Appendix A:

Flood Warning Procedures – Doniford Stream, Hawkcombe Stream, River Sheppey, River Winniford, Burton and Bradstock

River: Doniford Stream (RAPID RESPONSE CATCHMENT)

Gauge: Sampford Brett (ST 09042 40420) **Datum: 28.43 mAOD**

Stage (m)	Flow (m^3/s)	Effect/ Historic flood	Time Lag	Action	Warning Code
0.6				**ACTION:** Enhance Detection & Forecasting 75% Flood Alert Sampford Brett	
0.8 & rising				**ACTION:** Issue **Flood Alert** for West Somerset Streams – if not already issued	**112WAF TWSS**
0.8 with 1.2 Exp		0.4m/hr rate of rise for Q_{100} and for observed event 28th May 2008.	1	**ACTION CONSIDER:** Issue **Flood Warning** for Doniford Stream in the Sampford Mill Farm area	**112FWF DON10A**
1.2		Property flooding expected at Sampford Mill Farm		**RESULT:** **Flood Warning** for Doniford Stream in the Sampford Mill Farm area	**112FWF DON10A**
1.2 with 1.4 Exp		0.4m/hr rate of rise for Q_{100}	0.5	**ACTION CONSIDER:** Issue **Flood Warning** for Doniford Stream at Sampford Brett and upstream properties	**112FWF DON10B**
				ACTION CONSIDER RECON: Issue **Flood Reconnaissance** Doniford Stream in the Sampford Mill Farm area	**112FWF DON10A**
				ACTION CONSIDER RECON: Issue **Flood Reconnaissance** Doniford Stream at Sampford Brett and upstream properties	**112FWF DON10B**
1.3 with 1.5 Exp				**ACTION CONSIDER:** Issue **Flood Warning** for Doniford Stream at Swill Bridge	**112FWF DON20A**
1.4		Peak level 26th May 2008. Property flooding at Sampford Mill Farm.		**RESULT:** **Flood Warning** for Doniford Stream at Sampford Brett and upstream properties	**112FWF DON10B**
1.498		Peak level 29th April 2012 Confirmed report of fluvial flooding of outbuildings at 'Mill Stream' in Sampford Brett			
1.5		1st property flooding expected at Rose Cottage adjacent to Swill Bridge gauging station		**RESULT:** **Flood Warning** for Doniford Stream at Swill Bridge	**112FWF DON20A**

River: Hawkcombe Stream **(RAPID RESPONSE CATCHMENT)**

Gauge: Parsons Street (Porlock) (SS 886 467) **Datum: 38.85 mAOD**

Stage (m)	Ft at culvert	Effect/ Historic flood	Time Lag	Action	Warning Code
0.35	1' 1½"	75% Alarm	0	**ACTION:** Enhance Detection & Forecasting (M&FDO)	
0.4	1' 4"	High flows but no flooding	0		
0.5	1' 8"	Bankfull conditions in upper reaches of Hawkcombe Valley. Risk of flooding to gardens	0	**ACTION:** Issue **Flood Alert** for West Somerset Streams – if not already issued	**112WA FTWSS**
0.51		Peak level 30th Oct 2000			
0.7	2' 3"	Risk of flooding to property in upper reaches. Bankfull conditions around Glen Lodge area.	½ hour u/s	**ACTION:** Issue **Flood Warning** for Hawkcombe Stream, Hawkcombe Valley to Porlock Bowling Green	**112FW FHAW10A**
				ACTION CONSIDER RECON: Issue **Flood Reconnaissance** for Hawkcombe Stream, Hawkcombe Valley to Porlock Bowling Green	**112FW FHAW10A**
2.0 with 3.0 Exp		Bankfull conditions in Parsons Street with flooding of road likely	0	**ACTION:** Issue **Flood Warning** for Hawkcombe Stream at Porlock Centre	**112FW FHAW20A**
				ACTION CONSIDER RECON: Issue **Flood Reconnaissance** for Hawkcombe Stream at Porlock Centre	**112FW FHAW20A**
				ACTION CONSIDER: MFDO to consider if 3m is likely to be reached in less than 2 hours	
3.0		Parsons Street culvert fully surcharged with side walls overtopped. High risk of severe flooding in High Street, Sparkhayes and Parsons Street	0	**ACTION CONSIDER:** Issue **Severe Flood Warning** for Hawkcombe Stream at Porlock Centre **DATA COLLECTION** – see section 4	**112FW FHAW20A**

River: Sheppey **(RAPID RESPONSE CATCHMENT)**

Rain Gauge: Downhead (ST 686 457)

Rainfall depth (mm) OBSERVED OR FORECAST	Effect/ Historic flood	Time Lag	Action	Warning Code
10mm in 1-hour **OR** Any River Sheppey CATMAX alarm on receipt of 1st alarm			**ACTION:** 1. Enhance Detection & Forecasting (M&FDO) 2. Commence monitoring of river levels at Garston Street bypass channel (M&FDO)	
Any River Sheppey CATMAX alarm on receipt of 2nd alarm wthin a 3 hour period **OR** 0.4 at Garston Street bypass			**ACTION:** Issue **Flood Alert** for East Somerset Rivers – if not already issued	**112FAFTESR**
Any River Sheppey CATMAX alarm on receipt of 3rd alarm within a 3 hour period **OR** 0.4 at Garston Street bypass with rate of rise >0.4 m/h			**ACTION CONSIDER:** Issue **Flood Warning** for River Sheppey – if not already issued	**112FWFSHE 10A**
			ACTION CONSIDER RECON: Issue **Flood Reconnaissance** for River Sheppey	**112FWFSHE 10A**

River: **Sheppey** (RAPID RESPONSE CATCHMENT) **Rain Gauge: Doulting (ST 645 417)**				
Rainfall depth (mm) OBSERVED OR FORECAST	Effect/ Historic flood	Time Lag	Action	Warning Code
10mm in 1-hour **OR** Any River Sheppey CATMAX alarm on receipt of first alarm			**ACTION:** 1. Enhance Detection & Forecasting (M&FDO) 2. Commence monitoring of river levels at Garston Street bypass channel (M&FDO)	
Any River Sheppey CATMAX alarm on receipt of 2nd alarm within 3 hour period **OR** 0.4 at Garston Street bypass			**ACTION:** Issue **Flood Alert** for East Somerset Rivers – if not already issued	**112WAFTESR**
Any River Sheppey CATMAX alarm on receipt of 3rd alarm within a 3 hour period **OR** 0.4 at Garston Street bypass with rate of rise >0.4 m/h			**ACTION CONSIDER:** Issue **Flood Warning** for River Sheppey – if not already issued	**112FWFSHE10A**
			ACTION CONSIDER RECON: Issue **Flood Reconnaissance** for River Sheppey	**112FWFSHE10A**

River: Sheppey **(RAPID RESPONSE CATCHMENT)**

Gauge: Shepton Mallet Garston Street **(ST 622 437)**

Stage (m)	Flow (m^3/s)	Effect/ Historic flood	Time Lag	Action	Warning Code
0.4 OR Any River Sheppey CATMAX alarm on receipt of 2nd alarm within a 3 hour period				**ACTION:** Issue **Flood Alert** for East Somerset Rivers – if not already issued	**112WAF TESR**
0.4 with rate of rise >0.4 m/h OR Any River Sheppey CATMAX alarm on receipt of 3rd alarm within a 3 hour period				**ACTION CONSIDER:** Issue **Flood Warning** for River Sheppey	**112FWF SHE10A**
0.6 with rate of rise > 0.4 m/h				**ACTION:** Issue **Flood Warning** for River Sheppey	**112FWF SHE10A**
				ACTION CONSIDER RECON: Issue **Flood Reconnaissance** for River Sheppey	**112FWF SHE10A**
1.0				**RESULT:** **Flood Warning** for River Sheppey	**112FWF SHE10A**
1.37				**ACTION CONSIDER:** Issue **Severe Flood Warning** for River Sheppey	**112FWF SHE10A**

Outstation: (Winniford) Chideock RL

Grid Reference: SY4229792818
Postcode: DT6 6JN

Watercourse: Winniford
Recording start date: March 2007

Additional Information:

RAPID RESPONSE CATCHMENT

Outstation Links:

Site Map (Easimap2 Incidents)

Information | Action | Action Consider | Result |

Stage m	Criteria	Information/Other	FIDO Actions	FWDO Actions	Alarms
0.00	17.99 mAOD				
0.67		75% alarm	**ACT**: Review conditions and check rainfall forecast **ACT**: During daylight hours, check with field team leader or ODC if check rounds have been carried out by field team on the West Dorset streams **ACT**: Feed back opinion on threshold of 'Inform FIDO' alarm on Gripe Sheet if it needs modification		**ACT ENHANCE DETECTION & FORECASTING**: 75% Flood Alert Chideock **ALARM**: ACT OPS Inform FIDO Chideock
0.89 AND	1.16 expected & rate of rise >=0.44m/hr		**ACT CON**: Request field team initiates West Dorset streams Flood Patrol to monitor water levels and keeps water courses clear of potential blockages where safe to do so **ACT CON**: Create NIRS for Flood Patrol or add flood information line to existing Flood Alert NIRS **ACT**: Discuss situation on the West Dorset streams with FWDO and ABC	ACT CON FAL 111WAFWDRS CONSIDER ISSUING FLOOD ALERT: West Dorset Rivers and Streams (unless already issued) **ACT CON RECON** Flood Reconnaissance	**ALARM**: ACTCON FAL (WDRS) West Dorset Rivers and Streams Chideock
0.89 AND	1.33 expected		**ACT**: Carry out all actions as per the 0.89 m stage, if not already done	ACT CON FW 111FWFWIN001 CONSIDER ISSUING FLOOD WARNING: River Winniford at Chideock	**ALARM**: ACTCON FW (WIN001) River Winniford at Chideock Chideock
1.16			**ACT**: Carry out all actions as per the 0.89 m stage, if not already done	ACT FAL 111WAFWDRS ISSUE FLOOD ALERT: West Dorset Rivers and Streams (unless already issued) **ACT CON RECON** Flood Reconnaissance	**ALARM**: ACT FAL (WDRS) West Dorset Rivers and Streams Chideock
1.33			**ACT**: Carry out all actions as per the 0.89 m stage, if not already done	RES FW 111FWFWIN001 River Winniford at Chideock **ACT CON RECON** Flood Reconnaissance	**ALARM**: RES FW (WIN001) River Winniford at Chideock Chideock
1.57		Peak level reached 07-Jul-2012 - report of 4 properties flooded to approx 2.5 cm			
1.73			**ACT**: Carry out all actions as per the 0.89 m stage, if not already done	ACT CON SFW 111FWFWIN001 CONSIDER ISSUING SEVERE FLOOD WARNING: River Winniford at Chideock **ACT CON RECON** Flood Reconnaissance	**ALARM**: ACTCON SFW (WIN001) River Winniford at Chideock Chideock

Outstation: (Bride) Burton Bradstock FQ

Grid Reference: SY4884089362
Postcode: DT6 4GG

Watercourse: Bride
Recording start date: November 1992

Additional Information:

RAPID RESPONSE CATCHMENT

AKA Burton Bradstock FG (Swantel), Burton Bradstock RL (Easimap2)

Note: The mouth of the river at Freshwater between June to September is normally allowed to close for access purposes. The mouth blocks frequently between September and June.

Operational notes

Burton Bradstock Gates (Back Hatches): The gates are closed in non-flood conditions. The gates will open to allow flow into the by-pass stream when a high level is reached.

Outstation Links:

Action Plan for Rapid Response Catchments - Burton Bradstock
Alarm Response - Burton Bradstock Back Hatches
Contact - Freshwater Caravan Park (& Other Local Contacts)
Erosion Photographs
Escalation Checklist
Freshwater and Burton Bradstock Coastal Recon Map
Photos
Site Map (Easimap2 Incidents)
Trend View
Webcam - Burton Bradstock Gates

Information | Action | Action Consider | Result |

Stage m	mAOD	Information/Other	FIDO Actions	FWDO Actions	Alarms
0.50	4.17	Possible flooding at Burton Bradstock Mill Hatches with continued rise			**ALARM**: ACT OPS Inform FIDO Burton Bradstock
0.75	4.42	75% alarm			**ACT ENHANCE DETECTION & FORECASTING**: 75% Flood Alert Burton Bradstock
1.00	4.67	Freshwater Beach Holiday Park campsite on 'wet side' of defences may be affected. FWS will warn Freshwater Beach Holiday Park and Bredy Farm Bank full at some locations throughout catchment	**ACT**: Check on Swantel that the gates are operating correctly. If there is an issue, request field team attends site to operate the gates manually **ACT**: Check operation of gates via Burton Bradstock Gates webcam	ACT FAL 111WAFWDRS ISSUE FLOOD ALERT: West Dorset Rivers and Streams (unless already issued)	**ALARM**: ACT FAL (WDRS) West Dorset Streams Burton Bradstock
1.50	5.17		**ACT**: Follow Area Incident Room Protocol to determine status of AIR		
1.60	5.27	Road flooding at Bredy Farm. Risk of flooding at Bredy Saw Mill (owners will be contacted by FWS)	**ACT**: Request field team checks defences **ACT**: Inform FWDO and ABC of Freshwater Beach Holiday Park campsite status **ACT**: Request field team checks and reports back on the state of the outfall at Freshwater Beach Holiday Park **ACT**: If a blockage at the river mouth has occurred or seems likely, contact Freshwater Beach Holiday Park and discuss conditions on site (see Contacts link) **ACT**: Request field team monitors the water levels and keeps watercourses clear of potential blockages where safe to do so **ACT**: Request field team checks gates are operating **ACT**: Check operation of gates from Burton Bradstock Gate webcam	ACT CON FW 111FWFBRD160 CONSIDER ISSUING FLOOD WARNING: River Bride from Long Bredy to Burton Bradstock **ACT CON RECON** Flood Reconnaissance **ACT CON**: Opening the AIR	**ALARM**: ACTCON FW (BRD160) Bride Long Bredy to Burton Bradstock Burton Bradstock
1.70	5.37	B3157 at Burton Bradstock will flood. Garage forecourt may flood			
1.72	5.39	Peak level on 24-Dec-1999 (hydrograph)			
1.73	5.40	Peak level on 09-Nov-1994 (hydrograph)			
1.87	5.54	Peak level on 05-Jan-1998 (hydrograph)			
1.90	5.57	Bank full at telemetry site. Water flowing over fields to base of defences			
1.91	5.58	Bredy Farm Saw Mill flooded. Risk of Burton Bradstock village defence overtopping if further rise of 1m - possibly as little as 2.5 hrs			
2.00	5.67		**ACT**: Request field team checks defences and freeboard **ACT**: Request field team checks accumulation of water behind defences and pump away if necessary **ACT**: Follow Area Incident Room Protocol to determine status of AIR	**ACT**: Request site observations to assist with Severe Flood Warning decision making for Burton Bradstock: Consider feedback from gangs and partners. Refer to Escalation Checklist RES FW 111FWFBRD160 River Bride from Long Bredy to Burton Bradstock (issue if not in force) ACT FW 111FWFBRD161 ISSUE FLOOD WARNING: River Bride at Burton Bradstock **ACT**: Notify ABC of current situation **ACT**: Open the AIR (if not already open) **ACT**: Discuss rate of rise with MFDO	**ALARM**: ACT OPS Burton Bradstock site observations required Burton Bradstock **ALARM**: RES FW (BRD160) Bride Long Bredy to Burton Bradstock; Burton Bradstock **ALARM**: ACT FW (BRD161) Bride at Burton Bradstock, Burton Bradstock

2.21	5.88	Peak level on 01-Jan-2003 (hydrograph)			
2.60	6.27	Risk of Burton Bradstock defences overtopping with continued rise. (Est. rate 400mm/hr)		ACT CON SFW 111FWFBRD161 CONSIDER ISSUING SEVERE FLOOD WARNING: River Bride at Burton Bradstock (unless already issued). Refer to Escalation Checklist **ACT**: Discuss rate of rise with MFDO	**ALARM**: ACTCON SFW (BRD161) Bride at Burton Bradstock, Burton Bradstock
2.93	6.60	100 year design level Peak level May-1979 Peak level 07-Jul-2012 (hydrograph)			
3.05	6.72	Flood defences will overtop. Significant flooding of property in Burton Bradstock		**ACT**: Update ABC of the situation and request ABC to advise RBC that level has been reached	

Appendix B:

Met Office guide to merged radar and raingauge rainfall data

Overview

This product combines quality controlled rain gauge accumulations with the UK radar precipitation composite. This provides a 1km resolution product with the spatial sensitivity of radar data, but with an accuracy that aligns more closely with rain gauge point measurements. The product is designed for precipitation monitoring applications and for input into flood forecasting models.

Product description

The 1km resolution accumulation output is blended with 15-minute gauge accumulations from a network of around 1000 Met Office, Environment Agency and Natural Resources Wales rain gauges across England and Wales. The resulting product maintains the spatial resolution of the radar data but has improved accumulation accuracy due to the inclusion of the rain gauge "ground truth" data.

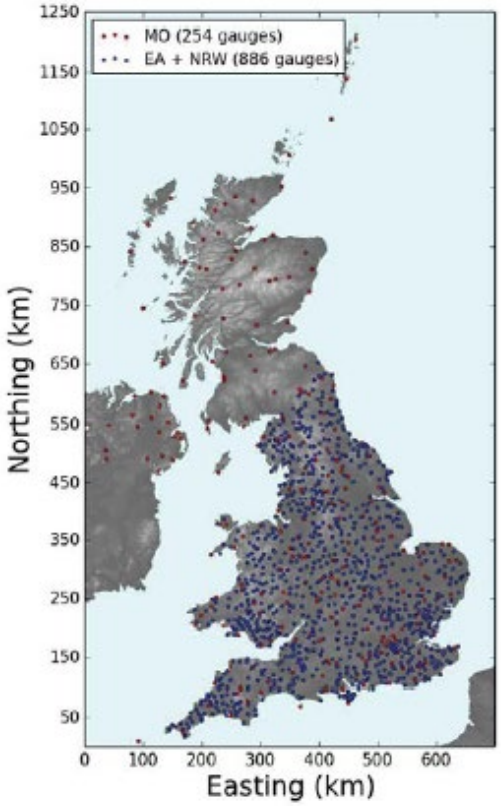

Figure 1 Locations of all gauges available for use in the merged product, sorted by gaugeowner

The gauge radar merged product combines 15-minute gauge and radar accumulations to generate two products:

- A near-real-time product (delivered within 1 hour of the accumulation validity time) designed for hydrological applications; and
- A delayed-mode product (delivered within 24.5 hours) designed for post-event analysis.

The merging region currently covers a 525 km x 580 km region over England and Wales. The British National Grid coordinates for the extremes of the area are as follows:

Region Parameter	Value

Lower-left corner	132500 E, 007500 N
Upper-right corner	657500 E, 587500 N
Area of coverage (E x N)	525 km x 580 km

The size of the merging region minimises the processing time whilst ensuring all landbased pixels within the coverage area are included in the merging process. To assist with accuracy and processing time, the domain is subdivided into four equal-sized, overlapping regions and these are recombined to produce the final merged product.

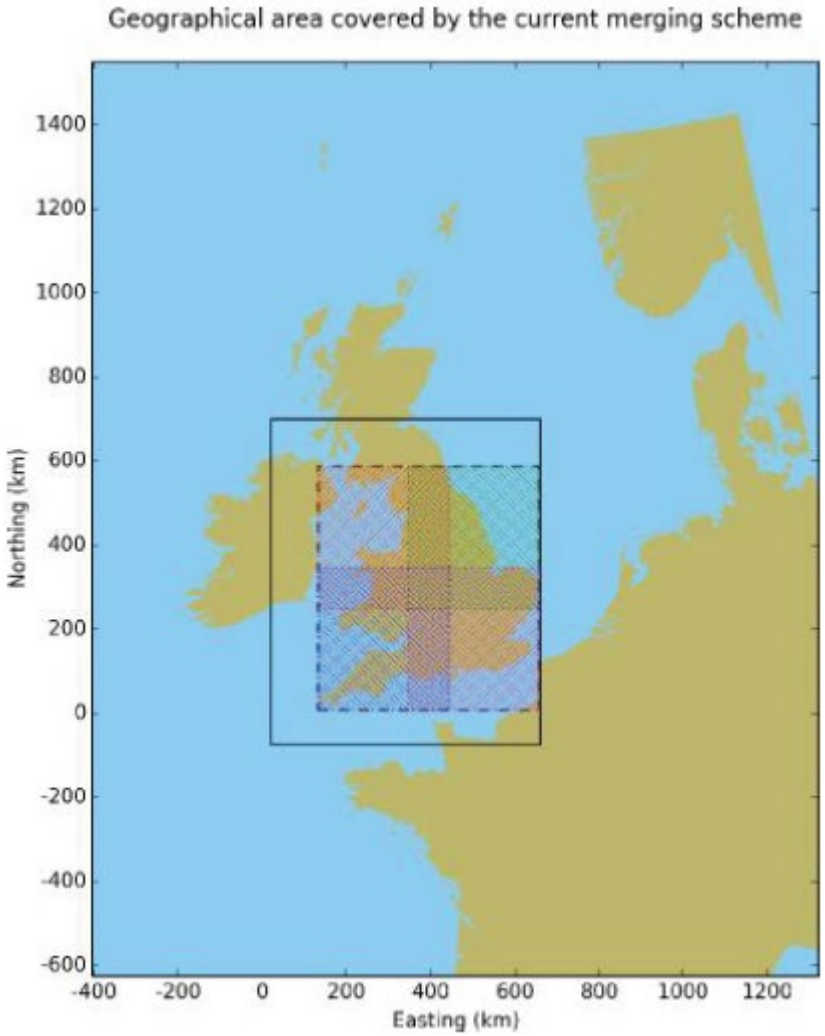

Figure 2 Illustration of the relative regions defined in the merged product.

Figure 2 shows the area covered by the entire UK radar product:

- The Environment Agency cut-out area, corresponding to the radar precipitation rate and radar precipitation accumulation products, shown by the outer black solid line;
- The dashed inner line shows the region over which the merging is performed;
  and
- The coloured hatched lines indicate the four sub-regions that the merging is performed over (this data is then recombined to generate the final composite).

The domain covered by the file (which aligns with other radar-derived products) is slightly larger than the merging region. For pixels outside the merging region, the original radar data is returned.

Characteristics of the merged product

The real-time merged product is intended to be the best near-real-time precipitation accumulation product available. Applications that require an assessment of recent precipitation accumulations can use this product. However, near-real-time polling regimes vary widely across the merging area and so the quality of this product will be strongly dependent on how many rain gauges are available shortly after the validity time.

The delayed merged product is expected to be the optimum quality product (compared to the near-real-time product, and either rain gauges or radar accumulations on their own). This would be most useful for any applications where timeliness is not critical, for example, post event reviews, establishing best estimates of antecedent precipitation estimates and putting events into context.

The following characteristics were noted in the product trial validation:

- In general, the real-time merged product tends to increase the original radar precipitation accumulation estimate;
- The delayed-mode product significantly reduces the error in the measured precipitation accumulation at high precipitation intensities and also has a better detection efficiency than the original radar data;
- Differences between the merged product and the radar data are particularly noticeable in upland areas prone to orographic enhancement; and
- A delayed-mode product is measurably different from the real-time product in regions where the gauges are only polled once or twice a day. However, for the precipitation experienced during the live trial, this was on average limited to less than 0.2mm in a 15-minute accumulation period.

Appendix C:

Discussion Paper

The following are extracts from a discussion paper prepared by Ollie Pollard (Modelling Technical Lead for the EA on this project) to help inform the scope for this project. The extracts provide useful guidance on the tasks required to achieve the stated aims and note potential limitations with the available data.

Rating Curve Uncertainty

Rating Curve uncertainty will be reduced by following the technical guidance LIT 14089 High flow rating curve development using hydraulic models July 2021

Table Appendix C-1 - Summarised Availability of Continuous Flow Measurement Data

Flood Warning Site or flow measurement site	Continuous flow measurement	Date of highest recorded flood	Period of observed or rated flow data
Chideock	No and no spot flows	7th July 2012	No observed or rated flow data
Porlock Parsons Street radar	Yes, nearby but not at flood warning site	30th Oct 2000	Observed flows (20/07/2017-present) No rated flow data
Shepton Mallet Garston Street	Yes, immediately upstream but not on bypass channel.	24th Dec 2013 21st Nov 2016 ***11th Jul 2012 suspect?***	Observed flows (26/07/2016-present) No rated flow data
Sampford Brett	No and no spot flows	29th Apr 2012 25th Nov 2012	No observed or rated flow data
Burton Bradstock flow	Yes, but not at flood warning site	7th July 2012	Observed flows (10/06/2010-present) No rated flow data

Raingauge Coverage

The raingauge coverage requirements are different for winter and summer flood events; this is because winter flood events are often driven by widespread frontal rainfall and summer flood events are often driven by highly localised intense convective rainfall that may not get detected by the raingauge network.

Table Appendix C-2 – Raingauge Record Availability

Flood Warning Site	Raingauge Name	Nearest Raingauge	Period of Record
Chideock (4.9km2)	Lodge House Farm replaced by Marshwood Lodge House Farm	Outside, 4km from centroid	22/04/1995-8/5/2010 30/04/2010-present
Porlock Parsons Street (5.3km2)	Lucott Farm	On boundary, < 1km from centroid	19/08/2008-present
Shepton Mallett Garston Street Bypass (8.3km2)	Doulting	On boundary, < 1.5km from centroid	24/03/2010-present
Sampford Brett (47.2km2)	Quantock Farm, Birds Hill	On boundary (<6km from centroid) Outside boundary (6km from centroid)	04/05/2006-present 28/02/2002-present
Burton Bradstock	Bredy Farm	In catchment (4km from	22/04/1995-present

(45.8km2)		centroid)	

Raingauge coverage is good for winter flooding caused by widespread rainfall.

For summer flood events caused by localised intense convective rainfall, raingauge derived rainfall may fail to detect heaviest rainfall; this is likely to be an issue for Chideock, Sampford Brett and Burton Bradstock. In the Combe Martin rapid response catchment flood forecasting study (JBA, 2016), the report stated that using radar derived catchment rainfall improved the timing error associated with flood events from localised intense rainfall.

~~It is a requirement of this study that two sets of PDM models are developed for each catchment:~~

- ~~One calibrated with raingauge derived rainfall suitable for widespread winter floods; and,~~
- ~~One calibrated with merged raingauge radar derived rainfall suitable for localised intense rainfall (based on the HYRAD radar archive best rainfall observation – 24 hour delay data product (H24) available between 10th Aug 2016 to present date and validated on the less accurate HYRAD radar archive radar rain rate data product (H17) for flood events between 1st Dec 2003 & 13th April 2010 and radar accumulation data product (H19) for flood events between 14th April 2010 and 10th Aug 2016.~~

Data Quality/Availability

It is a recommendation that data availability is defined as the availability of flood events which exceed each flood warning threshold.

Table Appendix C-3 - Data Availability of Flood Events Exceeding Flood Warning Result or Act Thresholds

Flood Warning Site	FW Warning Threshold	Times Exceeded
Chideock	1.33m (Result FW)	3 between 15/03/2007-present
Parsons Street	0.7m (Act FW)	0 between 1/1/1998-present
Shepton Mallett Garston Street Bypass	0.6m (Act FW)	4 between 22/04/2011-present
Sampford Brett	1.4m (Result FW)	4 between 17/05/2004-present
Burton Bradstock	2.0m (Result FW)	2 between 01/11/1992-present

Based on a review of the available data, several key questions to be explored by this study include:

- Is it correct to assume that Hawkcombe Stream at Parsons Street not flood very often?
- Is the Parsons Street 0.7m flood warning threshold representative?
- The velocity variation (0-3 m/s) at the Parsons Street radar flow gauge is significantly more sensitive than the water level variation – Is velocity better correlated with flood impact at Porlock and the Hawkcombe valley?

The lack of crossings of the 0.7m Act FW threshold at Parsons Street between Dec 1992 and the present date, the relatively steep nature of the catchment (gradient of slope or DPSBAR =247m/km) and the relatively high velocity variation (0-3 m/s) means that the river flow may be supercritical for this rapid response catchment.

It is recommended that there is a project task to review the flood warning thresholds at Parsons Street and derive Flood Warning Thresholds based on both river level and river flow and comment on the pros and cons of each option.

Hydrological/Hydraulic Complexity

Table Appendix C-4 – Details of Potential Hydraulic/Hydrologic Complexity

Flood Warning Site	Hydrological complexity	Hydraulic complexity
Chideock	Yes, very small size means that delivering forecast lead time will be a challenge and	n/a

	there is a need to minimise timing error (4.9km2). BFIHOST=0.65 significant baseflow DPSBAR=132m/km (steep)	
Parsons Street	Yes, very small size means that delivering forecast lead time will be a challenge and there is a need to minimise timing error (5.3km2) BFIHOST=0.65 significant baseflow **DPSBAR=247m/km (very steep)** 4 inconsistent observed water level time series not co-located	Yes, the velocity recorder uses different water level data to flood warning site.
Shepton Mallett Garston Street Bypass	Yes, very small size means that delivering forecast lead time will be a challenge and there is a need to minimise timing error (8.3km2) BFIHOST=0.77 significant baseflow DPSBAR=60m/km (not steep) 11 Jul 2012 flood event looks suspect. 7 inconsistent observed water level time series not co-located	Yes, the FW site is on a bypass channel downstream of the velocity recorder.
Sampford Brett	Area=47km2, BFIHOST=0.64 significant baseflow DPSBAR=125m/km (steep)	n/a
Burton Bradstock	Area=46km2 BFIHOST=0.61 significant baseflow DPSBAR=105m/km (steep)	Yes, the velocity recorder uses different water level data to flood warning site.

It is recommended that the inception stage report reviews the lessons learnt from developing a PDM flood forecasting model for the Combe Martin rapid response catchment in North Devon and for the Cheddar rapid response catchment in Somerset. The false alarm ratio of the Combe Martin flood forecast PDM model was reduced by development of a dual-PDM model and timing error was improved through calibration against radar derived catchment rainfall.

The flood forecast inception stage project needs to be aware that the preferred option to consider in the flood forecasting main stage project will be the delivery of a dual PDM model for all five rapid response catchments based on the following requirements:

1. the primary PDM model to simulate the storm event runoff is calibrated on merged radar raingauge derived catchment rainfall available since 10th Aug 2016 and described in Appendix B;
    - It is important to identify flood events due to intense localized rain (ie convective rain) that is not well detected by the raingauge network in addition to flood events caused by widespread winter rainfall and multi-peaked flood events where catchment is saturated prior to 2nd peak;
2. the primary PDM model is validated using raingauge derived catchment rainfall events for the same flood events used for calibration and for rainfall events that precede the 10th Aug 2016;
3. sensitivity analysis is carried out to assess the impact on amplitude and timing error of the flood forecast due to using catchment rainfall based on merged radar data and based on raingauge data.
4. the secondary PDM model to simulate the seasonally varying baseflow is calibrated on raingauge derived catchment rainfall.

The flood forecast inception stage project also needs be aware that the preferred option to consider in the main stage flood forecast project will be the development of a hydraulic model & associated cross-section survey data to predict water levels at the Shepton Mallet Garston Street Bypass flood warning site from the upstream PDM model at Shepton Mallet Garston Street.

It is anticipated that well calibrated PDM models at Chideock, Parsons Street and Shepton Mallet Garston Street Bypass flood warning sites will deliver 1 hour of accurate flood warning lead time in the winter. Well

calibrated PDM models at Burton Bradstock and Sampford Brett will deliver 1.5 hours of accurate flood warning lead time in the winter

It will be very challenging, if not impossible, for the PDM rainfall-runoff models to deliver accurate flood warning lead time for flash flood events caused by severe convective rainfall; these flash flood events occur mainly in June,July and August.

During flash flood events due to severe convective rainfall, it is recommended that the probabilistic radar rainfall nowcast alerts configured in the Incident Management Forecasting System (IMFS) for high priority rapid response catchments (RRC) are used in conjunction with the PDM models to deliver at least one hour flood warning lead time in the Chideock, Parsons Street and Shepton Mallet Garston Street high priority RRC's and at least two hours flood warning lead time in the Burton Bradstock and Sampford Brett RRC's.

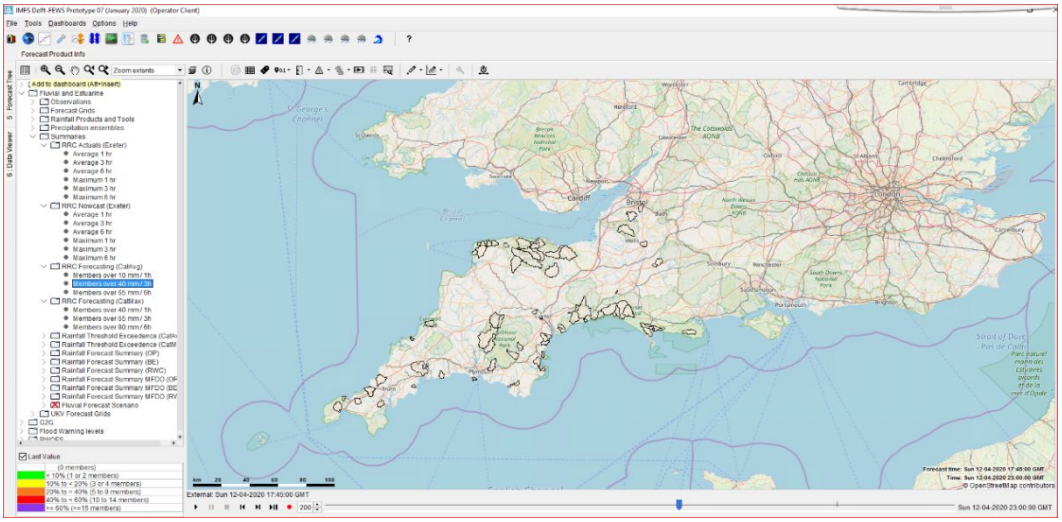

Figure Appendix C-1 - IMFS screenshot showing the location of high priority RRC and probabilistic radar nowcast alerts for 40mm/3hr occurring in next 6 hours

It is recommended that an internal project is set up to identify the MFDO and FWDO actions associated with the following radar rainfall forecast likelihoods at both the 1, 2 and 3 hour lead times:

- <10% (1-2 members) very low
- 10%-20% (3-4 members) low
- 20-40% (5-9 members) medium
- 40-60% (10-14 members) high
- >60 % (15-24 members) very high

Note that the proposed nationally consistent radar nowcast rainfall depth-duration alert thresholds will be: 40mm/3hr and 65mm/6hr CatAvg and 40mm/1hr, 65mm/3hr and 80mm/6hr CatMax and could be triggered with between 1 to 6 hours lead time.

It is recommended that the sensitivity to extreme rainfall of the best performing PDM model and the PDM model calibrated with raingauge derived rainfall for each rapid response catchment is assessed under both "dry" typical summer and "wet" typical winter initial starting conditions for the 40mm/1hr, 40mm/3hr, 65mm/3hr, 65mm/6hr and 80mm/6hr rainfall depth-durations. Areal reduction factors will be applied to the Catmax thresholds (40mm/1hr, 65mm/3hr and 80mm/6hr). This sensitivity test will deliver a set of water level hydrographs with all the flood warning thresholds and a tabular assessment of the cumulative time taken from crossing the 75% Flood Alert threshold (i.e. time zero) to crossing the Act or Result Flood Warning thresholds and Actcon Severe Flood Warning thresholds.

If it is important to increase the flood warning lead at Burton Bradstock above 1.5 hours, then it is recommended that a request is submitted to the Incident Management Forecasting System (IMFS) configuration team to add the Burton Bradstock medium priority rapid response catchment polygon to the set of high priority rapid response catchment polygons configured in the IMFS.

Technical risk assessment, calibration event selection and agreement of calibration target ranges (defined in pages 8-13 of the RT model development guidance)

A key source of uncertainty/error is the number and magnitude of observed flood events relative to flood warning thresholds and the record length.
In order to carry out the technical risk assessment, the bank full and flood warning thresholds need to be derived before calibrating the PDM models in order to provide context and to assess the flood event data availability relative to each flood warning threshold.

At least 10 calibration flood events need to be identified and these need to be primarily above bank full flows, and cover the range of levels where key flood warning thresholds are reached. Some flood events due to heavy rainfall which remain in-bank and do not cross thresholds are also required.

A score should be derived for each of four contributing components of modelling uncertainty/'challenge' following the inception stage data/catchment review:

1. rating curve,
2. raingauge coverage,
3. data quality/availability (i.e. flood events that exceed the flood warning thresholds),
4. hydrological / hydraulic complexity.

The Environment Agency has deliberately not defined the criteria to achieve very good, good, fair or poor status for these four sources of uncertainty. Justification should be provided by the model developer for the choice of scores, within the model documentation; and score agreed with the Environment Agency, before proceeding with model calibration.

For example, for winter flood events caused by widespread frontal rainfall, may be accurately detected by a raingauge that is not located in the catchment. However, for summer/early autumn flood events due to localised intense thunderstorms or embedded convection, there will be a requirement to have a raingauge in the catchment in order for the heavy rain to be accurately detected.

It is an opinion that the small, rapid response catchments defined in this project will be vulnerable to flooding due to both summer and winter heavy rainfall events. There are quality issues with both radar derived catchment rainfall and raingauge derived catchment rainfall.

There is large random error in most of the weather radar rainfall data product due to the practice by the Met Office of applying a raingauge adjustment over the whole of the radar domain and allowing it to vary on an hourly basis. Raingauges are sometimes not located within the small catchments identified by the FWEP project which means that they will not detect localised intense rain that falls in the summer and is sometimes responsible for severe flash flooding.

The best quality grid radar rainfall dataset suitable for accurately detecting localised intense rain will be the merged radar raingauge rainfall dataset available in the Environment Agency HYRAD radar rainfall archive since 10th Aug 2016 and known as "best rainfall observation – 24hr delay (H24)"; more information on this dataset is in a presentation on "Merging rain-gauge and radar data" by S. Jewell, Feb 2014 (downloaded from the internet on 17th Sep 2020).

The Environment Agency was impressed with the quality of the PDM modelling carried out for the Combe Martin rapid response catchment and feel that the lessons learnt from this project could be usefully applied to the Wessex rapid response catchment flood forecasting project; A 5 page extract of the PDM modelling approach for the Combe Martin Flood Forecasting project, (JBA, April 2018), will provide useful background information for the project *Consultant*. If there is a risk of flash flooding in the small rapid response catchments during the summer months, then it is essential that they are calibrated using the merged radar rainfall data described above.

Appendix D:

In accordance with Schedule 19 of the conditions of the contract, the *Consultan*t shall adhere to the Environment Agency's Employers Information Requirements (EIR) framework level minimum technical requirements.

All *Clien*t issued information referenced within the Information Delivery Plan (IDP) requires verifying by the *Consultant* unless it is referenced elsewhere within the Scope. https://www.asite.com/login-home

The *Consultant* shall register for an Asite Account and request access to the project workspace to view the IDP.