Dŵr Cymru
Welsh Water

Developer Services Hydraulic Modelling Report

135-N156-Land at New Brighton Road, Mold – Mold WwTW - 00491

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Contents

Figures

Tables

Executive Summary

RPS were appointed in November 2018 to undertake a Hydraulic Modelling Assessment (HMA) for a proposed development of 103 homes on land at New Brighton Road, Mold, in the north east of the Mold Wastewater Treatment Works (WwTW) sewerage catchment. Dŵr Cymru Welsh Water (DCWW) has advised that the existing public sewerage system is unlikely to have sufficient capacity to accommodate the additional flows generated by the development. The proposed development has been assessed using one connection point, at manhole SJ25653408, just south of the existing Cae Isa estate to the north of the A5119 in New Brighton. The connection will be via a gravity sewer in the south east of the development.

Prior to carrying out the hydraulic modelling assessment the model was upgraded as part of the Mold Sustainable Drainage Plan (SDP). As part of this project, a full flow survey, along with additional asset, manhole and impermeable area surveys, were proposed in key areas of the catchment. The flow survey was undertaken between January and May 2019, with the flow survey including five monitors in the vicinity of the proposed connection point for the development and the key assets downstream of the development. The surveys were supplemented for the purposes of the HMA with a manhole survey, an outfall survey, a sewage pumping station (SPS) survey at Mold Argoed SPS and an impermeable area survey. The model was then verified based on the five flow monitors from the 2019 flow survey.

There were several assumptions and limitations in the model. The pumping station at Argoed SPS has been modelled as having a duty-assist pumping regime as one of the three pumps was not operating during the flow survey, whilst the pumping regime at Argoed SPS varied between duty-assist and duty-standby during the survey; this may not be representative of the future operation of SPS if the pump is fixed. Additionally, the modelling of the inlet works at the WwTW has not been updated since 2005 and does not represent any changes in operation since then. The model has also only been verified to the five monitors impacted by the flows from the development.

The hydraulic assessments revealed that the development could cause increases in predicted flooding in several manholes downstream of the development, as well as an increase in spill volume at Mold Old St David's Lane/Bridge St NRA Combined Sewer Overflow (CSO), Argoed SPS Emergency Overflow (EO) and Bryn Awelon CSO.

Three options have been developed to resolve the predicted detriment. These are briefly outlined below.

- Option 1 - Additional online storage in New Brighton. This option requires an upgrade of one section of sewer just downstream of the connection point and additional 230 m^3 of storage at Bryn Awelon CSO.
- Option 2 - Removal of 0.174 ha impermeable area from properties around New Brighton Road.
- Option 3 - This option requires an upgrade of one section of sewer just downstream of the connection point and the removal of 0.189 ha impermeable area from properties around New Brighton Road and the Flintshire County Council offices.

Estimated costs are provided for each of the options in Section 7 of this report.

1 Introduction

1.1 Appointment

RPS were appointed in November 2018 to undertake an HMA for a proposed development of 103 homes on land at New Brighton Road, Mold, in the north east of the Mold WwTW sewerage catchment.

DCWW has advised that the existing public sewerage system is unlikely to have sufficient capacity to accommodate the additional flows generated by the development. An HMA has been undertaken to establish whether a point of adequacy exists within the network. The purpose of this HMA is to quantify the effects that the development would have on the existing combined sewer network performance and identify notional solutions to resolve any potential detriment and consider further recommendations.

This report presents the findings of the HMA for the proposed New Brighton Road development.

1.2 Development Site

• **Size** – Approximately 3.51 hectares.

• **Location** – South of New Brighton Road and North of the A5119 in New Brighton, Mold, Flintshire.

• **Topography** – The site is relatively flat, with a very gentle slope from west to east. The site lies between approximately 140mAD and 145mAD, with the highest elevation at the west of the site and with New Brighton Road to the north east of the site being the lowest point.

• **Previous/ Current Usage** – The land to be developed is predominantly greenfield, previously used for agriculture.

• **Proposed Usage** – The proposed development will be residential.

• **Sewerage Details** – DCWW records show an existing surface water sewer just within the north of the proposed development site.

• **Connection Type** – The connection will be via a gravity sewer in the south east of the site to a connection point just south of the existing Cae Isa estate. The connection point has been proposed as manhole SJ25653408.

• **Phasing** – No phasing will be undertaken in this development.

• **Surface Water** – Surface water drainage to be adopted by Local Authority via SABS

1.3 Background Information

The proposed development is within the Mold WwTW catchment.

The model was originally built and verified as part of an AMP4 UID strategy in 2005. The model has subsequently been updated and re-verified as part of AMP5 flooding investigations.

2 Land Usage

The site covers an area of approximately 3.51 hectares, according to plans of the development received from the developer. An existing surface water sewer runs to the north of the development and will be used as the discharging sewer for the surface water from the development at manhole SJ25652601. There will be an attenuation pond in the north of the development with a flow control limiting discharges to the existing surface water sewer.

The development will not be phased and will comprise of 103 units.

Total Development		Domestic Populations	
Type	Number of Units	People per Dwelling	Number of Residents
Housing	103	2.5	258
		Total	258

Table 1 – Proposed Domestic Development Contribution – Total

Note: Population dwelling density of 2.5 used following the DCWW HMA specification as information relating to dwelling sizes was unavailable.

2.1 Proposed Connection Details

One connection point has been assessed for the development:

Connection Point: Connection of the development to manhole SJ25653408 through a gravity sewer.

The receiving sewer is a 150 mm diameter gravity sewer that joins the trunk sewer close to the A5119, and then runs south west towards Mold WwTW.

See Figure 1 for a plan of the development site and proposed connection points. Based on the development details provided and a desktop assessment of the site topography, flows from the development will connect by gravity to the connection point.

A simplified network within the proposed development has been modelled for this HMA. Should further details of the drainage within the proposed development be available, this could impact on the results of this HMA.

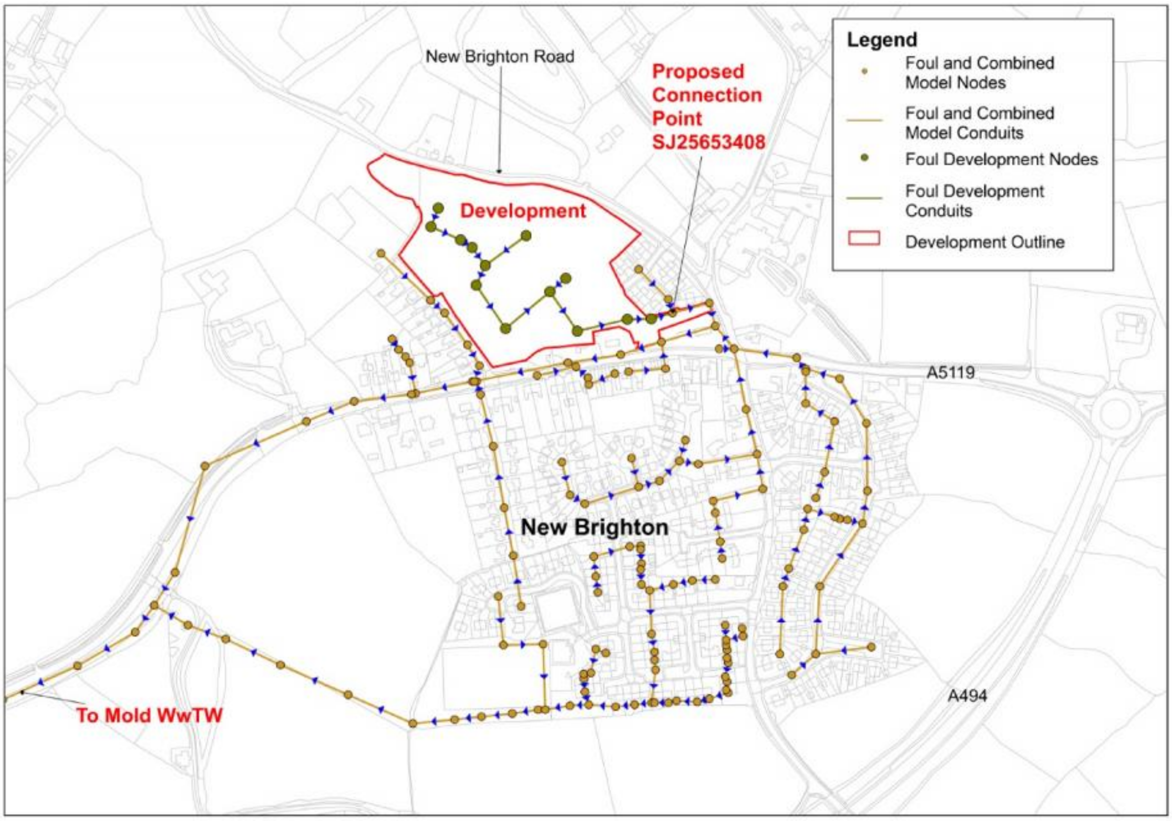


Figure 1 – Development Site Overview Plan – Including Connection Point.

3 Developed System Modelling

3.1 Model Build / Enhancement

The proposed development is within the Mold WwTW catchment. The model was originally built and verified as part of an AMP4 UID strategy in 2005. The model has subsequently been updated and re-verified as part of AMP5 flooding investigations.

RPS updated the Mold model during early 2019 as part of the Mold SDP project. As part of Stage 1 of the SDP, a detailed model audit was undertaken by RPS to assess the accuracy and reliability of the model.

As part of the SDP, a flow survey, along with additional asset, manhole and impermeable area surveys (IAS), was undertaken in key areas of the catchment. The flow survey was undertaken between January and May 2019, with the flow survey including five monitors in the vicinity of the proposed connection point for the development and the key assets downstream of the development. Generally, the asset and manhole surveys being undertaken for the SDP were considered to provide sufficient confidence for the HMA. One additional manhole survey was required for the HMA at the proposed connection point, a survey of Mold Argoed sewage pumping station (SPS) was undertaken to improve confidence in the modelling of the asset and an IAS was completed to increase confidence for surface water removal opportunities for any proposed solutions.

Data to assist the model build / enhancement was obtained from the following sources:

- Existing DCWW Geographical Information Systems (GIS).
- Manhole surveys
- Asset surveys
- Impermeable area surveys
- Engineering drawings provided by DCWW/developers.
- Flow surveys
- Site visits

The following sections detail the infill data used to build / enhance the hydraulic model and the other model build activities undertaken to ensure the model was suitable to undertake the HMA.

3.1.1 STC25 Manhole Survey

As part of this study additional manhole surveys were commissioned to supplement the existing DCWW GIS data. This included a manhole survey at the proposed connection point, and two of the manholes and the outfall at Argoed SPS.

This survey data was identified with the InfoWorks flag “SA” and notes included within the model.

3.1.2 SPS Survey

As part of this study a SPS survey of Mold Argoed SPS was undertaken to improve confidence in the modelling of the asset. The survey included photos, dimension and drop test of all the working pumps.

The SPS has 3 pumps and is designed to operate with a rotating duty-assist-standby pumping configuration between the 3 pumps, with the assist pump operating with a start level 150mm higher than the duty pump.

During the survey, it was found that one of the pumps was not operating. During a subsequent site visit, the surveyor suggested that the pumps are currently operating in a duty-standby pumping configuration, and Argoes SPS was therefore initially modelled with one of the two modelled pump links set to discharge at 0 l/s (i.e. only one operational pump was modelled). However, the results obtained in the model were not matching the available telemetry data and it was confirmed by operations that the SPS was operating as a duty-assist.

This survey data was identified with the InfoWorks flag "SA" and notes included within the model.

3.1.3 Impermeable Area Survey

As part of this study an IAS was undertaken to increase confidence in flows from impermeable areas draining into the network downstream of the proposed development and to find opportunities for surface water removal solutions. The IAS consisted of 7 areas downstream of the development, with a total area of 5.5 ha surveyed for the HMA.

This survey data was used to improve the existing impermeable area layer, which was used to represent runoff areas in the upgraded model subcatchments.

This survey data was identified with the InfoWorks flag "IA" and notes included within the model.

3.1.4 Summary of Model Build / Enhancement Activities

In addition to updates to the model from the surveys undertaken as part of the HMA, the model was also improved using existing and SDP manhole and ancillary surveys, as well as as-built plans of key ancillaries where available. The model was also updated using additional information provided by the newest version of the DCWW sewer records to include any recent changes to the Mold sewer network any additional sewers connecting from recent developments. In some cases, the drainage layout was known but invert and cover levels were not, and so ground levels were obtained using LiDAR data and then invert levels were interpolated.

For the purposes of the HMA, one development at Argoed Service Station, New Brighton, which was under construction during the flow survey, was included in the baseline model for the HMA.

3.2 Verification

A short-term flow survey that was carried out in early 2019 was used to verify the model. There were 21 flow monitors (FMs) installed as part of this survey, however for the HMA, 5 were used for verification these were in the sewers most likely to be affected by the proposed development, and are summarised in Table 2. 4 of the flow monitors were installed on the trunk sewer running from the development towards the treatment works on the eastern side of the river, with a fifth installed on the alternative route to the treatment works on the west of the river. The location of the flow monitors can be seen below in Figure 2.

The flow survey began on 29/01/2019 and was terminated on 08/05/2019, a total duration of 99 days.

The performance of the system was initially verified for dry weather flows. The model was then run using three storm events observed during the flow survey that achieved the specific requirements stipulated in the CIWEM UDG Code of Practice.

The resulting model predictions of the flow, depth and velocity were compared to those observed during the flow survey. Where significant differences were found between predicted and observed data, justifiable amendments to the model were made, especially where previously interpolated levels had been used. The model was then refined by a process of continuing iteration until reasonable verification plots were obtained.

Flow/Depth Monitor	Manhole Ref.	Model Conduit Ref.	Pipe Size (mm)	Date Installed	Date Removed
FM01	SJ24658102	SJ24658202.1	180	31/01/2019	08/05/2019
FM04	SJ24642705	SJ24642802.1	225	30/01/2019	25/03/2019
FM09	SJ24634404	SJ24634408.1	600	30/01/2019	08/05/2019
FM10	SJ24638801	SJ24638802.1	600	31/01/2019	08/05/2019
FM21	SJ24642803	SJ24642801.1	225	25/03/2019	08/05/2019

Table 2 – Flow Monitor Location Details.

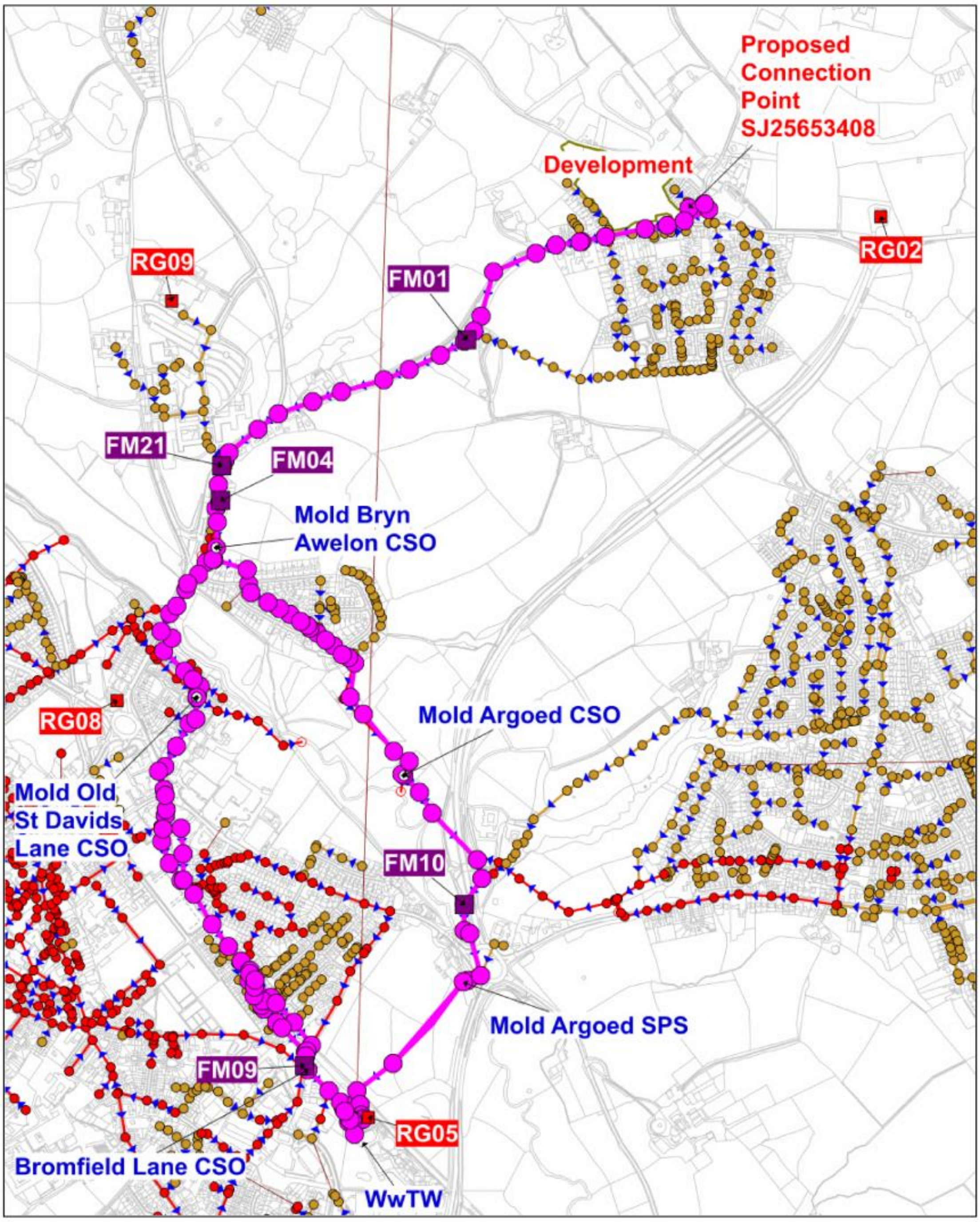


Figure 2 – Flow Monitor & Rain Gauge Location Plan

3.2.1 Dry Weather Flow Verification

Two dry days were selected for the Dry Weather Flow (DWF) verification:

- **DWF 1** – 17/02/2019 at 00:00 to 18/02/2019 00:00, 24 hours (Sunday).
- **DWF 2** – 22/04/2019 at 00:00 to 23/04/2019 00:00, 24 hours (Monday).

The following notes summarise changes made to achieve verification at each of the key monitors.

FM01

Throughout both DWF days, there are very low flows observed at this flow monitor. There is a good match between the predicted and observed velocity and peak flows during both days, with the observed and predicted flows showing a good match in diurnal profiles. The model is over-predicting the total volume, which is likely to relate to low flows causing poor velocity data. There is a reasonable match between the observed and predicted depths, although the model is slightly over-predicting depths on both DWF days.

FM04

The monitor was only installed during DWF day 1, and during the period that the monitor was installed heavy ragging was frequently observed on the monitor. As a result, velocity and flow readings were compromised and the monitor has been verified to depths only. The modelled depth profile initially differed from the observed depth profile, which was corrected by changing the trade profile and reducing the trade flows in the subcatchments covering County Hall to the north west of the monitor. Additionally, the wastewater profile was adjusted to reduce the residential flows in the early morning hours. The model slightly over-predicts the depths at this monitor but shows a better comparison with the observed depth profile.

FM09

For DWF day 1, the model under-predicts flows and depths, however the shape of the predicted flow profile compares well with the observed diurnal profile. For DWF day 2, the model provides a much better prediction of the flow and peak depths.

FM10

For DWF day 1 and DWF day 2, the model under-predicts flows and depths, however ragging was frequently observed at the monitor during DWF, which may have affected the quality of the data at the monitor. During DWF day 2, the observed data from the monitor shows signs of corruption and grease was observed on the sensor during the succeeding site visit. Despite these issues, the profile of flows compares well with the observed profile, and the volume of flows compares well during DWF day 2.

FM21

The monitor was only installed during DWF day 2, and during the period that the monitor was installed heavy ragging was frequently observed on the monitor. As a result, velocity and flow readings were compromised and the monitor has been verified to depths only. Initially the model was under-predicting depths when compared with the observed data. As for FM04, the trade profile was changed and the trade flows reduced in the subcatchments covering County Hall to the north west of the monitor. The model slightly over-predicts the depths at this monitor but shows a better comparison with the observed depth profile.

3.2.2 Storm Flow Verification

Three storm events were selected for storm flow verification. These are detailed in Table 3 below. The peak intensity is the peak intensity from the most applicable rain gauge. Verification changes are summarised below.

Event	Date	Weekday	Start Time	End Time	Duration (hrs.)	Peak Intensity (mm/hr.)
A	12/03/2019 – 14/03/2019	Monday - Wednesday	00:00	00:00	48	24
B	24/04/2019 – 25/04/2019	Wednesday - Thursday	12:00	06:00	6	6
C	07/02/2019 – 10/02/2019	Thursday - Sunday	00:00	00:00	72	6

Table 3 **– Flow Survey Storm Events**

FM01

Due to issues with the installation of the monitor, FM01 could only be verified to Events A and B. The model initially overpredicted peak flows and depths yet under-predicted the volume of flow at FM01 during Event A, whilst underpredicting peak depths but over-predicting peak flows and the volume of flow during Event B. In the hydrograph of both storms, slow response flows were observed. The verification was improved by including ground infiltration subcatchments in areas where infiltration was observed upstream of the monitor.

FM04

The monitor was only installed during Events A and C, and was faulty during Event C, so has only been verified to Event A. During the flow survey, heavy ragging was frequently observed on the monitor and as a result, velocity and flow readings were compromised, therefore, the monitor has been verified to depths only. Initially the model slightly under-predicted depths at the monitor, despite good confidence in the model near the monitor with most of the surrounding manholes modelled from survey data. However, there is low confidence in the flows from County Hall to the north west of the monitor, and in the current condition of the pipes surrounding the monitor. Following discussions with DCWW, sediment was added to the model surrounding the monitor and base flow was added to the subcatchments close to County Hall to improve verification at FM04. With these adjustments, the model-predicted depths provide a better comparison with the observed depths during Event A.

FM09

The monitor was verified for all three events during the flow survey. For all three events, the model initially under-predicted peak flows, whilst the peak depths were under predicted for Events A and C. The impermeable area was increased upstream of the monitor between the bifurcation close to Bryn Awelon CSO and FM09, which improved the verification of the peak flows and depths at the monitor. However, during Event A the model over-predicts depths, whilst the model under-predicts depths in Event C. There is low confidence in the modelling of the WwTW in the model, and it is possible that the operation of the inlet works can cause the variation in depths at FM09. Nevertheless, there is a good comparison between model predicted flows and observed flows at FM09.

FM10

FM10 was installed for all 3 events, however due to grease on the flow monitor during Event B, the model was only verified to Events A and C. Initially the model significantly under-estimated predicted volumes at this monitor during both events, and the peak depths were not matching the observed peaks.

By using telemetry and surveys at the downstream Argoed SPS, it was noted that during the flow survey, the operation of the pumps at Argoed SPS differed from the surveyed conditions, with the two operating pumps varying between duty-assist and duty-standby pumping regimes during the survey. During Events A and C, DCWW telemetry suggested that the pumps were operating as duty-assist, and the model was adjusted to match this regime to improve the predicted flows at FM10 during these events. Additionally, ground infiltration was also applied upstream of FM10 to improve the confidence in predicted storm flows. Observations by the survey crew during the flow survey interim site checks also noted that when compared with manual observations, the monitor was frequently over-estimating depths and flows, due to issues with the monitor during the survey. The modelled depths at the wet well at Argoed SPS compared well with the observed depths from DCWW telemetry at the wet well, suggesting that the high depths and flows observed at the monitor were likely caused by these issues with the monitor. Hence there was low confidence in the peak observed flows at FM10, and the model is considered to be verified given the limited confidence of the flow survey data.

FM21

The monitor was only installed during Event B, and heavy ragging was frequently observed on the monitor during the flow survey which compromised velocity and flow readings, so FM21 has only been verified to depths during Event B. Initially the model slightly under-predicted depths at the monitor, despite good confidence in the model near the monitor with most of the surrounding manholes modelled from survey data. However, there is low confidence in the flows from County Hall to the north west of the monitor, and in the current condition of the pipes surrounding the monitor. Following discussions with DCWW, sediment was added to the model surrounding the monitor and base flow was added to the subcatchments close to County Hall to improve verification at FM21. Similar to FM04, these adjustments have increased the model predicted depths, and to provide a better comparison with the observed depths during Event B.

3.2.3 Changes between verified model and baseline model

Once the model was verified to the 2019 flow survey data, changes were made to the modelled network.

The model was modified to provide a clean system to test the hydraulic capacity of the network, with any sediment included in the model removed.

3.3 Historical Flooding Verification

A review of DCWWs flooding incident databases has been undertaken to determine where historical reports of flooding have been recorded within the catchment.

Design storms based on 2, 5, 10, 20 and 30-year return periods were simulated with the clean verified model to determine where the model predicts flooding. A summary of the flooding predicted by the model is shown below in Table 5 and , including comparisons with DCWW's Definitive Flooding List (DFL).

The model predicts flooding in several areas of interest along the trunk sewer downstream of the proposed development. These areas can be seen in Figure 3 which highlights nodes with a predicted flood volume of more than 10 m^3.

The area of most significant predicted flooding is at Argoed Hall Lane. Whilst there are no properties on DCWW's hydraulic flooding register adjacent to the predicted flooding, there are five properties near to Argoed Hall Lane where flooding has occurred due to hydraulic overload, several with multiple reported historical flooding instances. The model suggests that this area floods in all the tested 30-year return period storms in both summer and winter, with the highest flood volumes seen in the summer M30-120 storm. The flooding in the model appears to originate from hydraulic overload in the line downstream. However, the predicted flooding in this area may be attributed to low confidence in the modelling at the flooding manholes SJ24638801 and SJ24638702, and there is limited confidence in the modelling of the network surrounding the DFL properties.

Another area of model predicted flooding is observed at Ffordd Argoed. Whilst there are no properties on DCWW's hydraulic flooding register immediately adjacent to these model nodes, there is a reported OC flooding from a blockage at manhole SJ24644403, and 3 properties registered as at risk of hydraulic flooding close to these nodes. The flooding in the model appears to originate from hydraulic overload in the line downstream. There is reasonable model confidence in this area, with the modelled inverts inferred from upstream and downstream, however the gradient of main sewer at manhole SJ24644403 may be steeper, and some manholes may be sealed or buried. Further investigation in this area is recommended.

Just upstream of Ffordd Argoed, flooding was predicted at Bryn Awelon, adjacent to 2 properties on the hydraulic flooding register. Similar to the flooding at Ffordd Argoed, the predicted flooding appears to originate from hydraulic overload in the line downstream, and floods at these nodes as the modelled ground-to-invert depth is lower than surrounding nodes.

Just upstream of Bryn Awelon CSO, flooding is predicted at Cwrt Rhyd Galed, adjacent to a property on the hydraulic flooding register. Flooding is predicted at manhole SJ24642803 in 15 to 2160-minute duration 30-year return period summer storms and 15 to 960-minute duration 30-year return period winter storms. The predicted flooding appears to originate from hydraulic overload in the line downstream, and floods at this manhole because the ground-to-invert depth is less than one metre.

In Cae Isa, close to the connection point of the development, flooding is predicted adjacent to a property on the hydraulic flooding register. Flooding is predicted at manhole SJ25653507 in 15 to 2160-minute duration 30-year return period summer storms and 90 to 720-minute duration 30-year return period winter storms. Similarly, flooding is predicted nearby at Moor Croft adjacent to a DFL property. Flooding is predicted at manhole SJ25655304 in 15 to 2160-minute duration 30-year return period summer storms and 90 to 720-minute duration winter storms. The predicted flooding at both locations appears to originate from hydraulic overload in the trunk sewer downstream of New Brighton, and floods at manhole SJ25653507 and SJ25655304 as the modelled ground-to-invert depth at both nodes is lower than the surrounding nodes.

Model predicted flooding is also observed at several nodes on or close to the bifurcated sewer between Mold Old St David's Lane/Bridge St NRA CSO and Mold Entrance/Bromfield Lane CSO. These areas include Chester Street, Grosvenor Street, Tyddyn Street, Woodlands Close, Wood Green and Ffordd Pentre. There is no historical hydraulic flooding in these areas, with only a few other cause flooding incidents reported nearby to these locations. However, there is low confidence in flows from this area, including pipe sizes and invert levels. All these areas only contribute to the western bifurcation route from the developments to the works, from which flows were verified at flow monitor FM09. In addition, the flooding at these nodes is not predicted to increase with the inclusion of the development.

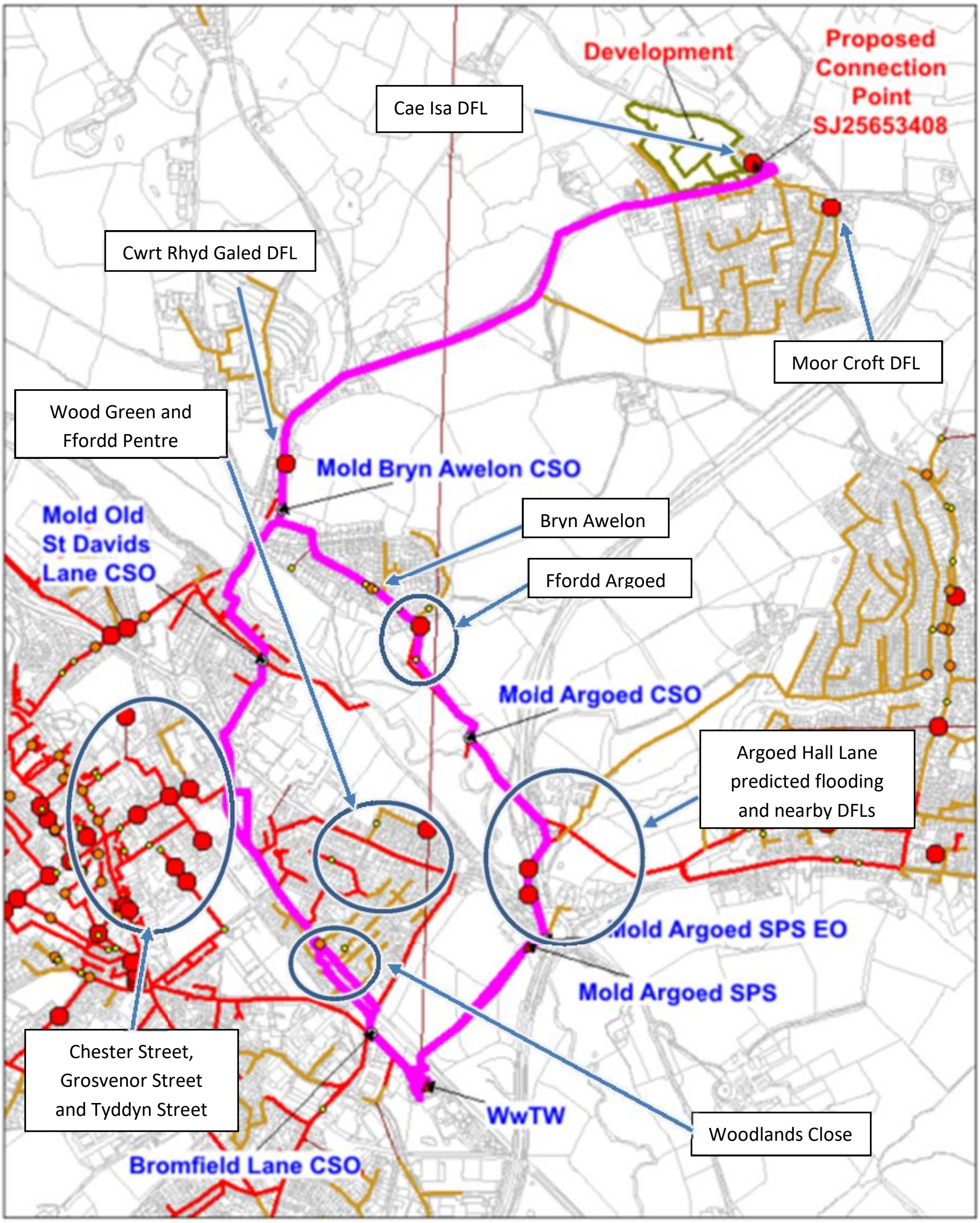


Figure 3 –Historical Verification Map with Predicted Model Flooding Areas.

3.4 Historical Spill Frequency Verification

A typical year rainfall dataset was also run to determine CSO spill frequency. This was compared to DCWW telemetry data, where available, and also to the previous model, before the updates outlined in section 3.1 were completed. A summary of the results of the typical year rainfall CSO assessments can be seen in Table 4.

CSO Name	Current Spill Count	Current Spill Volume (m^3)	Telemetry 2018
Bryn Awelon CSO	7	440	24
Argoed CSO	0	0	1
Argoed SPS EO	65	38,259	4
Mold Old St Davids Lane/Bridge St NRA CSO	8	727	2
Mold Entrance/Bromfield Lane CSO	51	25,482	23

Table 4 – Current model-predicted spill frequency and volume in a 'typical' year

Four CSOs and one EO are considered important for the HMA: Bryn Awelon CSO, Argoed CSO, Argoed SPS EO, Mold Old St David's Lane/Bridge St NRA CSO and Mold Entrance/Bromfield Lane CSO.

Telemetry data showed that Bryn Awelon CSO spilled 24 times during 2018 and model predictions indicate 7 spills. The reduction in the number of spills predicted in the clean system model can be explained by operational issues during that year.

At Argoed CSO, telemetry data showed that there was 1 spill during 2018. The baseline clean system model used for the HMA predicted 0 spills in a typical year. The difference in the number of spills is likely to be caused by the rainfall in 2018 differing from the 'typical' year of rainfall data applied to the hydraulic model used for this HMA. Hence, the verification and the modelling of the CSO are considered acceptable and this CSO could be adequately assessed for any detriment caused by the new development.

At Argoed SPS EO, telemetry showed 4 spills during 2018. However, 65 spills are predicted at the EO in the baseline clean system model. The high number of spills predicted is caused by the modelling of the operation of the pumps at Argoed SPS. The modelled operation is based on the existing survey and may increase the number of spills caused by flows backing up from the SPS due to a limited pass forward flow caused by only two of the three pumps operating. This may not be representative of the operation as the SPS during 2018. Additionally, there is low confidence in some of the invert levels of pipes in the model close to the EO, which may cause an increase in the spill number and volumes at the EO. Nevertheless, there is reasonable confidence in the flows upstream of the EO at FM10, and in the depths at the SPS wet well from during the flow survey.

Telemetry data showed that Mold Old St David's Lane/Bridge St NRA CSO spilled twice in 2018. The baseline clean system model used for the HMA predicted a slightly higher number of spills, with 8 spills in a typical year. The CSO is modelled based on a 2005 survey, and the invert to spill is identical to that shown on the installation sheet for the telemetry monitor. However, it is possible that since then the orifice plate on the continuation pipe may have been removed, increasing the pass forward flow and reducing the number of spills when compared with the existing model. The confidence in the number of spills predicted in the model may also be limited by the low confidence in the invert levels and pipe sizes upstream and downstream of the CSO. Further surveys are recommended to increase the confidence in the predicted number of spills at the CSO.

The Mold Entrance/Bromfield Lane CSO is just upstream of Mold WwTW, and telemetry data shows that it spilled 23 times in 2018. In the current clean model, 51 spills are predicted at the CSO. There is good confidence in the flows at flow monitor FM09 upstream of the CSO, and the CSO is modelled based on as built plans and a CSO survey from 2011. The model predicts that flows are backing up from an inlet penstock at the inlet works of the WwTW. There is low confidence in the operation of the inlet works, which has not been updated for this HMA, and appears to be modelled based on surveys undertaken in 2005. Hence the model is unlikely to represent any changes in operation since 2005, and to improve the confidence in the number of spills at Mold Entrance/Bromfield Lane CSO, a survey is recommended to accurately represent the current operation of the WwTW in the model.

3.5 Verification Summary

DWF verification was good for the flow monitors that were assessed as part of this HMA. There were some issues at the flow monitors regarding often erratic velocity data due to ragging, particularly at FM04 and FM21, but generally monitors were well verified to depth.

Historical verification was acceptable for the HMA, with modelled flooding generally matching observed flooding. For instance, the DFL properties which are most likely to be affected by the development at Moor Croft, Cae Isa, Bryn Awelon, Ffordd Argoed and Cwrt Rhyd Galed are all close to model-predicted flooding. There are other areas which predict flooding where no flooding due to a lack of hydraulic capacity has been reported, such as Grosvenor Street and Woodlands Close, but there is some doubt as to the confidence in the model in this area.

The model is considered acceptable for assessing the impact of the proposed housing development on the existing combined network. Verification graphs are presented in Appendix B.

3.6 Model Assumptions & Limitations

The hydraulic model utilised for this HMA study is considered to have the following limitations and assumptions:

The layout and invert levels of the sewers in the development were modelled using engineering drawings provided by the developer. As some of these invert levels were lower than the sewer at the connection point, the level of some of these sewers were increased uniformly to prevent a backfall at the connection point. The sewers and levels may not match the final layout of sewers.

Argoed SPS has been modelled as having a duty-assist pumping regime. The modelled operation is based on the existing survey where one pump is not operating during the flow survey. The pumping regime varied during the flow survey, with the pumps acting as duty-standby during some periods and duty-assist during other periods, which has not been reflected in the baseline model. With the operation of only two of the three pumps modelled, the representation of Argoed SPS in the baseline model may not be representative of the future operation of the pumping station once the pump which is not operating has been fixed.

There is low confidence in the operation of the inlet works at the WwTW, which has not been updated for this assessment, and appears to be modelled based on surveys undertaken in 2005. Hence the model is does not represent any changes in operation since 2005.

The model has only been verified in areas which could be impacted by the flows from the development using 5 flow monitors. However, there may be a small influence on other areas of the model which haven't been verified. Additionally, the storm network has not been verified, and has not been considered for this assessment.

4 Development System Analysis

4.1 Dry Weather Flow

The DWF for the residential properties has been calculated as below for the total Land at New Brighton Road, Mold development and the initial phase.

Parameter	Value	Comment
Population - P	258	103 properties with population as outlined in Error! Reference source not found.
Per Capita Return to Sewer Flow Rate – G	180 l/hd/day	The wastewater profile used for the HMA has a per capita return to sewer flow of 180 l/hd/day. This figure is a standard design figure adopted by DCWW for new developments.
Infiltration	0.0538 l/s	10% DWF (PG) assumed
Total DWF Calculations		
P * G	0.538 l/s	Population multiplied by the per capita return to sewer flow rate.
Total DWF	0.591 l/s	
DWF Peak Hydraulic Assessment Multiplier	1 and 2	DWF Peaking factor for CSO (1) and flooding (2) level of performance investigation.

Table 5 – Land at New Brighton Road, Mold - DWF Parameters

4.2 Surface Water Run-off

The developer has been advised that surface water runoff is to be separated from foul flows and it will not be discharged into the existing foul/combined system. The scope of this HMA is limited to the impact on the existing combined system, hence surface water systems within the separated areas have not been considered.

Whilst the surface water network of the proposed development has not been modelled, a nominal allowance of 2% of the total contributing area has been allocated to represent possible future misconnections between the foul and storm systems and the impact of urban creep.

The contribution of impermeable areas to the combined sewer network was calculated by digitising the paved and roofed areas from developer-provided plans. The area of the total development covered by paved surfaces was calculated to be 28.3% and for roofs was 16.3%, this therefore comprises the total contributing area. 2% of this total contributing area has been assumed to add flows to the combined network. For a detailed breakdown of the values used, see Table 6 below.

Total developed area (ha)	Total Impermeable Area - paved and roof – (ha)	Total Road Area (ha)	2% Road Area – value used in model (ha)	Total Roof Area (ha)	2% Roof Area - value used in model (ha)
3.51	1.57	1.00	0.020	0.58	0.012

Table 6 – Development Impermeable Areas

5 Existing / Developed Comparison

5.1 Hydraulic Assessment

Design storms based on a 30-year return period were used to determine the potential flood volumes in the existing and development scenarios.

Winter and summer design storms with durations of 15, 30, 60, 90, 120, 240, 360, 480, 720, 960, 1440 and 2160 minutes were applied to the existing and developed models. Model predicted flood volumes vary with the duration of event and therefore all storm durations have been assessed to highlight the worst-case scenario.

Flooding is predicted at several locations downstream and upstream of the connection point of manhole SJ25653408. The flooding is caused by a localised hydraulic incapacity and is affected by the development flows. The flooding reported in the Table 7 below focuses on the locations where there is historically reported flooding, or the model-predicted detriment is greater than $1m^3$. See Figure 4 for an overview of the location of the manholes in Table 7.

Model Node ID	Manhole ID	Critical Duration (min)	Flood Volume (m^3)		Flooding Detriment	
			Existing	Developed	Absolute (m3)	Percentage (%)
SJ24642803	SJ24642803	M30-960 - summer	62.1	66.4	4.3	7%
SJ25653408	SJ25653408	M30-240 - summer	3.6	4.7	1.1	31%
SJ25653507	SJ25653507	M30-960 - summer	80.4	98.3	17.9	22%
SJ25655404	SJ25655404	M30-2160 - summer	45.8	52.6	6.8	15%

Table 7 - Hydraulic Assessment Results.

The hydraulic detriment assessment in Table 7 shows that there is a small increase in the amount of flooding predicted in nodes close to the sewers immediately downstream of the development.

The model predicts that manhole SJ25653507 has the highest increase in flooding by volume and by percentage. It is located just upstream of the connection point near to the historical flooding location of Cae Isa.

The total increase in flooding is predicted to be 30.1 m3 in the nodes highlighted above for the total development. The manholes with predicted detriment can be found at Cae Isa, Moorcroft and Cwrt Rhyd Galed.

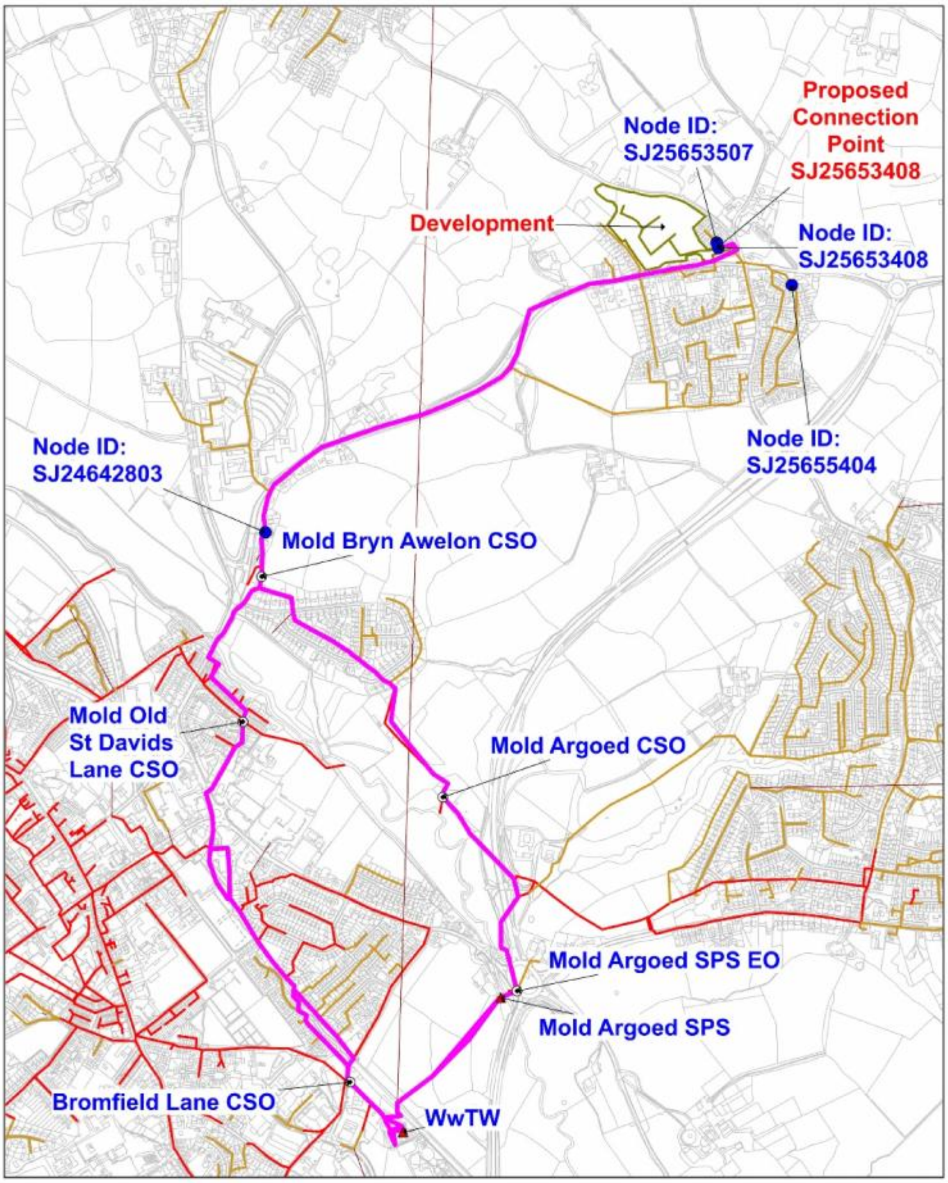


Figure 4 – Model Predicted Flooding Location Plan

5.2 CSO Assessment

Spill volume analysis of the overflows that could be impacted by the proposed development was carried out using a typical year rainfall dataset generated previously for the Mold WwTW catchment. This was provided by DCWW as part of a previous modelling study for Mold. Four CSOs and one EO were included in the assessment, three of which are on the main trunk sewer between the proposed development and Mold WwTW (Bryn Awelon CSO, Argoed CSO and Argoed SPS EO) and two of which are on a bifurcation from the trunk sewer to the west (Mold Old St David's Lane/Bridge St NRA CSO and Mold Entrance/Bromfield Lane CSO).

A summary of the analysis is shown below in Table 8.

CSO Name	Spill Frequency							
	Existing		Developed		Spill Frequency Difference		Spill Volume Difference	
	Spills (No.)	Total Spill Vol. (m^3)	Spills (No.)	Total Spill Vol. (m^3)	Absolute (No.)	Percentage (%)	Absolute (m^3)	Percentage (%)
Argoed CSO	0	0	0	0	0	0%	0	0%
Mold Old St Davids Lane/Bridge St NRA CSO	8	727	8	734	0	0%	7	1%
Mold Entrance/Bromfield Lane CSO	51	25,482	52	25,516	1	2%	34	1%
Argoed SPS EO	65	38,259	67	39,342	2	3%	1,083	3%
Bryn Awelon CSO	7	440	7	474	0	0%	34	8%

Table 8 - CSO Assessment – Total Development

The analysis of scenarios reveals that there is no increase in the number of spills predicted or the predicted spill volumes at Argoed CSO, Mold Old St David's Lane/Bridge St NRA CSO and Bryn Awelon CSO.

Bryn Awelon CSO shows no change in the number of spills predicted during a typical year's rainfall with the inclusion of the development. However, there is a small increase in the predicted spill volumes in a typical year's rainfall with the inclusion of the development.

At Argoed SPS EO and Mold Entrance/Bromfield Lane CSO, there are increases in both the number of spills predicted in a typical year's rainfall. At Mold Entrance/Bromfield Lane CSO, there is 1 additional spill predicted, with a 1% increase in the predicted spill volumes; whilst at Argoed SPS EO, there are 2 additional spills predicted, with a 3% increase in the predicted spill volumes.

The CSO assessment suggests that the development is having a small impact on the volume of spills at Mold Entrance/Bromfield Lane CSO and Argoed SPS EO. The development is having a more significant impact on Bryn Awelon CSO, with the highest percentage increase in the predicted spill volumes of all the CSOs.

5.3 Formula 'A' Assessment

The value of Formula 'A' has been determined at each CSO considered to be impacted on by the development. The Formula 'A' flow is a measure of the continuation flow required at a CSO prior to spill occurring.

The calculated Formula 'A' figures are presented in Table 9 to Table 13, below.

Model	Pass Forward Flow (l/s)	Formula A (l/s)	DWF (l/s)	Passes Formula A
Existing	46*	20.57	7.04	Yes
Total Development	46*	21.95	7.81	Yes

Table 9 - Formula 'A' Assessment – Argoed CSO.

*No spills predicted in 30-year return period storms, figures shown are the maximum pass forward flow during 30-year return period storms.

Model	Pass Forward Flow (l/s)	Formula A (l/s)	DWF (l/s)	Passes Formula A
Existing	54	78.71	19.65	No
Total Development	54	78.71	19.65	No

Table 10 - Formula 'A' Assessment – Mold Old St Davids Lane/Bridge St NRA CSO.

Model	Pass Forward Flow (l/s)	Formula A (l/s)	DWF (l/s)	Passes Formula A
Existing	208	215.84	49.14	No
Total Development	208	215.84	49.14	No

Table 11 - Formula 'A' Assessment – Mold Entrance/Bromfield Lane CSO

Model	Pass Forward Flow (l/s)	Formula A (l/s)	DWF (l/s)	Passes Formula A
Existing	62	98.48	18.93	No
Total Development	62	104.48	19.70	No

Table 12 - Formula 'A' Assessment – Argoed SPS EO

Model	Pass Forward Flow (l/s)	Formula A (l/s)	DWF (l/s)	Passes Formula A
Existing	29	15.95	6.65	Yes
Total Development	29	21.95	7.42	Yes

Table 13 - Formula 'A' Assessment – Bryn Awelon CSO

The contributing catchment has been assessed as partially separate from the results of the flow survey and the model verification achieved.

The model has been assessed to ensure that the CSOs downstream of the proposed development meet the requirements to pass forward Formula 'A' flows and that this requirement is not unduly affected by the addition of the development. In calculating the DWF and Formula A at Mold Old St Davids Lane/Bridge St NRA CSO and Mold Entrance/Bromfield Lane CSO, the split of flows during a DWF simulation has been used to determine the split of DWF and Formula A between the two sewers which split just downstream of Bryn Awelon CSO. As all DWF passes through the eastern trunk sewer, it has been calculated that Formula A for these CSOs does not include flows from the development.

The CSO setting or Pass Forward Flow (PFF) has been determined by assessing the flow at first spill for a range of low return period events (such as the verification events and 1 in 1-year return period design events).

Argoed CSO was not predicted to spill in a 1-year event or a 30-year event, so the PFF is greater than the maximum pass forward flow during 30 year return period storms shown in Table 9.

Bryn Awelon CSO and Argoed CSO both pass formula A in the current scenario and after the proposed development is built. The PFF at both CSOs is significantly higher than the formula A calculation.

Argoed SPS EO fails formula A both in the current scenario and after the proposed development is built.

Both Mold Old St Davids Lane/Bridge St NRA CSO and Mold Entrance/Bromfield Lane CSO also fail formula A in both the current scenario and after the proposed development is built. The PFF is 54 l/s for Mold Old St Davids Lane/Bridge St NRA CSO and 208 l/s for Mold Entrance/Bromfield Lane CSO, and the New Brighton Development does not contribute to increases in Formula A or DWF at either of these CSOs. The risk for this CSO is from flows during storm conditions causing additional flow in the bifurcation sewer.

5.4 SPS Assessment

The impact of development flows has also been assessed at Argoed SPS in relation to operational performance including number of pump starts, pump runtimes and pump volumes. The assessment also determines the impact on emergency storage requirements.

The normal requirements for emergency storage are for 2 hours of storage at 3 times dry weather flow.

Storage calculations are presented in Table 14.

	3DWF	Pump Rate	Storage (2hrs @ 3DWF)	Pump Rate Acceptable	Storage Acceptable
Current	-	62.0l/s	80m^3		
Existing	49.7 l/s	-	357m^3	Yes	No
Developed	51.8 l/s	-	373m^3	Yes	No

Table 14 - Assessment of SPS Emergency Storage - Argoed SPS

The existing storage volume in the pump wet well at Argoed SPS and the upstream network below the emergency overflow was calculated as approximately 80m³. The emergency requirement in the existing situation is 357m³ rising to 373m³ following the development. The addition of the development increases the required emergency storage by 16m³.

No storage requirement is stipulated within the consent for this pumping station, however the pumping station does not meet the required emergency storage of 2 hrs at 3 times dry weather flow. However, the pump rate at Argoed SPS is greater than the pump rate required to pump 3 times dry weather flow which was based on the 2019 survey.

Pump performance results are presented in Table 15.

SPS Name	Existing		Developed		Run Time Difference		Run Volume Difference	
	Run Time (minutes)	Run Volume (m^3)	Run Time (minutes)	Run Volume (m^3)	Absolute (minutes)	Percentage (%)	Absolute (m^3)	Percentage (%)
Argoed SPS	562	1476.9	586	1540.0	24	5	63.1	5

Table 15 - SPS Assessment - runtime & volume

The results indicate that there is an increase in run time and in run volume at Argoed SPS downstream of the development connection point.

In accordance with Sewers for Adoption, all pumping stations should operate with a maximum of 15 starts per hour. Table 16 gives the maximum number of dry weather starts per hour for all pumps, on a weekday 26/07/2019 and weekend 27/07/2019. The assessment compares the predicted number of starts per hour for the existing system with the number for the developed system.

SPS Name	Existing Pump Starts		Developed Pump Starts	
	Dry Day 1	Dry Day 2	Dry Day 1	Dry Day 2
Argoed SPS	5	5	5	5

Table 16 - SPS Assessment - Number of Pump Starts

There is no difference in the maximum number of starts at Argoed SPS with the inclusion of the development. However, the run times of the pumps are increased as it takes the pump slightly longer to drain down the wet well. The max number of starts per hour at Argoed SPS on both weekdays and weekends in both the baseline and developed model is well below 15, the maximum recommended in Sewers for Adoption.

5.5 Flows Arriving at Mold WwTW

Using the annual time series 'typical year', it was calculated that 1,847,097m³ of flow arrives at Mold WwTW. With the new development, this figure increases to 1,868,312m³. This corresponds to an increase of 21,215m³ or 1.149%. This is slightly greater than the expected annual water consumption from the New Brighton Road development, which is calculated to be approximately 18,638m³ (excluding allowances for creep).

5.6 Network Performance Assessment Summary

The development was found to be causing increases in predicted flooding in three areas. These are all located at locations where flooding has been reported previously, at Cae Isa, Moorcroft and Cwrt Rhyd Galed. The CSO assessment has highlighted increases in spill volume in the full development scenario of 1% at Mold Old St Davids Lane/Bridge St NRA CSO, 1% at Mold Entrance/Bromfield Lane CSO 3% at Argoed SPS EO and 8% at Bryn Awelon CSO during the full year time series rainfall data.

The development does not cause any additional risk to compliance with Formula A.

Similarly, the development does not cause any additional risk at Argoed SPS but the inclusion of the development causes a 5% increase in pump runtime and pumped volume at Argoed SPS.

6 Solution Development

The hydraulic assessment has indicated that the addition of development flows has caused detriment with regards to network performance. Therefore, a solution has been investigated to resolve the detriment caused by the development flows.

The notional solutions described in the following sections show conceptual arrangements only and are presented to illustrate the adequacy of the solutions in terms of gross parameters (e.g. pipe capacities); their inclusion does not infer buildability and they are not to be considered as detailed design proposals.

6.1 Discounted Solutions

The following solutions were considered but discounted because they were unlikely to resolve the predicted detriment and/or were not considered feasible:

- Adjust bifurcation at manhole SJ24642601 so that more flow passes down the western bifurcation to Mold WwTW. The solution was discounted as whilst this would free up capacity in the network upstream of the bifurcation, increasing flows in the western bifurcation is likely to increase the number of spills at both Mold Old St David's Lane/Bridge St NRA CSO and Mold Entrance/Bromfield Lane CSO.

- Install an onsite pumping station at the development. The solution was discounted due to the additional maintenance costs associated with a new asset. In addition, if the SPS is to discharge at the present connection point, it is unlikely to reduce the predicted detriment caused by the development.

- Changing the connection point to SJ25651403 and providing additional online storage on the development. The solution was discounted due to the additional costs of maintenance associated with the operation of a storage facility on site at the development, and the impact this would have on space available within the development.

6.2 Solution 1 – Additional online storage in New Brighton and Bryn Awelon

6.2.1 Description

This solution requires an upgrade of one section of sewer just downstream of the connection point between manholes SJ25653401 and SJ25653451 and 230 m^3 of additional storage at Bryn Awelon CSO.

This solution elements are as follows:

- Abandon 65m of existing 225mm diameter sewer between manholes SJ25653401 and SJ25653451. Install new sewer with 64m of 600mm diameter sewer and 10m of 225mm diameter sewer between manholes SJ25653401 and SJ25653451 at a flatter gradient to provide additional online storage. Install one new 1.5 m diameter manhole between the 600mm diameter sewer and the 225m diameter sewer.

- Provide 230 m^3 at Bryn Awelon CSO below the spill level of the screen at the CSO (109.649 m AD).

6.2.2 Notional Design Solution

There is reported and model-predicted flooding both upstream and downstream of the connection point. The solution proposal is to install additional storage in the network just downstream of the development in New Brighton by increasing the capacity of the combined system. This would create headroom for the development flows to connect to the network and prevent flooding detriment at Cae Isa and Moor Croft. The storage at Bryn Awelon CSO has been included to reduce the flooding detriment at Cwrt Rhyd Galed and to limit the increase in spill volumes at Bryn Awelon CSO.

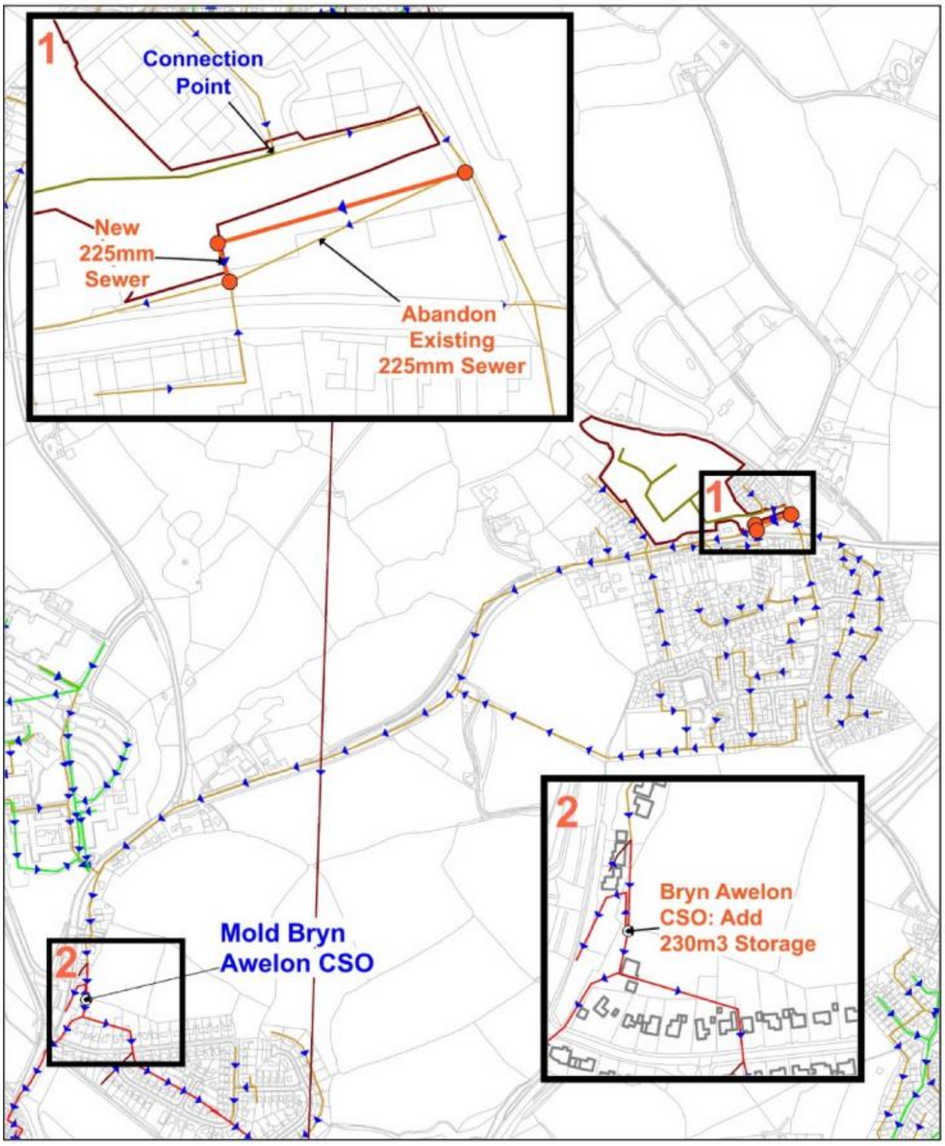


Figure 5 – Solution 1

Dŵr Cymru
Welsh Water

6.2.3 Solution Assessment

Model Node ID	Manhole ID	Critical Duration (min)	Flood Volume (m3)		Flooding Detriment	
			Existing	Solution 1	Absolute (m3)	Percentage (%)
SJ24642803	SJ24642803	M30-15 - summer	8.0	0	-8.0	-100%
SJ24643901	SJ24643901	M30-240 - summer	7.6	8.3	0.7	9%
SJ25653408	SJ25653408	M30-480 - summer	1.3	1.2	-0.1	-8%
SJ25653507	SJ25653507	M30-720 - summer	80.3	79.8	-0.5	-1%
SJ25655404	SJ25655404	M30-60 - summer	39.7	31.4	-8.3	-21%

Table 17 - Solution 1 Hydraulic Analysis – Additional Online Storage in New Brighton and Bryn Awelon

Table 17, above shows that there is no flooding detriment greater than 1m^3 predicted compared to the current model when the additional online storage is added at New Brighton Road. The detriment caused by the development has been completely mitigated at manholes SJ24642803, SJ25653408, SJ25653507 and SJ25655404. Additionally, there is 0.7m^3 of detriment just upstream of Cwrt Rhyd Galed at manhole SJ24643901.

CSO Name	Spill Frequency							
	Existing		Developed		Spill Frequency Difference		Spill Volume Difference	
	Spills (No.)	Total Spill Vol. (m3)	Spills (No.)	Total Spill Vol. (m3)	Absolute (No.)	Percentage (%)	Absolute (m3)	Percentage (%)
Argoed CSO	0	0	0	0	0	0%	0	0%
Mold Old St Davids Lane/Bridge St NRA CSO	8	727	6	521	-2	-25%	-206	-29%
Mold Entrance/Bromfield Lane CSO	51	25,482	52	25,476	1	2%	-6	-1%
Argoed SPS EO	65	38,259	63	39,030	-2	-4%	771	3%
Bryn Awelon CSO	7	440	2	433	-5	-72%	-7	-2%

Table 18 - CSO Analysis - Solution 1 - Additional Online Storage in New Brighton and Bryn Awelon

Table 18, above, shows the impact of the development and proposed solution on the spills predicted by the model in a typical year. There is a slight increase in the number of spills predicted at Mold Entrance/Bromfield Lane CSO when compared to the current model, likely to be caused by variations in the activation times at the WwTW storm return pumps in the model.

Additionally, there is an increase in the predicted spill volumes at Argoed SPS EO when compared with the existing model. As outlined in Section 3.4, there is low confidence in the number of predicted spills at Argoed SPS EO, due to the modelling of the operation of the pumps at as duty-assist. When compared with the development scenario spill volumes in Table 8, the inclusion of the solution reduces the predicted spill volumes at the SPS. With the exception of these limitations of the model, the solution is predicted to fully mitigate the predicted increase in spill numbers and volumes at the CSOs and EOs with the inclusion of the development.

6.2.4 Option Considerations

- It is assumed that there is sufficient space to construct the new sewers between manholes SJ25653401 and SJ25653451. Similarly, it is assumed that there is sufficient space to construct the additional storage at Bryn Awelon CSO, which can be included in any shape providing it is below weir level. Visual inspection of background mapping and Google Street View suggests the new sewers and storage could be accommodated; however it is unknown at this stage if available space could be limited by existing underground infrastructure, and should be investigated at the detailed design stage.

- Upsizing of the existing sewer was not considered since the pipe was crossing a private property. It is required to abandon this sewer or impact won't be mitigated downstream.

- No data on private connections is available to confirm the impact that the new sewer may have on existing connections. Investigations into the impact on private drainage connections is recommended at the detailed design stage.

- The streets in this area are predominantly residential and construction should be planned to minimise impact on these DCWW customers where possible.

- Cost of further investigations has not been included explicitly in the solution costs below.

6.3 Solution 2 – Surface Water Removal

6.3.1 Description

This solution requires the disconnection of 0.174 ha of impermeable roof areas that currently connect to the foul system close to Mold Road in New Brighton. 0.071 ha of impermeable roof areas have been confirmed to connect to the foul system by an IAS carried out in February 2019.

The solution elements below give an option / suggestion for the makeup of achieving the 0.174 ha of surface water removal and is how the solution was modelled, but the makeup can be achieved by any combination of impermeable area connected to the network, providing that it totals 0.174ha and is upstream of manhole SJ25651403.

The solution elements are as follows:

- Removal of 0.047 ha of surveyed roof area from St James Church, three residential buildings and one outbuilding surrounding the crossroads between the A5119 and Bryn Lane/New Brighton Road, by diverting to existing highway drainage (area A in Figure 6).

- Removal of 0.024 ha of surveyed roof area and 0.013 ha of unsurveyed roof area from Beaufort Park Hotel, by diverting to existing soakaways (area B in Figure 6).

- Removal of 0.025 ha of unsurveyed roof area from 2 properties on Bryn Offa Lane towards existing soakaways at Beaufort Park Hotel (area C in Figure 6).
- Removal of 0.065 ha of unsurveyed roof area from 16 terraced properties on the A5119, by conveyance to storm system at manhole SJ25650454 (area D in Figure 6).

6.3.2 Notional Design Solution

There is reported and model-predicted flooding both upstream and downstream of the connection point. The solution proposal is to remove surface water from the combined system, creating headroom for the development flows to connect to the network and reduce the hydraulic load on downstream areas during high flows. Several of the roof areas are part of buildings where other roof sections drain to soakaways, or close to existing highway or surface water networks. Figure 6 shows the locations of the premises in relation to existing storm network.

The solid red areas indicate the surveyed impermeable area which has roof areas connecting to the foul network, whilst the shaded red areas are unsurveyed areas assumed to be connecting to the foul network. The pink lines and dots show proposed sewers and manholes for conveyance to existing highway drainage (green dots), soakaways (yellow dots) and surface water system (green lines).

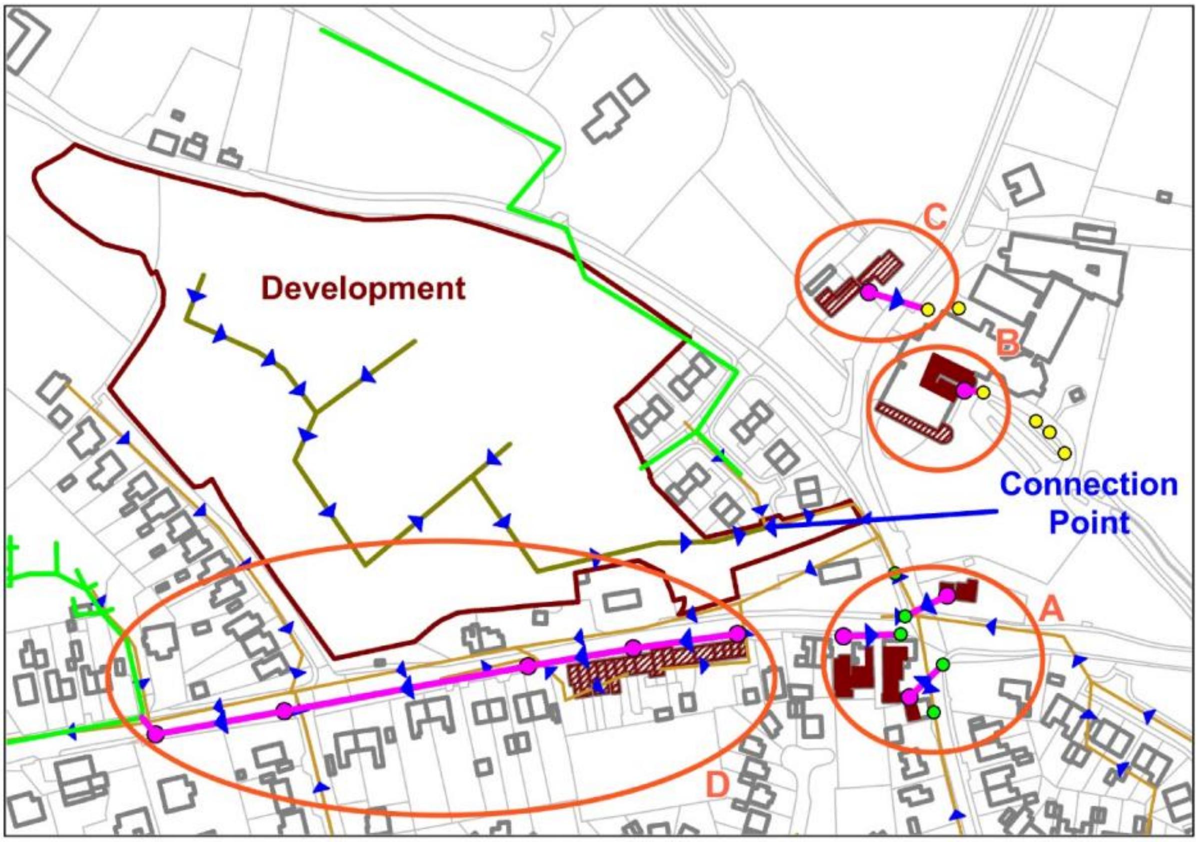


Figure 6 –Solution 2

6.3.3 Solution Assessment

Model Node ID	Manhole ID	Critical Duration (min)	Flood Volume (m3)		Flooding Detriment	
			Existing	Solution 1	Absolute (m3)	Percentage (%)
SJ24642803	SJ24642803	M30-15 - winter	8	1	-7	-88%
SJ25653408	SJ25653408	M30-960 - summer	0.2	0.1	-0.1	-50%
SJ25653507	SJ25653507	M30-1440 - summer	60.4	59.6	-0.8	-1%
SJ25655404	SJ25655404	M30-15 - summer	9.2	0	-9.2	-100%

Table 19 - Solution 2 Hydraulic Analysis – Removal of 0.174 ha of impermeable area from New Brighton.

Table 19, above shows that there is no remaining flooding detriment predicted compared to the current model when 0.174 ha of impermeable area is removed from New Brighton. The detriment caused by the development has been reduced to 1m³ or less at nodes impacted by the development in the full development model when compared with the existing model.

CSO Name	Spill Frequency							
	Existing		Developed		Spill Frequency Difference		Spill Volume Difference	
	Spills (No.)	Total Spill Vol. (m^3)	Spills (No.)	Total Spill Vol. (m^3)	Absolute (No.)	Percentage (%)	Absolute (m^3)	Percentage (%)
Argoed CSO	0	0	0	0	0	0%	0	0%
Mold Old St Davids Lane/Bridge St NRA CSO	8	727	8	712	0	0%	-15	-3%
Mold Entrance/Bromfield Lane CSO	51	25482	52	25479	1	2%	-3	-1%
Argoed SPS EO	65	38259	65	38394	0	0%	135	1%
Bryn Awelon CSO	7	440	6	413	-1	-15%	-27	-7%

Table 20 - CSO Analysis - Solution 2 - Removal of 0.174 ha of impermeable area from New Brighton.

Table 20, above, shows the impact of the development and proposed solution on the spills predicted by the model in a typical year. There is a slight increase in the number of spills predicted at Mold Entrance/Bromfield Lane CSO when compared to the current model. Additionally, there is an increase in the predicted spill volumes at Argoed SPS EO when compared with the existing model. The increase in predicted spill numbers at Mold Entrance/Bromfield Lane CSO is likely to be caused by variations in the activation times at the WwTW storm return pumps in the model causing a slight increase in the predicted spill numbers at the CSO. With the exception of this limitations in the model, the solution is predicted to fully mitigate the predicted increase in spill numbers and volumes at the CSOs and EOs with the inclusion of the development.

6.3.4 Option Considerations

- It is assumed that the existing soakaways, surface water systems and existing highway systems in New Brighton have the capacity to accept additional flow from the impermeable areas. Confirmation of this is beyond the scope of this HMA. However, it is recommended this is investigated in further detail at the design stage.

- New Brighton was subject to an IAS in 2019 which indicated several areas where removing surface water from the combined system was attainable; these consist of 0.071 ha of roof area, which are indicated in Figure 6. Whilst some of the surface water removal opportunities in this solution have been surveyed, it has been necessary to supplement these areas with 0.103 ha of impermeable area which has been assumed from model verification to connect to the combined system in New Brighton. It is assumed that these residential properties in the New Brighton area could be disconnected from the combined network. Further investigation into the nature of the impermeable area connections is recommended at detailed design stage.

- Whilst this option assumes that the roofs indicated in Figure 6 are disconnected, there are other road/roof areas which have been assumed from model verification to connect to the combined system in New Brighton. These impermeable areas could be considered as alternative areas to disconnect from the combined network in the detailed design phase if the proposed areas are unfeasible.

- Construction of any new surface water pipes should be feasible at a minimal depth and primarily will be located within the highway. No detailed assessments of other infrastructure assets (i.e. clean water, gas and electricity) have been undertaken as part of this study.

- Whilst initial investigations have been carried out for the area, it is assumed that there are no other existing storm sewers in the area and that the topography of the area will allow for the storm lines to be connected as proposed.

- The impact to businesses and any residents should be considered, as, there will likely be some disruption whilst work is being undertaken. The streets in this area are predominantly residential and construction should be planned to minimise impact on DCWW customers where possible. The A5119 is a major road with a 30mph speed limit and work undertaken here will likely cause disruption to the flow of traffic. As such, the installation of any new storm sewers will require traffic management and will cause some disruption to traffic. Furthermore, there may be some disruption and noise experienced by residents of the two roads where storm network would be installed.

- No data on private connections is available to confirm the impact that the new sewer may have on existing connections. Investigations into the impact on private drainage connections is recommended at the detailed design stage.

- RPS are currently investigating flooding in New Brighton and Bryn Awelon on behalf of DCWW as part of the Mold SDP and are involved in an Integrated Catchment Study for Mold in partnership with Flintshire County Council assessing the surface water drainage network in Mold. This presents opportunities for working in partnership to deliver flooding solutions and surface water removal schemes.

6.4 Solution 3 – Hybrid; Storage and Surface Water Removal

6.4.1 Description

This solution requires an upgrade of one section of sewer just downstream of the connection point between manholes SJ25653401 and SJ25653451 and the disconnection of 0.189 ha of impermeable roof areas that currently connect to the foul system close to Mold Road in New Brighton, and from the Flintshire County Council offices. The connectivity of the impermeable areas has been confirmed by an impermeable area survey carried out in February 2019. 0.138 ha of these impermeable roof areas have been confirmed to connect to the foul system by an impermeable area survey carried out in February 2019.

This option requires removal of more impermeable area than solution 2, however the roof areas proposed for surface water removal are larger and may therefore be easier to disconnect from the surface water network than the roofs proposed in solution 2. Model tests have shown the impermeable area element of solution 3 does not resolve the predicted detriment when applied by itself.

This solution elements are as follows:

- Abandon 65m of existing 225mm diameter sewer between manholes SJ25653401 and SJ25653451. Install new sewer with 64m of 300mm diameter sewer and 10m of 225mm diameter sewer between manholes SJ25653401 and SJ25653451 at a flatter gradient to provide additional online storage. Install one new 1.5 m diameter manhole between the 600mm diameter sewer and the 225m diameter sewer.
- Removal of 0.081 ha of surveyed and unsurveyed roof area from St James Church, seven residential building and three outbuildings surrounding the crossroads between the A5119 and Bryn Lane/New Brighton Road, by diverting to existing highway drainage (area A in Figure 7).
- Removal of 0.037 ha of surveyed and unsurveyed roof area from Beaufort Park Hotel, by diverting to existing soakaways (area B in Figure 7).
- Removal of 0.071 ha of surveyed roof area from Flintshire County Council Offices, by diverting to existing storm networks (area C in Figure 7).

6.4.2 Notional Design Solution

There is reported and model-predicted flooding both upstream and downstream of the connection point. The solution proposes combining surface water removal with installing additional online storage. The removal of surface water from the combined system creates headroom for the development flows to connect to the network. Several of the roof areas are part of buildings where other roof sections drain to soakaways, or are close to existing highway or surface water networks.

Figure 7 shows the locations of the premises in relation to the existing soakaways and highway and surface water networks. The solution also proposes a slight increase in additional storage in the network just downstream of the development in New Brighton, increasing the capacity of the combined system to prevent flooding detriment at Cae Isa and Moor Croft. This passes more flow down to Bryn Awelon CSO, and the RainScape shown in area C in Figure 7 is included to mitigate the impact of this.

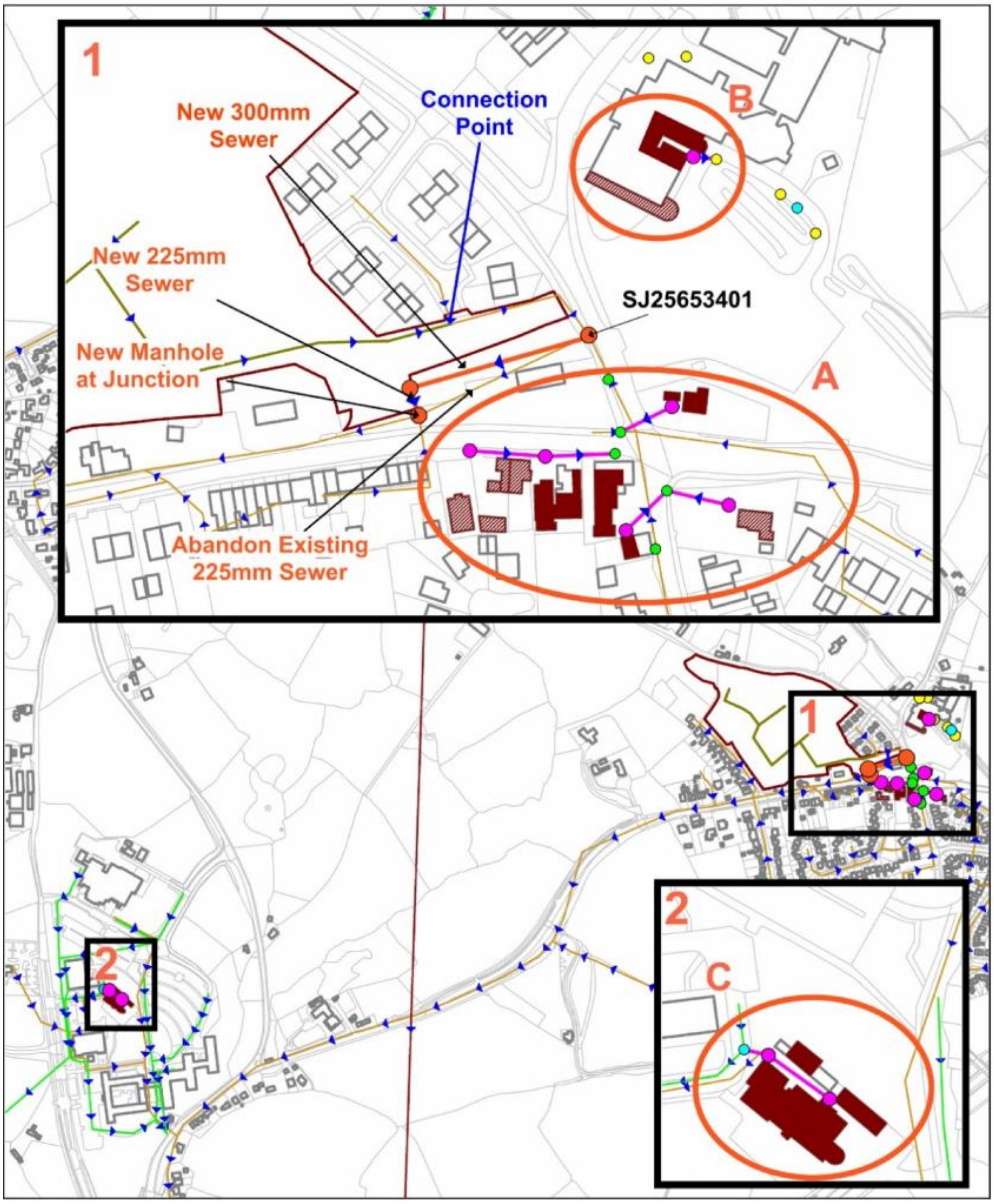


Figure 7 – Solution 3

Dŵr Cymru
Welsh Water

6.4.3 Solution Assessment

Model Node ID	Manhole ID	Critical Duration (min)	Flood Volume (m3)		Flooding Detriment	
			Existing	Solution 1	Absolute (m3)	Percentage (%)
SJ24642803	SJ24642803	M30-2160 - summer	35	35.6	0.6	2%
SJ25653408	SJ25653408	M30-960 - summer	0.2	0.1	-0.1	-50%
SJ25653507	SJ25653507	M30-15 - summer	4.5	0	-4.5	-100%
SJ25655404	SJ25655404	M30-15 - summer	9.2	0	-9.2	-100%

Table 21 - Solution 3 Hydraulic Analysis

Table 21, above shows that there is no remaining flooding detriment greater than 1m³ predicted compared to the current model when the hybrid solution of additional online storage and impermeable area removal is implemented. The detriment caused by the development has been completely mitigated at manhole SJ25653507 and SJ25655404, whilst there is only 0.6m³ of detriment at manhole SJ24642803. In all storms, the model predicts detriment of 1m³ or less at nodes impacted by the development in the full development model when compared with the existing model.

CSO Name	Spill Frequency							
	Existing		Developed		Spill Frequency Difference		Spill Volume Difference	
	Spills (No.)	Total Spill Vol. (m3)	Spills (No.)	Total Spill Vol. (m3)	Absolute (No.)	Percentage (%)	Absolute (m3)	Percentage (%)
Argoed CSO	0	0	0	0	0	0%	0	0%
Mold Old St Davids Lane/Bridge St NRA CSO	8	727	8	716	0	0%	-11	-2%
Mold Entrance/Bromfield Lane CSO	51	25482	51	25485	0	0%	3	1%
Argoed SPS EO	65	38259	66	38609	1	2%	350	1%
Bryn Awelon CSO	7	440	7	461	0	0%	20	5%

Table 22 - CSO Analysis - Solution 3

Table 22, above, shows the impact of the development and proposed solution on the spills predicted by the model in a typical year. There is a slight increase in the number and volume of spills predicted at Argoed SPS EO when compared to the current model. Additionally, there is an increase in the predicted spill volumes at Mold Entrance/Bromfield Lane CSO and Bryn Awelon CSO when compared with the existing model. The increase in predicted spill numbers at Mold Entrance/Bromfield Lane CSO is likely to be caused by variations in the activation times at the WwTW storm return pumps in the model causing a slight increase in the predicted spill numbers at the CSO. As outlined in Section 3.4, there is low confidence in the number of predicted spills at Argoed SPS EO, due to the modelling of the operation of the pumps at Argoed SPS as duty-assist.. With the exception of these limitations of the model, the solution is predicted to fully mitigate the predicted increase in spill numbers and volumes at the CSOs and EOs with the inclusion of the development.

6.4.4 Option Considerations

- It is assumed that there is sufficient space to construct the new sewers between manoles SJ25653401 and SJ25653451. Visual inspection of background mapping and Google Street View suggests the new sewers could be accommodated; however, it is unknown at this stage if available space could be limited by existing underground infrastructure and should be investigated at the detailed design stage.

- It is assumed that the existing soakaways, surface water systems and existing highway systems in New Brighton and close to the Flintshire County Council offices have the capacity to accept additional flow from the impermeable areas. Confirmation of this is beyond the scope of this HMA. However, it is recommended this is investigated in further detail at the design stage.

- Whilst this option assumes that the roads / roofs indicated in Figure 7 are disconnected, there are other impermeable areas which have been assumed from model verification to be connected to the combined system in New Brighton. These impermeable areas could be considered as alternative areas to disconnect from the combined network in the detailed design phase if the proposed areas are unfeasible.

- Construction of any new surface water pipes should be feasible at a minimal depth and primarily will be located within the highway. No detailed assessments of other infrastructure assets (i.e. clean water, gas and electricity) have been undertaken at this point.

- Whilst initial investigation has been carried out for the area, it is assumed that there are no other existing storm sewers in the area and that the topography of the area will allow for the storm lines to connect as proposed.

- The impact to businesses and any residents should be considered, as, there will likely be some disruption whilst work is being undertaken. The streets in this area are predominantly residential and construction should be planned to minimise impact on these DCWW customers where possible. The A5119 is a major road with a 30mph speed limit and work undertaken here will likely cause disruption to the flow of traffic. As such, the installation of any new storm sewers will require traffic management and will cause some disruption to traffic. Furthermore, there may be some disruption and noise experienced by residents of the two roads where storm network would be installed.

- No data on private connections is available to confirm the impact that the new sewer may have on existing connections. Investigations into the impact on private drainage connections is recommended at the detailed design stage.

- There is limited data available for the size and gradient of the sewers surrounding the Flintshire County Council Offices and their exact connection point to the trunk sewer. Investigations into these sewers is recommended at the detailed design stage.

- Cost of further investigations has not been included explicitly in the solution costs below.

- RPS are currently investigating flooding in New Brighton and Bryn Awelon on behalf of DCWW as part of the Mold SDP and are involved in an Integrated Catchment Study for Mold in partnership with Flintshire County Council assessing the surface water drainage network in Mold. This presents opportunities for working in partnership to deliver flooding solutions and surface water removal schemes.

6.5 Solution Summary

A detailed detriment assessment was carried out on the solution. This comprised of a time series rainfall and full suite of 30-year return period design storms with a duration of 15 - 2160 minutes.

The three solutions described above were found to mitigate the flooding detriment caused by the proposed New Brighton development in nodes upstream and downstream of the development, to a level acceptable to DCWW.

7 Solution Costs

The solution costs provided are based on the DCWW Solution Target Pricing Tool (STPT). This cost model predicts costs based on final costs of completed schemes. **These are intended to be high level cost estimates and are for option comparison only**. It is recommended that a detailed cost estimate is undertaken during the detailed design phase.

Solution	Description	Cost
1	Additional Online Storage in New Brighton and Bryn Awelon	£434,103
2	Surface Water Removal	£612,298
3	Hybrid; Storage and Surface Water Removal	£502,969

Table 23 - Solution Costs

The costs for solution 1 have been calculated based on the assumptions outlined in section 6.2.

The costs for solution 2 have been calculated based on several assumptions in addition to the assumptions outlined in section 6.3. The solution assumes that there is a requirement for 353m of new 150mm surface water sewer to convey the flows from the disconnected roofs to the nearest soakaway, highway drain or surface water manhole, with the installation of 10 new 1.2 m diameter manholes. As previously mentioned in section 6.3.4 there are other premises which could be considered for impermeable area removal. Connecting to existing soakaways, highway drainage or surface water sewers would require a detailed investigation into the existing capacity of these drainage systems. As such, the quoted value should be considered a conservative estimate.

The costs for solution 3 have been calculated based on several assumptions in addition to the assumptions outlined in section 6.4. The solution assumes that there is a requirement for 72m of new 150mm surface water sewers to convey the flows from the disconnected roofs to the nearest soakaway, highway drain or surface water manhole, with the installation of 4 new 1.2 m diameter manholes. As previously mentioned in section 6.4.4 there are other premises which could be considered for impermeable area removal. Connecting to existing soakaways, highway drainage or the surface water network would require a detailed investigation into the existing capacity of these drainage systems. As such, the quoted value should be considered a conservative estimate.

All the costs have been approved by DCWW Unit Cost Database (UCD) Team.

8 Conclusions & Recommendations

- The developer aims to build a development of 103 properties in a single phase. The development is proposed to be entirely residential with no allowance for commercial premises.

- The proposed development – Land at New Brighton Road, Mold - has been assessed using one connection point, at SJ25653408, just south of the existing Cae Isa estate to the north of the A5119 in New Brighton. The connection will be via a gravity sewer in the south east of the development.

- Prior to carrying out the hydraulic modelling assessment the model was upgraded as part of the Mold SDP project. A full flow survey, along with additional asset, manhole and IAS, were proposed in key areas of the catchment. The flow survey was undertaken between January and May 2019, with the flow survey including five monitors in the vicinity of the proposed connection point for the development and the key assets downstream of the development. The surveys were supplemented for the purposes of the HMA with a manhole survey, an outfall survey, a SPS Survey at Mold Argoed SPS and an IAS. The model was then verified based on the five flow monitors from the 2019 flow survey.

- There were several assumptions and limitations in the model. The pumping station at Argoed SPS has been modelled as having a duty-assist pumping regime due to one pump not operating during the flow survey, while the pumping regime at Argoed SPS normally varies between duty-assist and duty-standby; this may not be representative of the future operation of SPS if the pump is fixed. Additionally, the modelling of the inlet works at the WwTW has not been updated since 2005 and does not represent any changes in operation since then. The model has also only been verified to the five monitors impacted by the flows from the development.

- The hydraulic assessments revealed that the development caused increases in predicted flooding in several manholes downstream of the development, as well as an increase in spill volume at Mold Old St David's Lane/Bridge St NRA Combined Sewer Overflow (CSO), Argoed SPS Emergency Overflow (EO) and Bryn Awelon CSO.

- Three solutions have been developed to resolve the predicted detriment. These are briefly outlined below.

  - Solution 1 – Additional online storage in New Brighton Road. This solution requires an upgrade of one section of sewer just downstream of the connection point and 230 m^3 of additional storage at Bryn Awelon CSO. The estimated cost for this option is £434,103.
  - Solution 2 – Impermeable area removal in New Brighton Road. This solution requires removal of 0.174 ha impermeable area from properties around New Brighton Road. The estimated cost for this option is £612,293.
  - Solution 3 – Hybrid of impermeable area removal and online storage. This solution requires an upgrade of one section of sewer just downstream of the connection point and the removal of 0.189 ha impermeable area from properties around New Brighton Road and the Flintshire County Council offices. The estimated cost for this option is £502,969.

- Solution 3 is the preferred solution, subject to confirmation of impermeable area connectivity, as this is the most long term sustainable option, as well as the least disruptive for the residents.

Appendix A – Drawings & Plans

ROAD 1
ROAD 2
ROAD 3
ROAD 4
POND
EXG. MH
KEY
PRELIMINARY DRAWING
Sutcliffe
STEWART MILNE HOMES
NEW BRIGHTON ROAD
MOLD
PRELIMINARY DRAINAGE LAYOUT
SHEET 4 OF 4
29949-656

Appendix B – Verification Plots & Comparative Analysis

Flow survey: >SDP Stage 2A>S2A Model Build _Verification>Rainfall>EventA_12032019 (11/06/2019 13:56:53)
Sim: >SDP Stage 2A>S2A Model Build _Verification>Verification 2019 (HMA)>Runs>EventA_190312_v94!>v94a (03/07/2019 14:34:57)

Flow Survey Location (Obs.) F01, Model Location (Pred.) D/S SJ24658202.1, Rainfall Profile: 2

	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	11.000	24.000	0.230							
Observed				0.023	0.076	0.000	0.013	489.191	0.000	1.690
...v94!>v94a				0.030	0.096	0.001	0.016	735.408	0.374	1.184

Observed / Predicted Report (Custom graph) - EventA_ 12032019

Powered by InfoWorks®

Observed / Predicted Report Produced by Robert.Farrington (03/07/2019 15:27:50) Page 1 of 21
Flow survey: >SDP Stage 2A>S2A Model Build _Verification>Rainfall>EventB_24042019 (11/06/2019 13:56:53)
Sim: >SDP Stage 2A>S2A Model Build _Verification>Verification 2019 (HMA)>Runs>EventB_190424_v94>v94b (03/07/2019 15:21:56)

Flow Survey Location (Obs.) F01, Model Location (Pred.) D/S SJ24658202.1, Rainfall Profile: 2

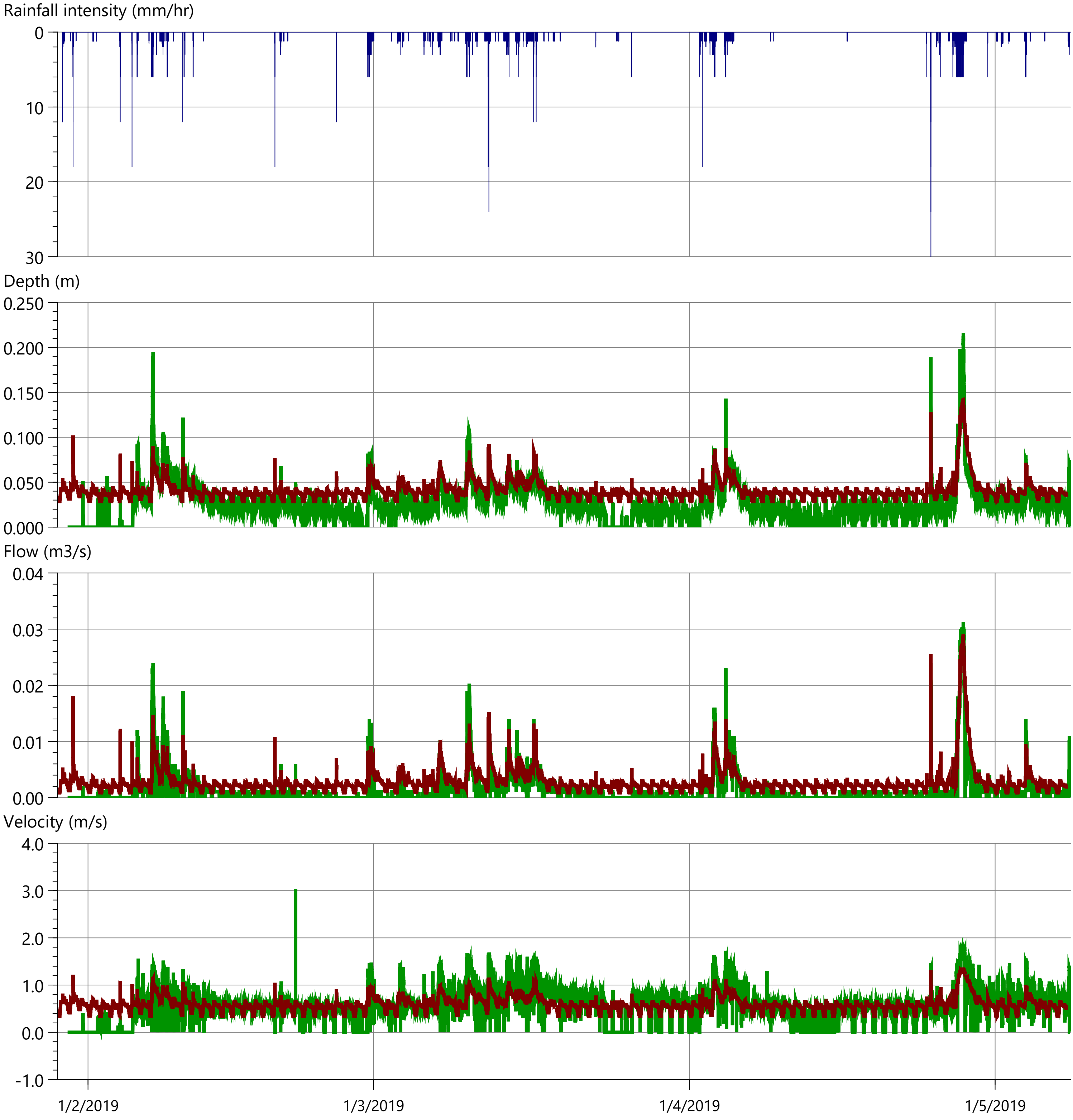
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	9.800	30.000	0.204							
Observed				0.000	0.189	0.000	0.024	129.000	0.000	1.470
...v94>v94b				0.028	0.138	0.001	0.028	658.930	0.335	1.334

Observed / Predicted Report (Custom graph) - EventB_ 24042019

Powered by InfoWorks®

Flow survey: >SDP Stage 2A>S2A Model Build _Verification>Rainfall>2019 Flow survey (11/06/2019 13:56:53)
Sim: >SDP Stage 2A>S2A Model Build _Verification>Verification 2019 (HMA)>Runs>full flow survey 2019v93>v93 FP (02/07/2019 16:37:16)

Flow Survey Location (Obs.) F01, Model Location (Pred.) D/S SJ24658202.1, Rainfall Profile: 2



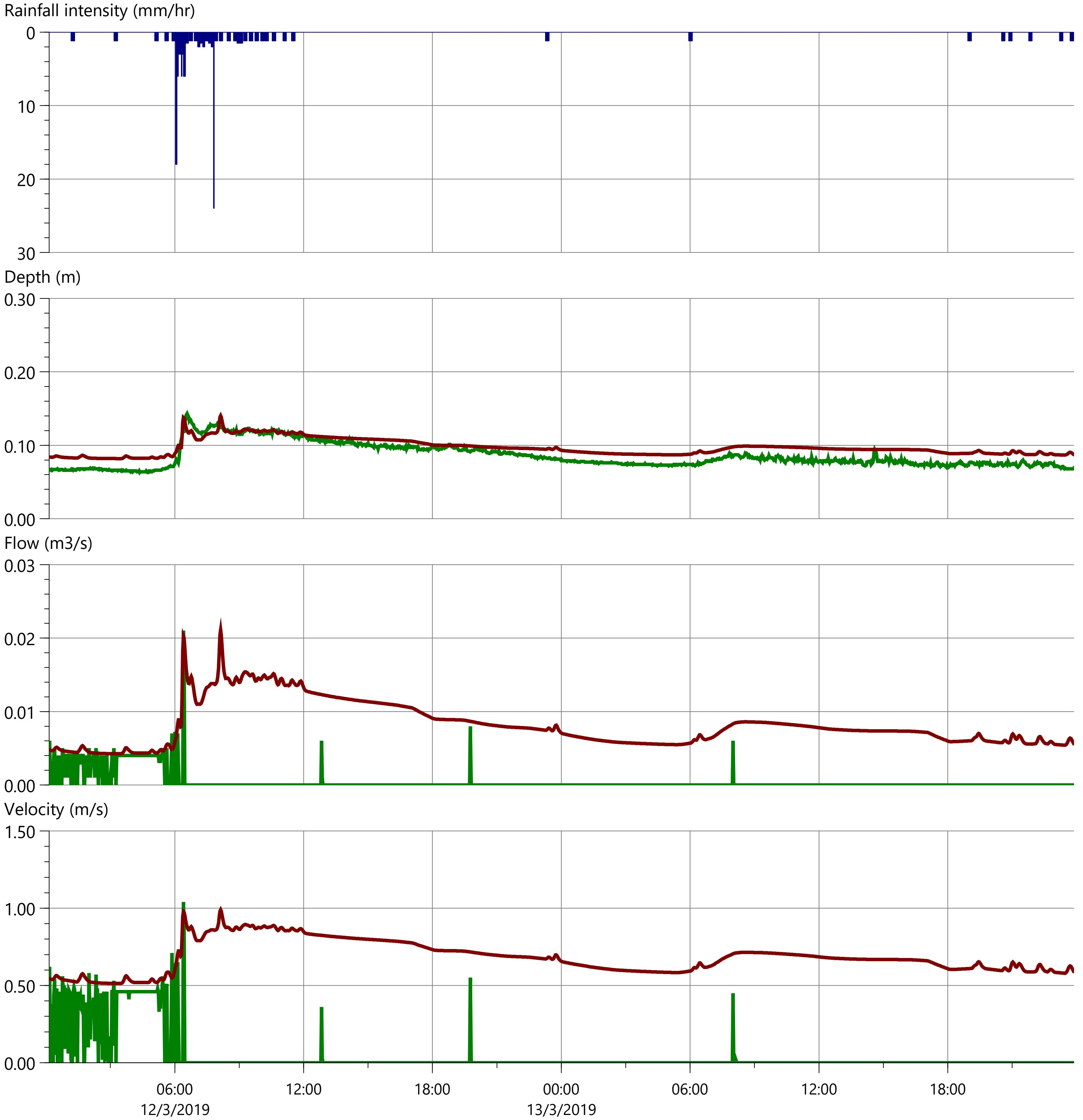
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	254.400	30.000	0.107							
Observed				0.000	0.216	0.000	0.031	12005.280	-0.010	3.040
...93>v93 FP				0.028	0.143	0.001	0.029	23868.107	0.335	1.339

Observed / Predicted Report (Custom graph) - 2019 flow survey_full

Powered by InfoWorks®

Flow survey: >SDP Stage 2A>S2A Model Build _Verification>Rainfall>EventA_12032019 (11/06/2019 13:56:53)
Sim: >SDP Stage 2A>S2A Model Build _Verification>Verification 2019 (HMA)>Runs>EventA_190312_v94!>v94a (03/07/2019 14:34:57)

Flow Survey Location (Obs.) F04, Model Location (Pred.) D/S SJ24642802.1, Rainfall Profile: 2



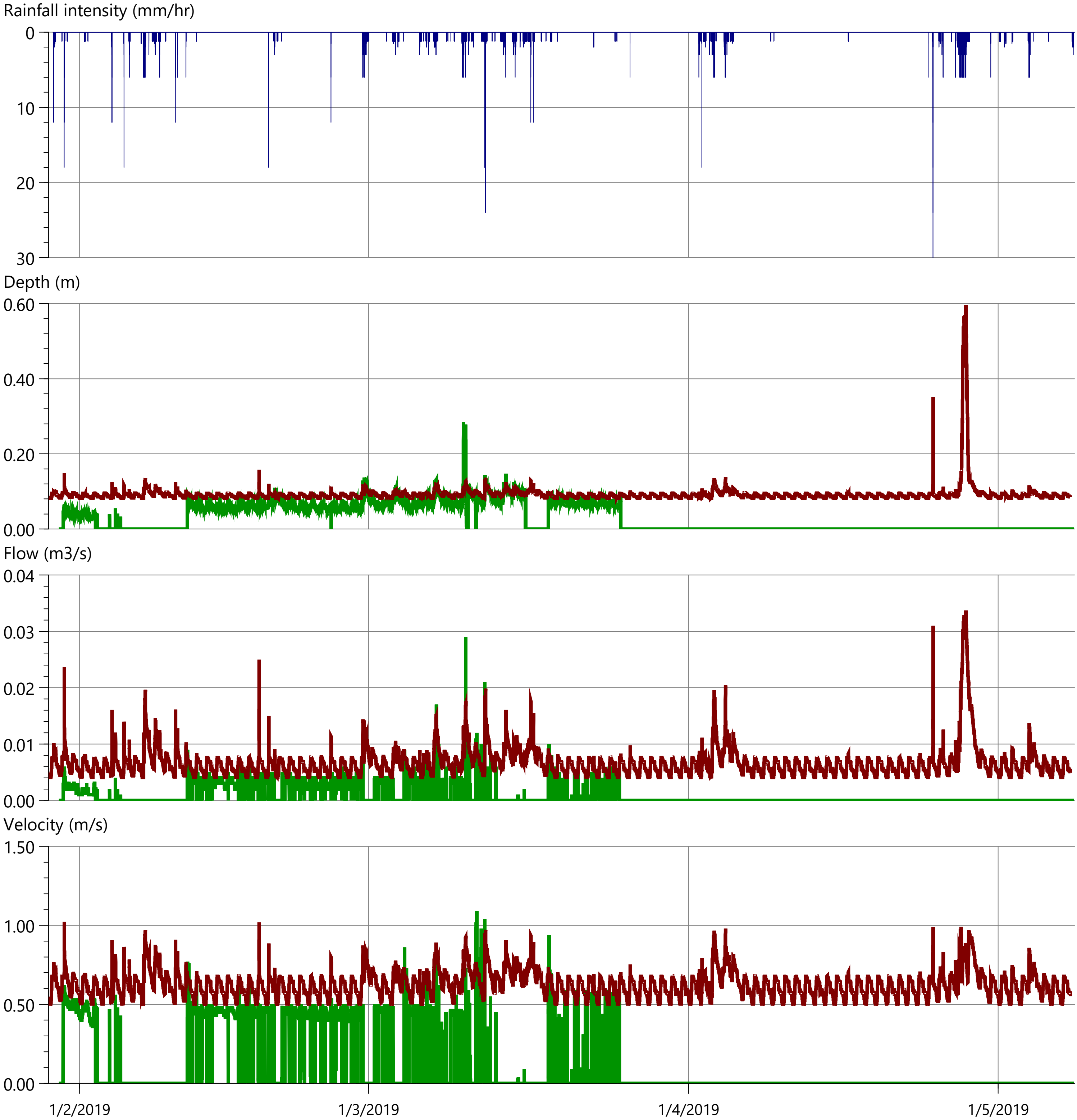
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	11.000	24.000	0.230							
Observed				0.063	0.143	0.000	0.021	73.576	0.000	1.040
...v94!>v94a				0.082	0.140	0.004	0.021	1400.128	0.513	0.990

Observed / Predicted Report (Custom graph) - EventA_ 12032019

Powered by InfoWorks®

Flow survey: >SDP Stage 2A>S2A Model Build _Verification>Rainfall>2019 Flow survey (11/06/2019 13:56:53)
Sim: >SDP Stage 2A>S2A Model Build _Verification>Verification 2019 (HMA)>Runs>full flow survey 2019v93>v93 FP (02/07/2019 16:37:16)

Flow Survey Location (Obs.) F04, Model Location (Pred.) D/S SJ24642802.1, Rainfall Profile: 2



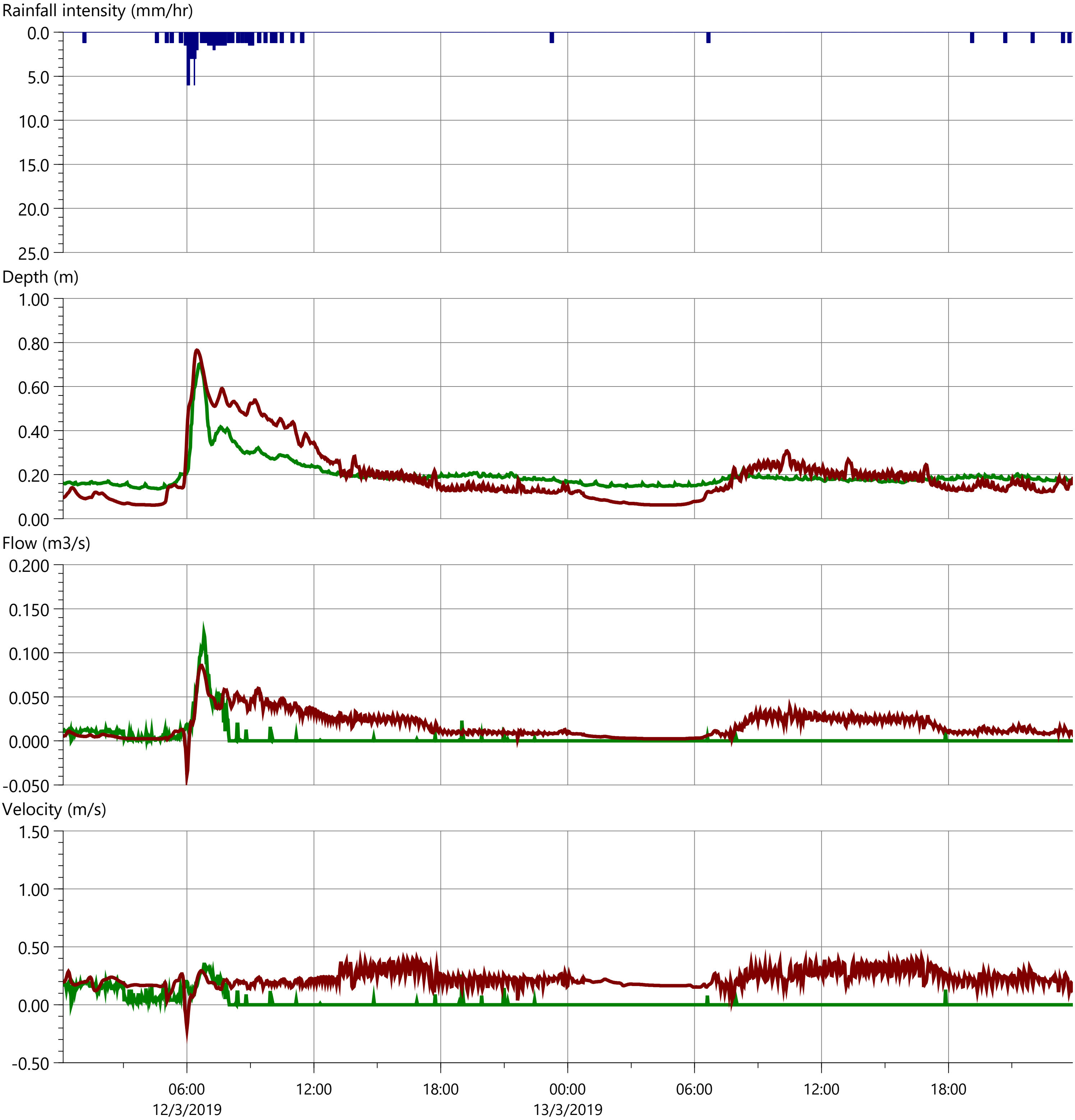
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	254.400	30.000	0.107							
Observed				0.000	0.284	0.000	0.029	6629.760	0.000	1.090
...93>v93 FP				0.081	0.596	0.004	0.034	56623.240	0.502	1.023

Observed / Predicted Report (Custom graph) - 2019 flow survey_full

Powered by InfoWorks®

Flow survey: >SDP Stage 2A>S2A Model Build _Verification>Rainfall>EventA_12032019 (11/06/2019 13:56:53)
Sim: >SDP Stage 2A>S2A Model Build _Verification>Verification 2019 (HMA)>Runs>EventA_190312_v94!>v94a (03/07/2019 14:34:57)

Flow Survey Location (Obs.) F09, Model Location (Pred.) D/S SJ24634408.1, Rainfall Profile: 6



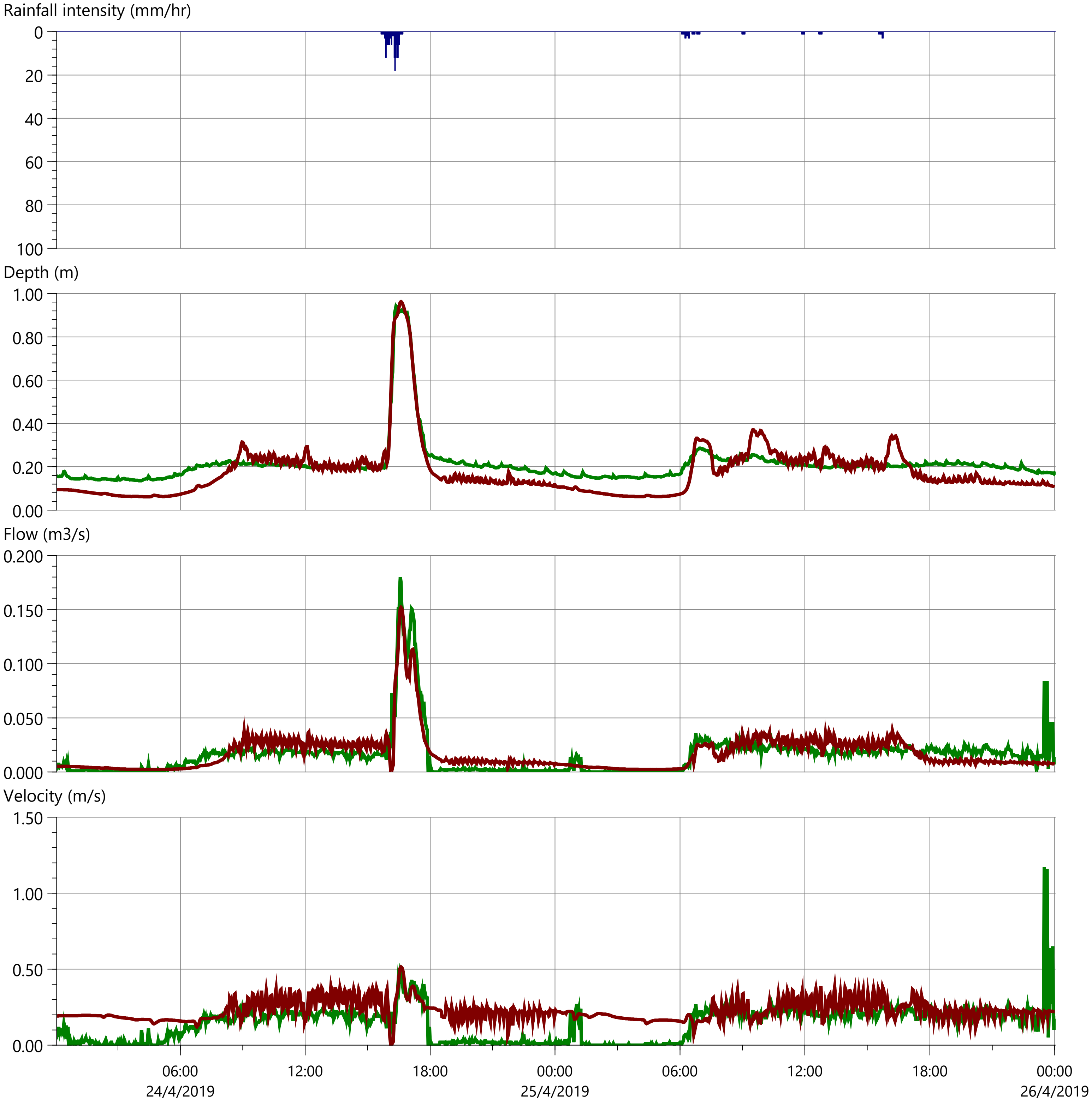
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	9.200	6.000	0.193							
Observed				0.136	0.702	0.000	0.122	560.023	0.000	0.350
...v94!>v94a				0.062	0.765	-0.038	0.086	3024.827	-0.203	0.406

Observed / Predicted Report (Custom graph) - EventA_12032019

Powered by InfoWorks®

Flow survey: >SDP Stage 2A>S2A Model Build _Verification>Rainfall>EventB_24042019 (11/06/2019 13:56:53)
Sim: >SDP Stage 2A>S2A Model Build _Verification>Verification 2019 (HMA)>Runs>EventB_190424_v94>v94b (03/07/2019 15:21:56)

Flow Survey Location (Obs.) F09, Model Location (Pred.) D/S SJ24634408.1, Rainfall Profile: 6

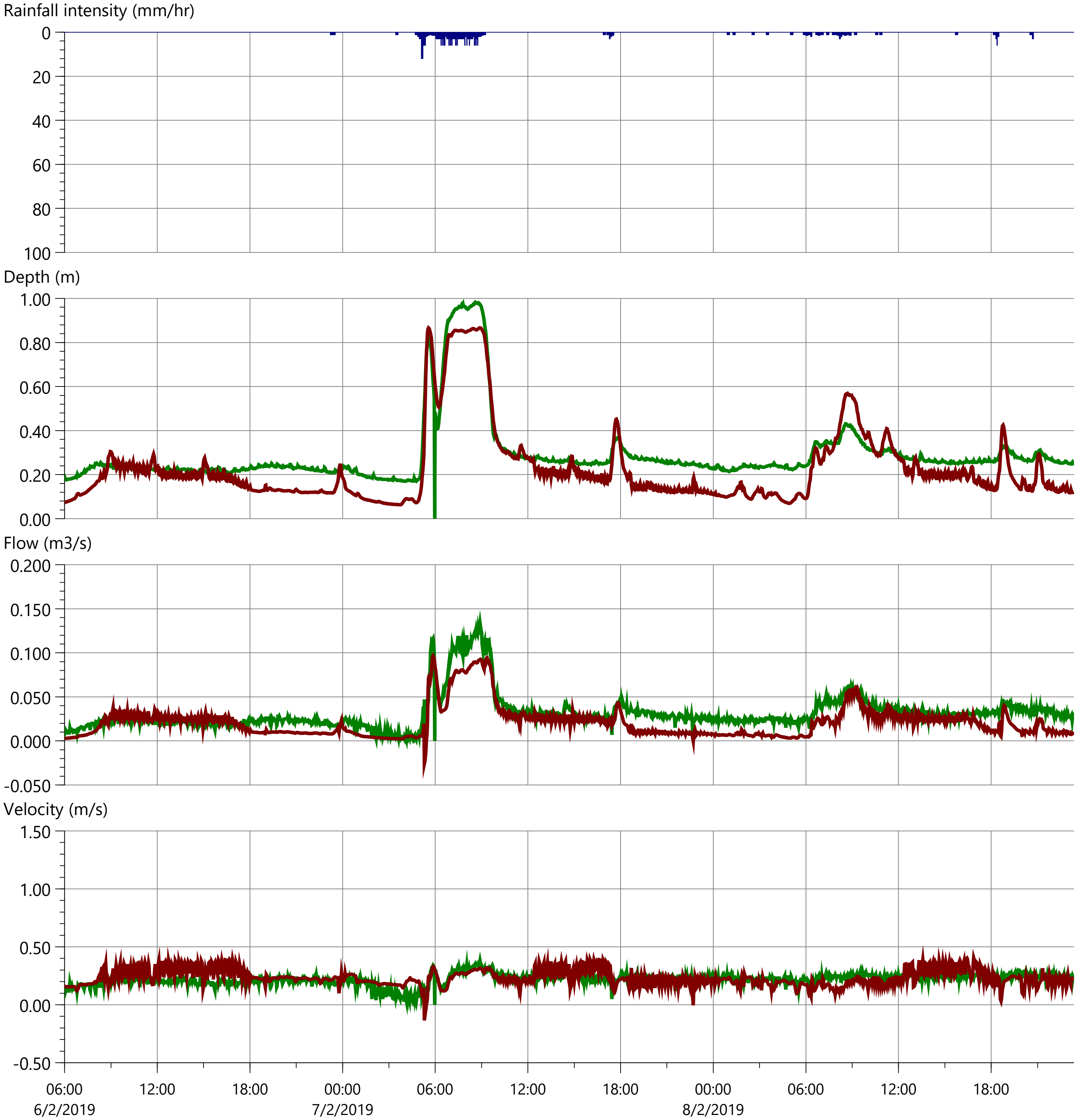


	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	7.600	18.000	0.158							
Observed				0.136	0.942	0.000	0.180	2666.855	0.000	1.170
...v94>v94b				0.062	0.962	0.002	0.152	2929.853	0.007	0.515

Observed / Predicted Report (Custom graph) - EventB_ 24042019

Observed / Predicted Report Produced by Robert.Farrington (03/07/2019 15:48:47) Page 9 of 21
Flow survey: >SDP Stage 2A>S2A Model Build _Verification>Rainfall>EventC_07022019 (11/06/2019 13:56:53)
Sim: >SDP Stage 2A>S2A Model Build _Verification>Verification 2019 (HMA)>Runs>EventC_190207_v94!>v94c (03/07/2019 14:35:09)

Flow Survey Location (Obs.) F09, Model Location (Pred.) D/S SJ24634408.1, Rainfall Profile: 5

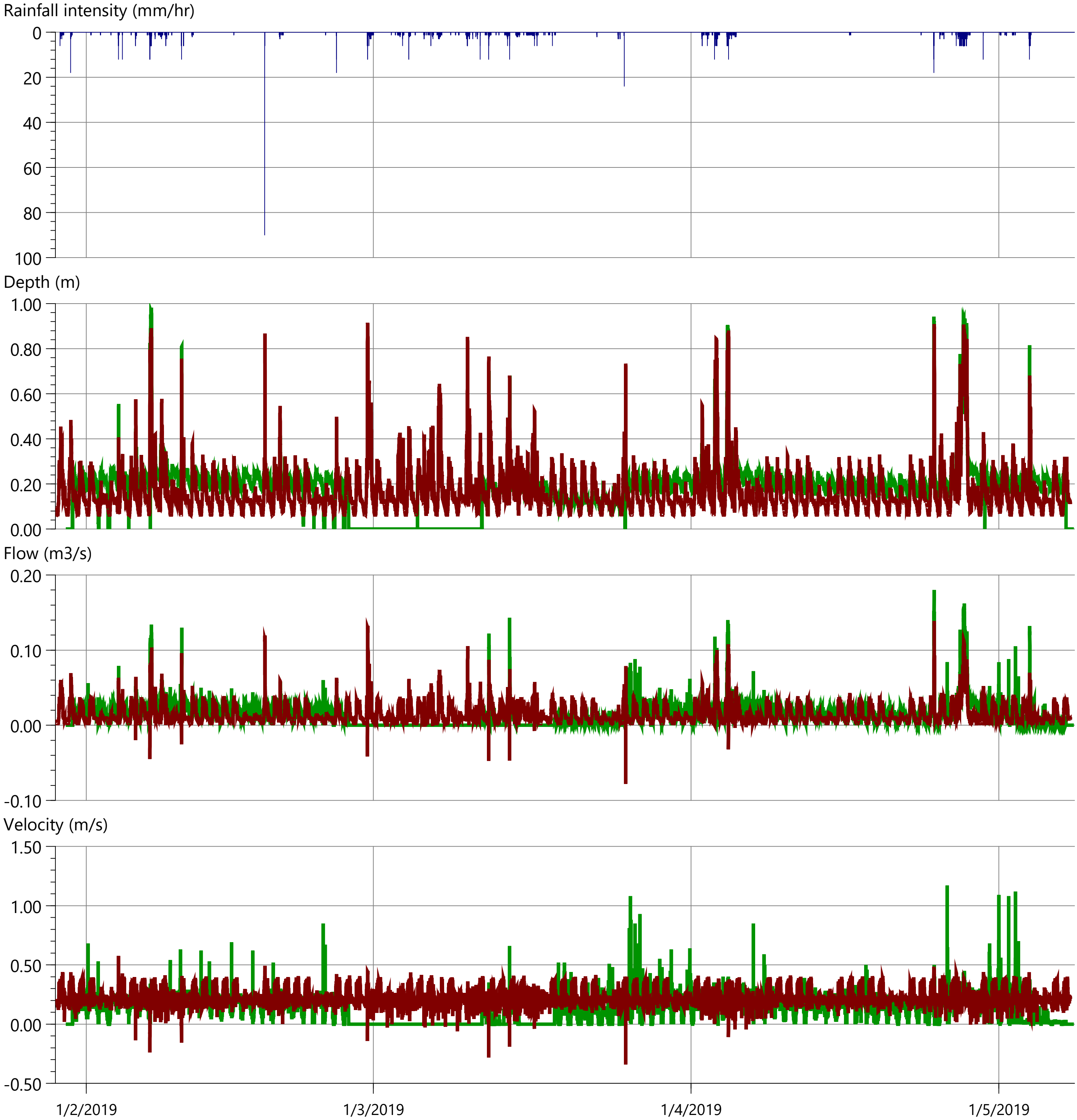


	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	22.000	12.000	0.337							
Observed				0.000	0.982	0.000	0.134	7406.397	0.000	0.380
...v94!>v94c				0.064	0.867	-0.026	0.097	5009.156	-0.135	0.405

Observed / Predicted Report (Custom graph) - EventC_ 07022019

Powered by InfoWorks®

Flow Survey Location (Obs.) F09, Model Location (Pred.) D/S SJ24634408.1, Rainfall Profile: 6



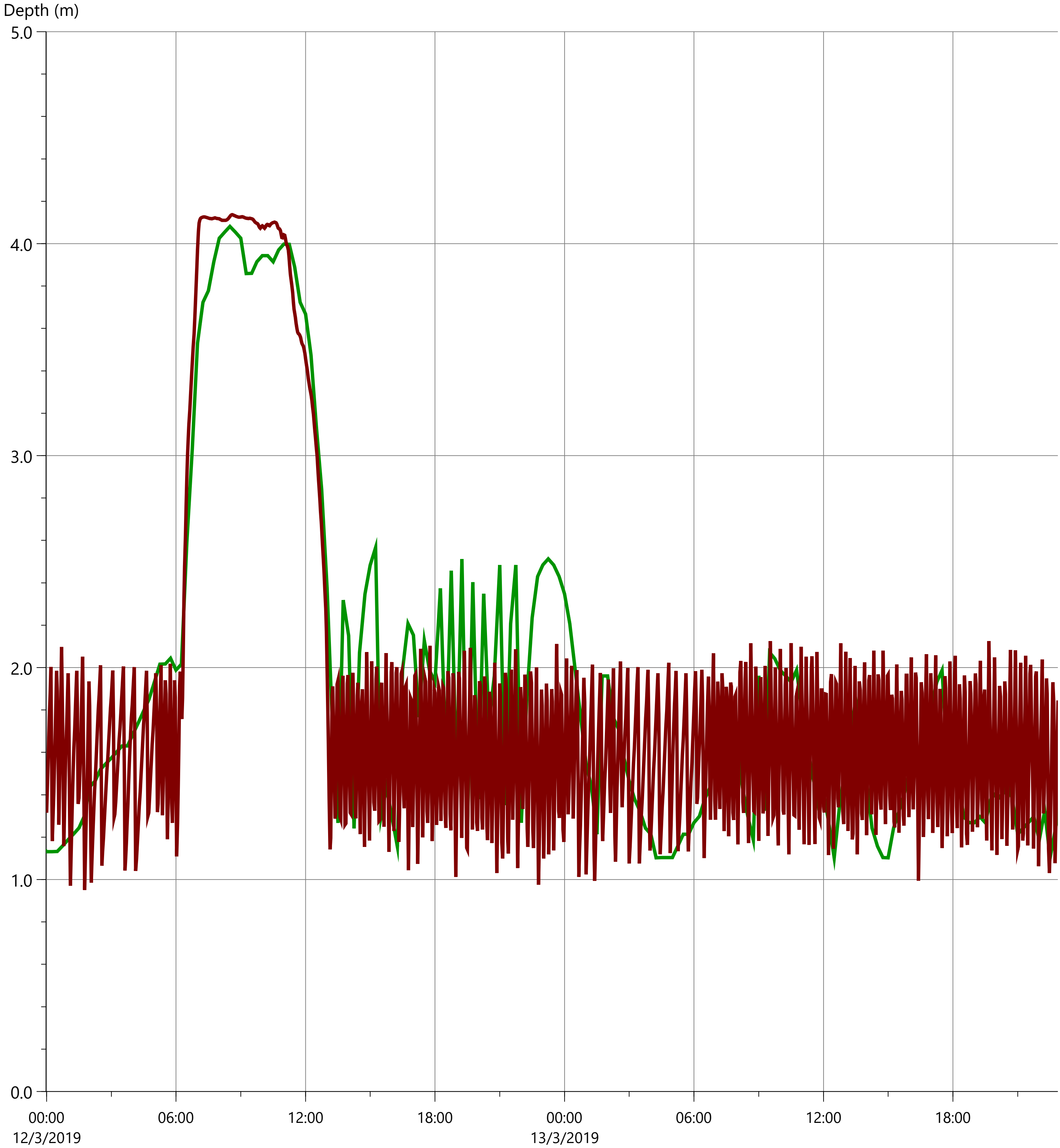
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	262.800	90.000	0.111							
Observed				0.000	0.982	0.000	0.180	122574.000	0.000	1.170
...93>v93 FP				0.062	0.916	-0.078	0.139	123830.506	-0.340	0.576

Observed / Predicted Report (Custom graph) - 2019 flow survey_full

Powered by InfoWorks®

Observed / Predicted Report Produced by Robert.Farrington (03/07/2019 16:05:03) Page 1 of 1
Flow survey: >SDP Stage 2A>Telemetry>Argoed WW Level Adjusted (27/06/2019 12:25:20)
Sim: >SDP Stage 2A>S2A Model Build _Verification>Verification 2019 (HMA)>Runs>EventA_190312_v94!>v94a (03/07/2019 14:34:57)

Flow Survey Location (Obs.) Argoed Wet Well Level Adjusted, Model Location (Pred.) D/S Dum_ArgoedSPS.1



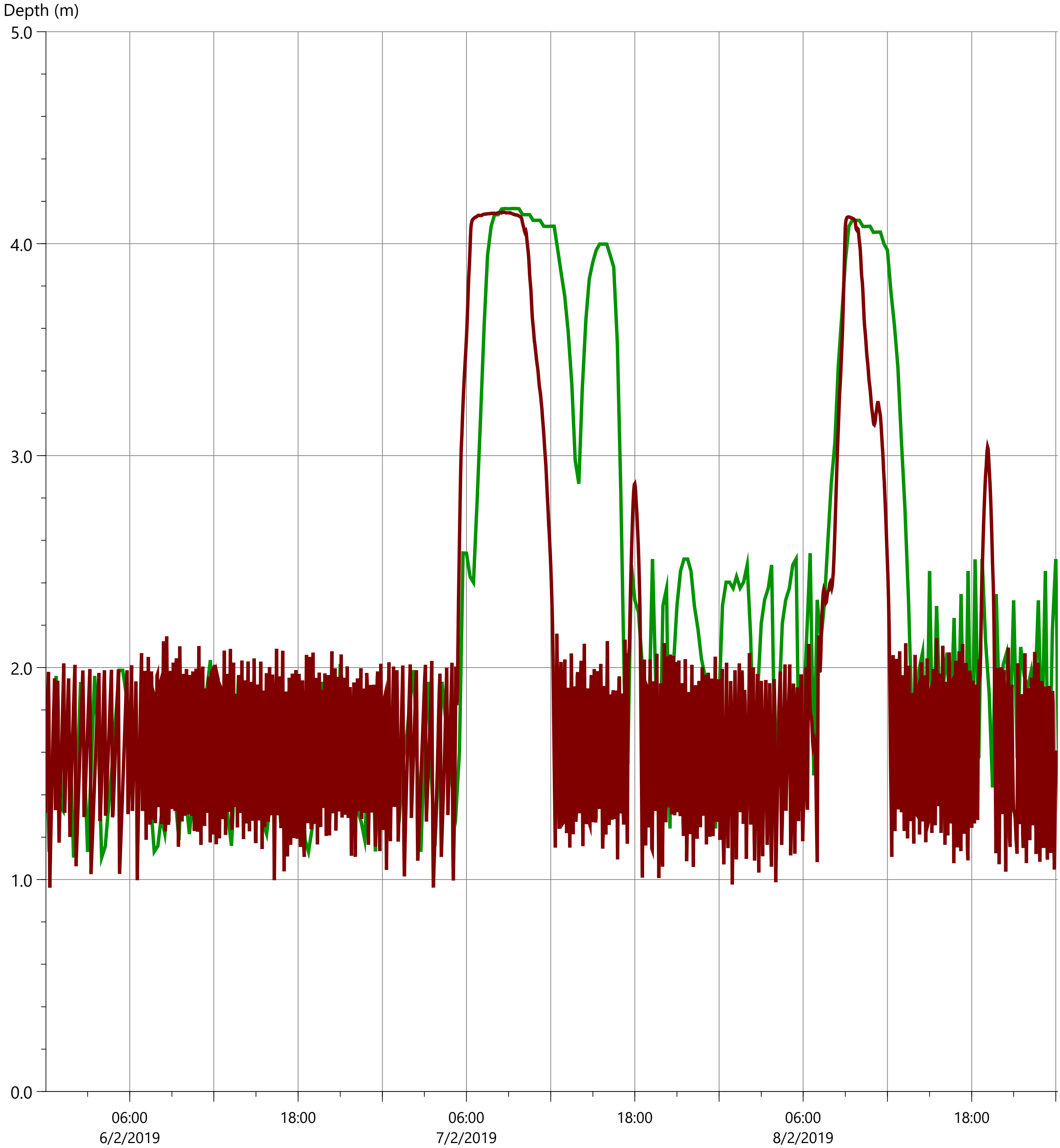
		Depth	
		Min (m)	Max (m)
Observed	green line	1.103	4.082
EventA_190312_v94!>v94a	dark red line	0.951	4.137

Observed / Predicted Report (Custom graph) - 2019 flow survey_ArgoedWW

Powered by InfoWorks®

Observed / Predicted Report Produced by Robert.Farrington (03/07/2019 16:02:42) Page 1 of 1
Flow survey: >SDP Stage 2A>Telemetry>Argoed WW Level Adjusted (27/06/2019 12:25:20)
Sim: >SDP Stage 2A>S2A Model Build _Verification>Verification 2019 (HMA)>Runs>EventC_190207_v94!>v94c (03/07/2019 14:35:09)

Flow Survey Location (Obs.) Argoed Wet Well Level Adjusted, Model Location (Pred.) D/S Dum_ArgoedSPS.1



	Depth	
	Min (m)	Max (m)
Observed	1.103	4.165
EventC_190207_v94!>v94c	0.962	4.148

Observed / Predicted Report (Custom graph) - 2019 flow survey_ArgoedWW

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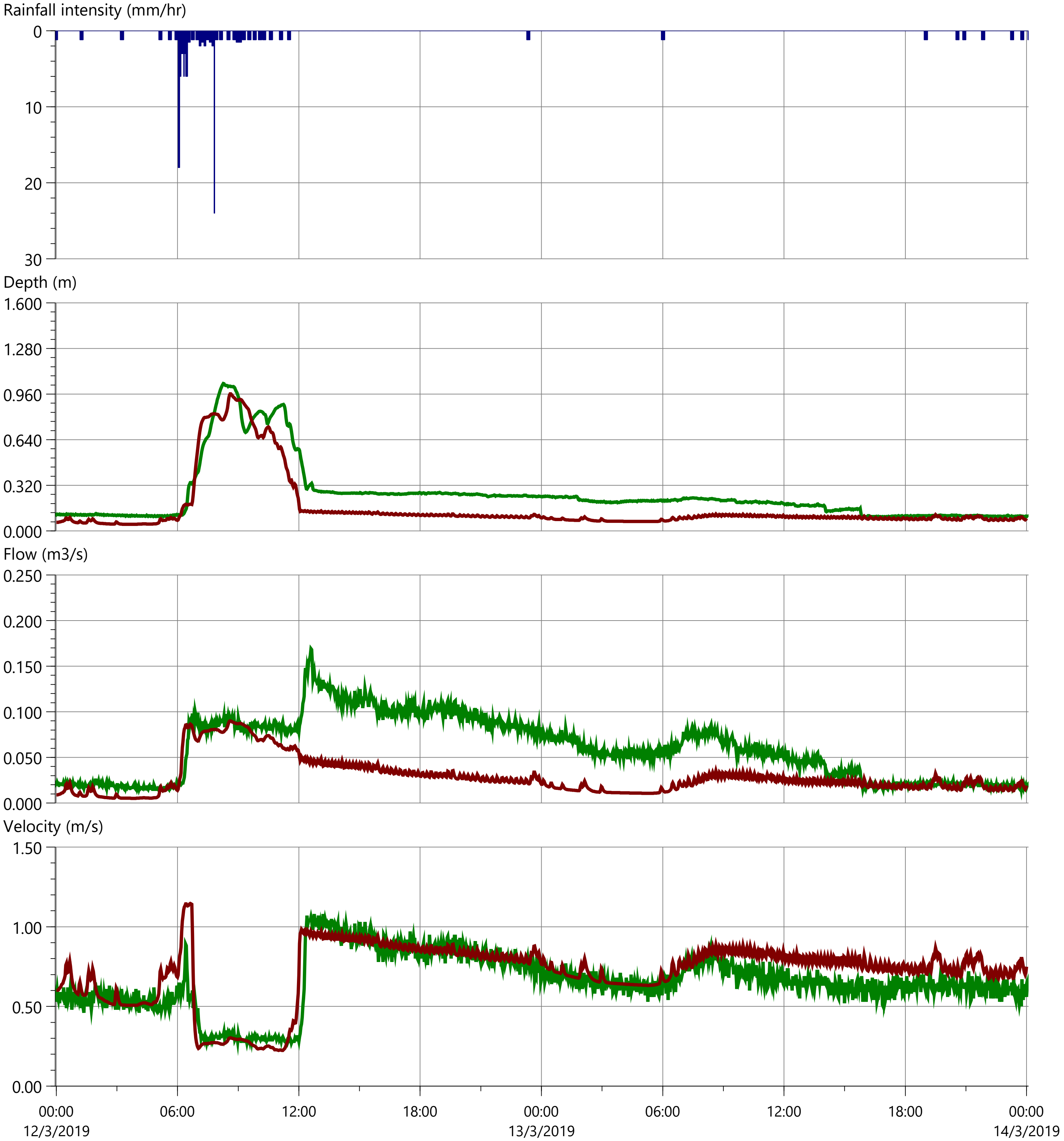
Flow Survey Location (Obs.) F10, Model Location (Pred.) D/S SJ24638802.1, Rainfall Profile: 2



	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	11.163	24.000	0.232							
Observed				0.097	1.034	0.014	0.169	10426.328	0.270	1.080
...18>v118a				0.047	0.962	0.005	0.090	4968.722	0.224	1.146

Observed / Predicted Report (Custom graph) - 2019 flow survey_full monitor 10 only

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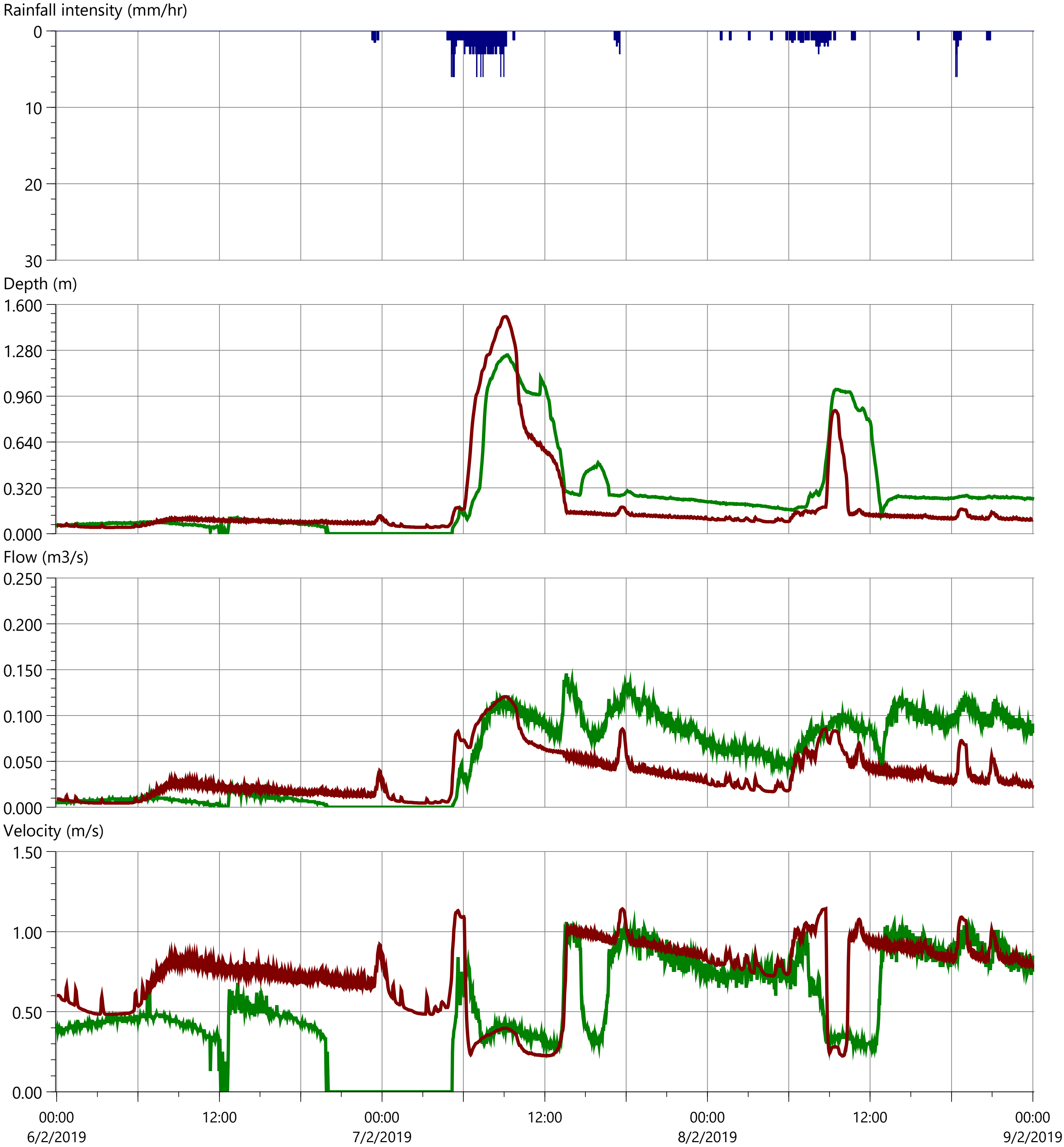
Flow Survey Location (Obs.) F10, Model Location (Pred.) D/S SJ24638802.1, Rainfall Profile: 2



	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	20.400	6.000	0.283							
Observed				0.000	1.247	0.000	0.146	14161.425	0.000	1.060
...18>v118c				0.044	1.515	0.004	0.120	8959.816	0.223	1.142

Observed / Predicted Report (Custom graph) - 2019 flow survey_full monitor 10 only

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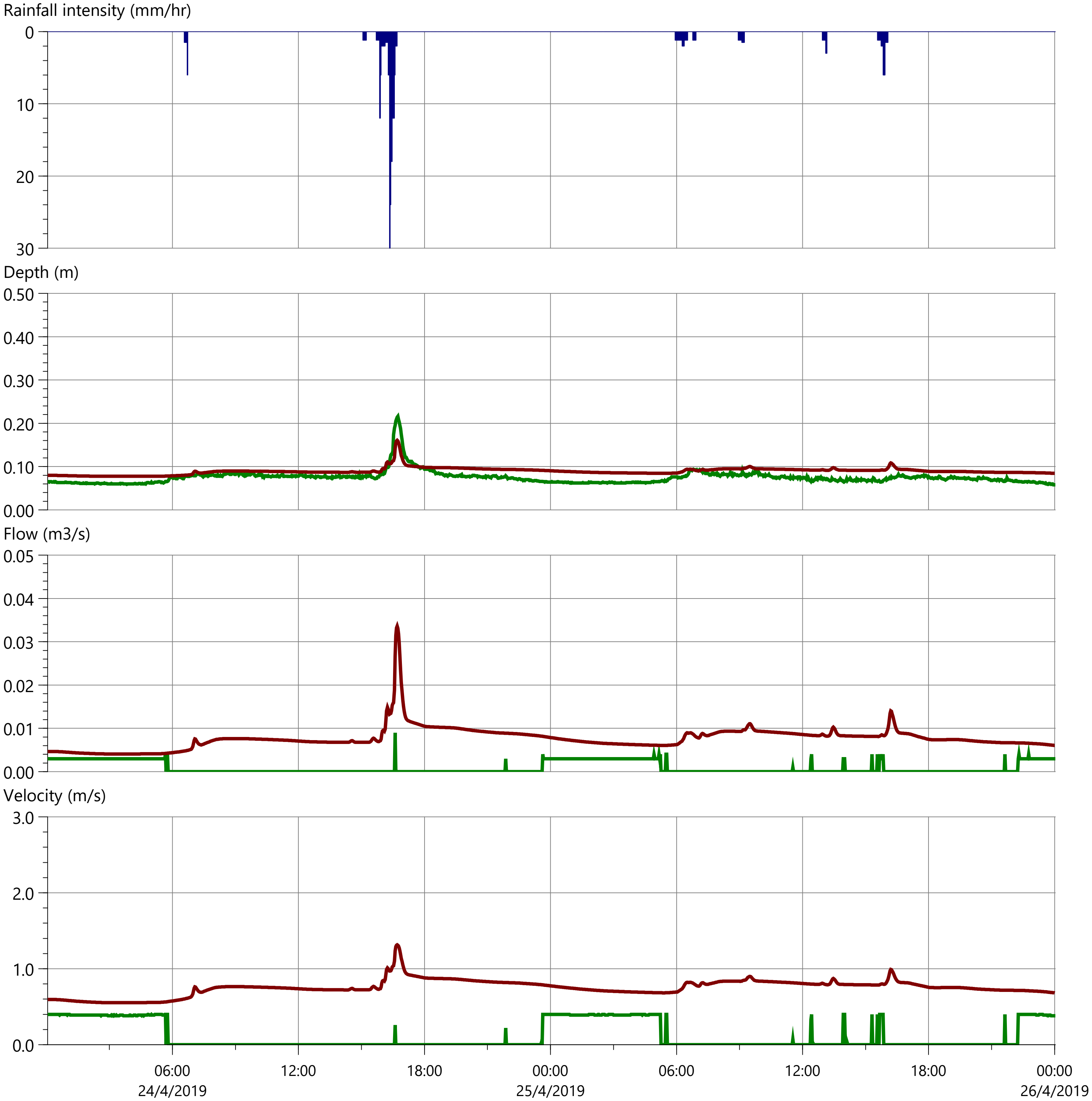
Observed / Predicted Report Produced by Robert.Farrington (03/07/2019 15:27:50) Page 19 of 21
Flow survey: >SDP Stage 2A>S2A Model Build _Verification>Rainfall>EventB_24042019 (11/06/2019 13:56:53)
Sim: >SDP Stage 2A>S2A Model Build _Verification>Verification 2019 (HMA)>Runs>EventB_190424_v94>v94b (03/07/2019 15:21:56)

Flow Survey Location (Obs.) F21, Model Location (Pred.) D/S SJ24642801.1, Rainfall Profile: 2



	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	9.800	30.000	0.204							
Observed				0.058	0.216	0.000	0.009	150.775	0.000	0.400
...v94>v94b				0.078	0.161	0.004	0.034	1320.350	0.554	1.314

Observed / Predicted Report (Custom graph) - EventB_ 24042019

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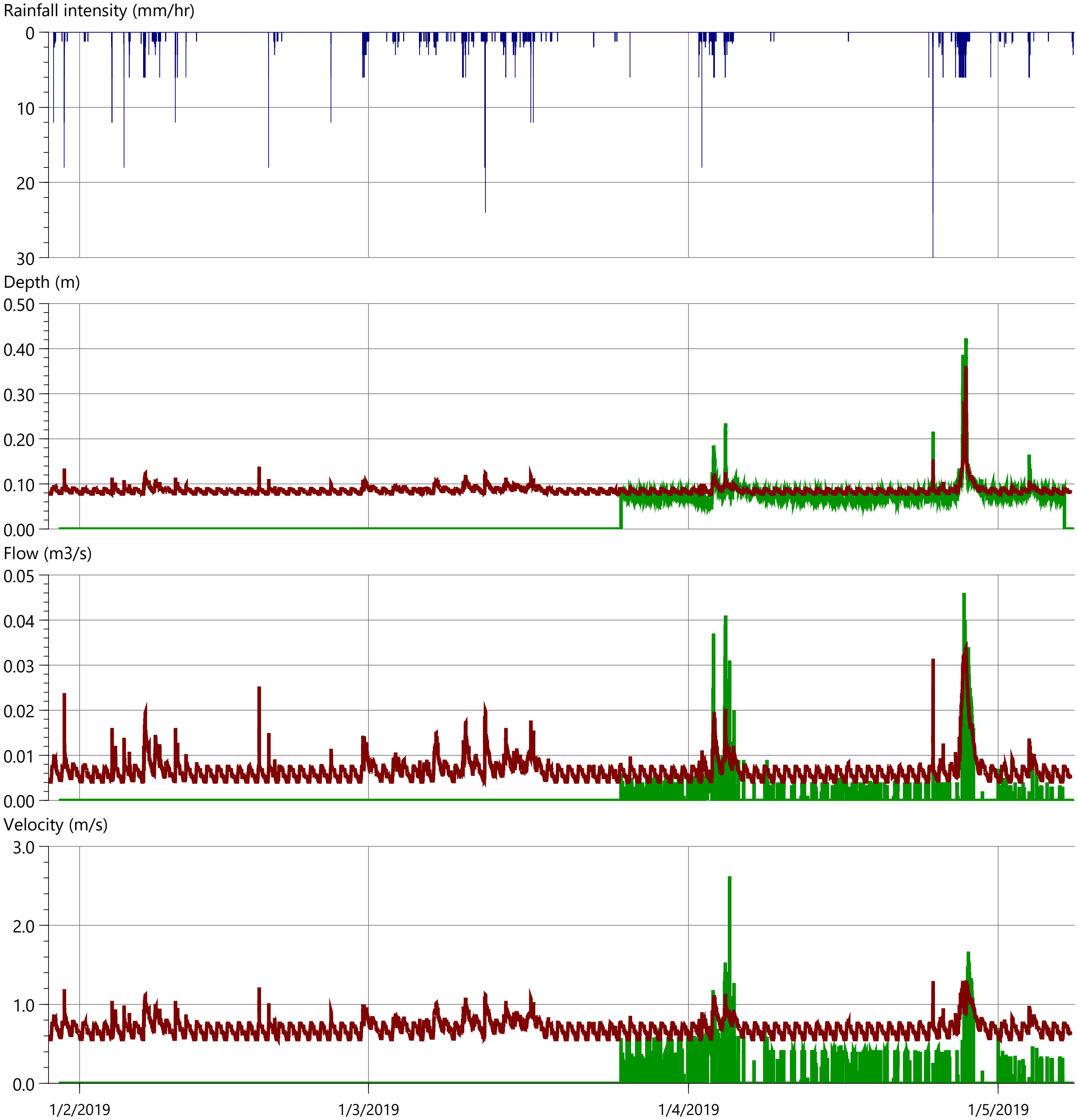
Observed / Predicted Report Produced by Robert.Farrington (03/07/2019 16:58:51) Page 19 of 21
Flow survey: >SDP Stage 2A>S2A Model Build _Verification>Rainfall>2019 Flow survey (11/06/2019 13:56:53)
Sim: >SDP Stage 2A>S2A Model Build _Verification>Verification 2019 (HMA)>Runs>full flow survey 2019v93>v93 FP (02/07/2019 16:37:16)

Flow Survey Location (Obs.) F21, Model Location (Pred.) D/S SJ24642801.1, Rainfall Profile: 2



	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	254.400	30.000	0.107							
Observed				0.000	0.423	0.000	0.046	3414.360	0.000	2.620
...93>v93 FP				0.078	0.361	0.004	0.034	56546.834	0.554	1.296

Observed / Predicted Report (Custom graph) - 2019 flow survey_full

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