the south by the Millstone Grit, and underlain to the north by the Devonian Old Red Sandstone. The sequence is described in more detail below and is summarised in Table 8-2.

The regional dip is 21 – 23 º to the south of the Site. The sequence is broken by a number of minor north/south faults generally with small throws (<5 m). Two larger faults with downthrow to the west are shown to displace the outcrop of the Basal Grit at the western end of Crwbin Quarry and to the east of Garn-ffrwd (**Figure 8-2** - **Appendix 8.8** of ES Volume 2). However, the displacement is not sufficiently large to completely disrupt the limestone sequence. Detailed geological investigations in the vicinity of the Torcoed quarry area have identified an unmapped fault zone that crosses this quarry about 100 m from its western end.

A north east/south west trending fault is located along the Gwendraeth Fach river valley to the north.

Two joint sets are well developed (75º/351º north/south and 89º/225º south west/north east).

North-south cross sections through Torcoed and Torcoed Fawr quarries, as taken from ESI (2006), are shown on **Figure 8-3 (Appendix 8.8** of ES Volume 2), with the section location shown in **Figure 8-2 (**also **Appendix 8.8** of ES Volume 2).

Solid Geology

The Devonian Brownstones (the upper unit of the Old Red Sandstone sequence) crop out along the northern slopes of the Mynydd-Llangyndeyrn ridge. RMC (2000) describes the brownstones beneath the Site to consist of moderately to slightly weathered red, fine to medium grained sandstone with interbedded purple and green fissile siltstone bands.

The Brownstones are overlain by the Lower Limestones Shales, which comprise interbedded mudstones, calcareous siltstones and thin limestones. This formation varies significantly in thickness from 4.5 m at Crwbin (RMC, 2000) to 12 m in borehole 15A at Torcoed.

The main Carboniferous Limestone (Main Limestone) in the area is subdivided into six sub-units, based on cores from boreholes in Torcoed Quarry.

- The two lower limestone units are the principal formations worked at the quarries. They comprise the lowermost hard, fine grained Cilyrychen Limestone (92 to 104 m thick) which contains occasional bioclasts and thin shale-rich mudstone bands and the medium to coarse grained uppermost Penderyn Oolite (10 to 13 m thick) which has a 0.4 m thick black shale-rich mudstone band at its base.

- The upper four units are sub-units of the Mynydd-Y-Garegg Limestone that contains more shale than the underlying units. The lowest of the four units is the Oolitic Conglomerate which comprises an irregular unit with coarse to medium grained limestone and shales. Sometimes these form discrete beds, but elsewhere the unit is highly disturbed, with irregular limestone supported within contorted crumbly shales. At the base of the Oolitic Conglomerate there is a discrete, shale-rich, pyritic mudstone. The other units are: the Coarse Grained Shelly Limestone; the Interbedded Limestone and Shale; and the Limestone with Shale-rich Partings. These other units comprise shale-rich, fine to coarse grained limestones.

The Upper Limestone Shale separates the Main Limestone from the overlying Millstone Grit and comprises 5 m of pale to mid-grey laminated shale.

The Basal Grit, the lowermost formation of the Millstone Grit sequence, is a series of massively bedded quartzitic sandstones with some shales. The Basal Grit forms the crest of the Mynydd Llangyndeyrn ridge. The shales become increasingly abundant upwards with a transition to the Shale Group.

Table 8-2 Summary of local solid geologic succession

	Unit	Sub-unit		Predominant lithologies	Approximate thickness (m)
Carboniferous	Millstone Grit	Basal Grit		Massively bedded quartzitic sandstone with shales.	>120
	Upper Limestone Shale			Pale to mid grey laminated shale	5
	Main Limestone	Mynydd-Y-Garegg Limestone	Limestone with Shale-rich partings	Dark-grey, fine grained limestone. Shale-rich mudstone at the base, increasing thin shale-rich laminations towards the top.	<25
			Interbedded Limestone and Shale	Thin shales with limestones	<4.5
			Coarse Grained Shelly Limestone	Hard, coarse grained shelly bioclastic limestone with fine to medium grained limestones	<25
			Oolitic Conglomerate	Irregular unit with coarse to medium grained limestones and shales. At the base shale rich pyritic mudstone.	7 – 16
		Penderyn Oolite		Hard, medium to coarse grained, mid-grey oolitic limestone.	10 – 13
		Cilyrychen Limestone		Hard, dark grey, fine grained limestones with occasional bioclasts.	92 – 104
	Lower Limestone Shales			Interbedded mudstones, calcareous siltstones and thin limestones.	4.5 – 12
Devonian	Old Red Sandstone	Brownstones		Sequence of Interbedded fine to medium grained sandstones and red, purple and green mudstones and siltstones	>1500

The main low permeability formations in the sequence are shaded grey

Superficial Geology

Some superficial deposits of Glacial Till overlie the Millstone Grit on the southern slopes of the Mynydd Llangyndeyrn ridge and comprise bluish-grey Glacial Till. Some peat deposits are also present. Till also covers the lower land on the Main Limestone south east of the Torcoed quarry and at Garn-Ffrwd where it forms the base of the Garn-Ffrwd lake. The average thickness of these superficial deposits measured in 42 boreholes in these areas was 1.4 ± 0.8 m (ESI, 2006). BGS (1967) shows Glacial Till to be present directly to the south of Crwbin quarry and being marginally within the site boundary in the south west; with fluvio-glacial sand and gravel deposits also located about 350 m to the south of the quarry.

8.4.3 Hydrology

Rainfall and Recharge

Daily rainfall volumes have been measured by a rain gauge at Torcoed quarry since 2000. Whilst this period includes both wet and dry periods, it is useful to consider data over a longer period. In order to do this, the sequence at the Site was combined with data from nearby rain gauges (NRW's Gorslas and Margam Park rain gauges) to form a continuous synthesised rainfall set for the area. The full methodology for this process is detailed in ESI (2015a).

In summary, the data synthesis process is as follows: A correlation has been calculated based on the ratio of the LTA rainfalls measured at Torcoed and these external gauges. Multiplication of external rainfall data by these site specific correlation factors has enabled an artificial data set to be synthesised over periods of missing Torcoed data.

Figure 8-4 (Appendix 8.8 of ES Volume 2), shows total monthly rainfall as well as the cumulative departure from the mean for the period 2000 to 2014 while Table 8-3 presents the rainfall data for the recent period as a percentage of long term average (LTA) for the same period.

Whilst the accuracy of the data series generated inevitably suffers as a result of the processes applied to synthesise missing data, the results in Table 8-3 still show some patterns that are useful to note when interpreting other hydrometric data for this period. Key periods include:

- The severe drought in 2003.
- Wet summers of 2007 to 2012.
- High autumn/winter rainfall in 2013/2014
- High annual total of 2000, 2012 & 2014.

The long term average effective precipitation, available from MORECS square 144, during this period was around 0.60 m/a compared to an annual rainfall of 1.79 m/a.

The continuous daily rainfall series was used to carry out detailed recharge calculations for the Site in **Appendix 8-5 (**ES Volume 2),. These are discussed in more detail in Section 8.4.7.

Table 8-3 Monthly total rainfall as a percentage of the LTA for each month

Month	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Jan		66%	96%	102%	105%	63%	49%	103%	98%	141%	40%	92%	70%	124%	217%
Feb	112%	84%	210%	76%	95%	51%	60%	152%	67%	34%	43%	147%	65%	69%	235%
Mar	60%	170%	79%	73%	105%	82%	194%	108%	144%	83%	135%	39%	45%	87%	97%
Apr	195%	151%	68%	75%	104%	131%	60%	59%	76%	99%	52%	43%	155%	77%	154%
May	127%	61%	152%	103%	44%	68%	153%	138%	76%	79%	47%	84%	93%	154%	122%
Jun	133%	57%	58%	90%	74%	114%	34%	172%	85%	68%	29%	164%	262%	79%	80%
Jul	94%	85%	71%	121%	38%	73%	63%	148%	112%	186%	153%	107%	131%	51%	68%
Aug	98%	95%	65%	17%	140%	55%	60%	88%	181%	109%	110%	75%	167%	132%	108%
Sep	196%	89%	22%	32%	112%	134%	81%	77%	109%	62%	192%	168%	118%	84%	25%
Oct	173%	150%	75%	36%	124%	85%	92%	36%	124%	83%	92%	82%	87%	139%	123%
Nov	145%	94%	147%	92%	38%	94%	111%	41%	88%	158%	97%	62%	115%	84%	132%
Dec	184%	38%	118%	77%	70%	47%	133%	85%	61%	92%	25%	123%	175%	173%	98%
Annual Sum as % of LTA	127%	95%	101%	75%	88%	80%	92%	95%	103%	105%	83%	98%	121%	111%	127%

Notes:

1 - Months shaded brown have less than 70% LTA rainfall for the respective month (85% for annual sum values given the lower variability of annual data).

2 - Months shaded blue have more than 130% LTA rainfall for the respective month (115% for annual sum values given the lower variability of annual data)

Surface Water Features

Main surface water features in the area

The main surface water features in the area are shown in **Figure 8-5 (Appendix 8.8** of ES Volume 2),

North and south of the Mynydd-Llangyndeyrn ridge the terrain slopes steeply down to two westward flowing rivers; Gwendraeth Fach to the north and Gwendraeth Fawr to the south.

A large number of tributaries drain the Mynydd-Llangyndeyrn ridge towards the north to Gwendraeth Fach and towards the south to Gwendraeth Fawr. Most of these are unnamed, but the Afon Dulais drains the land to the east of Torcoed Quarry towards the north and the Afon Berem and Aber Lledle drain the land the south of the quarries towards the south.

A number of key streams have been named for the purpose of this assessment as shown in Figure 8-5. The following streams rise close to the contact of the Carboniferous Limestone and the Old Red Sandstone.

- Ffrwd-gain stream, located about 120 m to the north west of the Site, rises from a spring at approximately 145 m AOD.
- Crwbin stream, located about 240 m to the west of the proposed western limit of extraction, rises from a spring at approximately 160 m AOD.
- Felindre stream, located about 1.7 km to the south west of the Site, rises from two springs at approximately 105/109 mAOD and joins the Nant Drysgeirch downstream.

Henblas stream, located about 600 m to the south west of the Site, rises from a spring at approximately 200 m AOD in the Basal Grit and flows across the Carboniferous Limestone and Old Red Sandstone.

Garn-Ffrwd stream, the main outflow from the Carboniferous Limestone to the east of the Site, is located about 1 km from the eastern Site boundary, rising from a spring at approximately 137 m AOD.

Water features in the vicinity of the quarries receive baseflow from the three principal formations in the area: the Millstone Grit to the south; the Carboniferous Limestone along the upper flanks of the ridge; and the Old Red Sandstone on the lower flanks of the ridge.

In general, north of the Mynydd-Llangyndeyrn ridge, the streams on the Millstone Grit flow northwards and sink into the limestone via a series of sink holes. Some springs then rise from the northern edge of the Carboniferous Limestone receiving flow from groundwater that has crossed the strike of the strata. However, some of the larger Carboniferous Limestone springs gain water from flow along strike (i.e. east-west flow) and then overflow to the north or south.

The springs rising from the Old Red Sandstone are all fairly minor and flow north to join the Gwendraeth Fach.

Springs to the south on the Millstone Grit are not considered to be hydraulically connected to the Main Limestone due to the presence of the Upper Limestone Shale between these formations.

Water features survey

A comprehensive water features survey of the area was carried out and is presented in **Appendix 8-1 (**ES Volume 2),. Several of the locations were revisited during a site visit in June 2015. The following features were identified:

- shallow wells
- springs
- sinkholes

- private water supplies sourced from wells, springs and boreholes (data provided by Carmarthenshire County Council)
- licensed abstractions sourced from wells, springs and boreholes (data provided by the NRW)

Shallow wells, springs and sinkholes are shown in **Figure 8-6** while private water supplies and licensed abstractions are shown in **Figure 8-7 (Appendix 8.8** of ES Volume 2).

For the purposes of this impact assessment, water features have been categorised according to whether they are potentially at risk of being affected by the proposed development of the Site (i.e. whether there is a hydrogeological connection between the water feature and the Carboniferous Limestone which the quarries are dewatering). This is discussed in more detail in Section 8.6.

Sinkholes feeding the Carboniferous Limestone

There are a number of sinkholes into the Main Limestone in the vicinity of the Site which confirms the karstic nature of this aquifer unit. **Figure 8-8 (Appendix 8.8** of ES Volume 2), shows proven karst connections. The largest sinkhole is Garn Bwll sinkhole (SH1) just east of Garn Bwll Farm (NGR: 249870, 213910). It comprises a topographically closed depression fed by a substantial stream draining the local till, and rising on the south flank of Mynydd-Llangyndeyrn south of Creg-eidon. It is reported that this stream used to drain the headwaters of the Afon Berem, but that these were diverted by local landowners southwards towards Waunfawr (Smart, 2001). This sinkhole has been traced to Garn-ffrwd Spring with no recovery of dye at the much closer Garn Bwll Spring. This emphasizes the dominance of strike orientated flow in the Mynydd-y-Garegg Limestone.

Other significant sinkholes in the area include:

- The Torcoed quarry sinkhole (SH6) (NGR: 249600, 213860) takes drainage from the ditch which bounds the eastern spoil mound and the lower reaches of the well-developed valley followed by the track leading to Clos-yr-yn (Smart and Halton, 2002). This has been traced to Garn-ffrwd Spring and is the proposed site of the discharge of water to augment the spring.
- Ty'r Garn sinkhole (SH4) (NGR: 250200, 213900) has also been traced to Garn-ffrwd Spring (Smart and Halton, 2002).
- Tan-y-Banc sinkhole (SH9) is located on the high ground to the south east of Torcoed Fawr Quarry (NGR: 248600, 213600) and has been traced to Garn-ffrwd Spring although at high flows there is some overflow into Torcoed Fawr Quarry (Smart and Halton, 2002).
- To the west of Crwbin a small sinkhole (SH10) was found during a water features survey conducted in August 2008 at NGR: 247048, 212751 at an elevation of about 170 m AOD with a small flow of approximately 1 to 2 l/s observed derived from a small catchment area.

A well-developed valley system of the Mynydd-y-Garegg Limestones and the Basal Grit drains the highest part of the Mynydd-Llangyndeyrn. This now cascades down the walls of Torcoed Fawr Quarry. There may previously have been a stream sink at this point (Smart, 2001).

Springs from the Carboniferous Limestone

There are a number of springs fed by the Carboniferous Limestone in the area which are shown in **Figure 8-6 (Appendix 8.8** of ES Volume 2). The two largest springs which have a major influence on the outflow from the Carboniferous Limestone are listed below:

S54/S55 (Felindre springs)

These two springs are located some 1.7 km to the south west of the Site at an elevation of about 105 and 109 m AOD respectively. This is the largest spring outflow to the west of the Site and drains a substantial catchment between Crwbin and Meinciau. Spot gauging, as reported in more detail below, on three occasions in 2009 gave an average combined flow of 76 l/s, with 64 l/s recorded on 11 June 2015 in dry conditions. The average flow at the spring is estimated to be approximately 8,023 m^3/d (93 l/s), as calculated in the water balance presented in **Appendix 8-5 (**ES Volume 2).

S09 (Garn Ffrwd spring)

This spring is at an elevation of about 137 m AOD some 1.1 km to the east of Torcoed quarry. It feeds a series of fish ponds with the outflow from the ponds forming Garn-ffrwd stream. Flows at the spring are monitored by Tarmac as part of the Torcoed hydrometric network and are further discussed below.

Other significant springs

Other significant springs in the vicinity of the quarries include:

- S53 (Crwbin spring) at an elevation of about 160 mAOD about 200 m to the west of the proposed extraction area.
- S25-A (Ffrwd-Gain spring) at an elevation of about 145 mAOD about 120 m to the north of the Crwbin quarry area. This is actually located on the Old Red Sandstone but may possibly receive contribution from the Carboniferous Limestone along Crwbin Fault.

The stream which runs through Henblas Farm (S30), about 600 m to the south west of the Site, rises from a spring in the Millstone Grit at an elevation of about 200 mAOD. Where the stream flows off the Carboniferous Limestone it is at approximately 150 mAOD. Little accretion occurs over the 500 m distance over which is flows on the limestone. This is based on observations from a site visit in August 2008 as well as from flow data presented below.

S07/S41 (Garn Bwll spring) to the east is at an elevation of about 145 mAOD and is already dry due to the quarry working as reported in ESI (2006). Smart (2001) reported that flow at that time was “very small” and that a second stronger spring emerges some 70 m down the valley, roughly coincident with the outcrop of the Old Red Sandstone at 137 mAOD. A flow of about 1 l/s was observed during a site visit on 26 May 2015 some 500 m downsteam.

A number of small springs that used to rise on the northern edge of the Carboniferous Limestone in the vicinity of the quarries have been affected by the quarries and no longer flow; including Torcoed Quarry (S21) and Craig Llydidad Spring (S42). Torcoed Quarry Farm Spring (S19) has also been affected but received quarry discharge water.

Springs from the Old Red Sandstone

A number of springs to the north of Crwbin and Torcoed quarries are present. Some of these may receive some water from the Carboniferous Limestone (this is discussed further in Section 8.6).

Surface water flow

Garn-ffrwd spring (S09) to the east

Regular flow data are available for a thin plate weir at Garn-ffrwd spring since January 1999 when monitoring by the Environment Agency started. Since March 2001, this monitoring has been undertaken by Lafarge Tarmac. There is a gap in the data from early 2012, but the issue has been resolved going forward with monitoring now resumed.

Figure 8-9 (Appendix 8.8 of ES Volume 2), shows that flow at the spring is relatively flashy (as would be expected in a karstic aquifer) but that there is also a fairly steady low-flow that helps to maintain flows during dry periods. Water balance modelling of the spring (see Appendix 8-5) supports the evidence from tracer tests that the flows at the spring are derived from catchments on the Millstone Grit and Mynydd-y-Garegg Limestone, rather than from the lower limestone units that are the main economic units at the quarries.

Springs to the west of Crwbin quarry

Spot flow gauging was undertaken by Hydro-Logic Ltd. at five locations to the west of Crwbin quarry on three occasions (25 March 2009, 30 March 2009 and 3 April 2009) and again on 11 June 2015. Results are presented in **Appendix 8-2 (**ES Volume 2), and are summarized in Table 8-4, with stream flow gauging locations shown in **Figure 8-10 (Appendix 8.8** of ES Volume 2).

Table 8-4 Flow gauging results to west of Crwbin quarry (l/s)

Site	Location	25 Mar 2009	30 Mar 2009	3 Apr 2009	11 Jun 2015
1	Felindre stream	84.24	75.06	71.29	65.36
2	Crwbin stream	10.05	8.71	7.37	6.62
3	Henblas stream	1.38	0.58	0.17	0.59
4	Unnamed. Joins Crwbin stream to north	1.44	1.71	1.39	0.43
5	Unnamed. Between Henblas and Crwbin stream	1.22	1.15	0.57	Dry

Spot flow gauging results show that stream flows in Henblas stream (Site 3), Ffrwd-gain stream (Site 4) and an unnamed tributary of Felindre Stream (Site 5) are very low (<2 l/s). During a site visit in August 2008 no obvious flow accretion in Henblas Stream was observed as it flowed across the Carboniferous Limestone.

Flow in Crwbin stream (Site 2) was recorded between 6 and 10 l/s and at Felindre at between 65 and 84 l/s. Although this is a limited data set, these flows are broadly consistent with water balance calculations of flow in these streams in **Appendix 8-5** (further discussed in Section 8.6).

Additionally, flow at Crwbin spring (S53) has been measured as part of Tarmac's ongoing monitoring using a flow impeller on 32 occasions between Feb 2009 and Oct 2013 as shown in Table 8-5 with an average flow of 12.5 l/s recorded. A flow at Crwbin Spring of 9.6 l/s was estimated on 25 March 2009 which corresponds closely to the Hydro-Logic gauging carried out on the same day on Crwbin Stream about 280 m downstream where a flow of 10.05 l/s was recorded.

Table 8-5 Crwbin spring spot gauging

Date	Flow at Crwbin spring (l/s)	Date	Flow at Crwbin spring (l/s)
24-Feb-09	12.3	10-Nov-09	46.3
17-Mar-09	7.0	07-Dec-09	26.2
19-Mar-09	7.0	28-Jan-10	23.0
25-Mar-09	9.6	24-Feb-10	14.2
28-Mar-09	3.9	18-Jan-11	32.1
04-Apr-09	1.5	16-Feb-11	14.1
20-Apr-09	1.5	21-Mar-11	3.9
25-Apr-09	0.2	23-Feb-12	0.7
25-Apr-09	0.2	12-Sep-12	16.8
18-May-09	2.2	30-Oct-12	33.2
20-May-09	2.2	12-Feb-13	0.3
20-Jul-09	14.8	07-Mar-13	2.8
28-Jul-09	21.4	15-Apr-13	0.0
21-Aug-09	10.6	13-Jun-13	0.0
03-Sep-09	41.3	12-Sep-13	16.8
07-Oct-09	27.0		
21-Oct-09	5.7		

8.4.4 Hydrogeology

Relevant properties of the main formations

The Old Red Sandstone is a secondary aquifer which attains great thicknesses but has limited primary permeability. This is due in part to the variety of lithologies, with low permeability mudstones, marls and siltstones interbedded with the sandstones. Thick calcrete deposits may, in contrast, provide zones of high permeability. Primary porosity is generally low and the predominant groundwater flow mechanism is via fractures (Jones et al., 2000). The aquifer is generally only significant on a local scale, providing a source for small springs and private water supplies.

The Lower Limestone Shales generally form a barrier to flow between the Old Red Sandstone and the Main Limestone aquifer units. However, there is potential for flow between the formations along faults and joints which cut this unit, and dissolution of limestone bands and calcareous units can permit the development of locally highly transmissive flow routes along the strike and dip of the beds (Smart, 2001).

The Carboniferous Limestone is classified by NRW as a Principal Aquifer and is the main aquifer unit in the area. Its primary porosity is very low, and water movement is along fractures and dissolution fissures developed along joints and bedding planes (Allen, 1997). In this area it can be divided into two separate aquifers:

Penderyn Oolite and Cilyrychen Limestone: Smart (2001) reports several significant caves (up to 300 m in length) at Crwbin quarry and also reports that there are minor caves in the cliffs to the north of Garn-ffrwd Lake to the east of Torcoed quarry. Where exposed at depth in Torcoed Quarry, there is little direct evidence for development of karstic voids, but conduits are clearly evident in the cliffs at Garn Bwll spring-head.

Mynydd-y-Garegg Limestone: The shalier Mynydd-y-Garegg unit appears to be more karstic in nature than the underlying formations. Laterally continuous (~4 m thickness) mudstones are known from boreholes, and these appear to limit cross-stratal movement of groundwater and reduce the hydraulic connection with the underlying Penderyn Oolite. Movement along the strike within the more soluble limestones is more likely and has been demonstrated by tracer tests (Smart and Halton, 2002). Some of the shales in the Mynydd-y-Garegg Limestone are pyritiferous (especially in the Oolitic Conglomerate), and this may lead to enhanced dissolution and development of collapse breccias (Smart, 2001).

There are a number of minor north/south faults that cut the Main Limestone. Therefore, some cross-stratal movement of water is possible, especially when hydraulic gradients are large (Smart, 2001), including one fault at the western end of Crwbin Quarry and another to the east of Garn-ffrwd (Figure 8-2).

The Upper Limestone Shales is likely to act as an aquitard between the Mynydd-y-Garegg Limestone and the Basal Grit aquifer unit. Jointing and minor north/south faults may limit the effectiveness of this aquitard, and some leakage between the Basal Grits and Mynydd-y-Garegg Limestone is possible (Smart, 2001).

The Basal Grits are generally well-cemented and hard with very low primary porosity and intergranular permeability. Groundwater movement and storage is probable within fractures along the Mynydd-Llangyndeyrn. Borehole yields in the Basal Grits are commonly of the order of <250 m^3/d but can attain 865 to 1030 m^3/d, particularly where associated with faulting. Springs capable of providing similar yields occur where shales are faulted against sandstones (Jones, 2000).

Groundwater level datasets

Groundwater levels are available for a large number of monitoring wells across the Site with locations shown in **Figure 8-11 (Appendix 8.8** of ES Volume 2). Monitoring wells installed in 2013 are suffixed with "/13".

Torcoed/Torcoed Fawr quarries: Groundwater level hydrographs of piezometers in the Main Limestone and Old Red Sandstone are shown in **Figure 8-12 (Appendix 8.8** of ES Volume 2). Reliable monitoring data are available for some of these sites since 2000. Table 8-.6 presents a summary of groundwater level statistics.

Crwbin quarry: Information on historical groundwater levels at Crwbin Quarry is available between October 1992 and July 1997 from RMC (2000), generally at monthly monitoring intervals. The raw data and hydrographs are presented in **Appendix 8-3** and borehole locations shown in **Figure 8-11 (Appendix 8.8** of ES Volume 2).

Several new boreholes were installed in Crwbin quarry 2013 to improve the spatial coverage of the network. Table 8-7 present a summary of groundwater level statistics. Data recorded since 2000 is shown in **Figure 8-13 (Appendix 8.8** of ES Volume 2).

Piezometers BH4a, BH4b, BH17a and BH17b were found in May 2009 during a walkover of Crwbin quarry and have been monitored at monthly intervals since that time. The recently recorded groundwater levels are similar to those recorded between 1993 and 1997.

For the Crwbin quarry area, the frequency of monitoring has not been high enough to determine the upper and lower groundwater levels likely to occur due to the rapid fluctuations typical in the Main Limestone as in Torcoed quarry. However, Table 8.7 confirms minimum and maximum groundwater levels based upon historical and more recent data. In addition, RMC (2000) reported that monitoring boreholes around Crwbin showed similar ranges to the boreholes in the Torcoed quarries.

Table 8-6 Groundwater level statistics for Torcoed (2000 - 2015)

Location	Minimum groundwater level measured (mAOD)	Maximum groundwater level measured (mAOD)	Average groundwater level measured (mAOD)	Range in recorded groundwater levels (m)	Data Period
Limestone					
BH 16	147.4	158.3	150.7	11.0	2000-present
BH 17	190.0	200.9	197.0	10.9	2000-present
BH3B/13	203.0	207.8	205.1	4.8	2012 - present
BH5B	135.34	175.3	154.9	40.0	2000-2005
BH 95/5	175.6	224.1	167.1	48.5	2000-present
BH 95/7	155.7	177.6	167.1	22.0	2000-present
BH7/13	145.0	147.4	146.0	2.4	2012-present
BH8B/13	150.0	153.7	151.8	3.7	2012-present
Sandstone					
BH3A/13	191.7	209.8	202.0	18.1	2012-present
BH5A	146.0	155.1	148.8	8.9	2000-2008
BH6/13	206.0	213.6	210.6	7.7	2012-present
BH8	177.3	183	181.0	5.6	2013-present
BH8A/13	148.3	152.2	150.8	3.8	2012-present
BH 95/3	141.4	176.8	164.5	35.4	2000-present
BH 95/4	170.9	196.3	182.9	25.4	2000-present

Table 8-7 Crwbin quarry groundwater level statistics (October 1992 to May 2015)

Location	Easting	Northing	Minimum groundwater level measured (mAOD)	Maximum groundwater level measured (mAOD)	Range in recorded groundwater levels (m)	Data Period
Limestone						
BH1B	247792	213449	**178.4**	186.2	**7.8**	1992-1997
BH1/13	247594	213164	164.5	172.4	7.9	2013-ppresent
BH3	247889	213382	179.4	195.1	15.7	1992-1997
BH4b	247833	213368	**178.5**	186.2	**7.8**	1992-1997
BH4B/13	247730	213268	172.4	176.7	4.3	2014-present
BH6	247854	213234	172.9	191.9	19.0	1992-1997
BH9	247705	213229	**<175.5**	179.9	>4.4	1992-1997
BH13a	247542	213238	156.6	179.7	23.1	1992-1997
BH14	247495	213221	153.5	166.1	12.6	1992-1997
BH17a	247485	213300	152.8	162.0	9.1	1992-present
BH17b	247485	213300	182.8	188.5	5.7	1992-present
Sandstone						
BH2	247854	213442	166.5	185.9	19.4	1992-1997
BH2/13	247750	213434	172.0	173.5	1.5	2012-present
BH3A/13	247927	213252	191.7	209.8	18.1	2012-present
BH4a	247833	213368	177.7	184.4	6.8	1992-1997
BH4A/13	247703	213218	172.5	173.8	1.4	2012-present
BH5/13	247496	213344	152.4	156.9	4.5	2012-present
BH7	247769	213351	168.1	183.8	15.7	1992-1997
BH18	247415	213307	152.4	157.6	5.1	1992-1997

Bold values are close to base of the piezometer and may not represent minimum groundwater levels

Main Limestone groundwater levels

Piezometers generally show fairly large ranges of fluctuation in response to variations in recharge. Responses to rainfall are typically rapid with a fairly rapid decline afterwards. Both of these features are indicative of an aquifer with low storage capacity as would be expected for the Carboniferous Limestone. Three different time series patterns are apparent from Torcoed/Torcoed Fawr piezometers:

- Boreholes 5B and 97/1 both show generally flat hydrographs with upwards spikes during rainfall events. BH 5B was quarried out in 2005. These boreholes are located close to Torcoed quarry and it is likely that elevations are strongly influenced by the water level in the quarry sump.
- Boreholes 16, 17 and 95/7 show more regular responses to seasonal fluctuations in rainfall although the amplitude varies from 10.91 m (BH 17) to 21.96 m (BH 95/7). The difference in amplitudes may reflect the distance from the nearest sump. The effect of deepening Torcoed Fawr Quarry may have affected water levels at borehole 95/07 where levels declined by around 3 m over 2006/2007. Levels at this location show a return to pre-2006 levels in more recent monitoring data (since 2014). No long term trends of falling water levels are seen in any of the other boreholes.
- Borehole 95/5 shows very large fluctuations in groundwater level (48.52 m in monitoring period September 2000 to 2015). It is likely that this borehole penetrates two different groundwater systems. The deeper system is probably the same as that monitored at BH 95/7 as the hydrographs correlate reasonably well at low levels. The upper water levels may represent water levels in the overlying Mynydd-y-Garegg Limestone that is only active at times of heavy and persistent rainfall. These periods show a good correlation with the periods during which peaks flows occur at Garn-ffrwd spring as reported in ESI (2006).

The Crwbin quarry floor is typically flooded to a level of approximately 184 m AOD in winter with the lowest level of the quarry floor currently at approximately 180 m AOD. Adjacent to the flooded area, BH4b has recorded groundwater levels in the Main Limestone between 178 and 186 m AOD with BH3 and BH 6 recording groundwater levels up to 195.1 and 191.9 m AOD respectively.

Main Limestone groundwater flow

Evidence from spatial distribution of groundwater levels

The spatial distribution of high and low groundwater levels are shown on Figure 8-11. These groundwater levels can be compared with the elevation of some of the main surface water features shown in Figure 8-5.

Examination of the groundwater levels shows that a groundwater divide is located near to the boundary between Torcoed Fawr and Crwbin quarry (see **Figure 8-11 Appendix 8.8** of ES Volume 2). To the east of this, the hydraulic gradient in the Carboniferous Limestone is predominantly from west to east (with the majority of discharge to Garn Ffwrd spring), and to the west of this the hydraulic gradient is predominantly from east to west (with the majority of discharge to Crwbin spring).

It is possible that the large fault mapped to the east of Crwbin village could act as a barrier to groundwater flow. If this were the case, the fault itself would form the groundwater divide point. However, groundwater levels do not suggest a significant change in the hydraulic gradient over this area. The presence of spring 25-A roughly along the line of the fault (Figure 8-6), may be due to cross-stratal movement of water along the fault.

It is noted there is a clear, very steep hydraulic gradient between the Mynydd-y-Garegg Limestone in the south (i.e. high levels in BH17 & BH95/5) and the Cilyrychen Limestone/Penderyn Oolite to the north. Examination of the geological cross section in **Figure 8-14 (Appendix 8.8** of ES Volume 2) suggests that the low vertical hydraulic conductivity of the lower parts of the Mynydd-y-Garegg Limestone is probably ‘supporting’ groundwater levels in this southern groundwater system in which flow is predominantly eastwards to Garn-ffrwd spring. Very steep hydraulic gradients within the limestone are generally observed across the Site. **Figure 8-15 (Appendix 8.8** of ES Volume 2) presents an assessment of the elevation of groundwater levels within the Cilyrychen Limestone/Penderyn Oolite relative to the nearest sump in Torcoed Fawr quarry as presented from ESI (2006) which indicated low transmissivities (in the range 10 to 20 m^2/d).

Evidence from Tracer tests

Dye tracing tests were undertaken during 2002 which confirmed that the sinks to spring connections in the Crwbin/Torcoed area are vadose karst conduits, which at times become pressurised, causing surcharge of the adjacent diffuse flow zone (Smart and Halton, 2002).

The tests indicated that the Garn-ffrwd Spring is a major outlet for streams sinking on the ridge to the east (Figure 8-8). The sinkholes identified as feeding the spring were the Garn Bwll Sink (SH1), the Quarry Sink (SH6), the Tree Seep (S45) (which comprises overflow from the Mynydd-y-Garegg Limestones) and the Tan-y-banc seep (SH9) (which comprises flow from the Millstone Grit and Mynydd-y-Garegg Limestone further west from the other sinks). The catchment of the Garn-ffrwd spring is considered to extend up to 1.35 km to the west of Garn Bwll sink, and to include a substantial discharge contribution from the Millstone Grit and Mynydd-y-Garegg Limestones. This is consistent with the water chemistry (discussed below). These results suggest the presence of strike-oriented conduits between the sinks to the spring. The tracer tests indicated that these are isolated from the Cilyrychen Limestone as tracer was generally not detected in the quarries, although the Tyn-y-banc sink was considered to have an overflow connection with Torcoed Fawr Quarry.

No tracer tests are known to have been carried out on the Crwbin and Felindre catchments to the west. However, from the available groundwater level data (see above), it appears that the groundwater divide with the Garn-ffrwd lies close to the boundary of Crwbin quarry and Torcoed Fawr quarry.

Old Red Sandstone groundwater levels

In contrast to the hydrographs in the Carboniferous Limestone, those in the Old Red Sandstone are much smoother, indicating a more diffusive aquifer (higher storage/lower permeability). In a similar manner to the Carboniferous Limestone, there is a fairly steep hydraulic gradient within the Old Red Sandstone from west to east towards the discharge at Garn Bwll spring. However, whilst to the west, the groundwater levels in the Carboniferous Limestone are up to 30 m higher than in the Old Red Sandstone (i.e. in boreholes 95/4 and 95/5, 17a and 17b), to the east the levels are much closer (i.e. boreholes 5A and 5B). This may reflect proximity to a common discharge point.

However, it is important to note that, whilst there is a clear hydraulic gradient observable in boreholes completed in the Old Red Sandstone along the east-west strike of the strata, there is probably a steeper hydraulic gradient northwards to the series of springs and small streams that emerge from the lower slopes of the ridge. The predominant direction of groundwater flow within the Old Red Sandstone is thus probably to the north.

Groundwater and Surface Water Quality

Water samples have been collected and analysed quarterly from boreholes, wells, and springs between 2001 and 2011 (see **Figure 8-16** for locations - **Appendix 8.8** of ES Volume 2). ESI (2006) reported the following:

- All sampling locations, apart from Garn Farm well (W11), indicate a water that is well buffered by the bicarbonate system. BH5B, developed in the Main Limestone, shows high calcium, manganese, sulphate and bicarbonate concentrations.
- Torcoed, Torcoed Fawr and BH5B show slightly higher sulphate concentrations that reflect a Main Limestone origin and may result from pyrite oxidation due to pyrite exposure during quarrying. The effect of pyrite oxidation cannot be seen from the pH values, which is probably due to the high buffering capacity of the water.

- Garn Bwll (W03) well shows high calcium and manganese.

- The Old Red Sandstone borehole BH5A is characterised by moderate calcium, manganese and bicarbonate concentrations and relatively low sulphate concentrations.

- Garn Bwll spring (S41/S07), Garn Farm well (W11) and Tyr Garn pool (S40) have significantly lower total dissolved solid concentrations than all other sampling locations. The chemical composition indicates that, apart from water originating from the Main Limestone, these locations also receive water from overlying drift deposits or the Millstone Grit.

Table 8-8 presents averages of chemical monitoring data in 2010 as taken from ESI (20101b). The results are broadly consistent with observations reported above.

RMC (2000) reported on surface water sampling carried out in August 1994. Sample locations are shown in **Figure 8-16 (Appendix 8.8** of ES Volume 2). It was reported that:

- Samples 1 and 2 are derived from springs on the Old Red Sandstone but show a hydrochemistry indicative of water derived from the Limestone, possibly due to their location along a fault. However, the flow represented is a small percentage of the Limestone catchment water balance.
- Samples 3 and 4 (from Crwbin Stream) showed a hydrochemistry indicative of water derived from the Limestone. This is consistent with the surface water flow data and water balance calculations (Appendix 8-5).
- Samples 5 and 6 are taken from Henblas Stream, which rises from a spring at approximately 200 m AOD in the Basal Grit. Both samples were taken after the stream has crossed the Carboniferous Limestone. The data shows low bicarbonate, magnesium and sulphate relative to Carboniferous Limestone groundwater and support the view that base-flow from the Carboniferous Limestone to this stream is not significant. This is consistent with site observations in August 2008 when no significant accretion of flow was observed as well as with flow data (Section 8.4.3 indicates that this stream does not represent a major outflow point for the Carboniferous Limestone).

Table 8-8 Averages of 2010 chemical monitoring data

Analyte:	Unit	Torcoed Discharge	Torcoed Fawr Discharge	Garn Ffrwd Trout Fishery Spring	Garn Farm Well	Tyr Garn Well	Garn Bwll Well
No, of samples	-	4	4	4	4	3	4
Ammonia (as N)	mg/l	0.087	0.320	0.033	0.052	0.343	0.073
Chloride	mg/l	13.15	9.02	13.08	12.73	6.59	10.98
Nitrite	mg/l	0.011	0.004	0.023	0.037	0.005	0.004
Nitrogen	mg/l	2.56	0.27	1.07	1.42	0.30	0.22
Ortho-Phosphate	mg/l	0.020	0.028	0.036	0.052	0.036	0.020
Phosphate	mg/l	0.020	0.155	0.040	0.162	0.142	0.064
Iron	mg/l	41.2	107.9	47.8	86.5	701.3	1631.3
Nitrate	mg/l	2.6	0.3	1.0	1.4	0.2	0.2
Alkalinity pH4.5	mg/l	130.8	177.3	169.5	33.7	142.0	330.3
Bicarbonate	mg/l	159.5	216.3	207.0	41.1	173.3	403.0
Conductivity @ 20°C	mS/cm	793.0	373.8	354.3	144.5	262.3	541.3
pH	pH Units	7.8	7.8	7.4	6.3	5.7	7.5
Calcium	mg/l	168.8	75.8	71.4	18.5	55.6	114.5
Magnesium	mg/l	11.0	3.9	2.3	1.7	1.2	8.4
Manganese	mg/l	10.0	37.3	10.8	10.8	230.7	648.0
Potassium	mg/l	1.9	3.1	1.1	0.6	1.1	0.7
Sulphate	mg/l	338.0	37.4	16.2	12.2	7.5	16.3
Sodium dissolved	mg/l	8.7	6.0	7.8	8.1	4.5	5.8

8.4.5 Environmental designations

Sites of Special Scientific Interest (SSSIs) are shown in **Figure 8-17 (Appendix 8.8** of ES Volume 2).

Ynys Uchaf SSSI is located about 750 m to the north of the Site and consists of a flood plain mire in the Gwendraeth Fach river valley. It is fed by springs which flow northwards from the Mynydd-Llangyndeyrn ridge. RMC (2000) reported that the Countryside Commission for Wales (now NRW) indicated it had no concerns regarding the SSSI in relation to the development of Crwbin quarry. The feature is likely to receive baseflow from the Old Red Sandstone and is not considered to be at significant risk from the proposed development. This site has therefore not been taken forward for impact assessment.

The **Mynydd-Llangyndeyrn ridge** is a SSSI on the basis of the heathland, semi natural grassland, mire and rock outcrops. The mire habitat is located on the Millstone Grit that overlies the Carboniferous Limestone and is developed in poorly drained, shallow depressions and is therefore not at risk from quarry dewatering. This site has therefore not been taken forward for impact assessment.

Coedydd Capel Dyddgen SSSI covers an area of about 27 hectares about 500 m to the south west of the Site. It comprises a mosaic of ash-hazel woodland, scrub and grassland. Re-vegetated old quarry workings and a cave system are also present. The site is of special interest principally for its ash-hazel woodland and unimproved neutral grassland but various mammal, invertebrate and plant species also contribute to the biological interest of the site. NRW reports that the SSSI may potentially be damaged by "alterations to water levels and tables and water utilisation including irrigation, storage and abstraction from existing water bodies and through boreholes". It is therefore taken forward to the impact assessment stage.

Coedydd y Garn SSSI is located c. 800 m to the north east adjacent to the Garn ffrwd fisheries. It is taken forward to the impact assessment stage.

8.4.6 Conceptual model

This section summarises the hydrogeological conceptual model of the area around the Site and surrounding area. The conceptual model is supported by the extensive data sets available from the hydrometric monitoring system operated by Lafarge Tarmac and by the works of Smart (2001 and 2002). A schematic 3D diagram illustrating key features of the conceptual model is provided in **Figure 8-18 (Appendix 8.8** of ES Volume 2). A quantitative water balance to support the conceptual model is presented in **Appendix 8-5 (**ES Volume 2).

The local geology comprises Old Red Sandstone, overlain by Carboniferous Limestone, overlain by Millstone Grit and Coal Measures. The strata dip uniformly to the south-south east at approximately 18 – 23 degrees. Old Red Sandstone crops out to the north of the quarry, which has worked the Carboniferous Limestone. The Mynydd-Llangyndeyrn ridge comprises Millstone Grit, with younger strata overlying to the south-south east.

The Carboniferous Limestone is subdivided into the Lower Limestone Shales, the Main Limestone, and the Upper Limestone Shale. The main limestone itself can be sub divided into two contrasting aquifer systems: the relatively ‘clean’ lower limestones (Penderyn Oolite and Cilyrychen Limestone) which are the main economic mineral for the quarries, and the overlying, much shalier Mynydd-y-Garegg Limestone. Evidence from groundwater levels and tracer tests suggests that there is relatively little hydraulic connection between these two aquifer systems.

Superficial deposits in the area are generally thin or absent with variable cover of Boulder Clay across the area with some glacial sand and gravel and peat in places. Generally the cover of superficial material has little effect on the local hydrogeology other than to help to route recharge into particular locations.

Several north-north west faults are mapped in the area. However these do not appear to completely disrupt the geological sequence at any point and there is no evidence that these act as barriers to groundwater flow.

Groundwater flow in the Carboniferous Limestone is predominantly through karstic features (secondary permeability). Several sinkholes are observed in the Carboniferous Limestone and these have been traced to springs issuing from the Carboniferous Limestone. The main outflows from the Carboniferous Limestone system are the Felindre springs (S54 and S55), about 1.8 km to the west of the proposed Crwbin quarry excavation, and Garn Ffrwd spring (S09), about 1 km to the east of Torcoed quarry. Other significant springs in the vicinity of Crwbin quarry include Crwbin spring (S53), about 200 m to the west of Crwbin quarry, and Ffrwd-Gain spring (S25-A), about 120 m to the north of Crwbin quarry.

The predominance of along-strike flow in the Mynydd-y-Garegg Limestone and the shaley nature of the formation, means that the zone of influence of Crwbin quarry is largely constrained to the underlying limestones (Penderyn Oolite and Cilyrychen Limestone) at present.

The influence of the karst system on groundwater levels is seen as flashy responses to rainfall with little evidence of groundwater storage, and also gives rise to the 'dual water table' effect observed in water levels recorded in borehole BH95/5. The Old Red Sandstone is a more diffusive aquifer (higher storage and lower permeability) than the Carboniferous Limestone and this is reflected in the nature of the hydrographs.

Groundwater elevations indicate that the groundwater in the Main Limestone and the Old Red Sandstone are not in hydraulic continuity due to the presence of the intervening Lower Limestone Shales which effectively isolate the two groundwater systems.

8.4.7 Water Balance

A detailed, transient water balance for the area is presented in **Appendix 8-5 (**ES Volume 2). This work is an update of that originally carried out to support the EIA for the consolidation of the Torcoed /Torcoed Fawr planning applications (ESI, 2006).

The technical aspects of this work have subsequently been the subject of a peer reviewed paper (Streetly, 2008).

The water balance considers an area as far east as Garn Ffrwd catchment and as far west as Felindre Springs (S54/S55) catchment.

The calculation of a water balance for an area provides important quantitative support for a conceptual model by demonstrating that it has included all the important flow processes. Detailed daily water balance calculations were calculated for Garn-ffrwd spring and the quarries for the period for which there is accurate flow data against which to calibrate the model. The details of the approach are summarised below.

The methodology applied uses catchment-averaged, daily rainfall and potential evapotranspiration data series to calculate recharge which is then processed via a series of 'stores' to generate a time series of total catchment flow (e.g. in a spring) that can be compared directly to measured data.

This 'lumped' approach to modelling flows is commonly applied in hydrology and is particularly appropriate for karstic systems which in many ways resemble surface water systems more closely than groundwater systems. However this approach has also proved to be successful in simulating saturated flow in small to medium sized, groundwater dominated aquifer systems and is used extensively by the Environment Agency in South East Region (Catchmod). The approach has also been used effectively for similar EIA exercises including at Cornelly Quarry (ESI, 2004, and 2014) and at Penderyn Quarry (ESI, 2014).

A series of sub-catchments were defined across the area of interest. Each of these represents a particular combination of geology and surface water catchments (e.g. the part of the surface water catchment of a particular sink that is underlain by Millstone Grit). The flows estimated from each of the sub-catchments feeding a particular feature (i.e. spring or quarry discharge) were summed to give the combined estimated flow at that feature. These combined estimated flows were then compared to the actual flows in order to assess the adequacy of the model calibration.

The approach used was very successful in simulating the observed flow at Garn-ffrwd spring and the discharge form Torcoed quarry and Torcoed Fawr quarry over the period for which data were available. In general, the mean simulated flow differed from the mean observed flow by less than the level of accuracy associated with the measuring equipment (typically 5-10%).

The success of the transient water balance approach provided useful support to the other evidence such as tracer tests for deriving the estimated catchment areas of the springs and quarries.

In summary, the transient water balances of the Site and surrounding area indicated that:

- The spring flows recorded at Garn-ffrwd spring could be entirely accounted for by the groundwater flow from the Mynydd-y-Garegg Limestone and discharge/runoff from the Millstone Grit to the south. This is consistent with the results of tracer tests and hydrochemistry in this area. It is possible that the spring did receive some discharge from the Cilyrychen Limestone that is worked at Torcoed quarry in the past. However, it is more likely that any such groundwater flow would have made its way to the springs at Garn Bwll which is now dry. Any discharge from this route would have ceased when the quarries were first significantly dewatered.

- The discharges from Torcoed and Torcoed Fawr Quarries can be accounted for by recharge on the Cilyrychen Limestone in the immediate vicinity of the quarries. The indications from these calculations are that the groundwater catchments of the combined quarries potentially extend marginally into the Felindre catchment in the west and into the Garn ffwrd spring catchment to the east.

The flows at the other discharge points from the system were estimated by using the model calibrated against the Garn-ffrwd spring flows and changing the relevant areas. Clearly there are some potentially significant assumptions in adopting such a process and the results should be treated with some caution. However, the results (particularly the mean flow) are useful for comparative purposes. The resultant estimated flow statistics for the period 1961 to 2014 are given below in Table 8-9. These flows have been calculated based on the catchment areas take as the baseline in ESI (2006). The modelled impact assessment effects are then compared to this "baseline".

The estimated mean flow for Crwbin Spring of 1,016 m^3/d (11.88 l/s) is broadly consistent with spot flow gauging results presented in Section 8.4.3 with an average flow of 12.5 l/s from readings at the spring and four reading taken about 280 m downstream (average of 8 l/s).

The estimated mean flow for Felindre Spring of 8,083 m^3/d (94 l/s) is broadly similar to the four spot flow gauging results presented in Section 8.4.3 with an average flow of 74 l/s.

In conclusion, the recently collected stream flow data to the west of the quarries has tended to validate both the conceptual model of the local groundwater systems and the associated water balance methodology.

Table 8-9 Simulated flow statistics in m^3/d - baseline

Flow percentile	Garn-ffrwd	Felindre	Crwbin	Garn ffwrd lake	Garn Bwll	Gro gwynion
Mean	2090	8023	1016	905	564	255
95%	584	1220	461	262	202	121
90%	665	1477	535	308	236	140
75%	863	2168	664	400	303	176
50%	1428	4480	895	609	441	235
25%	2667	10425	1233	1115	695	316
10%	4340	18623	1640	1831	1037	402
5%	5596	25012	1994	2402	1291	455

Note: Generated from 1961 to 2014 climatic sequence

8.4.8 Uncertainties

As discussed previously, there is a degree of uncertainty in the predictions made here and therefore in the impact assessment results. This derives from inherent uncertainties in the underlying conceptual model of the hydrogeological system (as discussed in Section 8.4).

In order to address these uncertainties, sensitivity analysis has been used where appropriate to define the likely error margin for all model predictions. However, some of the predictions are dependent on the extent to which conduits are intercepted during the working of the land on the south of the quarry. The probability of intercepting these features cannot be determined in advance and therefore, the predictive scenarios are on the conservative side and include a worst case scenario that all active conduits are intercepted.

8.5 Methodology: Approach to Impact Assessment

On the basis of the conceptual model developed for the area, an approach to the impact assessment has been adopted which incorporates a quantitative simulation of groundwater flows within the impact assessment framework.

The impact assessment considers the likely impact of quarrying compared to a baseline position presented in the water balance in Appendix 8-5. This is not a true baseline in the sense that it incorporates the effects of the quarry workings at Torcoed/Torcoed Fawr quarry prior to the Torcoed/Torcoed Fawr 2006 consolidation application. However, the impact of quarry dewatering on the surrounding water features has been relatively restricted to date and comments on existing impacts are made throughout the text as appropriate.

The assessment of impacts has been performed either by qualitatively (or, if appropriate, quantitatively) considering their impact in the light of the groundwater level or flow predictions, or through the application of previous experience and expert knowledge.

The risk assessment is carried out in accordance with Environment Agency (2007) which describes a methodology and suite of tools for assessing the hydrogeological impact of the abstraction of groundwater for dewatering purposes.

8.5.1 Hydrogeological Impact Assessment Methodology

A source-pathway-receptor methodology has been applied to the impact assessment. In the context of the impact assessment for Torcoed/Crwbin quarry these elements may be defined as:

Source	:	Dewatering associated with further working of the quarry/quarries
Pathways	:	The groundwater flow pathways or hydrogeological linkages identified in the conceptual model.
Receptors	:	Key water features.

The risk assessment process can be sub-divided into a number of steps as described below.

Step 1: Identification of Receptors. The identification of a risk requires the presence of all three elements in the source-pathway-receptor chain. The source for this assessment is by definition Torcoed, Torcoed Fawr and Crwbin quarries (specifically, the reduced groundwater levels in the quarries). The first task in the risk assessment process is therefore to identify any relevant receptors.

Step 2: Identification of Pathways. Having established all potential impact sources and receptors, it is then necessary to identify potential pathways between the quarry (the source) and each water feature (the potential receptors) (i.e. determine all source-pathway-receptor linkages). In simple terms, the assessment process must establish whether the groundwater level effects of quarry dewatering could potentially affect any of the identified water features. This has been achieved by considering each potential source-pathway-receptor chain in the context of the conceptual model. Hence, where there is believed to be no significant groundwater pathway between the quarry and a given receptor, this receptor can be removed from the impact assessment process (note: where a pathway linkage is unclear, possibly due to uncertainty in the conceptual model, the pathway is assumed to exist at this stage of the assessment process). In effect, the risk assessment approach serves to filter the list of potential receptors.

The complete list of potential receptors presented in **Appendix 8-1 (Appendix 8.8** of ES Volume 2) is divided into potentially vulnerable receptors and those not considered to be vulnerable. For those receptors that are considered to be potentially vulnerable a second more detailed table in Appendix 8-1 provides more information on the local hydrogeology and the potential pathways between the quarries and the receptor. Where more than one potential receptor ID is located at the same location, for example spring S25-A and licensed abstraction LA26, these are grouped together for consideration.

Note: Nine small springs may already have been impacted to some extent by operations at the Torcoed quarry site, as indicated in Appendix 8-1.

Step 3: Quantification of Effects. The presence of a hydrogeological pathway between the quarry and a receptor does not on its own indicate that an effect will occur at the receptor. The next step in the impact assessment process must therefore be to address whether or not there is likely to be an effect at each potential receptor resulting from quarry development (and decommissioning) works. This requires a degree of quantification. It is therefore necessary to quantify the degree of groundwater level change at each receptor, or alternatively the change in water balance components (i.e. groundwater inflows and outflows) surrounding that receptor.

Step 4: Assessment of Significance. The demonstration and quantification of a potential effect does not in itself represent a significant potential impact as this requires an assessment of the significance of the effect. This is conducted individually for each receptor.

There are two aspects to the assessment of significance:

1) it is necessary to compare the size of the potential effect with a **relevant criterion**. If the size of effect is smaller than the criterion then the effect does not represent a significant impact. In some cases it may be more appropriate to determine this on a qualitative basis.

2) if the size of effect is potentially greater than the relevant criterion, it is necessary to assess the significance that the potential impact represents. The significance of an impact is dependent on the magnitude of the effect and the **importance of the receptor**.

1. Relevant Criteria

Step 4 requires a measure of impact significance (i.e. when does a predicted effect become a potentially significant impact?). The impact significance at each receptor site has been evaluated separately on the basis of the conceptual understanding of the local groundwater system. To assist in this evaluation, the following interim, conservative guidelines have been adopted for screening purposes:

- For licensed groundwater abstraction boreholes a predicted groundwater level reduction in excess of 0.5 m is taken to indicate a potentially significant impact.

- For shallow wells and ponds, a predicted groundwater level reduction in excess of 0.25 m is taken to indicate a potentially significant impact.

- For spring flows, a derogation of flow in excess of 10% of mean long-term flows is taken to indicate a potentially significant impact.

Where an effect falls below the threshold criteria described above, it is taken to be negligible. Where it exceeds the critical threshold, a site specific assessment of the degree of effect (low, medium, or high) is applied based on the particular conditions at that receptor (e.g. large natural variation in groundwater levels compared to the predicted change).

2. Importance of Receptors

The second factor in the consideration of degree of impact is the importance of the receptor. Receptors have been assigned to one of three status categories – low, medium or high. The methodology for assigning to a particular category is based on the following general criteria although it is to some degree subjective:

- Low Status – Unlikely to be of significant ecological or societal value (e.g. small ephemeral pond); surface water and groundwater abstractions that supply or impact on an individual or small number of people (e.g. farm or home supply), although this may be locally significant;

- Medium Status – Of local ecological or societal value or supporting medium or high status ecological features (e.g. springs); surface water or groundwater abstractions that supply or impact on a local community (e.g. local water supply or water supply to a local amenity);

- High Status – Nationally and internationally designated ecological sites (e.g. SACs) or features supporting these (e.g. springs); surface or groundwater abstractions that feed into public water supply.

Degree of impact is determined by applying the degree of effect with the receptor status according to the matrix in Table 8-10 below:

Table 8-10 Hydrogeological Impact Assessment Matrix

		Receptor Value		
		Low	**Medium**	**High**
Degree of effect	**Negligible**	Negligible	Negligible	Negligible
	Low	Minor	Minor	Moderate
	Medium	Minor	Moderate	Major
	High	Moderate	Major	Major

Whilst the table above provides impact magnitude, impacts are further defined in terms of whether they are adverse (i.e. negative) or beneficial (i.e. positive).

Only adverse impacts that are Moderate or higher (highlighted with red text in the table above) are considered to be potentially significant and in need of mitigation.

8.6 Potential Impacts of Quarry development

The following potential effects are addressed by the hydrogeological impact assessment:

Table 8-11 Short List of Potential Impacts

Phase of Development	Activity	Potential Impact	Impact Duration[1]
Quarrying Phase	Dewatering	Change of current groundwater flow regime	T
		Reduction in stream baseflow contribution	T
		Ground instability associated with dewatering extent	P
		Reduction in spring flows	T
		Reduction in pond or pool levels	T
		Reduction in borehole performance / yield	T
	Quarry working	Groundwater pollution from accidental fuel spills, leaks etc.	T
		Surface water pollution from contaminated run off	T
		Loss of unsaturated zone (dry weather storage and groundwater quality protection)	P
	Disposal of dewatering water	Change of current groundwater flow regime (change in infiltration / recharge)	T
		Change of stream flows	T
		Increased surface water turbidity	T
Decommissioning Phase	Creation of permanent quarry lake (cessation of dewatering)	Change of current groundwater flow regime	P
		Change of stream baseflow contribution	P
		Change of spring flows	P
		Change of borehole performance / yield	P
		Change of pond or pool levels	P

T – Temporary, P – Permanent

8.6.1 Dewatering

Future quarry dewatering rates which determines the likely degree of effect on potential receptors have been simulated by the water balance calculations in **Appendix 8-5 (**ES Volume 2). Similar calculations were used to estimate future dewatering requirements by adjusting the catchment area of the quarries in light of the assessment of the effect of quarry development on groundwater levels as presented in Table 8-12.

Table 8-12 Simulated quarry discharges (m^3/d)

Stats	Torcoed			Torcoed Fawr + Crwbin		
	Baseline	Best estimate	Worst case	Baseline	Best estimate	Worst case
Mean	760	1663	2567	870	1919	2968
95%	352	529	706	400	603	806
90%	407	598	790	463	696	929
75%	508	769	1029	573	909	1245
50%	679	1230	1781	765	1462	2158
25%	935	2167	3398	1063	2531	3999
10%	1222	3314	5405	1406	3779	6153
5%	1409	4127	6846	1644	4639	7634

Note: Based on 1961 to 2014 climatic sequence

The principal area into which the zone of influence of the quarries will expand is into the Mynydd-y-Garegg Limestone sub-catchments to the south and south east of the quarries. As discussed above, the actual degree of influence will be very dependent on the timing of interception of the karst conduits. Due to this uncertainty, the assessment of impact on quarry dewatering rates is calculated for two scenarios: best estimate and worst case, rather than for specific quarry development stages.

The best estimate (most likely) scenario assumes that 50% of potential spring flow in each sub catchment is captured. The worst case scenario would occur if all the relevant karst conduits were intercepted. This could occur at any stage of the development at which there was significant deepening in the Mynydd-y-Garegg Limestone to the south of the quarries. The best estimate case is a less pessimistic scenario, although again this could occur at any stage at which there was significant deepening in the Mynydd-y-Garegg Limestone to the south of the quarries.

Under the worst case scenario the following effects are estimated at full quarry development:

- 78% of the catchment of Garn-ffrwd spring is predicted to be captured;
- 100% of the flow at Garn-Bwll spring is predicted to be captured by Torcoed Quarry. This is in line with site observations;
- Up to 100% of the spring outflow from the Crwbin block could potentially be captured by Crwbin quarry.
- 7% of the catchment of Felindre spring is predicted to be captured.

The effects under the best estimate case scenario are proportionally smaller. Table 8-12 shows that as a result of the capture of spring flows, the average inflows into/discharge required:

- from Torcoed is predicted to increase from 760 m3/d to 1,663 m3/d and 2,567 m3/d under the best estimate and worst case scenarios respectively.
- From Torcoed Fawr + Crwbin is predicted to increase from 870 m^3/d to 1,919 m^3/d and 2,968 m^3/d under the best estimate and worst case scenarios respectively.

The discharges are regulated by the two discharge consents issued by NRW as detailed in Table 8-1 with limits of 6,307 m^3/d and 5270 m^3/d for the Torcoed and Torcoed Fawr discharges respectively. This indicates that the limits are likely to be sufficient for average conditions and even Q_5 to Q_{10} conditions for the worst case scenario. If an increase is required in the future then a discharge consent variation would need to be agreed with NRW.

8.6.2 Groundwater Levels

Old Red Sandstone and Millstone Grit

Groundwater levels in the Old Red Sandstone to the north and the Millstone Grit to the south are separated from the quarries by relatively impermeable strata. Groundwater levels in these formations do not appear to have been affected by the quarry operations at Torcoed to date and it is not anticipated that the development will have any significant effect on these formations.

The springs that rise on the Old Red Sandstone north of Crwbin village may receive some groundwater from the Carboniferous Limestone due to faulting. These potential receptors, and associated wells and abstractions, are considered in the relevant sections below.

Mynydd-y-Garegg Limestone

Groundwater levels in the Mynydd-y-Garegg Limestone to the south are protected from the effects of quarry dewatering by the low vertical hydraulic conductivity of these strata (as described in Section 8.4 above). The development involves working close to some of these low permeability strata and this will create the potential for groundwater in this formation to flow northwards into the quarries.

Groundwater levels in this formation are currently at c. 190 to 200 m AOD to the south of Torcoed Quarry and at c. 190 to 210 m AOD to the south of Torcoed Fawr /Crwbin Quarry.

The profiles of the proposed development of the quarries shown on **Figure 8-3 (Appendix 8.8** of ES Volume 2) suggest that the Mynydd-y-Garegg Limestone will be exposed in the face of the quarry at 170 m AOD in Torcoed and 195 m AOD in Torcoed Fawr Quarries (referred to as the 'Main Limestone' in Figure 8-3). The amount of drawdown that this will cause in the formation is very dependent on the extent to which the relevant karst conduits are intercepted. The formation itself is very layered and shaley and this may limit the degree of drawdown across strike. However, given that the proposed working extends across the majority of the outcrop of the formation, it seems likely that there will be a significant degree of capture of groundwater flow from this formation in the vicinity of the quarry by the proposed development. Maximum drawdowns will therefore be of the order of 5 to 30 m in the immediate vicinity of the quarry and less than this elsewhere.

Given that groundwater flow in the formation appears to be predominantly karstic in nature and that the traced groundwater connections all show flow to the east, it is considered that the effect of this working on groundwater levels at potential receptors will be limited to those sourced from the formation between the quarries and Garn-ffrwd spring.

Assessment of the potentially vulnerable sites identified during the water features survey indicates that the following receptors are within this zone:

- Garn Bwll Farm disused well/borehole (W03)
- Ty'r Garn Pool (S40) – a natural pool in a steep sided depression

Note that the hydrochemistry of these sources (Section 8.4.4) suggests that they are at least partially sourced from local drift deposits. However, as a worst case scenario for the purposes of this assessment, it has been assumed that they are entirely sourced from the Mynydd-y-Garegg Limestone and are therefore potentially vulnerable to quarry working in this formation.

The amount of drawdown that is predicted to occur at these receptors has not been estimated due to the uncertainties in predicting such effects in a strongly karstic aquifer. Groundwater levels at these sites have been monitored over a long period which provides a good baseline for assessing future derogation.

Due to the karstic nature of the aquifer, it is assumed that there is the potential for effects on water levels at these receptors to occur at any stage of the development of the quarry although the probability of this occurring increases as the quarries expand.

Cilyrychen Limestone and Penderyn Oolite

Groundwater levels in the Cilyrychen Limestone and Penderyn Oolite will be affected by the deepening of the quarries; as well as lateral extension mainly associated with working in Crwbin quarry.

It is considered that drawdown in the Cilyrychen Limestone and Penderyn Oolite could potentially extend marginally into the Felindre catchment (C19) to the west. It is considered unlikely that drawdown in these limestones from the development will extend further east than Garn-ffrwd spring.

As groundwater flows within the limestone can be considered to be approximately one dimensional (1D - long, thin outcrop), this groundwater elevat ion profile can be simulated by a simple steady state, 1D analytical solution (simulating water levels between two fixed heads in an unconfined aquifer with recharge (Fetter, 1994))[6]. The effects of the proposed deepening can then be estimated by changing the fixed heads applied in the1D equation. The results of these calculations are shown in **Figure 8-19** and **Figure 8-20 (Appendix 8.8** of ES Volume 2) and suggest:

- that the groundwater divide between Crwbin quarry and the dominant discharge point to the west at Felindre Spring may extend west by about 300 m (**Figure 8-19**). This is considered to be a reasonable worst case scenario. The predicted groundwater profile is above ground levels across some of its length which may suggest a confined/conduit system discharging at Felindre and reducing groundwater heads along the profile. This would reduce the impact on Felindre if the case.

- that the groundwater divide between Torcoed quarry and the Garn-ffrwd Spring to the east may extend by about 200 m to the east, with the groundwater divide predicted to reach c. 475 m from the spring (**Figure 8-20**).

Clearly, due to the nature of the formation, there is a degree of uncertainty associated with these predictions. This affects the groundwater catchment area of the quarries and any spring discharges to the west and east and hence the amount of flow predicted at these sites. Any receptors that are dependent on groundwater levels in these formations and are vulnerable to water level changes are discussed below.

8.6.3 Spring/stream flows

Springs to the east and south

S07/S41 (Garn Bwll spring) – This location is c. 180 m to the east at an elevation of about 145 mAOD and is already dry. Flow from this route would have ceased when the quarries were first significantly dewatered and >10 years ago. Smart (2001) reported that flow at that time was "very small". This location is already derogated and therefore the impact from continued development of the quarry is considered to be negligible.

Torcoed Quarry Farm Spring (S19). Flow from this route would have ceased when the quarries were first significantly dewatered and >15 years ago. Smart (2001) reported that natural flow had ceased. This location is already derogated and therefore the impact from continued development of the quarry is considered to be negligible. It is noted this location provides the outlet for discharge from Torcoed quarry with the route being culverted for most of the section between the discharge point and where it meets a tributary of Gwendraeth Fach about 1 km to the north.

S09 (Garn-ffrwd Spring) - The potential effect on spring at this location was quantified in the Appendix 8-5 water balance. 78% of the catchment of Garn-ffrwd spring is predicted to be captured. As detailed in Table 5.4 of Appendix 8-5, an un-impacted flow average flow of 2090 m^3/d is predicted with a worst case reducing average flows to 454 m^3/d with a Q_{95} flow of 168 m^3/d. This compares to a worst case reducing average flows to 546 m^3/d with a Q_{95} flow of 208 m^3/d as presented in ESI (2006) for the Torcoed and Torcoed Fawr quarries consolidation planning application.

6 The 1D equation assumes that Darcy's law is valid and that the rate of recharge is that derived in the water balance calculations. Clearly, in a karstic formation such as the Carboniferous Limestone, this will only be a coarse approximation. However, this approach is likely to be more limited in the clearly karstic Mynydd-y-Garegg Limestone than in the Cilyrychen Limestone and Penderyn Oolite which appear to behave in a more uniform manner in the vicinity of the quarries.

The potential impact is deemed to be major. Mitigation measures have previously been agreed for this site and are incorporated into a legal agreement between Lafarge Tarmac and the spring owner. An outline of the agreement is provided in Appendix 8-6.

Four other small springs to the east and south are as follows; Tree Seep (S45), un-named (S44), Ty'r Garn pool (S40) and one near Garn-ffrwd (S11). These appear to be outflow springs from the Millstone Grit and as such will not be affected by the development. However, it is possible that some of the works involved in the southward development of the quarries could affect their catchment areas. Generally these small streams flow for a short distance (100 m or so) and then enter sink holes. The impact is deemed to be negligible.

Springs to the west and north west

S53 – (Crwbin spring) - emerges from the Carboniferous Limestone to the west of the Crwbin Fault at an elevation of approximately 160 mAOD. The worst case scenario predicts that this spring could potentially become completely dry during the proposed development (see **Appendix 8-5 (**ES Volume 2)). The drying up scenario is considered to be conservative and the spring may retain up to 50% of its flow. However, the potential impact is deemed to be moderate and monitoring and mitigation measures are detailed below.

S54/S55 – (Felindre Stream Springs) - These springs are located about 1.8 km to the west at an elevation of c. 105-109 mAOD. The water balance assessment in Appendix 8-5 predicts a worst case and best estimate reduction in flows of 7% and 3.5% respectively due to the proposed development. The impact of the potential loss of flow is considered to be low and no monitoring or mitigation is proposed.

S25-A has previously been identified as a spring, as PWS3 was previously reported as such, but spring has been located adjacent to W20. This spring is located on the Old Red Sandstone but is close to the contact with the Carboniferous Limestone and there may possibly be a contribution from the Carboniferous Limestone, particularly due to its location along Crwbin Fault. The spring flows fairly constantly but it is understood that flow can dry up from time to time (Wardell Armstrong, 1995). The stream meets Crwbin stream about 600 m to the north west of W20. The impact of the potential loss of flow is considered to be minor and no monitoring or mitigation is proposed. The potential impact on the water supplies in the area was considered separately.

S25-B – This location was also previously identified as a spring. During the site visit no spring was observed here, with the location being on the Crwbin stream about 280 m downstream of Crwbin spring (S53). A spring located about 100 m to the south is on the Old Red Sandstone and not considered at risk of impact. The impact of the potential loss of flow is considered to be negligible and no monitoring or mitigation is proposed.

Springs to the north

Three minor springs are present to the north of Torcoed Quarry, rising from the Old Red Sandstone at Near Torcoed Fach (S04&S05) and Near Torcoed Uchaf (S06). It is possible some of these may receive some water from the Carboniferous Limestone. The impact of the potential loss of flow is considered to be minor and no monitoring or mitigation is proposed.

8.6.4 Well & water supply features

The water features survey (**Appendix 8-1**- ES Volume 2)) identified the following wells & water supplies which are potentially vulnerable to the combined impacts of the Torcoed/Crwbin developments and therefore warranted further assessment.

- **W03 (Garn Bwll Farm)** – This well, to the east of Torcoed, is located on the Carboniferous Limestone and some effect cannot be ruled out: however, the impact of the effect is deemed to be minor. A data request to NRW and the local authority did not highlight any licensed abstraction or private water supply, and therefore any protected right, at this location and it is understood that the well is disused. No monitoring or mitigation is proposed.
- **W11/LA1 (Garn Farm)** – This well is beyond Garn-ffrwd spring to the east and is likely to be in a part of the system dominated by runoff-

recharge contributions from the nearby Millstone Grit sub catchments. Some effect cannot be ruled out, but the potential impact was deemed to be negligible. A data request to NRW and the local authority did not highlight any licensed abstraction or private water supply, and therefore any protected right, at this location and it is understood that the well is disused. No monitoring or mitigation is proposed.

- **LA5 (Ty'r Garn) -** A data request to NRW indicated that a deregulated abstraction "licence" is present for a well at this location. This is a licence which is authorised for abstraction of less than 20 m^3 per day. However, following a number of local enquires and site walkovers this feature cannot be located and it is not known to be used. Previous monitoring has been undertaken at Ty'r Garn pool (S40) rather than a well. Therefore, the potential impact is deemed to be low and no monitoring and mitigation measures are proposed.

- **W20/PWS4/LA3 (Ysgubor-fach)** – This well/borehole supply is from the Old Red Sandstone, but is close to the contact with the Carboniferous Limestone and there may possibly be a contribution from the Carboniferous Limestone, particularly due to its location along Crwbin Fault. PWS4 is understood to relate to well W20 but no licensed abstraction has been identified. It is at an elevation of about 145 mAOD, compared to a proposed working depth of 130 mAOD in Crwbin Quarry. The potential impact is deemed to be moderate. Monitoring and mitigation measures are detailed below.

- **PWS3/LA26** – Location S25-A has previously been identified as a spring but none was observed during a site walkover. A data request to NRW and the local authority indicates that there is a private water supply (PWS3), but no licensed abstraction, at this point. The source is thought be an abstraction from the stream, about 150 m to the north of well W20, at an elevation of about 145 mAOD. The potential impact is deemed to be moderate. Monitoring and mitigation measures are detailed below.

- **PWS5/LA2** - This private water supply is located about 500 m to the south west on Henblas stream. A data request to NRW and the local authority did not highlight any licensed abstraction or private water supply to be present. No impact is predicted on the Henblas stream as it is derived from the Basal Grit and is not thought to gain baseflow from the Carboniferous Limestone and therefore the potential impact on this supply is minor. Additionally, the potential impact is deemed to be minor as Wardell Armstrong (1995) reported that this source is no longer in use.

- **PWS6** – This private water supply is located some 1.8 km to the south west within the Felindre stream catchment at an elevation of about 155 mAOD and therefore the potential impact is deemed to be negligible.

- **PWS11** – This private water supply on the Old Red Sandstone is associated with Maes-y-Meillion farm to the north of Torcoed quarry with a small stream that runs east of the farm. Flows observed during the water features survey were minor. It is possible some of it may receive some water from the Carboniferous Limestone. The potential impact of the potential loss of flow is considered to be minor and no monitoring or mitigation is proposed.

- **W12/PWS12/LA13** - This private water supply and regulated abstraction licence on the Old Red Sandstone is associated with Torcoed Uchaf. It is thought to be associated with the licensed abstraction (LA13). It is possible it may receive some water from the Carboniferous Limestone. The impact of the potential loss of flow is considered to be minor and no monitoring or mitigation is proposed.

- **W02 -** This private water supply on the Old Red Sandstone could possibly receive some water from the Carboniferous Limestone. The impact of the potential loss of flow is considered to be minor and no monitoring or mitigation is proposed.

NRW and Carmarthenshire County Council have confirmed that there are no other abstraction licences or private water supplies in the vicinity of the Site.

8.6.5 Environmental designations

NRW reports that the Coedydd Capel Dyddgen SSSI, about 500 m to the south west of the Crwbin quarry, may potentially be sensitive to "alterations to water levels and tables and water utilisation including irrigation, storage and abstraction from existing water bodies and through boreholes". No surface water features are present and groundwater level changes are predicted to be minimal in this area. Therefore, the potential impact is considered to be negligible and no monitoring or mitigation is proposed.

Coedydd y Garn SSSI is located c. 800 m to the north east of the Site, adjacent to the Garn ffrwd fisheries. No surface water features are present and groundwater level changes are not predicted in this area. Therefore, the potential impact is considered to be negligible and no monitoring or mitigation is proposed.

8.6.6 Potential impacts on surface water and groundwater quality

There is a potential risk to groundwater quality from routine quarrying activities at the quarries, as is the case with the current quarry operation. This risk essentially relates to the accidental release of pollutants, which may enter the local groundwater system either through the quarry base or via water discharged off site. The likelihood of any pollution occurring can be reduced through sound operational practices including suitable pollution control measures. It is recommended that standard planning conditions relating to this type of operation should be applied consistent with the current planning conditions regulating operations at Torcoed and Torcoed Fawr. The quality of water discharged from the site will be regulated by a discharge consent issued by the NRW. It is therefore concluded that these measures will effectively control any risks of impacts on surface water and groundwater quality.

Working in the catchment area of the Garn-ffrwd Spring provides a potential mechanism for water quality impacts on the spring. Lafarge Tarmac monitors the quality of the spring water regularly and has been working in this area for several years now with no apparent detrimental effect.

The Flood Consequences Assessment provided in **Appendix 8-4** (ESI [2015c] - ES Volume 2)), assesses storm runoff water quality and concludes that based on an average outflow of 134 l/s (the combined discharge consent limit), an effective settling area of 964 m^2 to 536 m^2 would be required to achieve appropriate suspended solids concentrations for discharge. There will be adequate space within the quarry to provide this. This may be conservative given that there is likely to be dilution with groundwater inflows which are less likely to pick up suspended solids. An increased settlement area would be required if larger discharge rates are required in future.

8.6.7 Flood risk & drainage

A flood risk and drainage assessment is provided in **Appendix 8.4** (ESI [2015c]).

The risk of flooding from rivers or the sea has been assessed as being less than 0.1% annually by the Environment Agency and is therefore deemed not significant. The TAN 15 flood risk Development Advice Map (Welsh Assembly government, 2004) also classifies the Site area and surroundings as Zone A “Considered to be at little or no risk of fluvial or coastal/tidal flooding”.

During the development stage for the Torcoed and Torcoed Fawr & Crwbin catchments, run-off will collect in the base of the quarry voids with sufficient storage available.

For the restored stage, a possible overflow from the eastern lake at 160 m AOD will need to be controlled to prevent flooding and a spillway and channel should be designed to control the flow rate to ensure that there will be no increase in down-gradient flood risk.

Potential off site runoff from Torcoed Fawr North catchment can be achieved easily by a ditch running along the northern boundary of this catchment and directed to the outlet with nearby discharge point (see **Appendix 8-4**).

8.6.8 Other potential impacts

Loss of Unsaturated Zone Storage

In low storage aquifers such as the Carboniferous Limestone, the unsaturated zone can form an important source of storage of water to maintain spring outflows during dry periods. In the Carboniferous Limestone, the shallow epikarst is considered to be particularly important in this respect. In the present case, it is not considered that this is a significant issue as the proposal involves limited lateral extension.

8.7 Potential Impacts of Quarry Decommissioning and Restoration

The quarries will be restored as two separate bodies of open water by allowing groundwater water levels recover naturally at the end of quarry working. Those parts of the groundwater system in the Mynydd-y-Garegg Limestone to the south that have been 'captured' by the interception of conduits will continue to flow northwards into the restored quarries. Water will discharge from the water body in Crwbin / Torcoed Fawr Quarry (165 m AOD) into Torcoed Quarry (160 m AOD) and thence to the streams to the north east (discussed below). The original springs on the northern flanks of the hillside that have already been affected by quarry dewatering are at elevations of 175 to 236 m AOD and are unlikely to be re-activated on restoration.

8.7.1 Groundwater levels

Average Recovery Levels

The low point in the lip to the east of Torcoed Quarry is at around 160 m AOD. This therefore forms a maximum level for the restored lake.

Scoping calculations were carried out as follows to estimate whether it is likely that levels will recover to this level:

Considering flow through the Penderyn Oolite/ Cilyrychen Limestone aquifer to the stream to the north east the following dimensions/parameters can be estimated:

- Width = 200 m
- Distance to discharge point = 250 m

Elevation of discharge point = 140 m AOD (lower than the main spring elevation to take account of the implications of low groundwater levels at 97/01).

Using Darcy's Law, in order to discharge the combined inflow to the quarries under the base case scenario (3,580 m^3/d) and retain a restored head in the quarries of under 160 m AOD, the transmissivity of the intervening rock should be higher than 225 m^2/d. For the worst case scenario (inflows of 5,535 m^3/d), the transmissivity needs to be over 350 m^2/d.[7]

These values of transmissivity are on the high side for regional values of the Carboniferous Limestone and are significantly higher than those implied for the local system by the steep hydraulic gradients discussed above.

This suggests that it is likely that groundwater levels in Torcoed Quarry will rise to around 160 m AOD and discharge can occur via a proposed controlled outfall to Garn Bwll stream (S07/S41) and/or Torcoed Quarry Farm Spring (S19). Similarly, the water levels in Crwbin/Torcoed Fawr will be controlled by an overflow into Torcoed at c. 165 m AOD.

[7] Note that if the elevation of the discharge point is assumed to be 135 mAOD (the lowest groundwater level measured at borehole 97/01) the transmissivities required to be exceeded become 160 and 232 m^2/d.

Water levels in the Penderyn Oolite/Cilyrychen Limestone groundwater system to the west of the Site will recover as water levels in the sump recover from the low point of 130 m AOD to around 165 m AOD (overflow to Torcoed Quarry).

Residual groundwater levels in the Mynydd-y-Garegg Limestone to the south of the quarries will be dependent on the elevation of any conduits that are intercepted by working. The drawdowns that occur at maximum extent of the quarry working are likely to be permanent as the recovery water levels in the quarries (max 160 m AOD) will not reach the level of overflow from the Mynydd-y-Garegg aquifer (170 to 195 m AOD).

For the development stage, only water supplies W20/PWS4 and PWS3 were identified as having a potential impact greater than minor. It is considered that the potential impact will be minor at all of these locations following groundwater level recovery due to a reduced degree of effect and on mitigation measures are proposed. However, if these have not been impacted by the time the quarry is fully worked, they will not be impacted during restoration.

Fluctuation in Recovery Levels

The restored body of water will form a significant store of water in the local hydrological system and this, combined with the potential to overflow at 160 m AOD, will dampen any fluctuations in level. If most of the discharge is ultimately via the overflow (as seems likely), there will be relatively little fluctuation in groundwater levels around this point. However, if recovery is not as high as this, then there will be more fluctuation. Given that fluctuations in groundwater levels in the Carboniferous Limestone aquifer are typically under 10 m at present and the storage in the system is likely to be up to 100 times higher (unity as opposed to a specific yield of 1%), it seems likely that any fluctuations in the lake level are likely to be of the order of 1 m.

Period to Full Recovery

The period to full recovery will depend on the volume of the void to be filled by water and the climatic conditions at the time. Using the mean estimated groundwater inflows to the voids (3,582 to 5,535 m^3/d) and the estimated void size below 160 mAOD (c. 6,200,000 m^3), it seems likely that the void will take of the order of 3 or 5 years to infill.

(Note that the rate of inflow is dominated by local recharge and is therefore not likely to be head dependent).

8.7.2 Outflow from the restored quarries

When the quarries are restored to open water there is the potential that the rate of evaporation will be different from that assumed in the recharge model. The degree of difference is hard to quantify as, although (for equivalent climatic conditions) the evaporation rate from open water is typically higher than for grass (the assumption of the recharge model), the rate of potential evaporation is very dependent on sunshine, humidity and wind speed. In a deep, steep sided quarry it is very likely that sunshine and wind speed (which promote evaporation) will be lower and humidity (which reduces evaporation) will be higher. It is thus possible that the potential evaporation rate at the water surface will be lower than would be assumed by standard calculations.

However, in order to assess the potential significance of this uncertainty, the recharge model has been re-run in a way that simulates the effects of open water whilst ignoring the effect of the factors discussed above. The results of this model are as follows:

- Evapotranspiration rate (grass) 500 mm/a (average for period 1961 to 2003)
- Evapotranspiration rate (open water) 670 mm/a (average for period 1961 to 2003)
- Difference 170 mm/a.

Applying this difference over the potential area of open water suggests an equivalent abstraction rate of around 140 m^3/d. This effective abstraction rate is small relative to the natural outflows from the system and is not likely to have any discernible effect on the regional groundwater flow system.

During the period of recovery of water levels at the end of quarry operations, the total outflow from the Carboniferous Limestone will be reduced by the amount of inflow to the quarry void. This will lead to some reduction in the flow to local streams during this period unless some residual pumping is maintained for the recovery period.

8.7.3 Surface water/spring flows

As discussed above, the surface water outflow from the restored quarries will be via the stream from Garn Bwll stream and/or (S07/S41) and/or Torcoed Quarry Farm Spring (S19) to the north east of Torcoed. These features will thus benefit from restoration of flows (once the quarry void has been filled). The amount of fluctuation in groundwater outflows will depend to some extent on the proportion of outflow that is via the aquifer and that via the overflow channel. However, it is likely that the range of flows will be more subdued than that predicted for quarry dewatering at maximum extent due to the additional storage in the quarry void and the attenuating properties of the intervening aquifer.

The full extent of impact on the Garn-ffrwd spring will be determined by the extent to which the key conduits are intercepted. The predicted water levels in the restored quarries (160 to 165 m AOD) will be above current levels and also above levels in the Garn-ffrwd Spring (137 m AOD). It is therefore possible that there will be some groundwater discharge from the quarries to the spring via the deeper parts of the Mynydd-y-Garegg Limestone. However, for the purposes of this assessment, it has been assumed that this will not occur (worst case scenario). Options for mitigation of the spring following restoration of the quarries are discussed below.

A flow reduction of 50 to 100% during the development stage was estimated for Crwbin Spring. It is uncertain as to what degree the flows would recover and the spring could potentially remain impacted in the long term. This is further discussed in Section 1.1 below.

8.8 Summary of Effects

A summary of the development pre-mitigation and decommissioning/ restoration effects is provided in the following tables:

Table 8-13 Summary of development stage specific impacts (pre-mitigation)

Receptor	Type	Degree of effect	Receptor Value	Degree of impact	Monitoring proposed?	Mitigation proposed
S09 - Garn Ffrwd	Spring	Medium	High	Major	Yes	Yes. agreement with the owner of the Garn-ffrwd fish farm
S53 - Crwbin	Spring	High	Low	Moderate	Yes	Yes
S07, S41 - Garn Bwll	Spring	Negligible (already derogated)	Low	Negligible	No	No
S19 - Torcoed Quarry Farm	Spring	Negligible (already derogated)	Low	Negligible	No	No requirement. But currently augmented by quarry discharge water.
W20, LA3, PWS4 - Ysgubor fach	Well and private water supply	Medium	Medium	Moderate	Yes at W20.	If derogated
LA26, PWS3 - Ffrwd-gain	Private water supply	Medium	Medium	Moderate	No. W20 will inform any impact.	If derogated
LA5 - Ty'r garn	Deregulated abstraction “licence”	Medium	Low	Minor	No	No
W03 - Garn-Bwll	Disused well. No protected rights.	Medium	Low	Minor	Yes	No
W11, LA1 - Garn Farm	Disused well. No protected rights.	Negligible	Low	Negligible	No	No
S26, LA2, PWS5 - Henblas	Private water supply	Negligible	Low	Negligible	No	No
PWS6 - Felindre	Private water supply	Negligible	Low	Negligible	No	No
S45	Minor spring	Low	Low	Minor	No	No
S44	Minor spring	Low	Low	Minor	No	No
S40	Minor spring	Low	Low	Minor	No	No
S11	Minor spring	Low	Low	Minor	No	No
S54, S55 - Felindre	Major spring	Negligible	Medium	Negligible	No	No

Receptor	Type	Degree of effect	Receptor Value	Degree of impact	Monitoring proposed?	Mitigation proposed
S25-A	ORS spring	Low	Low	Minor	No	No
S25-B	ORS spring	Low	Negligible	Negligible	No	No
S04 & S05	Torcoed Fach	Low	Low	Minor	No	No
S06	Near Torcoed Uchaf	Low	Low	Minor	No	No
W12/LA13/PWS12	Well and deregulated abstraction “licence”	Low	Medium	Minor	No	No
PWS11	Private water supply	Low	Medium	Minor	No	No
Coedydd Capel Dyddgen SSSI	SSSI	Negligible	High	Negligible	No	No
Coedydd y Garn SSSI	SSSI	Negligible	High	Negligible	No	No

Table 8-14 Summary of decommissioning/post restoration specific impacts (pre-mitigation)

Receptor	Type	Degree of effect	Receptor Value	Significance of impact	Mitigation proposed
W20, LA3, PWS4	Well and private water supply	Low	Medium	Minor	No
LA26, PWS3	Private water supply	Low	Medium	Minor	No
S07, S41	Garn Bwll spring	Negligible (already derogated)	Low	Negligible	S07/S41 and/or S19 can receive controlled gravity outfall from quarry restoration lake.
S19	Torcoed Quarry Farm Spring	Negligible (already derogated)	Low	Negligible	
S09	Garn Ffrwd spring	Medium	High	Major	Yes.
S53	Crwbin Spring	High	Medium	Major	No

8.9 Mitigation Measures

8.9.1 Garn-ffrwd Spring (S09)

Tarmac has entered into an agreement with the owner of the Garn-ffrwd fish farm to augment flows at the spring when they drop below a prescribed level (8 l/s or 690 m^3/d). The outline of the agreement is provided in ESI (2006) and in **Appendix 8-6 (**ES Volume 2). The means of mitigation will be by pumping to the Quarry Sink, which has been shown to be connected to the spring.

It should be noted that the spring flow rate at which augmentation will commence (8 l/s) was agreed for practical purposes and does not indicate that the occurrence of flows below that rate means that the quarry has had an impact on the spring flows. Indeed, the water balance calculations presented in **Appendix 8-5 (**ES Volume 2) suggest that flows below 8 l/s have occurred regularly at the spring during dry weather in the past (prior to any quarry impacts occurring).

As detailed in ESI (2006), an augmentation test was carried out in December 2003, which demonstrated the feasibility of this approach to mitigation. The methodology for the test, including monitoring requirements, was agreed with the Environment Agency beforehand and no adverse effects on the quality of the spring flow were noted during the test.

In order to ensure that there is sufficient water available for augmentation, Lafarge Tarmac has agreed to maintain a sump with a volume of 10 000 m^3 in the floor of Torcoed Quarry. The size of sump was determined from the water balance calculations in order to meet the augmentation requirements under most natural conditions. The development plans have incorporated a sinking to the 115 mAOD level which will provide a suitable area to provide this storage. This will not be available during Phase 1 (0-5 years) or Phase 8 (33-39 years) and alternative supply will be required during these periods.

On final restoration of the quarry, if all the intercepted flows are allowed to flow straight into the quarry void, the requirement for augmentation at Garn-ffrwd will continue at the same rate as before. However, two options to provide a long term mitigation of these impacts are available:

- diversion of some of the outflow from Torcoed Quarry to Garn Bwll sink (which has a proven link to Garn-ffrwd spring); or
- diversion of intercepted flows either along the valley to the south of the quarries or along the upper benches of the restored quarry to the Quarry Sink.

Both of these options would comprise permanent, gravity fed mitigation measures and thus would represent long term, sustainable solutions.

8.9.2 Garn Bwll spring (S07/S41) and Torcoed Quarry Farm Spring (S19)

These locations are already derogated, and therefore the impact from continued development of the quarry is considered to be negligible and no formal mitigation measures are considered to be required. However, it is noted that after restoration, groundwater levels in Torcoed Quarry are likely to rise to around 160 m AOD and discharge via a controlled outfall to Garn Bwll stream (S07/S41) and/or Torcoed Quarry Farm Spring (S19) is proposed.

Garn Bwll stream is currently augmented with water from the Torcoed quarry discharge point and this will continue throughout the development stage. Following water level recovery, this stream will receive water from the proposed controlled outfall.

8.9.3 Crwbin Spring (S53)

A flow reduction of 50-100% was estimated for Crwbin Spring during the development stage. The drying up scenario is considered to be conservative and the spring may retain up to 50% of its flow. However, the potential impact is deemed to be moderate. No flow mitigation of Crwbin Spring is proposed.

8.9.4 Mitigation at other sites

Other sites identified as having impacts greater than minor included:

- Ysgubor-fach (W20/PWS4/LA3) – well and private water supply
- Ffrwd-gain (PWS3/LA26) – private water supply thought to be from stream

The proposed monitoring scheme below is judged to be appropriate for determining whether any impacts are caused by the dewatering in the future as, not only will these supplies be monitored, but there are also other monitoring points between the quarry and the supplies which will provide supporting information. Significant impacts on these receptors will be determined by reference to:

- The results of the ongoing monitoring at that time;
- The scale of dewatering activity at that time;
- The antecedent climatic conditions as demonstrated by results from other monitoring sites in the area;
- The baseline conditions outlined in Section 8.4;
- The consequence of any induced effects on the reliability of the private water supply.

If, in future, it is demonstrated that the quarry dewatering has had a significant effect on a private water supply as outlined above, Lafarge Tarmac will provide mitigation to the owners appropriately. In the event of derogation occurring, options for mitigation will be explored in the following order:

- Lowering of pumps;
- Deepening of boreholes/wells;
- Provision of alternative supplies (mains water in the event of complete derogation) or short term supplementary supplies if derogation is temporary.

8.9.5 Mitigation pumping during water level recovery

It is recommended that an agreement be reached with NRW for a minimum level of flow to be maintained in Garn Bwll stream (if appropriate) during the period that quarry water levels are recovering following the cessation of pumping.

It is not proposed to augment Crwbin Spring during this period.

8.9.6 Protection of groundwater quality

It is anticipated that standard clauses for the protection of groundwater quality by quarry operations will be applied as conditions to the planning permission.

8.10 Monitoring

In order to quantify the level of impact at key sites and to make sure that the system is continuing to behave as predicted on the basis of the current conceptual model, a draft update to the existing Water Management Plan (ESI, 2008) is provided in **Appendix 8-7 (**ES Volume 2).

The sections below set out revised proposals for monitoring the system around the Site. It is anticipated that these proposals will be included in an updated Water Management Plan for the site and that agreement of such a document with the relevant regulators will be a condition to the planning permission.

All monitoring should be continued until water levels in the quarries have recovered to their equilibrium position. It is anticipated that this will be three toor five years after quarry dewatering ceases.

Proposed monitoring locations are shown in **Figure 8-21 (Appendix 8.8** of ES Volume 2).

8.10.1 Proposed groundwater level monitoring

Old Red Sandstone

The long term monitoring of three boreholes completed in the Old Red sandstone provides a good record of baseline conditions in this aquifer. It is proposed to monitor the Old Red Sandstone at monthly intervals in the following locations, particularly with a view to extending the dataset in the Crwbin quarry area; BH95/4, BH5/13 and BH8A/13 and to giving an early warning of potential impacts to well W20, PWS3 and PWS4. A data logger to record levels at 1 hour intervals should be installed in at least 1 monitoring well in Crwbin quarry.

The need for continued monitoring at all of these locations should be reviewed after two years. As no effect appears to have occurred in the aquifer to date, and no effect is anticipated in the future, the number of monitoring location could potentially be reduced.

Main Limestone

It is proposed to monitor the Main Limestone at monthly intervals in the following locations, particularly with a view to extending the dataset in the Crwbin quarry area and to giving an early warning of potential impacts to well receptors to the east and west; BH95/7, BH17, BH1/13, BH3B/13, BH4A/13, BH7/13, BH8B/13 and BH9/13. A data logger to record levels at 1 hour intervals should be installed in at least 5 monitoring wells in Crwbin quarry.

The need for continued monitoring at all of these locations should be reviewed after two years.

8.10.2 Proposed flow monitoring

Continuous monitoring of Garn-ffrwd spring and the Torcoed quarry dewatering rates is currently undertaken using data loggers as per the Torcoed Quarry Water Management Plan and it is recommend that this continues.

It is recommended that monthly spot flow gauging is undertaken on Crwbin Stream (S53) at a location where suitable access arrangements can be obtained.

8.10.3 Well level monitoring

It is recommended that water levels at the well at Ysgubor-fach (W20) should also be monitored at monthly intervals to assess any possible impact. Monitoring at Old Red Sandstone monitoring well BH5/13 will also give an early warning of possible impact at this location.

No monitoring is proposed at private water supply PWS3, which is understood to take water from a stream. Monitoring of W20 will be sufficient to give a warning of possible impact on PWS3.

It is proposed to monitoring W20 (disused well with no protected rights) as an early warning system for potential impacts further to the east.

8.10.4 Proposed rainfall monitoring

The Torcoed on-site rainfall data record is required for accurate interpretation of the spring flow and quarry dewatering rates. It is therefore recommended that the current rainfall monitoring be continued.

8.10.5 Proposed water quality monitoring

A good baseline of water quality data is available for Torcoed quarry discharges and Garn-ffwrd spring on a monthly basis and at Garn Farm Garn Bwll and Tyr Garn on a quarterly basis. It is not considered necessary to continue any water quality sampling other than monthly suspended solids sampling at Torcoed quarry discharges and Garn-ffwrd spring.

8.10.6 Proposed reporting

Reporting of the data from the Torcoed hydrometric network is carried out on an annual basis with the data quality check on a monthly basis. It is proposed that this frequency of reporting should continue. Data may still need to be reviewed on an operational basis at more frequent intervals. However, it is anticipated that this will be carried out by Tarmac staff on site.

8.11 Recommendations

It is recommended that a revised hydrometric monitoring and reporting scheme be agreed with NRW for the combined Torcoed/Torcoed Fawr/Crwbin quarries.

8.12 Conclusions & recommendations

The proposed working involves deepening the quarries and combining them into a single operation.

ESI have a strong understanding of the local groundwater through several previous EIAs which have been subject to detailed review by regulators plus over 15 years of monitoring by Tarmac. The conceptual model has been given quantitative support by a series of detailed water balance calculations.

A similar impact assessment methodology to these previous hydrogeological impact assessments has been undertaken with conclusions drawn accordingly. Where any potentially significant impacts have been identified then appropriate mitigation measures have been proposed. A scheme is already in place to mitigate any negative effects at Garn-ffrwd spring.

It is recommended that a revised hydrometric monitoring and reporting scheme be agreed with NRW for the combined development of the quarries as part of an updated WMP. Details of the proposed scheme are set out in Section 8-10 and **Appendix 8-7 (Appendix 8.8** of ES Volume 2).

Figure 8-1 Site location

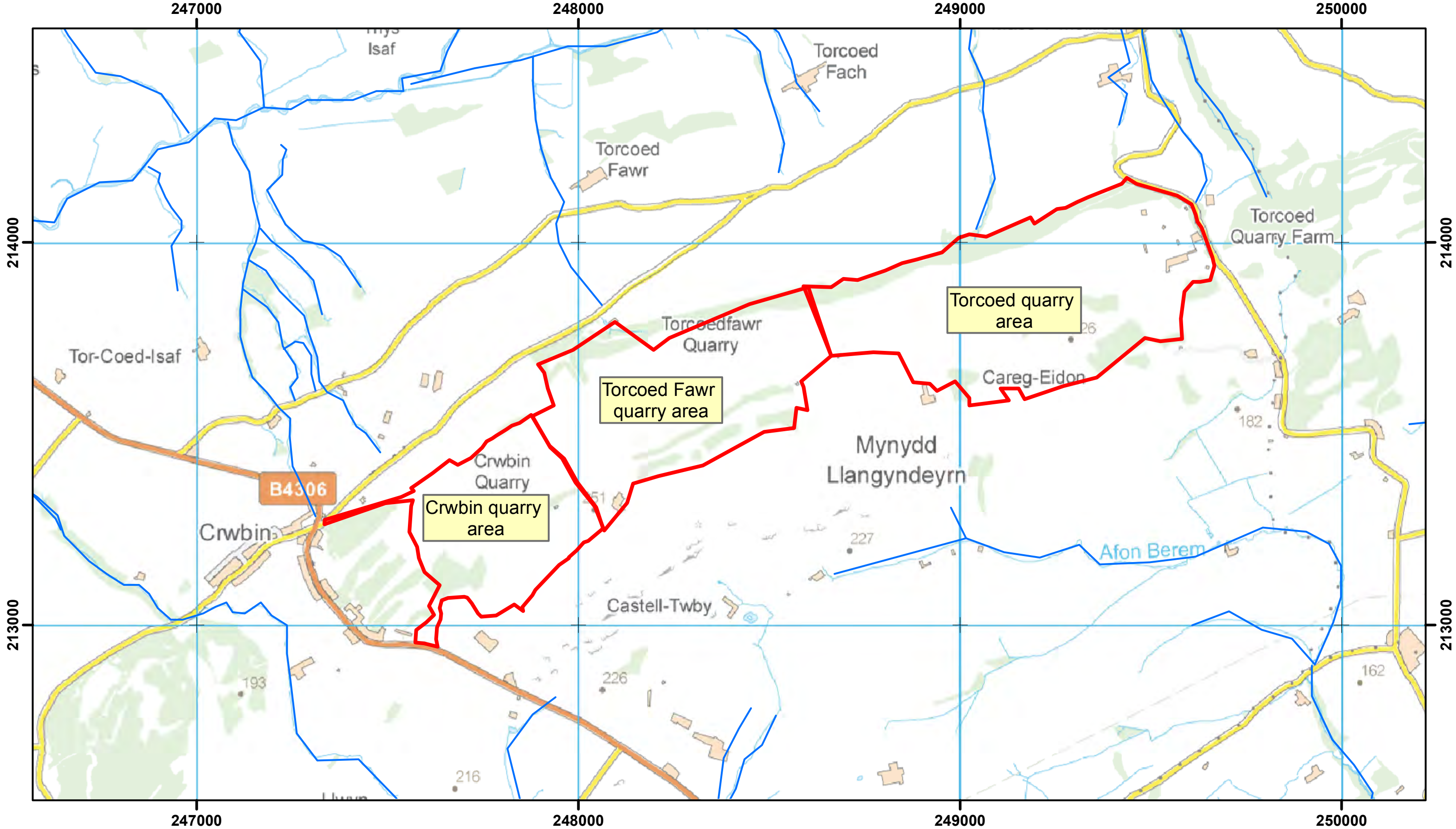


Figure 8-2 Local geology

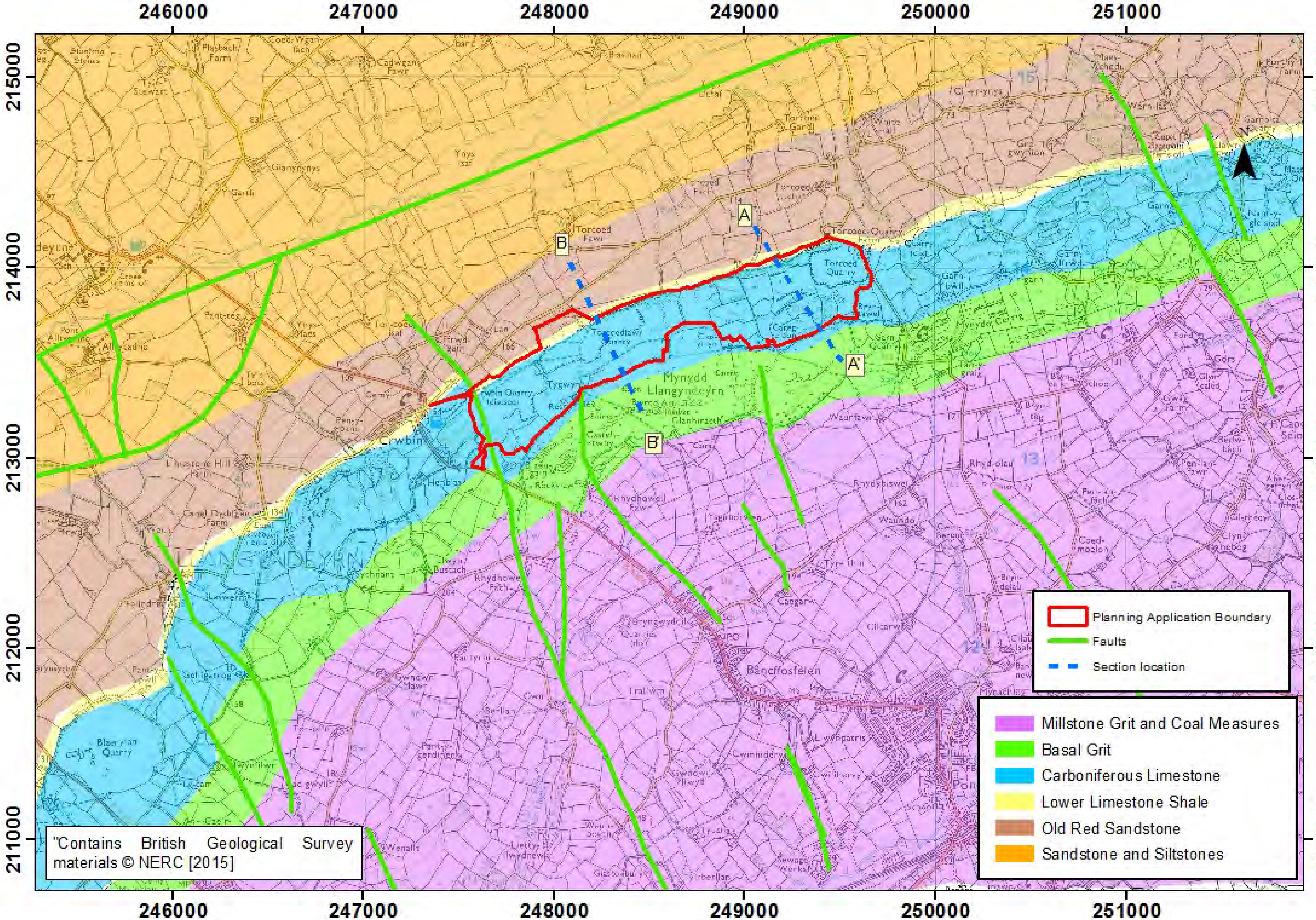


Figure 8-3 Cross section through Torcoed Fawr quarry – from ESI (2006)

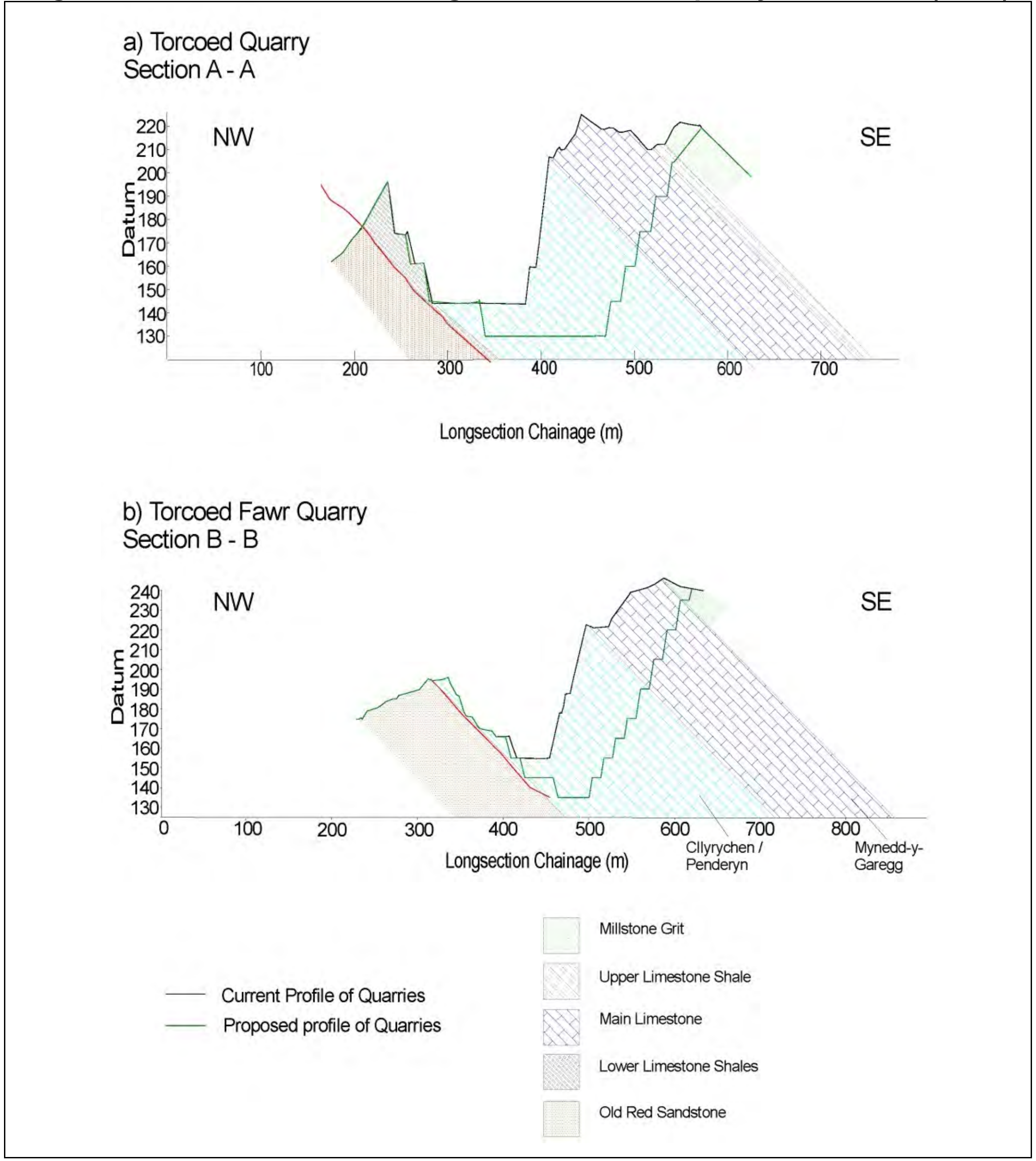
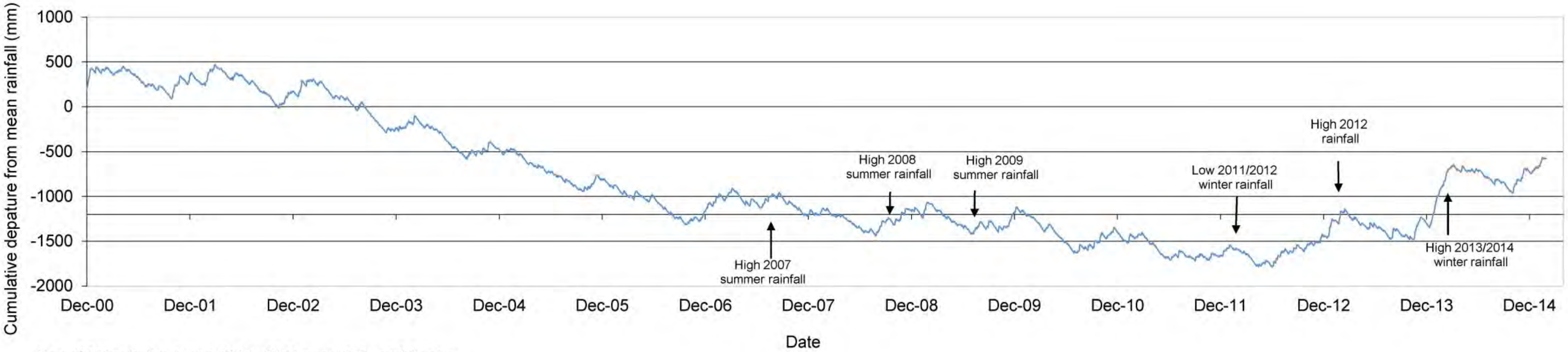


Figure 8-4 Cumulative surplus rainfall at Torcoed quarry (2001 to 2014)



Note: CDM calculated using 1961 - 2015 mean daily rainfall value

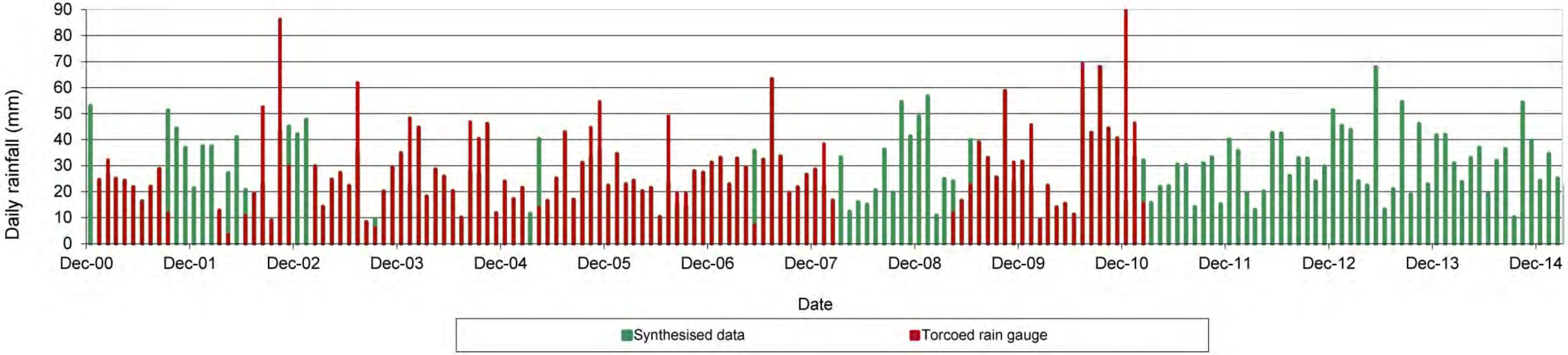


Figure 8-5 Surface water features

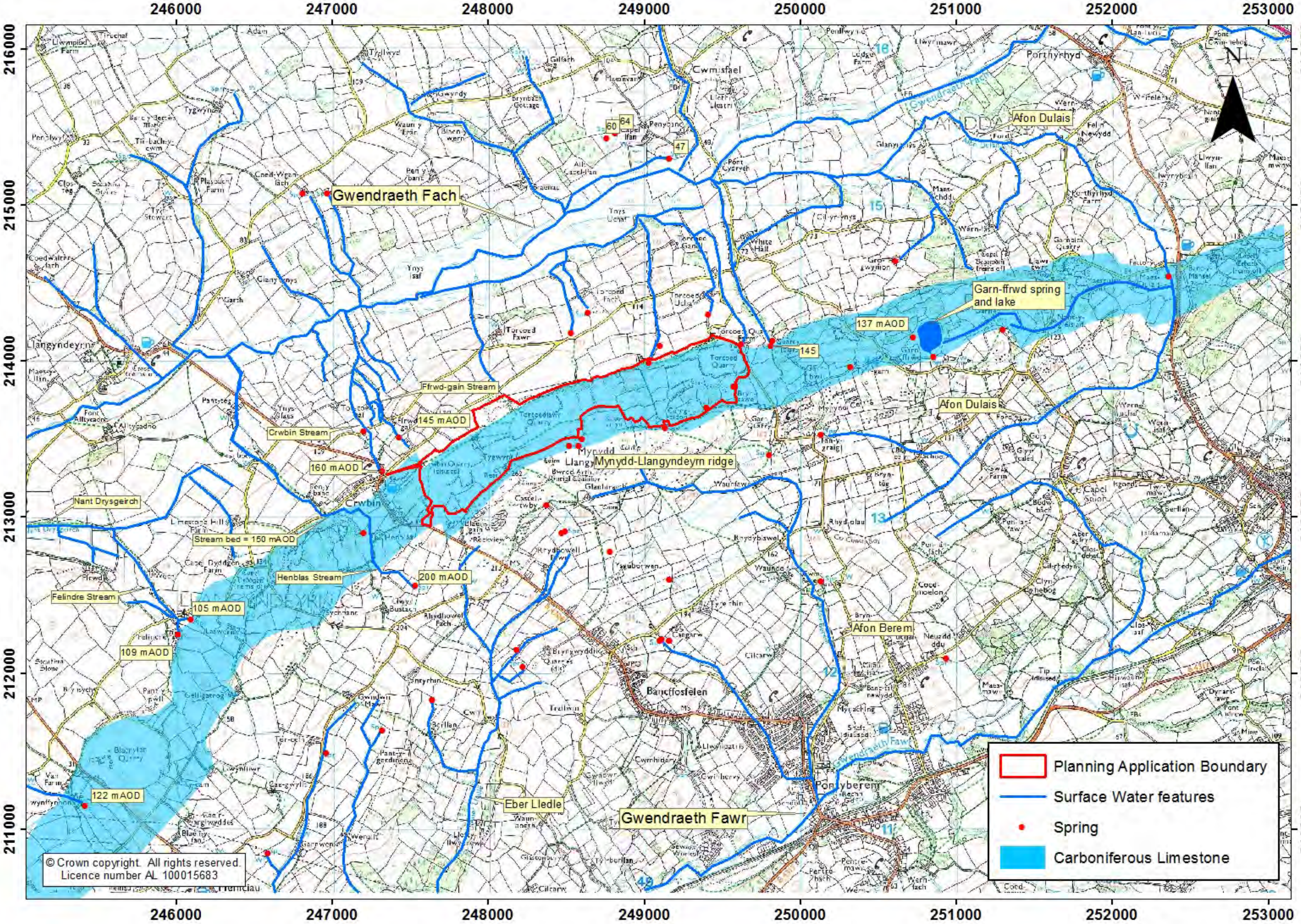


Figure 8-6 Location of wells, springs and sinkholes

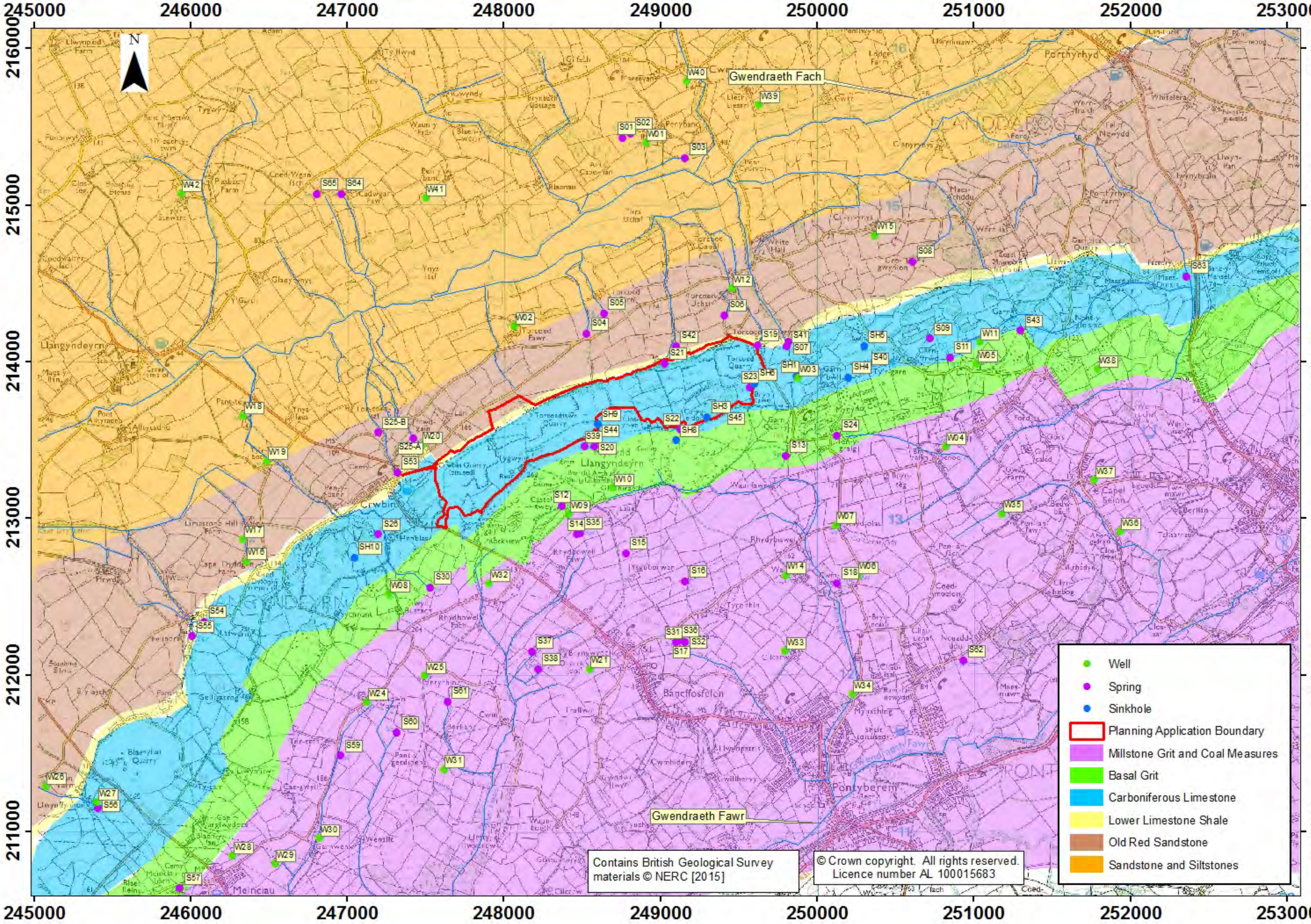


Figure 8-7 Location of licensed abstractions and private water supplies

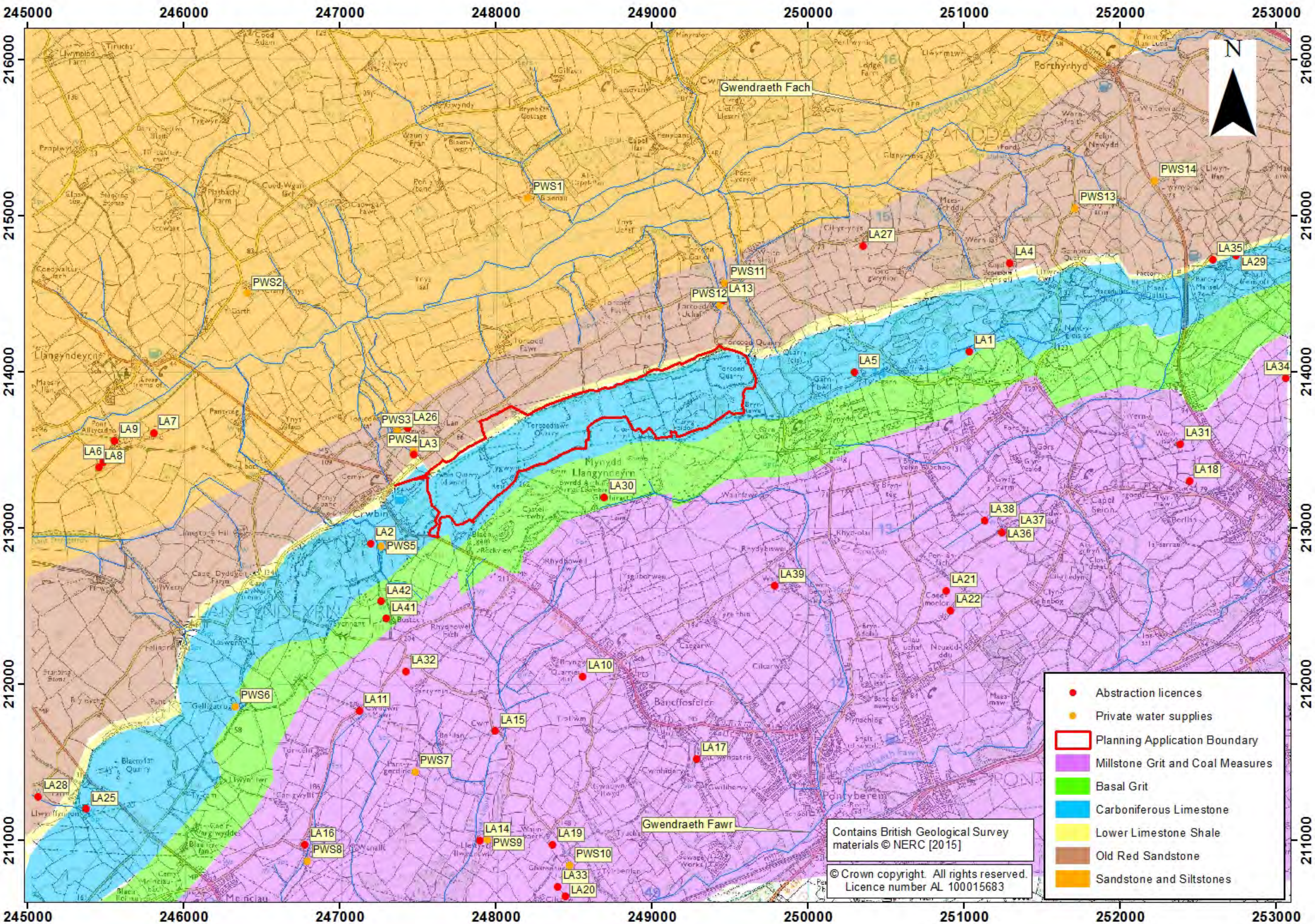


Figure 8-8 Proven karst connections

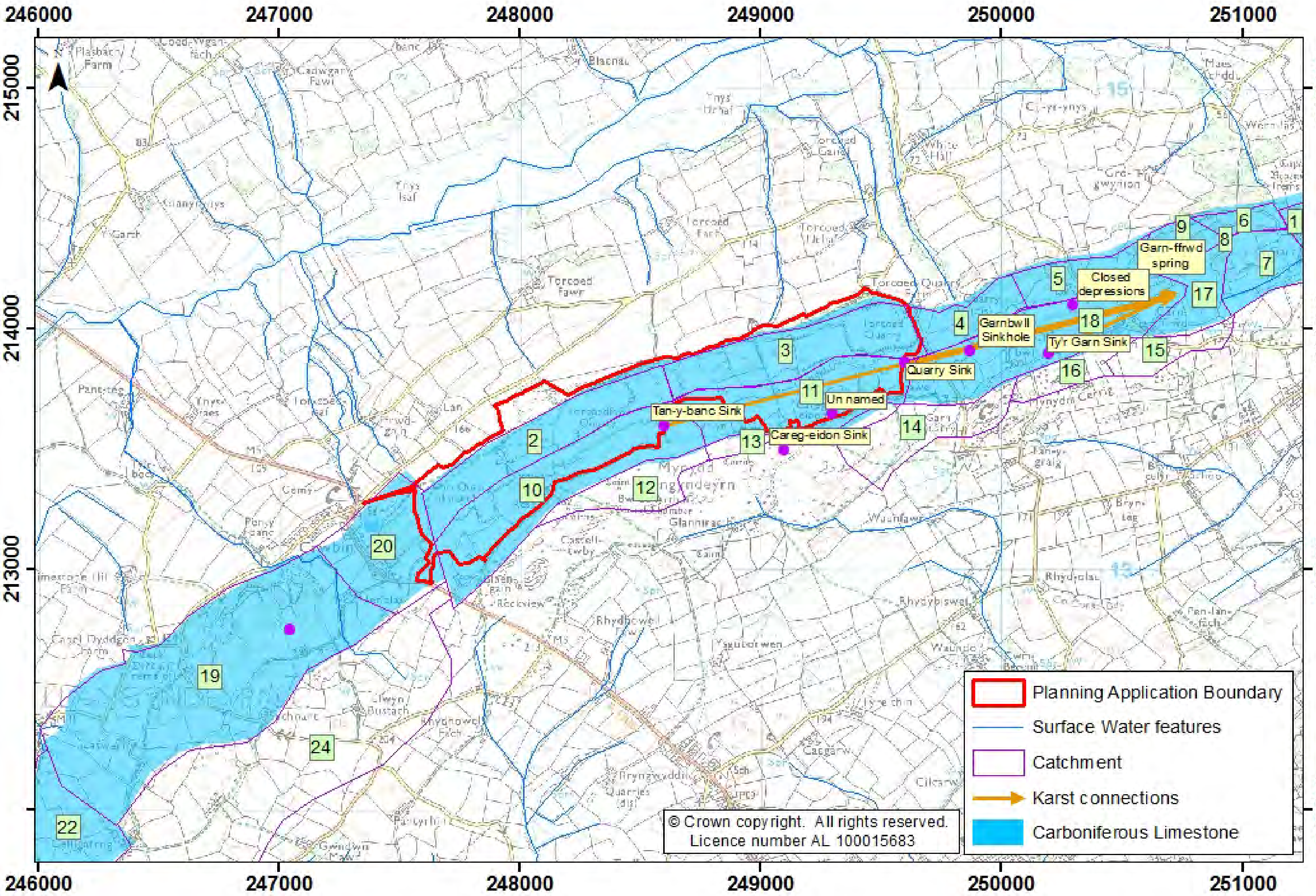
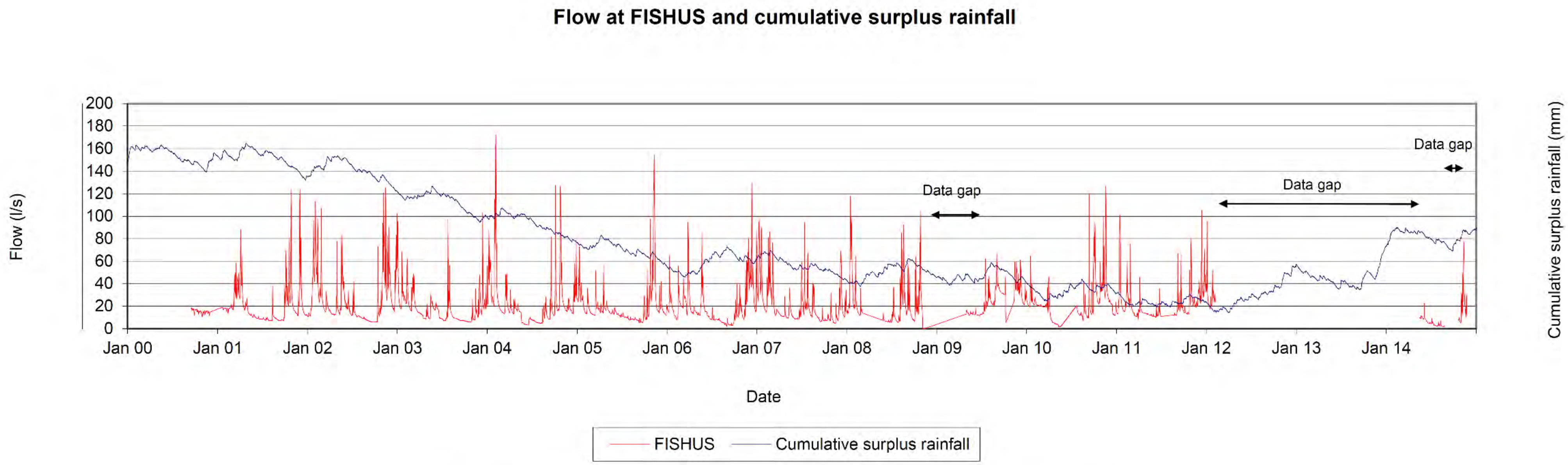


Figure 8-9 Flow at Garn Ffwd spring compared to cumulative surplus rainfall and monthly rainfall expressed as percentage of LTA (between 2000 and 2015)



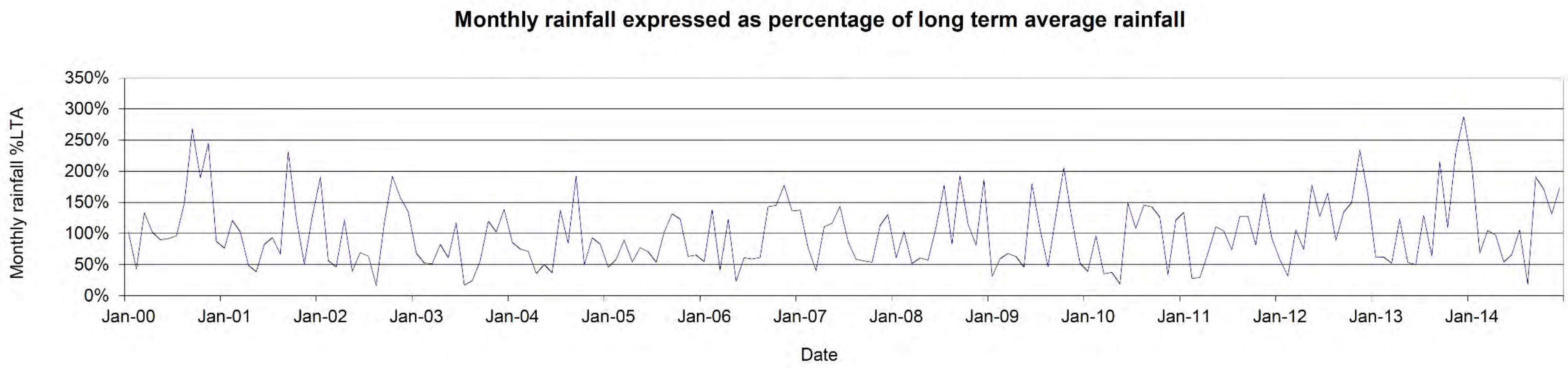


Figure 8-10 Stream gauging locations to the west of Crwbin

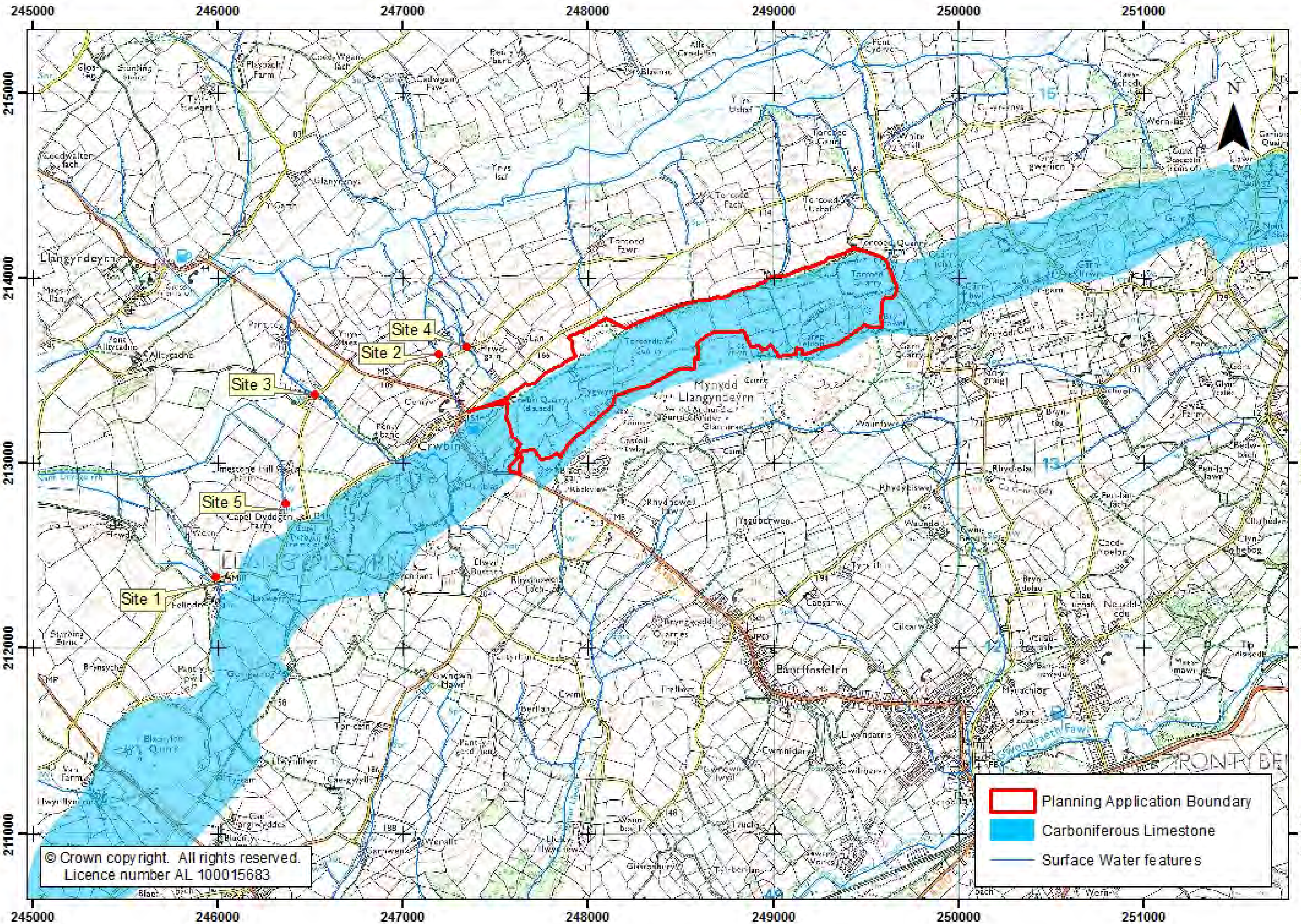


Figure 8-11 Borehole locations and maximum/minimum groundwater levels

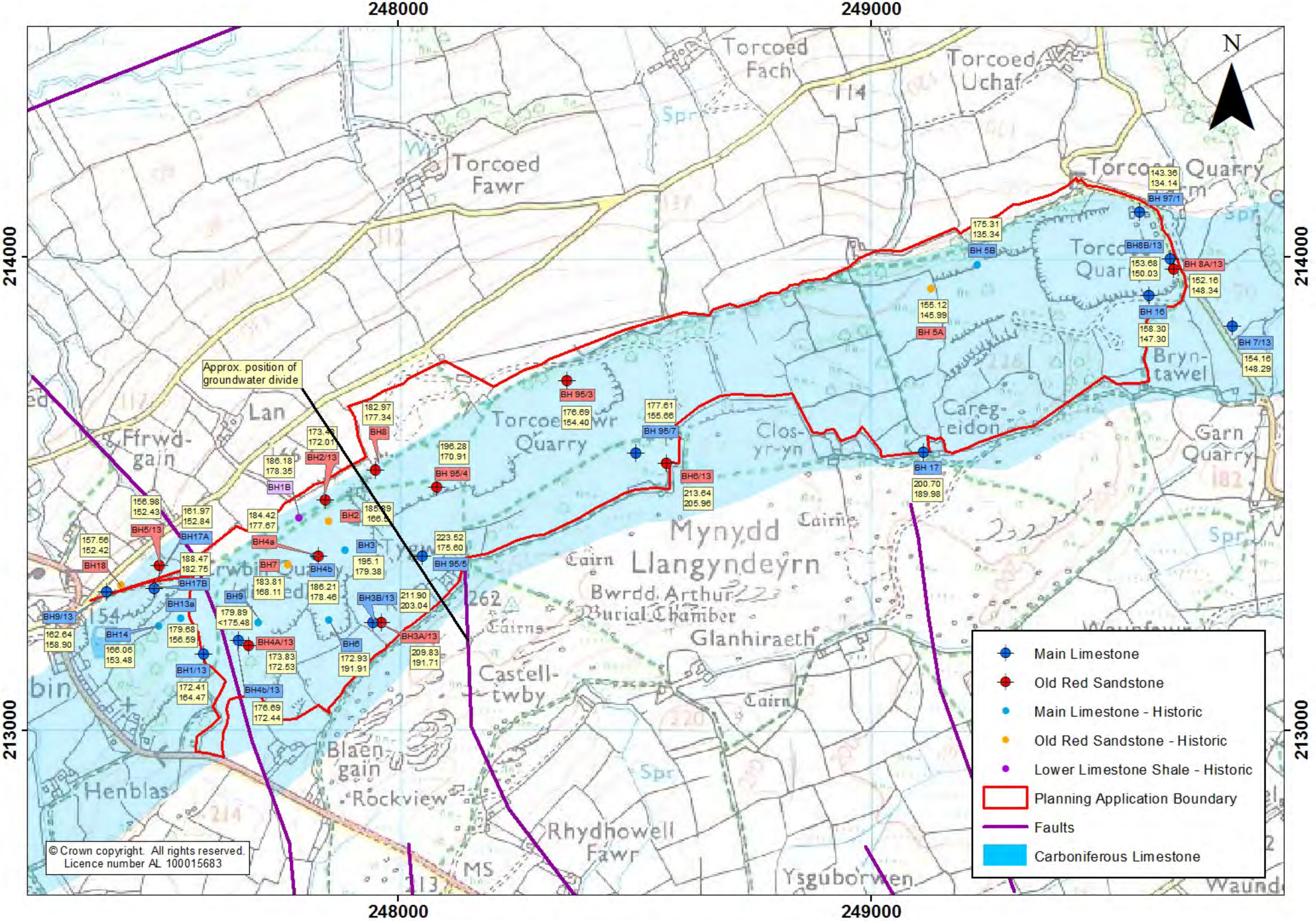
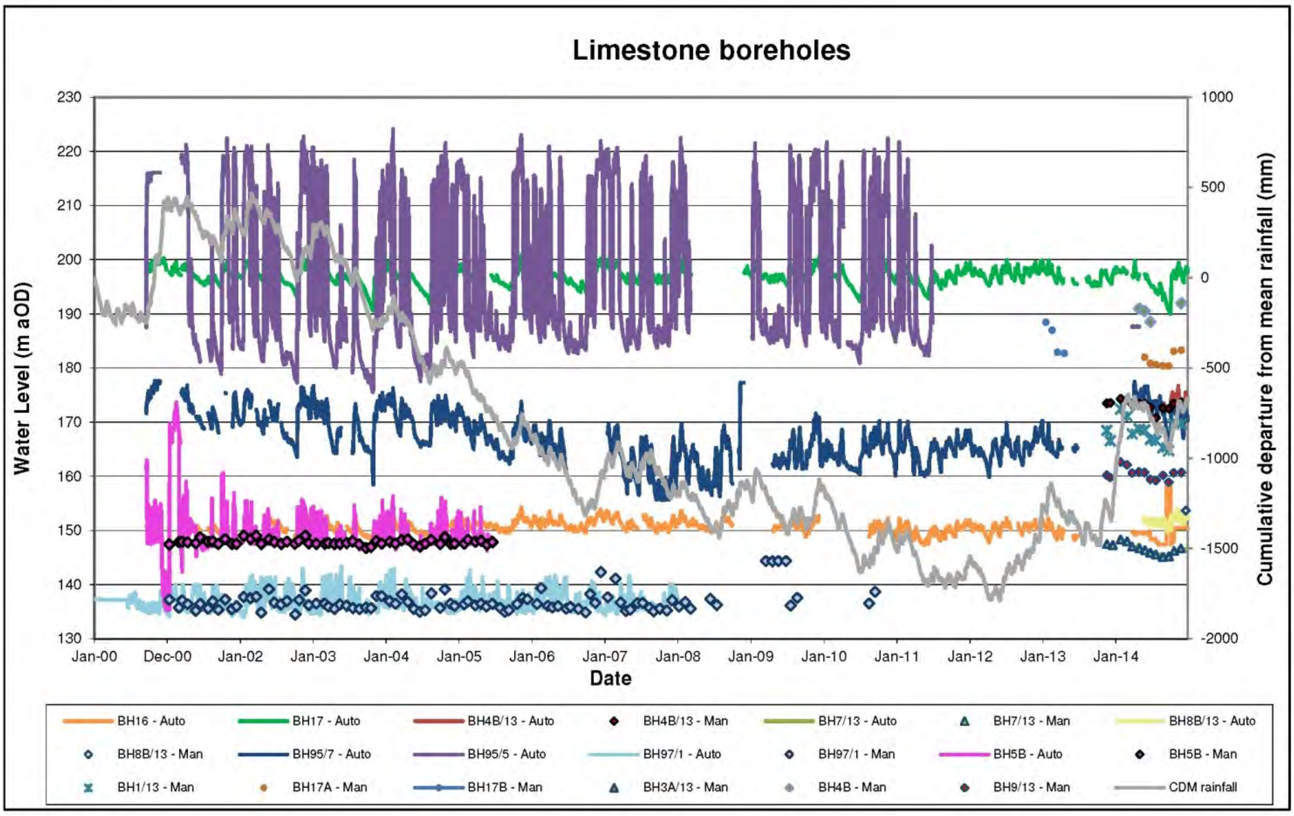


Figure 8-12 Hydrographs in Limestone and Old Red Sandstone Boreholes for the complete data record (2000 to 2009)



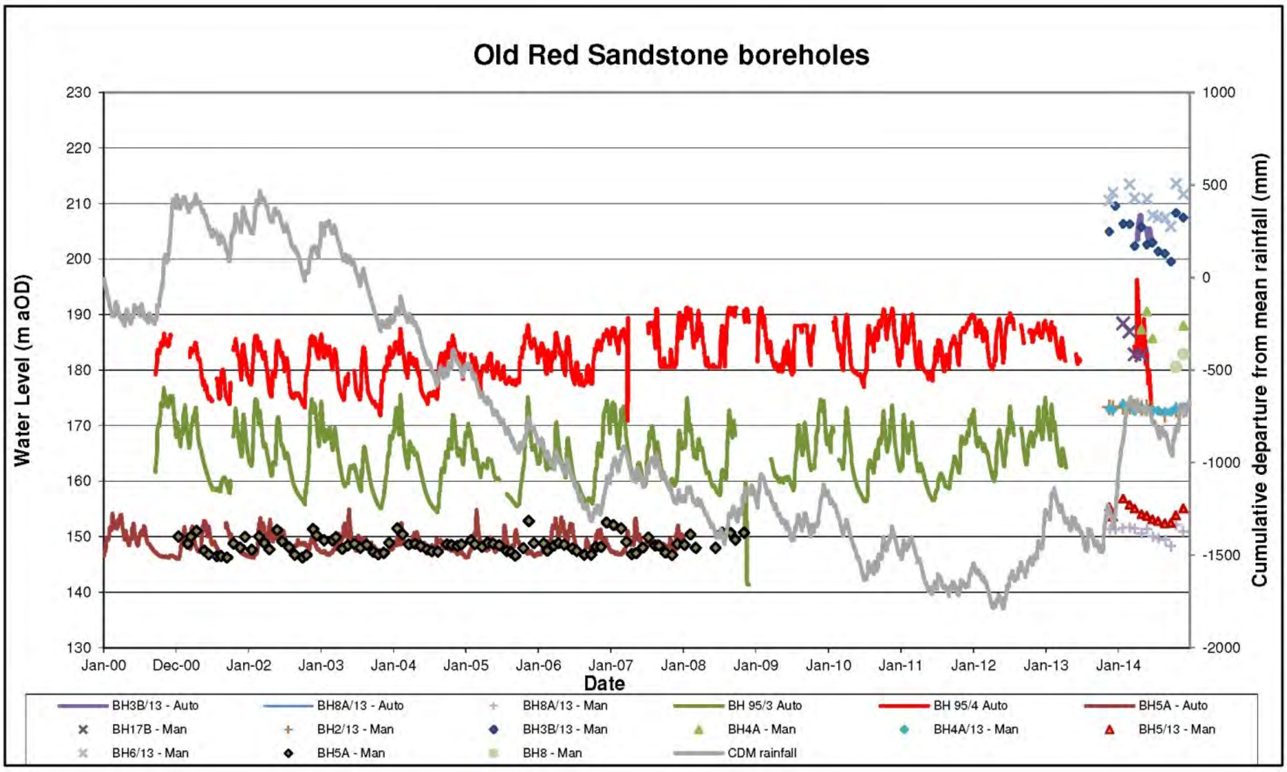
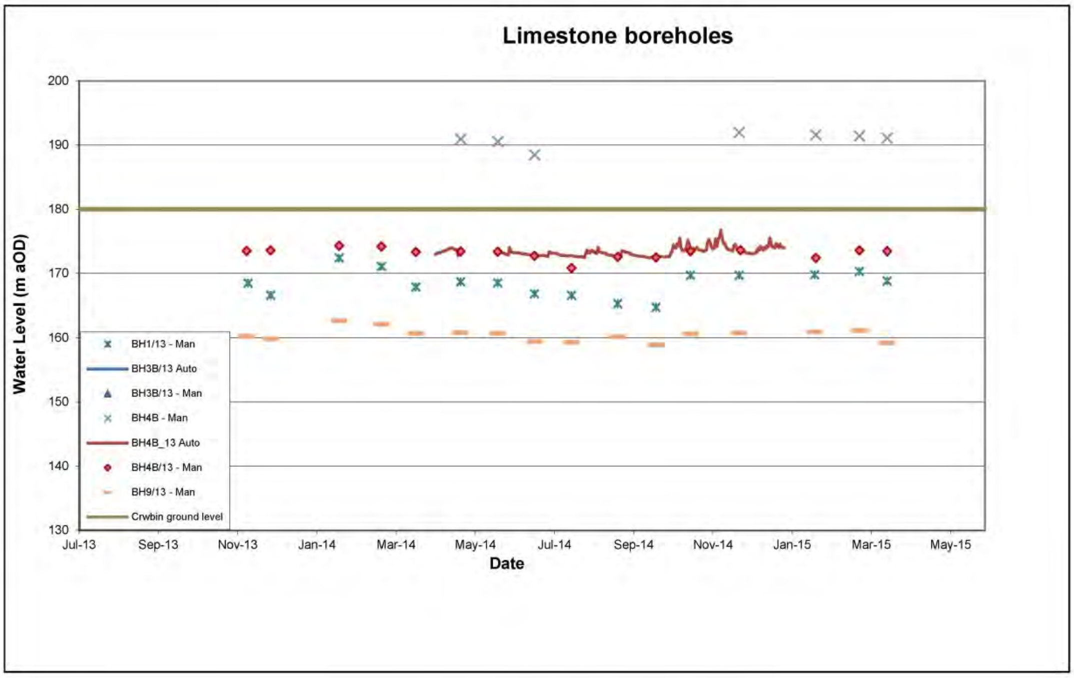


Figure 8-13 Crwbin quarry piezometer groundwater level hydrographs



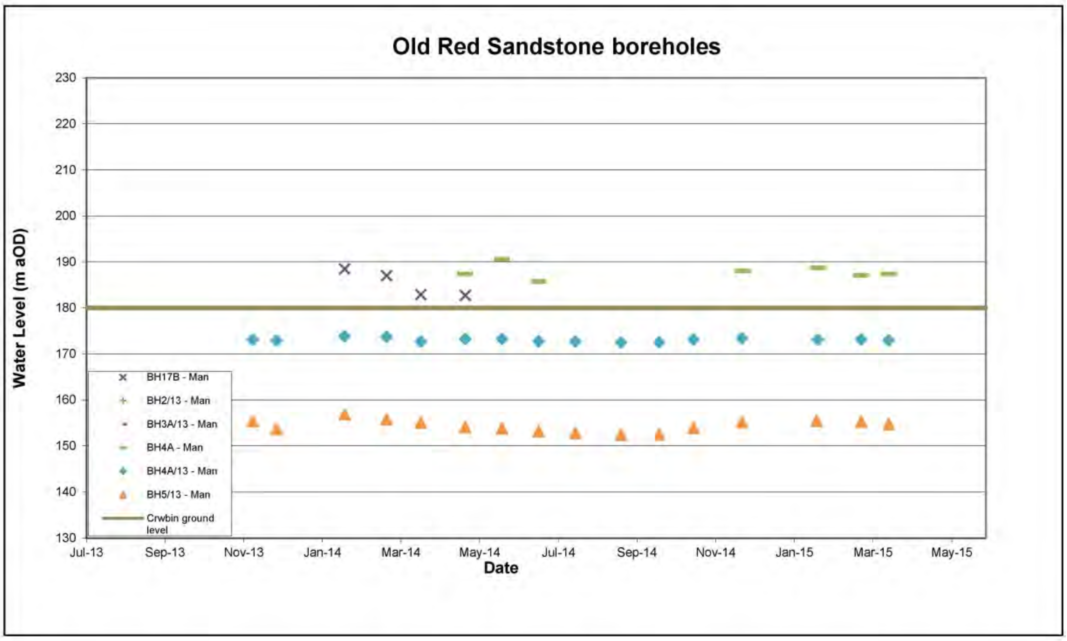


Figure 8-14 Schematic cross section showing relevant elevations of key features

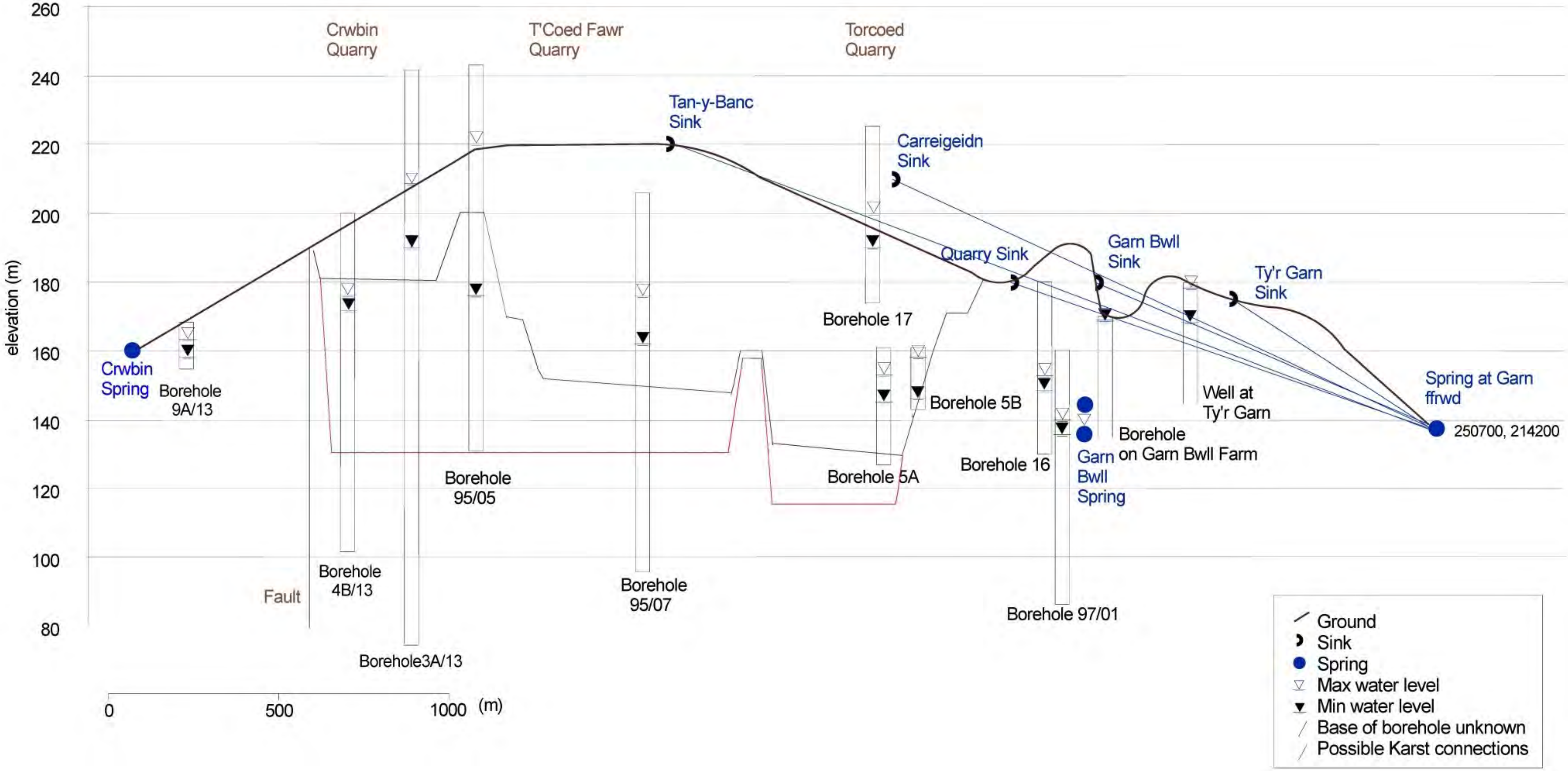


Figure 8-15 Scoping calculation showing a cross section of simulated and measured groundwater levels

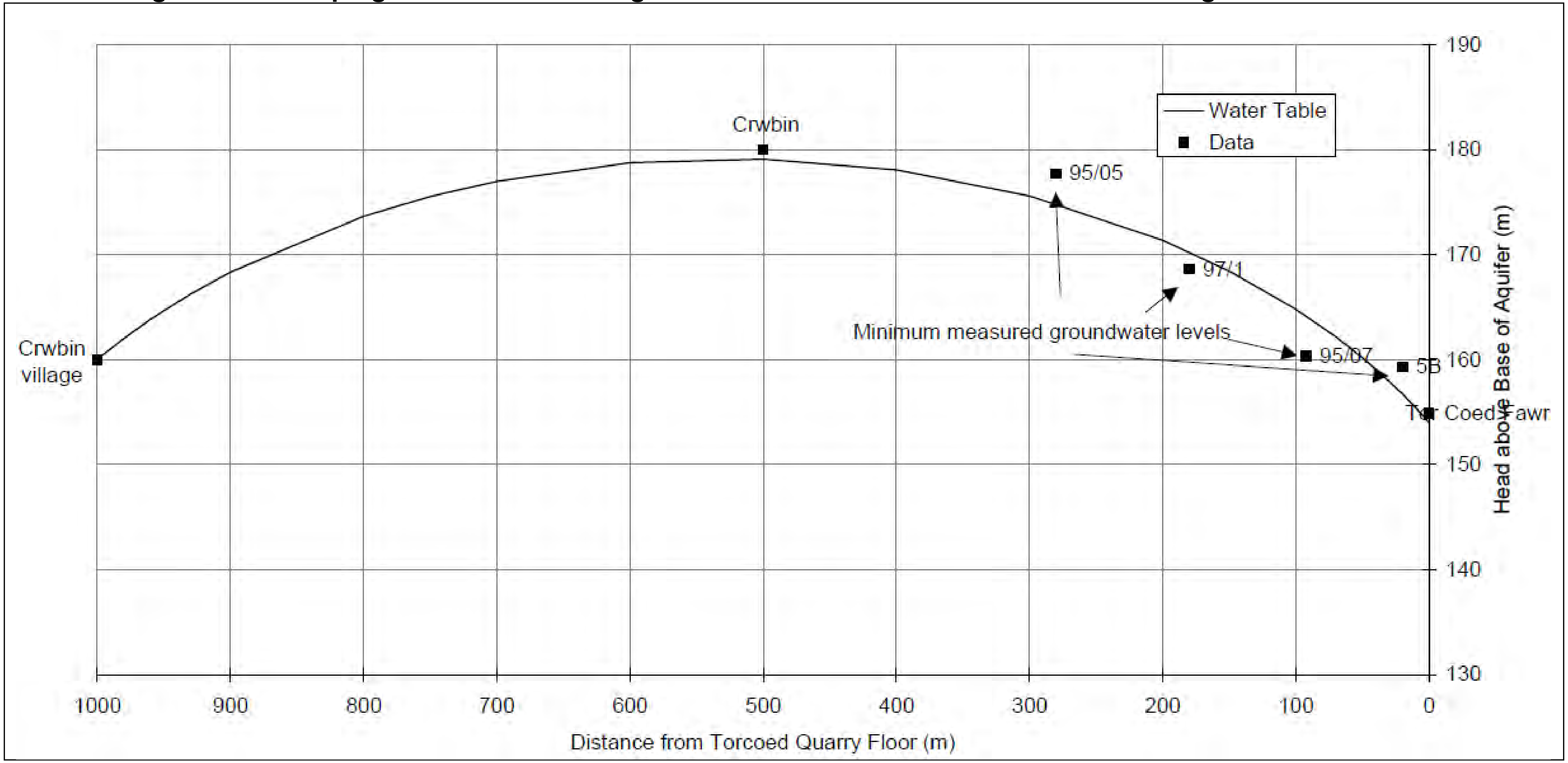


Figure 8-16 Location of sampling points for chemical analyses

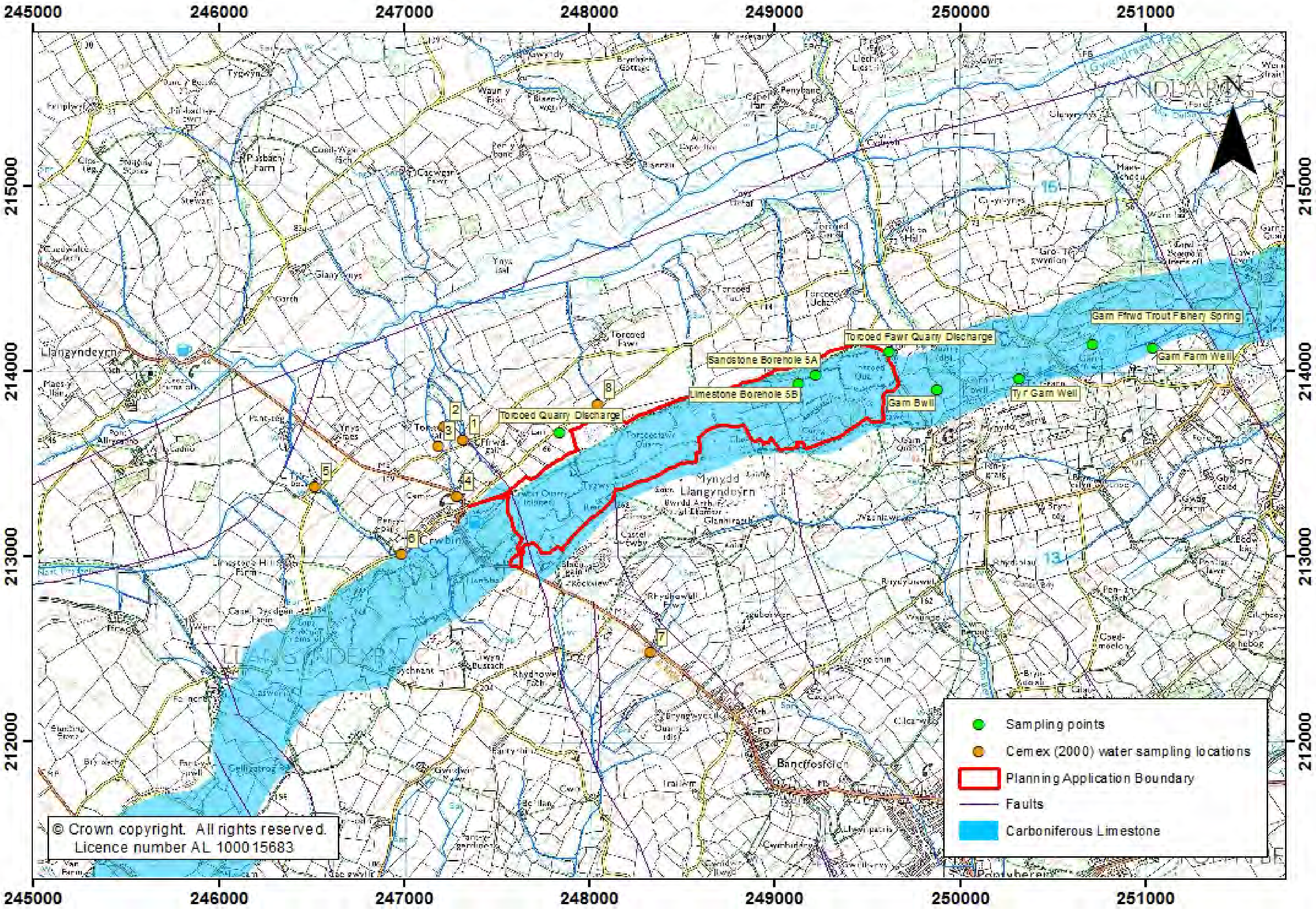


Figure 8-17 Environmental designations

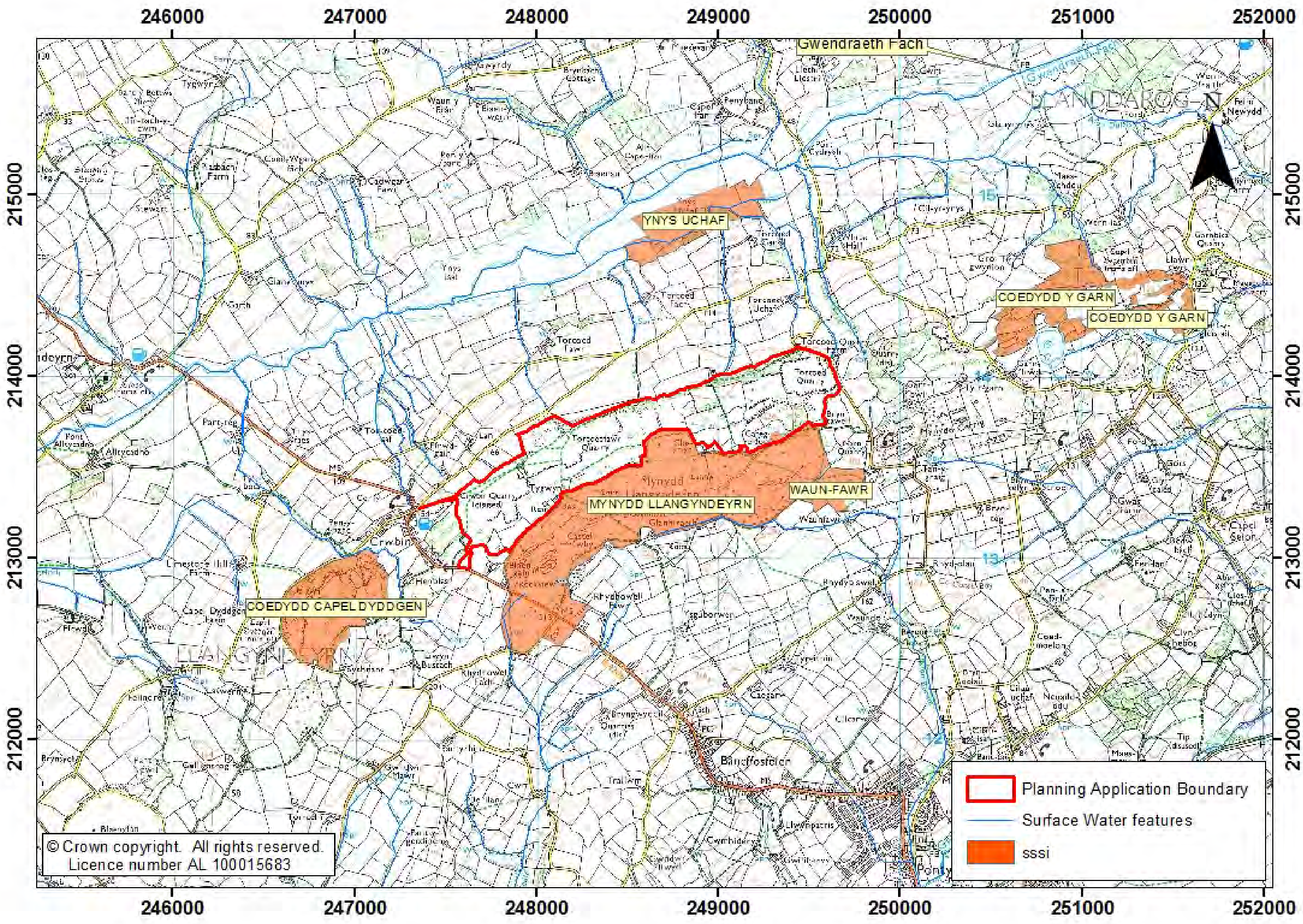


Figure 8-18 Conceptual model

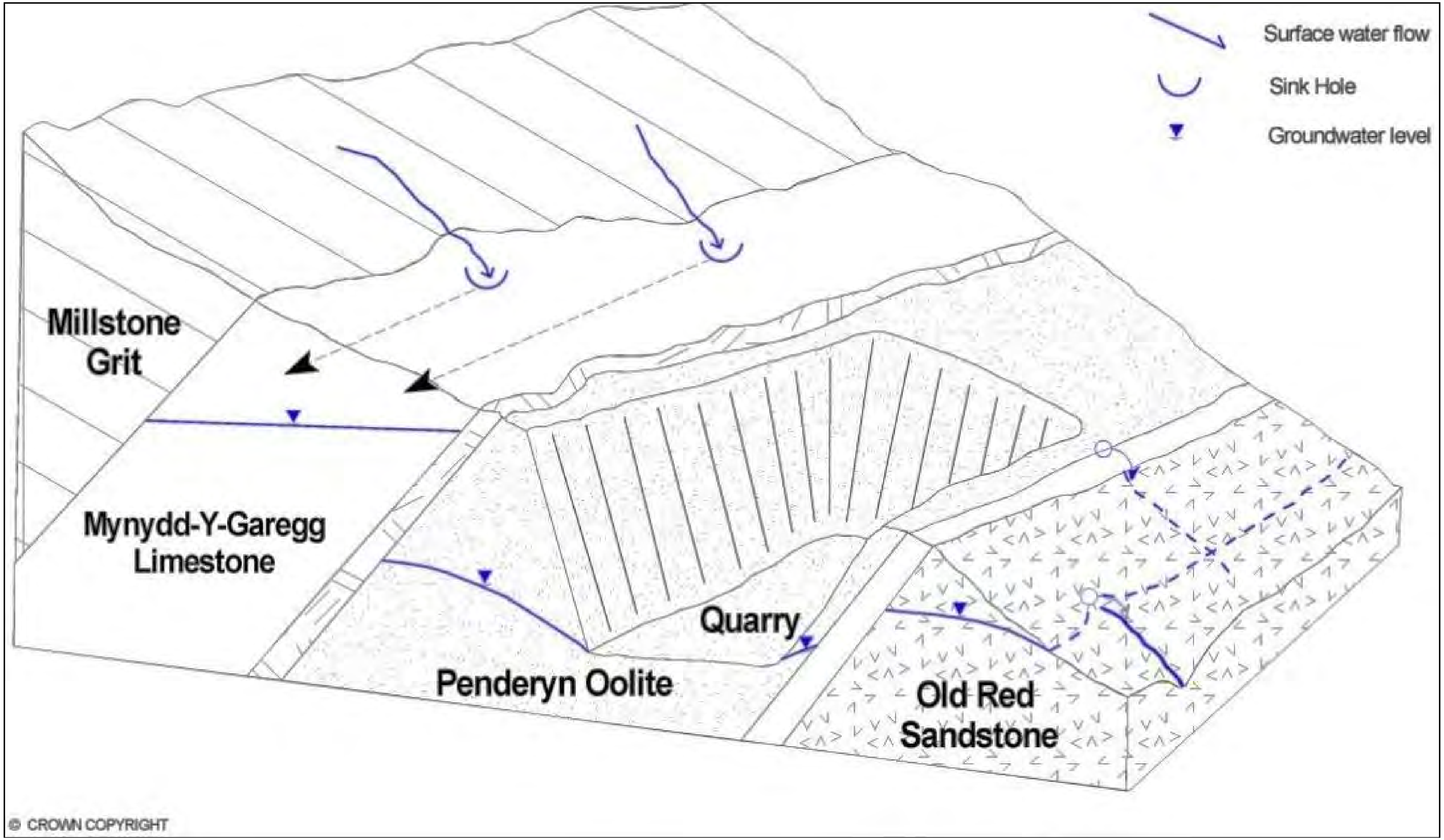


Figure 8-19 Scoping calculation showing a cross section of simulated and measured groundwater levels: current and future (west)

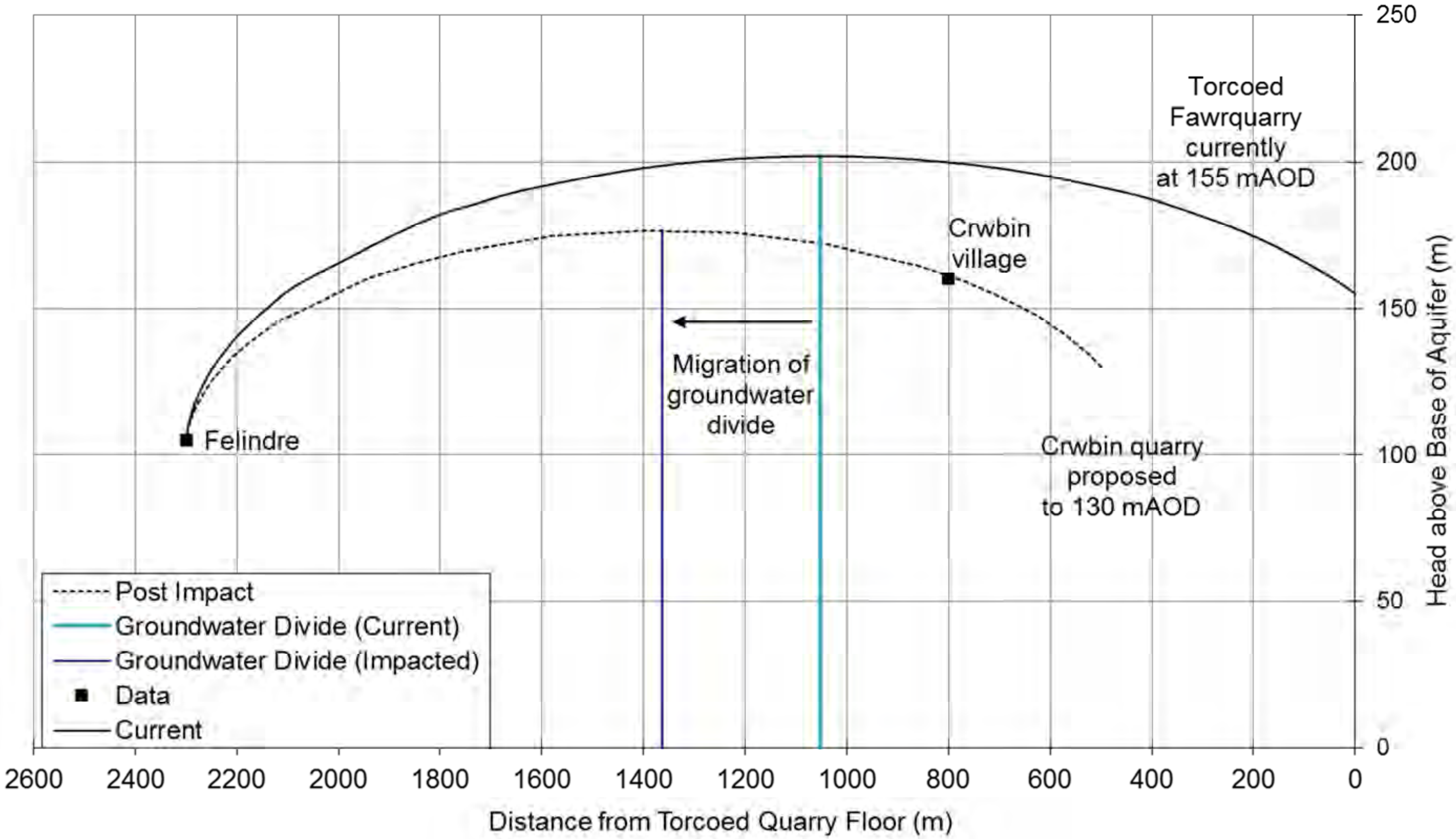


Figure 8-20 Scoping calculation showing a cross section of simulated and measured groundwater levels: current and future (east)

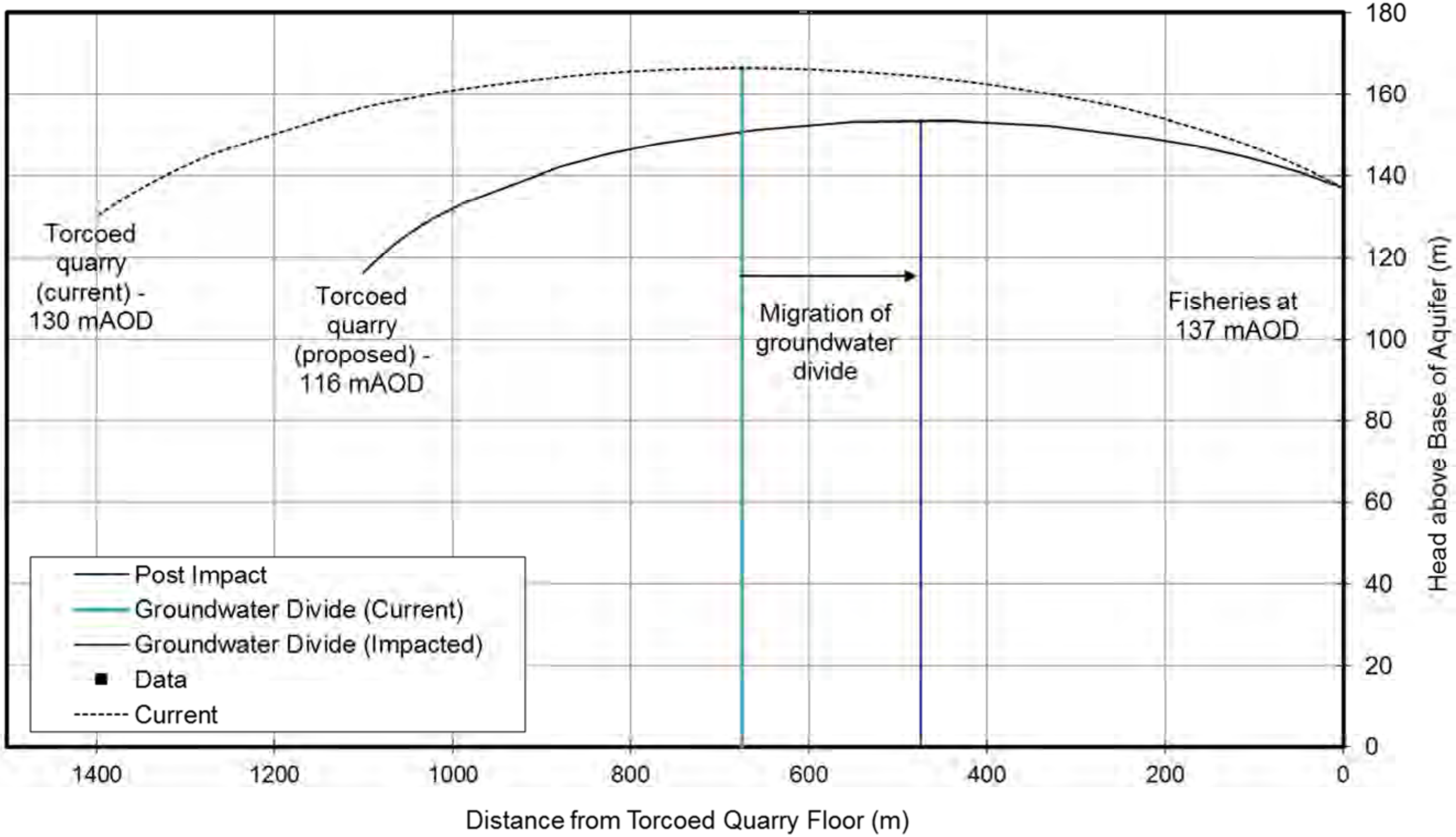
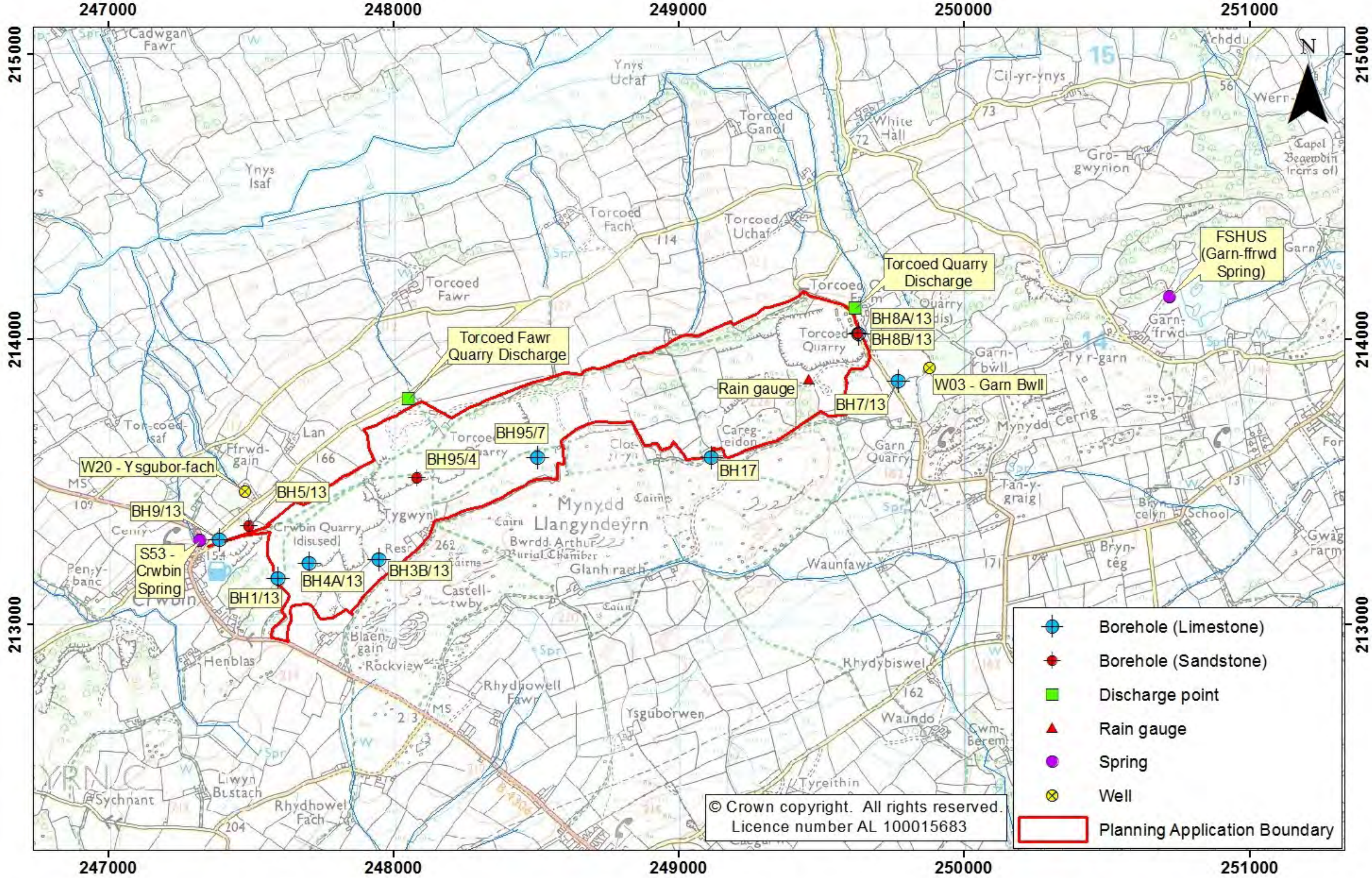


Figure 8-21 Proposed monitoring locations



Appendix F of Application

Legal Agreement Outline

Report Reference: 331201249TN1
Report Status: Final

Legal agreement between Lafarge Tarmac and Garn-ffrwd fisheries owner

Background

Lafarge Tarmac has entered into an agreement with the owner of the Garn-ffrwd fish farm to augment flows at the spring when they drop below a prescribed level (8 l/s or 690 m^3/d). The outline of the agreement is provided below. The means of mitigation will be by pumping to the Quarry Sink, which has been shown to be connected to the spring.

Note that, the spring flow rate at which augmentation will commence (8 l/s) was agreed for practical purposes and does not indicate that the occurrence of flows below that rate means that the quarry has had an impact on the spring flows. Indeed, water balance calculations suggest that flows below 8 l/s have occurred regularly at the spring during dry weather in the past (prior to any quarry impacts occurring).

An augmentation test was carried out in December 2003, which demonstrated the feasibility of this approach to mitigation. The methodology for the test, including monitoring requirements, was agreed with the Environment Agency beforehand and no adverse effects on the quality of the spring flow were noted during the test.

The water balance calculations were used to assess the current and likely future requirements for augmentation at this site. This showed an intermittent requirement to augment rising to a more continuous augmentation as the quarries progressively capture more and more of the spring flow.

In order to ensure that there is sufficient water available for augmentation, Tarmac has agreed to maintain a sump with a volume of 10 000 m^3 in the floor of Torcoed Quarry. The size of sump was determined from water balance calculations in order to meet the augmentation requirements under most natural conditions.

The period used for analysis includes some extreme drought periods (particularly during the mid to late 1970s) and, whilst no monitoring data are available to confirm this, it is likely that the spring at Garn-ffrwd would have flowed at a much lower rate than 690 m^3/d at this time. The analysis indicates that it would not be possible to maintain the target flows (even with a much larger sump) under such extreme conditions and this is acknowledged in the agreement with the licence owner. However, it is encouraging to see that it still appears to be feasible to maintain the target flows for the drought of 2003 which was generally considered to be very severe across most of South Wales.

After completion of working in the base of Torcoed, it is proposed to let water levels in the quarry sump recover whilst work continues in Torcoed Fawr. This will create a very large body of water in the quarry sump which will be more than sufficient for maintaining flows at the spring in any drought.

On final restoration of the quarry, if all the intercepted flows are allowed to flow straight into the quarry void, the requirement for augmentation at Garn-ffrwd will continue at the same rate as before. However, Tarmac is currently assessing two options to provide a long term mitigation of these impacts:

1. diversion of some of the outflow from Torcoed Quarry to Garn Bwll sink (which has a proven link to Garn-ffrwd spring); or
2. diversion of intercepted flows either along the valley to the south of the quarries or along the upper benches of the restored quarry to the Quarry Sink.

Both of these options would comprise permanent, gravity fed mitigation measures and thus would represent long term, sustainable solutions.

Outline of scheme

In the event that the owner of the trout farm believes that the flow from the Spring has fallen below the Target Rate, he may notify Tarmac and request that Tarmac supplement the flow of water at the Spring.

Upon receipt of a request from the owner of the trout farm, Tarmac shall have the option to establish, by conducting its own testing, that the flow from the Spring has fallen below the Target Rate.

If Tarmac, acting reasonably, does not accept the owner of the trout farm's assertion that the flow from the Spring has fallen below the Target Rate, Tarmac shall have no obligation to supplement such flow under this Deed.

Following receipt of a written request from the owner of the trout farm, Tarmac undertakes to pump Suitable Water (defined as such quantities of water as may naturally occur at the Quarry that might reasonably be expected to comply with the Discharge Consent and that are reasonably capable of being directed to the Sump for storage) from the Sump to the Sinkhole for such period until either the natural flow of the Spring recovers to greater than or equal to the Target Rate or until there is no Suitable Water in the Sump.

Tarmac agrees to use reasonable endeavours to comply with the conditions of its Discharge Consent at the point the water pumped under the Scheme enters the Sinkhole.

Tarmac agrees to create a Sump at the Quarry.

Tarmac agrees to use reasonable endeavours to ensure that the Sump contains at least 10,000 m^3 of Suitable Water for use in connection with the Scheme but it is acknowledged by Tarmac and Mr Miller that in dry periods this may not reasonably be achievable and therefore in the interests of preserving continuity of supply, the parties agree that, should the levels in the Sump fall below 10,000 m^3, the minimum flow rate shall be varied as follows:

Sump water capacity levels (percentage full)	**Minimum flow rate (litres per second)**
[100% - 51%]	[8 l/s]
[50% - 25%]	[7 l/s]
[24% - 15%]	[6 l/s]
[14% - 0]	[5.5 l/s until complete utilisation]

Whilst Tarmac will use reasonable endeavours to comply with its obligations above, it will be under no obligation to augment the flow from the Spring during any period where, due to heavy rainfall or other circumstance, the naturalised flow (observed minus discharge rate) is already the Target Rate or above.

In the event that at any time the Target Rate is naturally achieved, Tarmac will have the right to stop or adjust the augmentation for as long as the Target Rate can be achieved without the augmentation.

Notwithstanding Tarmac's obligations to augment the Spring, Tarmac will be permitted to use reasonable quantities of water from the Sump for routine operations within the Quarry.

Appendix G of Application

Augmentation Test Results Letter

Report Reference: 331201249TN1
Report Status: Final

Mr Colin Hume
Tarmac Western Ltd
PO Box 1
Kington
Herefordshire
HR5 3LQ

20 April 2004

Our Ref: 6257CH25.doc

Dear Colin

Re: Tor Coed Quarry - Augmentation Trial at Garn Ffrwd

Please find our comments on the trial to augment the flow volumes at Garn Ffrwd Spring (the Spring) by discharging water to a sinkhole located at the quarry (the Quarry Sink), which has been proven to have an underground connection with the Spring (Figure 1).

The trial commenced on 2 December 2003 and had a duration of 4 days. The trial consisted of pumping from the quarry sump to the Quarry Sink, and monitoring the emerging flows at the Spring. Field measurements and water sampling were undertaken at the Quarry Sink and at the Spring. Samples were also taken on the day before the trial commenced, and again upon completion of the trial to establish baseline conditions.

Discharge volumes

The rates of augmentation were varied during the test (Table 1) in order to establish the behaviour of the augmentation system under a variety of flow rates. Due to difficulties with the flow meter during the first two days of the trial, the flow rates during this period are estimates. From visual observations at the Quarry Sink, the augmentation volume was estimated to be approximately 8 l/s during the first 24 hours and around 4 l/s during the second day of the trial until 8:50 hours on 4 December 2003.

The flow meter was replaced on 4 December 2003 at 8:50 hours (Table 1). During the morning of 4 December the augmentation discharge was maintained at approximately 4 l/s and increased to around 10 l/s at midday, until the following afternoon at 12:30 when it was reduced again to 4 l/s. The augmentation discharge pump was stopped at 16:00 on 5 December 2004.

Table 1: Augmentation volumes during trial

	Date / Time	Reading (m^3)	Flow l/s	Comments of sampler Jason Linton
Pump started at:	02/12/2003 11:32	19.945		
Flow meter found not to be turning	02/12/2003 15:17	84.205	4.8	Water still heard flowing in the pipes
Flow meter and gate valve relocated in pipework. Restart reading:	03/12/2003 09:00	93.5	0.1	Faulty flow meter
Morning rounds:	03/12/2003 10:40	102.5	1.5	
Morning rounds - Return visit:	03/12/2003 11:38	127.2	7.1	
Afternoon Rounds: Flow meter clocks not turning.	03/12/2003 15:24	172.5	3.3	Water definitely still flowing.
Flow meter changed for a new one. Pump restarted at:	04/12/2003 08:50	9.5		Reading on new meter. Old meter reading:1725
Morning rounds:	04/12/2003 10:53	35.5	3.5	
Morning rounds - Return visit:	04/12/2003 12:12	54.1	3.9	
Valve opened to increase flow rate to 8lt/s	04/12/2003 12:22	59.9	9.7	
Afternoon Rounds:	04/12/2003 14:40	139.2	9.6	
Afternoon Rounds: Return visit	04/12/2003 16:02	170.12	6.3	
Morning rounds:	05/12/2003 10:34	728.9	8.4	
Morning rounds - Return visit:	05/12/2003 11:21	742.3	4.8	
Return flow rate to 4lt/s - before starting to adjust flow:	05/12/2003 12:15	770.2	8.6	
Return flow rate to 4lt/s - finished adjusting flow:	05/12/2003 12:25	773	4.7	
Afternoon Rounds:	05/12/2003 14:45	817.4	5.3	
Pump Switched off.	05/12/2003 15:45	822.08	1.3	Final reading.

Effects of rainfall on the flow of the Spring

Figure 2 shows the hydrograph of the Spring during the augmentation trial. Two responses to rainfall events are observed during the period of the test.

- Approximately 9 mm of rainfall fell during 1 December 2003 and this is observed as a peak in the hydrograph. Approximately 4 hrs after the rain had stopped the hydrograph of the Spring starts its recession curve.

- A rise in the hydrograph is observed in response to overnight rainfall as noted in Figure 2 during the early morning of 3 December.

In general, responses to rainfall were observed within approximately 1 hour of the start of the rainfall event and a recession in the spring flow commenced a few hours after the cession of rainfall.

A small ephemeral stream was observed to discharge directly into the Quarry Sink during the course of the trial. The discharge was measured as 1 l/s using a flow meter. It was noted that, after the third day of the trial, this stream had dried up, indicating that the stream was a direct and immediate result of rainfall (i.e. runoff rather than groundwater). Water samples were taken from the stream for laboratory analysis. Field analysis was also carried out.

Effects of the augmentation trial on the flow of the Spring

The hydrograph of flows at the Spring shows clear responses to changes in the augmentation volume (Figure 2):

- The augmentation test started at 11:32 on 2 December. The response in the spring flow hydrograph was observed at approximately 12:15, which indicates a delay of around three quarters of an hour.
- During the next morning (3 December), the discharge of the Spring was observed to fall after the augmentation volume is reduced. The exact discharge rate at this time is unknown as the flow meter was not operational. The discharge rate was estimated to be around 4 l/s which is consistent with the estimated change in flow observed at the Spring.
- On the morning of 4 December, the spring flow hydrograph showed a reduction in flow when the augmentation trial was stopped and the counter was replaced before 8:50.
- Later that morning a rise in the stream flow was observed at 10:00 following the resumption of augmentation at 8:50. The augmentation discharge varied between 3.5 and 3.9 l/s. The discharge rose by approximately 1 l/s (30% of the increase in augmentation discharge) – although it may not have dropped back to its baseline rate following the shut down in augmentation.
- The subsequent rise in the hydrograph at 13:00 was the result of an increase in augmentation volume to 9.7 l/s at 12:30 (Table 1; Figure 2). The spring flow rose sharply by approximately 4 l/s (66% of the increase in augmentation discharge).
- Following the reduction in discharge to around 5 l/s at 12:30 on 5 December, the hydrograph showed a drop of around 3 l/s (60% of the reduction in discharge rate). This was followed by a drop in flow of around 4 l/s (80% of the reduction in augmentation discharge) when the augmentation was stopped at 16:00 on the same day.

In summary:

- The spring flow shows a very rapid response to changes in augmentation rate (within 30 to 70 minutes). This response is faster than noted in tracer tests at the same sink (peak recovery after around 1 day). This is probably due to the tracer tests being carried out during low flow conditions but also reflects the difference between the time taken for a hydraulic response to occur and the time taken for the bulk of the tracer to be transported through the system.
- In the short term, the change in spring flow varied from 30 to 80% of the change in augmentation discharge. However, viewing the results on Figure 2 over longer

timescales, it is apparent that, over the course of the test, the change in flow in the Spring was generally very close to the augmentation rate.

- The most probable reason for the difference between short and long term responses is that not all of the augmentation flow will go via the fastest routes. Thus, whilst most of the response in the Spring flow rate to a change in discharge rate is fairly immediate, some of the response will take longer to break through. This suggests that the 'efficiency' of the augmentation scheme will be higher in the long term than in the short term. The Quarry Sink discharge point is clearly within the capture zone of the Spring and thus any water discharged at that point will ultimately reach the Spring.

Water Quality

During the trial, water samples and field measurements were taken. The results of the field measurements are shown in Table 2. Field measurements show that:

- During the trial, the temperature and pH of the Spring water remained stable despite the fact that the augmentation water was around 4^{o} cooler. It is likely that the passage of the augmentation water through the underground conduit has brought the water into equilibrium with normal underground temperatures. However, it should also be noted that the augmentation water only comprised a maximum of 30% of the observed Spring outflow.

- The Electrical Conductivity (EC) in the Spring rose by approximately 40 µS/cm over that period, approximately 7%. This increase may be caused by the higher EC of the augmentation water compared to the Spring water (Table 2) although it should be noted that the natural discharge from the stream that feeds the sink has a significantly higher EC than either the Spring or the augmentation water. Note that the two values of EC taken at the Spring before the start of the test were 11-17% higher than the range of values determined by sampling over the period 2002-3. This indicates that EC at the Spring naturally varies by at least this amount due to the variation in the proportion of runoff and baseflow emerging.

- Dissolved Oxygen at the Spring remained steady during most of the trial. However, during the last day of the trial it rose from around 10 mg/l to around 14 mg/l. This is higher than the value being discharged into the sinkhole and may therefore be due to other factors.

The results of the laboratory analyses of water samples taken before, during and after the test are shown in Table 4. EQS values for various determinands appropriate for salmonid fish are set out in Table 3 - Statutory Instrument 1997 No 1331, 'The Surface Waters (Fishlife)(Classification) Regulations, 1997'. Comparison between the results in Table 4 and the standards in Table 3 shows:

- Dissolved Oxygen was higher than the required 9 mg/l for all samples taken from the Spring;

- Both field and laboratory measurements of pH were between the limit of 6 – 9 units for all samples;

- Non ionised ammonia was less than the EQS of 0.025 mg/l for all samples taken during the trial and showed no rise in the Spring during the test;

- Total ammonium was below the detection limit of 0.5 mg/l for all samples taken during the trial (EQS 1 mg/l);

- In the EC Freshwater Fish Directive (78/659/EEC) and the Surface Waters (Fishlife) (Classification) Regulations 1997, the EQS for zinc, for the hardness of the water in this system (>100 mg/l $CaCO_3$), is a single value of 500 µg/l. The background concentrations detected at the Spring are below the concentration in the discharge water and there is a discernible rise in the concentration at the Spring during the course of the test (from 2 to 21 µg/l). However, the value recorded at the spring remained far below the EQS.

In addition, the level of suspended solids in the discharge water was significantly below the EC guideline value of 25 mg/l (Water Quality Standards for Designated Fishing Waters (directive 78/659/EEC)) during the course of the test and there was no sign of significant variation in this parameter at the Spring, despite the variations in flow.

Table 2: Field measurements

	Date/time	Temp °C	pH	EC µS/cm	DO_2 mg/l
Augmentation Flow into Sink Hole	02/12/2003 15:25	6.6	8.23	541	8.9
	03/12/2003 10:45	7.1	7.08	525	11.6
	03/12/2003 15:35	7.2	7.08	523	11.9
	04/12/2003 11:10	6.6	8.35	559	11.9
	04/12/2003 15:50	6.4	8.33	556	10.7
	05/12/2003 10:40	6.0	8.32	597	9.8
	05/12/2003 14:55	6.4	8.32	605	12.1
Stream / Drainage Ditch Feeding into Sink Hole	02/12/2003 15:25	10	7.31	868	6.8
	03/12/2003 10:45	10.2	7.33	835	7.1
	03/12/2003 15:35	10.2	7.08	804	7.3
	04/12/2003 11:10	9	7.46	824	6.2
	04/12/2003 15:50			Stream dried up	
Fish Farm	2002-3 range	9.7-10.5	6.9-7.4	325-377	
	01/12/2003	10.0	7.40	433	10.1
	02/12/2003 09:15	10.0	7.42	413	10.2
	02/12/2003 11:10				
	02/12/2003 16:00	9.9	7.39	434	13.9
	03/12/2003 11:10	9.9	7.42	470	10.3
	03/12/2003 15:57	9.9	7.41	473	10.1
	04/12/2003 11:35	9.9	7.42	452	9.8
	04/12/2003 15:30	9.9	7.37	451	10.0
	05/12/2003 11:00	9.9	7.38	469	14.4
	05/12/2003 15:10	9.8	7.38	467	14.8
	06/12/2003 10:25	9.9	7.41	471	10.3
	08/12/2003 11:40	10.0	7.41	416	9.4

Table 3: Relevant Water Quality Constraints

Parameter	Value
DO	> 9mg/l for 50% of samples
pH	within 6-9 pH units
Non ionised ammonia	< 0.025 mg/l for 95% of readings
Total ammonium	less than 1 mg/l for 95% of readings
Total zinc	For hardness >100 mg/l $CaCO_3$ annual average<500 µg/l

Table 4: Results of sample analyses

	Date and time of sampling	pH	Ammonium - As N	Chlorine (Total residual) - As Cl2	Zinc - As Zn	Ammonia Un-Ionised (Calculated by the laboratory)	Alkalinity pH 4.5 - As CaCo3	Suspended solids
			mg/l	mg/l	µg/l	mg/l	mg/l	(mg/l)
Augmentation Flow into Sink Hole	**02/12/2003 15:25**	7.97	<0.50	<0.020	121	0.01	90	4.48
	03/12/2003 10:45	7.94	<0.50	<0.020	174	0.01	93	3.45
	03/12/2003 15:35							5.83
	04/12/2003 11:10	8	<0.50	<0.020	225	0.01	95	4.67
	04/12/2003 15:50							4.21
	05/12/2003 10:40	7.98	<0.50	<0.020	162	0.01	99	6.54
	05/12/2003 14:50							5.43
Stream / Drainage Ditch Feeding into Sink Hole	**02/12/2003 15:25**	7.33	<0.50	<0.020	5.58	0.002	259	5.9
	03/12/2003 10:45	7.39	<0.50	<0.020	4.06	0.002	256	5.67
	03/12/2003 15:35							4.41
	04/12/2003 11:10	7.52	<0.50	<0.020	7	0.003	256	5.87
Fish Farm	01/12/2003 14:00							5.85
	02/12/2003 09:15	7.39	<0.50	<0.020	2.35	0.002	159	2.71
	02/12/2003 16:10	7.41	<0.50	<0.020	<2.000	0.002	168	2.32
	03/12/2003 11:10	7.37	<0.50	<0.020	5.98	0.002	156	5.52
	03/12/2003 15:55							1.96
	04/12/2003 11:35	7.39	<0.50	<0.020	7.36	0.002	159	2.1
	04/12/2003 15:30							1.66
	05/12/2003 11:00	7.3	<0.50	<0.020	14.5	0.002	154	1.18
	05/12/2003 15:10							2.02
	06/12/2003 10:25	7.32	<0.50	<0.020	21.6	0.002	155	1.65
	08/12/2003 11:40	7.44	<0.50	<0.020	14	0.003	169	2.07

Conclusions of Trial

The trial augmentation test showed that the flow at the Spring can be successfully augmented by discharge of water at the Quarry Sink. The quality of water at the Spring complied with all relevant water quality standards throughout the course of the test.

Due to the background variation in flow at the Spring during the course of the test (caused by rainfall during the test), it was not possible to quantify the efficiency of the discharge (i.e. how much of the discharge actually reached the Spring during the course of the test). However, the Quarry Sink is clearly within the source zone of the Spring and there is no reason to believe that water discharged at this point would travel in any other direction.

The sampling of the augmentation water showed concentrations of zinc that were higher than baseline concentrations at the spring (average 170 µg/l in discharge compared to baseline concentrations of 2 µg/l rising to 21 µg/l during the course of the test). However, these concentrations still comply with the relevant EQS (500 µg/l). It is desirable to have some zinc in the water (farmed fish are fed zinc supplements in some cases) so, as long as the water coming out of the Spring complies with the relevant EQS, it is my opinion that these concentrations should be acceptable. The zinc in the discharge water is most likely derived from mineralisation in the limestone and may well be particulate rather than dissolved (although the standard applies to total zinc so it does not make any difference whether it is dissolved).

In summary, the test was successful and demonstrates the feasibility of the methodology.

Outline of Augmentation Scheme

Rational & Augmentation Rates

Tarmac has agreed that the trigger (or benchmark) flow at the spring will be 8 l/s. At times when the flow is below this level, Tarmac will endeavour to augment the Spring to this flow rate. This will necessitate a certain volume of water being stored in the quarry (in a sump) to service the augmentation periods. The success of the Scheme will therefore depend, to some extent, on the volume of water in this quarry sump. I have therefore reviewed past climatic conditions at the site (going back to 1961) and undertaken calculations to establish the size of sump required to give a reasonable level of security. I enclose a summary plot (Figure 3) from those calculations that demonstrate that a sump of approximately 5,000 m^3 should provide reasonable storage to augment the spring to 8 l/s during the great majority dry periods, including 2002 and 2003 which were particularly dry summers.

The approach used is based on modelling of flows observed over the past five years using rainfall and other meteorological data combined with the known catchment of the springs. It is possible that in future the further development of the quarry may capture some of this flow. However, any future loss of flow in the spring will be balanced by increased flows to the quarry and thus the balance between quarry inflows and augmentation requirements will remain the same.

Several exceptionally dry periods are evident from the past climatic data, most notably the years 1976 and 1978. During those sustained dry periods, my calculations suggest that the flows at the spring would naturally have dropped below 4 l/s. Furthermore, future climatic conditions are of course unknown, and it is conceivable that these could be drier than in the past. In such dry conditions it is very likely that the natural flow at Garn Ffrwd spring would drop below flows previously experienced, irrespective of activities at Torcoed Quarry.

During exceptionally dry situations, such as those outlined above, it would not be feasible for Tarmac to maintain flows at the benchmark level over a sustained period of time. Indeed, the consequence of rigidly sticking to the target flow in such conditions would be that at some point the sump would dry out and augmentation would have to cease suddenly. It would therefore seem preferable to have a system in which the augmented flows were progressively decreased to agreed rates in dry conditions such that the augmentation could continue for a longer period, albeit at a slightly lower rate. The differential flow rates require to be considered in consultation with Mr Miller, I would however suggest the following: -

- the target flow will be 8 l/s until the volume of water in the sump drops to 50% of the full capacity; after which;
- the target flow will be 7 l/s until the volume of water in the sump drops to 25% of the full capacity; after which;
- the target flow will be 6 l/s until the volume of water in the sump drops to 15% of the full capacity; after which;
- the target flow will be 5.5 l/s until the volume of water in the sump is fully utilised.

These rates could be refined with operational experience of the system. However, the results on Figure 3 suggest that these reduced rates would only apply very rarely (i.e. 3 years out of 40). Further calculation suggests that, the method of reducing flows progressively outlined above would have been successful in maintaining some augmentation during the worst droughts on record.

During times when the sump storage is under capacity, Tarmac should utilise the sump as the preferred disposal option for suitable quality water, in preference to pumping that water off site. Notwithstanding, this overarching commitment, Tarmac will be permitted to utilise reasonable quantities of water from the quarry (or from the sump) for routine operations within the quarry. Tarmac may also choose not to discharge water into the sump when it is not full for reasons of maintaining the water quality for the discharge.

On cessation of quarrying at Tor Coed, there will be a period of several years when water levels in the quarry sump are recovering but during which natural flows to the spring will not have recovered. It will therefore be necessary to retain provision for augmentation of the spring during this period. Ultimately I anticipate that, upon full recovery of water levels at the quarry, the flows in the spring will be re-established and will in fact be much more reliable than in the past due to the storage effect of the lake in the quarry.

I would be happy to discuss these matters with Mr Miller and his representatives.

Augmentation Trigger

Mr Miller may, on reasonable belief that the Spring is flowing below the target flow, request that Tarmac augment the spring to the agreed flows. Upon any such request for augmentation Tarmac may measure flows at the Spring.

Marks can be established at the inlet weir at levels corresponding to the agreed flow rates. The gauging marks would then form basis Mr Miller's initial flow check and request for augmentation.

Whilst augmenting the Spring flow at rates exceeding the agreed target flow may be acceptable in terms of water flow at the Spring, it would be desirable to try and avoid any unnecessary augmentation in order to preserve water resources in the quarry sump. Therefore, if heavy rainfall occurs during an augmentation period, the flows at the spring should be checked and augmentation can be stopped or adjusted if the naturalised flows (observed minus discharge rate) exceeds the target flow prevailing at that time.

Quality Aspects

The augmentation discharge will be regulated at the Quarry Sink by a discharge consent, issued by the Environment Agency. That consent will contain relevant quality standards. The Agency will be required to take account of interested parties and the receiving groundwater in setting the consent conditions. Mr Miller will clearly be a principal consultee in that process. Once granted, Tarmac will need to ensure compliance with that consent. It is not envisaged that any additional quality parameters be included in the scheme beyond those measured during the trial.

Tarmac will undertake comprehensive monitoring of the augmentation discharge as outlined below.

Future Monitoring

Flows

Flows at the Garnffrwd spring will continue to be monitored at 15 minute intervals using the weir and data logger system that is in place.

The volumes discharged to the Quarry Sink will be monitored by means of a cumulative discharge impellor meter (or equivalent system). Values will be taken weekly during periods in which augmentation is occurring.

Water Levels

The water level in the quarry sump constructed for augmentation will be recorded daily during periods of augmentation.

Water Quality

The following chemical parameters will be monitored at the discharge point weekly during periods in which augmentation is taking place.

<u>Field Parameters:</u>

- pH;
- Electrical Conductivity;
- Dissolved Oxygen;
- Temperature;
- Suspended solids.

<u>Laboratory Parameters:</u>

- Non ionised ammonia
- Total ammonium
- Total zinc
- Hardness

I trust that he foregoing provides sufficient information at this time. It would probably be beneficial to you send this correspondence on to Mr Miller and that we then meet with him in the near future in order to finalise matters.

Yours sincerely

Mike Streetly
DIRECTOR

CC: J Miller

Appendix H of Application

Discharge Permit BP0235501 / BP0239301

Report Reference: 331201249TN1
Report Status: Final

creating a better place

Environment Agency

Mr Andrew Tait
ESI Ltd
New Zealand House
160 Abbey Foregate
Shrewsbury
SY2 6FD

Our ref: BP0235501/ BP0239301

Your ref:

Date: 23 February 2008

Dear Mr Tait

Application to discharge trade effluent consisting of Quarry Dewatering by Tarmac Limited from premises at Torcoed Quarry, Porthyrhyd, Carmarthen, Dyfed, SA32 8PY.
Application no: BP0235501/ BP0239301

Water Resources Act 1991 (as amended by the Environment Act 1995) Schedule 10

I enclose our formal notice of Variation of consent to discharge trade effluent consisting of Quarry Dewatering by Tarmac Limited from premises at Torcoed Quarry, Porthyrhyd, Carmarthen, Dyfed, SA32 8PY.

The changes to conditions in the consent may result in a change to the annual charge. If this is the case, we will send your client a revised bill. Information on our charges is available through our website at www.environment-agency.gov.uk/charges. If you do not have access to the internet, a hard copy is available from me on request.

If your client considers that the conditions of the Variation of consent are unreasonable, they have a right of appeal to:

National Assembly for Wales
Water Branch
Climate Change and Water Division
Department for Environment, Sustainability and Housing
Cathays Park
Cardiff CF10 3NQ

The appeal must be given in writing within three months of the date of issue of the Variation of consent and must include a statement of the grounds for the appeal. A copy of the appeal should also be sent to us at the address below.

Details of this Consent, and associated application, are placed on our Public Register which is open for inspection by the public.

Change of Consent Holder

If in the future the name of the Consent Holder is due to change, both your client and the new holder must inform us in writing before the change. We can then transfer the rights and charges to the new holder and send a certificate to confirm the transfer of consent.

If you have any queries please contact me.

Yours sincerely

M. Platts

Michaela Platts
Permitting Support Advisor

Direct dial: 0114 280 0683
Direct fax: 0114 262 6697
Direct e-mail: psc-waterquality@environment-agency.gov.uk

Enc

Environment Agency

Variation of Consent to Discharge

Water Resources Act 1991 (as amended by the Environment Act 1995)

Consent Holder	**Tarmac Limited** **Millfields Road** **Ettingshall** **Wolverhampton** **WV4 6JP**
Consent to Discharge from	**Torcoed Quarry** **Porthyrhyd** **Camarthen** **Dyfed** **SA32 8PY**
Company Registration Number	**00453791**
Consent Number	**BP0235501**

Environment Agency
Permitting Support Centre, PO Box 4209, Sheffield, S9 9BS
Customer services line: 08708 506 506
Email: enquiries@environment-agency.gov.uk
www.environment-agency.gov.uk

Consent to Discharge
Water Resources Act 1991
Section 88, Schedule 10
(as amended by the
Environment Act 1995)

Environment Agency

Variation of Consent to Discharge

Consent Number
BP0235501

To:
Tarmac Limited ("the Consent Holder")
Millfields Road
Ettingshall
Wolverhampton
WV4 6JP

Company Registration Number: **00453791**

The Environment Agency ("the Agency") in pursuance of its powers under the Water Resources Act 1991(as amended by the Environment Act 1995) hereby consents to the making of a discharge:

Of:
Trade effluent consisting of site drainage and dewatering effluent ("the Discharge")

With respect to Consent No. BP0235501 issued on the 15th February 1995

From:
Settlement tanks serving Torcoed Quarry

At:
Torcoed Quarry, Porthyrhyd, Carmarthen, Dyfed

To:
An unnamed tributary of Gwendraeth Fach

Subject to the conditions set out in this notice of Consent to Discharge.

Subject to the provisions of Paragraphs 7 and 8 of Schedule 10 of the Water Resources Act 1991(as amended by the Environment Act 1995), no notice shall be served by the Agency, altering this consent, without the agreement of the Consent Holder, during a period of 4 years from the date this notice is issued.

This Consent is issued on:	20 February 2009
This Consent takes effect on:	20 February 2009

Signed

Carl Sweeney

Permitting Team Leader

1 Conditions of Consent for trade effluent consisting of site drainage and dewatering effluent

1.1 Nature

1.1.1 The Discharge shall consist solely of trade effluent consisting of site drainage and dewatering effluent from an area of approximately 229,000 square metres.

1.2 Place of Discharge

1.2.1

The Discharge shall be made in the manner and at the place specified as:

a discharging to an unnamed tributary of the Gwendraeth Fach;

b at National Grid Reference SN 49620 14110;

c shown marked "Discharge and Sample Point" on the Site Plan attached to this consent.

1.3 Sampling Point Requirements

1.3.1 The outlet to controlled waters shall be constructed and maintained so that a representative sample of the Discharge may be obtained at National Grid Reference SN 49620 14110 as shown marked "Discharge and Sample Point" on the Site plan attached to this consent.

1.4 Rate

1.4.1 The volume of the Discharge shall not exceed 73 litres per second.

1.5 Volume

1.5.1 The volume of the Discharge shall not exceed 6304 cubic metres per day.

1.6 Flow Measurement

1.6.1 The consent holder shall install, operate and maintain a means of flow measuring to a specification and at a location required by the Environment Agency. The flow measurement installation shall enable the instantaneous flow from the settlement tanks to be recorded. The Consent Holder shall calibrate, operate and maintain the flow measurement and recording system to a standard specified by their quality management system, that has been approved by an independent expert. The flow and maintenance records shall be provided to the Environment Agency as and when requested.

1.7 Composition

1.7.1 The Discharge shall not contain more than 60 milligrammes per litre of suspended solids (measured after drying at 105°C).

1.7.2 As far as is reasonably practicable, the site and its facilities shall be operated so as to prevent the Discharge from containing any significant trace of visible oil or grease.

1.7.3 The pH of the Discharge shall not be less than 6 or greater than 9.

1.8 **Works Operation**

1.8.1 The settlement tanks shall be operated and the effluent shall be treated in a manner which, so far as reasonably practicable, minimises the polluting effects of the discharge made from the settlement tanks on controlled waters.

This condition does not require -

a any higher standard to be achieved in relation to any characteristic of the discharge which is specifically regulated by 1.7.1, 1.7.2 and 1.7.3 than is required by those conditions.

b any alteration of the works or a change in the type of treatment used.

1.9 **Maintenance**

a The settlement tanks shall be operated and maintained in accordance with good operational practice such that the settlement tanks shall be desludged at sufficient frequency and in such a manner to prevent excessive carryover of suspended solids.

1.10 **Recording and Reporting**

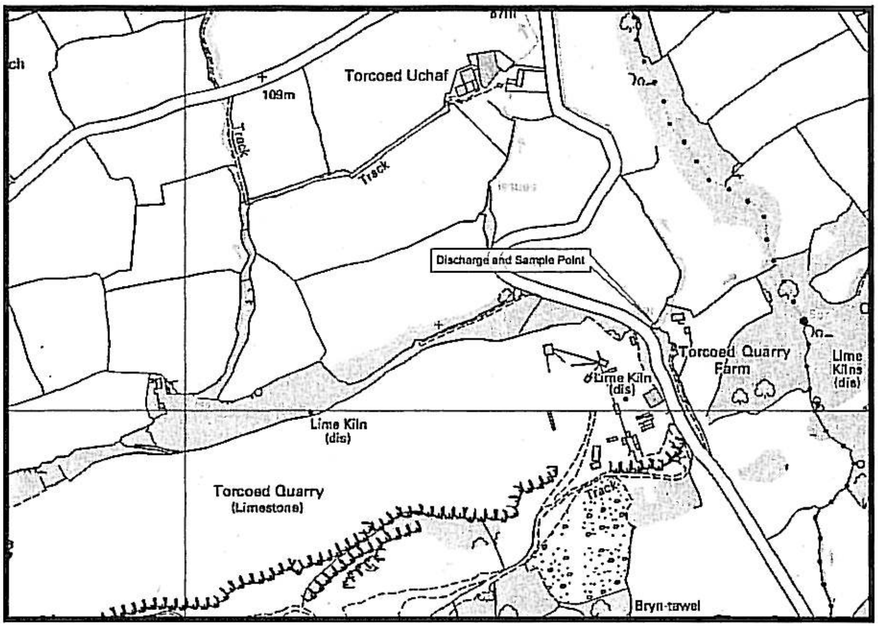
1.10.1

a The Consent Holder shall establish and operate a documented maintenance programme and record all non-routine actions undertaken that may have adversely affected effluent quality. Copies of the programme shall be made available for inspection by the Agency's officers at all reasonable times.

b On request the Consent Holder shall supply the Agency with a written report on the maintenance and all non-routine actions that may have adversely affected effluent quality

c The Consent Holder shall as soon as reasonably practicable report to the Agency all non-routine actions that may have adversely affected effluent quality.

2 Site Plan


Torcoed Uchaf
109m
Track
Track
Discharge and Sample Point
Torcoed Quarry Farm
Lime Kiln (dis)
Lime Kilns (dis)
Lime Kiln (dis)
Torcoed Quarry (Limestone)
Track
Bryn-tawel

Environment Agency

Variation of Consent to Discharge

Water Resources Act 1991 (as amended by the Environment Act 1995)

Consent Holder(s)	**Tarmac Limited** **Millfields Road** **Ettingshall** **Wolverhampton** **WV4 6JP**
Consent to Discharge from	**Torcoed Fawr Quarry** **Porthyrhyd** **Camarthen** **Dyfed** **SA32 8PY**
Company Registration Number	**00453791**
Consent Number	**BP0239301**

Environment Agency
Permitting Support Centre, PO Box 4209, Sheffield, S9 9BS
Customer services line: 08708 506 506
Email: enquiries@environment-agency.gov.uk
www.environment-agency.gov.uk

Consence to Discharge

Water Resources Act 1991
Section 88, Schedule 10
(as amended by the
Environment Act 1995)

Environment Agency

Variation of Consent to Discharge

Consent Number
BP0239301

To:
Tarmac Limited ("the Consent Holder")
Millfields Road
Ettingshall
Wolverhampton
WV4 6JP

Company Registration Number: **00453791**

The Environment Agency ("the Agency") in pursuance of its powers under the Water Resources Act 1991(as amended by the Environment Act 1995) hereby consents to the making of a discharge:

Of:
Trade effluent consisting of site drainage and dewatering effluent ("the Discharge")

With respect to Consent No. BP0239301 issued on the 4th March 1994

From:
Settlement tanks serving Torcoed Fwar Quarry

At:
Torcoed Fawr Quarry, Porthyrhyd, Carmarthen, Dyfed

To:
An unnamed tributary of Gwendraeth Fach

Subject to the conditions set out in this notice of Consent to Discharge.

Subject to the provisions of Paragraphs 7 and 8 of Schedule 10 of the Water Resources Act 1991(as amended by the Environment Act 1995), no notice shall be served by the Agency, altering this consent, without the agreement of the Consent Holder, during a period of 4 years from the date this notice is issued.

This Consent is issued on:	20 February 2009
This Consent takes effect on:	20 February 2009

Signed

Permitting Team Leader

1 Conditions of Consent for trade effluent consisting of site drainage and dewatering effluent

1.1 Nature

1.1.1 The Discharge shall consist solely of trade effluent consisting of site drainage and dewatering effluent from an area approximately 262,000 square metres.

1.2 Place of Discharge

1.2.1

The Discharge shall be made in the manner and at the place specified as:

- **a** discharging to an unnamed tributary of the Gwendraeth Fach;
- **b** at National Grid Reference SN 48060 13810;
- **c** shown marked "Discharge and Sample Point" on Site Plan attached to this consent.

1.3 Sampling Point Requirements

1.3.1 The outlet to controlled waters shall be constructed and maintained so that a representative sample of the Discharge may be obtained at National Grid Reference SN 48060 13810 as shown marked "Discharge and Sample Point" on the Site plan attached to this consent.

1.4 Rate

1.4.1 The volume of the Discharge shall not exceed 61 litres per second.

1.5 Volume

1.5.1 The volume of the Discharge shall not exceed 5247 cubic metres per day.

1.6 Flow Measurement

1.6.1 The consent holder shall install, operate and maintain a means of flow measuring to a specification and at a location required by the Environment Agency. The flow measurement installation shall enable the instantaneous flow from the settlement tanks to be recorded. The Consent Holder shall calibrate, operate and maintain the flow measurement and recording system to a standard specified by their quality management system, that has been approved by an independent expert. The flow and maintenance records shall be provided to the Environment Agency as and when requested.

1.7 Composition

1.7.1 The Discharge shall not contain more than 60 milligrammes per litre of suspended solids (measured after drying at 105°C).

1.7.2 As far as is reasonably practicable, the site and its facilities shall be operated so as to prevent the Discharge from containing any significant trace of visible oil or grease.

1.7.3 The pH of the Discharge shall not be less than 6 or greater than 9.

1.8 **Works Operation**

1.8.1 The settlement tanks shall be operated and the effluent shall be treated in a manner which, so far as reasonably practicable, minimises the polluting effects of the discharge made from the settlement tanks on controlled waters. This condition does not require -

a any higher standard to be achieved in relation to any characteristic of the discharge which is specifically regulated by 1.7.1, 1.7.2 and 1.7.3 than is required by those conditions.

b any alteration of the works or a change in the type of treatment used.

1.9 **Maintenance**

a The settlement tanks shall be operated and maintained in accordance with good operational practice such that the settlement tanks shall be desludged at sufficient frequency and in such a manner to prevent excessive carryover of suspended solids.

1.10 **Recording and Reporting**

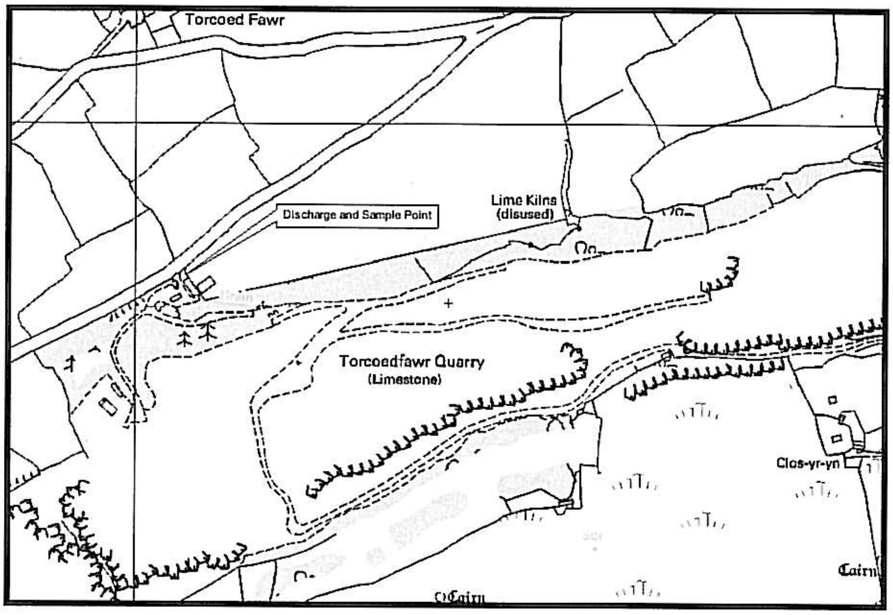
1.10.1

a The Consent Holder shall establish and operate a documented maintenance programme and record all non-routine actions undertaken that may have adversely affected effluent quality. Copies of the programme shall be made available for inspection by the Agency's officers at all reasonable times.

b On request the Consent Holder shall supply the Agency with a written report on the maintenance and all non-routine actions that may have adversely affected effluent quality

c The Consent Holder shall as soon as reasonably practicable report to the Agency all non-routine actions that may have adversely affected effluent quality.

2 # Site Plan


Torcoed Fawr
Discharge and Sample Point
Lime Kilns
(disused)
Torcoedfawr Quarry
(Limestone)
Clos-yr-ynn
Cairn
Cairn

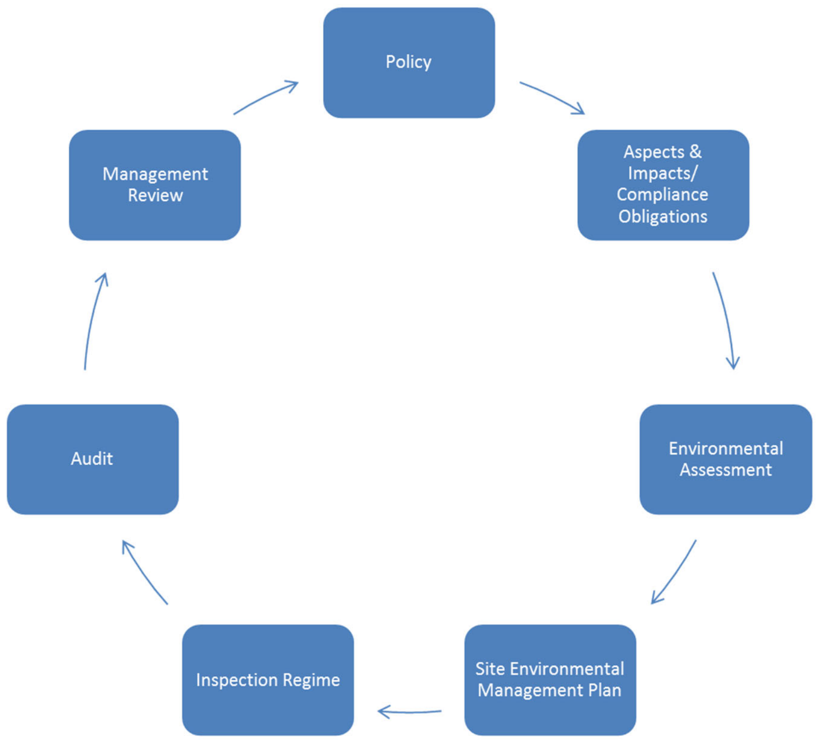
Appendix I of Application

Environmental Management System

Report Reference: 331201249TN1
Report Status: Final

Summary of Environmental Management System

Tarmac Trading Limited has in place an Environmental Management System (EMS) that is accredited to the international ISO 14001 standard. The site will be operated under the overarching EMS which covers a number of Tarmac sites across the UK. The specific EMS procedures to support the operation of this type of regulated facility under an Environmental Permit in England have been developed with reference to relevant guidance produced by the EA. The EMS follows the Plan Do Check Act (PDCA) cycle described in EA guidance [1] as illustrated below:



A copy of the EMS will be held at the site and will be available for inspection once the site is operational following the issue of the Environmental Permit for the site. A summary of the key elements of the EMS is provided below.

Company Environmental Policy

The EMS is underpinned by the company environmental policy which outlines how it expects operations to be managed and its environmental performance to be communicated to its stakeholders and to enable the effective deployment of the related principles across its operational sites.

[1] England and Wales - How to comply with your environmental permit.
Scotland –
Northern Ireland -

Tarmac is committed to preventing its activities polluting the environment and the continual improvement of its environmental performance. Through a dedicated environmental and sustainability panel business objectives are developed. Environmental performance measures are also monitored by these forums and targets set to enable performance levels to be continuously improved.

Tarmac aims to minimise the environmental impact of its activities by:

- regularly monitoring the effective deployment of the EMS through a series of graded audits
- prior to undertaking work on behalf of Tarmac, all sub-contract personnel will be made aware of site-specific environmental concerns and vulnerabilities through the site induction process
- reducing the amount of waste materials generated by their activities; attempting to recycle and reuse such materials wherever practical and where this is not achievable, disposing of such waste in a responsible manner
- seeking to use raw materials in an efficient manner, replacing them with substitute recycled raw materials where practicable and safe to do so
- promoting the efficient and reduced use of water, fuels and energy, thereby reducing carbon emissions and mitigating the potential for climate change
- purchasing, utilising and storing materials in a manner which poses minimal risk to both individuals and the environment, as far as is practical.
- Monitoring of consented discharges

The EMS will be deployed effectively through the company's management organisation. Managers and employees will be assigned environmental responsibilities and will be expected to play a full and active part in managing the environmental aspects of the activities for which they have responsibility. Operational management will be supported by a team of competent advisors and performance will be monitored by environmental auditors.

Company Environmental Standards

A core suite of aspects applied to activities controlled by TTL is audited to monitor compliance to the relevant environmental standards. All operational sites will be the subject of an Environmental Assessment and will maintain an up to date Site Environmental Management Plan (SEMP).

Permit for Discharge specific aspects

The following aspects have been identified having regard to the protection of the environment, compliance with any environmental permits and the highest standards of operation. These are in addition to the core company aspects described above.

The following aspects relevant to the discharge at Torcoed will be managed in accordance with any relevant company policies and procedures, site authorisations and statutory obligations.

1. Monitoring of site environmental impacts and aspects
2. Pollution of surface waters affected by the discharge
3. Identifying potentially polluting activities and substances
4. Visual monitoring and reporting of incidents to ensure prevention of spillages
5. Monthly monitoring of consented discharges to controlled waters
6. Remedial action and continuous improvement for environmental performance
7. Surface water from areas producing pollution runoff

Environmental Impact Review

The Site Manager shall be responsible for the Environmental Impact Review of the operations, in normal and abnormal conditions, to identify the key environmental aspects of its activities. Through this process the aspects of the operations, that may have a significant impact on the environment, can be identified, prioritised for corrective action and improvement together with an evaluation of legal compliance at the site. The site manager/ supervisor, together with representatives from the site/area and the compliance and environmental permitting personnel shall identify and prioritise the potential significant environmental impacts of the operations. The potential impacts most relevant to the discharge at Torcoed have been identified to be:

1. Pollution of surface waters from contaminants in the discharged waters
2. Bio-diversity and Ecological Management Visual Impact
3. Fuel & Chemical Storage
4. Groundwater monitoring Management
5. Legislation and Documentation
6. Surface water management
7. Groundwater management

Site Environmental Management Plan

The Environmental Impact Review provides the prioritised potential significant environmental impacts for inclusion in the SEMP. The plan shall identify objective(s)and target(s) for each significant impact and ensure that they are relevant to achieving the overall objectives of the Business Unit. The objective (the improvement action) shall be specific to the corrective/preventative action. The target for the improvement shall have a date for completion, the person responsible for the action and verification of the completion by the authorising person. The SEMP shall be reviewed regularly and shall be consistent with legislation, environmental procedures and the Tarmac environmental policy. The SEMP may be updated at anytime in order to implement changes/corrective actions identified by any management mechanism.

Each site shall undertake all necessary monitoring and measuring of operational activities, as required by legislation, such as environmental permits and planning consents. All such monitoring and measuring information shall be documented and recorded on a monitoring schedule.

Environmental occurrence/non-conformance reporting system

The environmental occurrence/non-conformance reporting system has been developed in order to document, investigate and mitigate significant impacts on the environment and for initiating and implementing corrective and preventative action. All incidents shall be reported, whether or not an external person/agency is involved. Any system non-conformances are also to be documented for corrective and preventative action.

Inspection regime and audit

The area manager shall establish and monitor an annual inspection programme ensuring that all sites under their control are audited by an ‘independent’ manager who has no responsibility for the site. The auditor shall complete an associated audit summary sheet, agreeing and summarising as necessary a list of recommended actions in consultation with the host manager. The audit summary sheet shall then be included in the SEMP and priorities and timescales assigned. A date for a follow-up visit to ensure close out of any actions has been completed will be set up by the visiting auditor and the manager/ supervisor. The follow up visit must also be used to ensure previous actions implemented are continuing to work and are effective.

In addition, the Company's own internal monitoring compliance team will carry out monthly monitoring across a range of determinands relevant to the discharge and watercourse to ensure that the compliance levels and consent are being complied with.

Management Review

There will be a tiered review of the EMS at top management level, local area level and at site management level including the procedures, environmental policy and the objectives and targets for the company in order to support its ongoing effectiveness, suitability, adequacy and stability.

Staff Training

All staff will be suitably trained through various mechanisms in line with company procedures and training schedules. Site staff are made fully aware of permit and other compliance requirements in line with legislative requirements to ensure legal compliance. Internal audits and inspection by the Compliance team and internal auditors will ensure that training has been completed and actions are in line with this by staff.

Toolbox talks, regular training updates and ensuring new staff to the company or activities are fully trained on these and how this can affect compliance and legislative requirements, further ensure that compliance is achieved. The company is committed to ensuring relevant site and compliance staff are fully aware of new legislation and guidance and that this is implemented while ensuring business unit continuity.

Maintenance

Plant and machinery are subject to maintenance schedules in line with manufacturer recommendations and requirements. Site staff report problems with equipment and this is then assessed and auctioned as necessary and as soon as possible.

It is in the company's interests to ensure all plant is operation and maintained which ensures both continuity of business and also greater environmental protection.