ERECTION OF BUILDING FOR BUILDERS MERCHANT, LAND OFF ST GEORGES ROAD, NANPEAN, ST AUSTELL.

FLOOD RISK ASSESSMENT

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J-056- Rev.01

Engineering & Development Solutions

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ERECTION OF BUILDING FOR BUILDERS MERCHANT, LAND OFF ST GEORGES ROAD, NANPEAN, ST AUSTELL.

FLOOD RISK ASSESSMENT

Report No.	Issue Detail	Originator	Date	Checked by	Date
J-056-01	01	JC	07/12/2016	JC	07/12/2016

For:
Mr Mike Tregunna
BLS Building Supplies Ltd
Unit 1 Southmoor
Winnard Perch
St Columb
Cornwall
TR9 6DG

Job No: J-056
Date: December 2016
Edition: 01

CONTENTS

APPENDICES

1.0 INTRODUCTION

Mr Mike Tregunna is proposing to construct a new storage building on an existing builders yard situated within the village of Drinnick near St Austell in Mid Cornwall. The site is located within the main village of Drinnick as shown on the location plan and boundary plan provided as Figures 1 and 2 below.

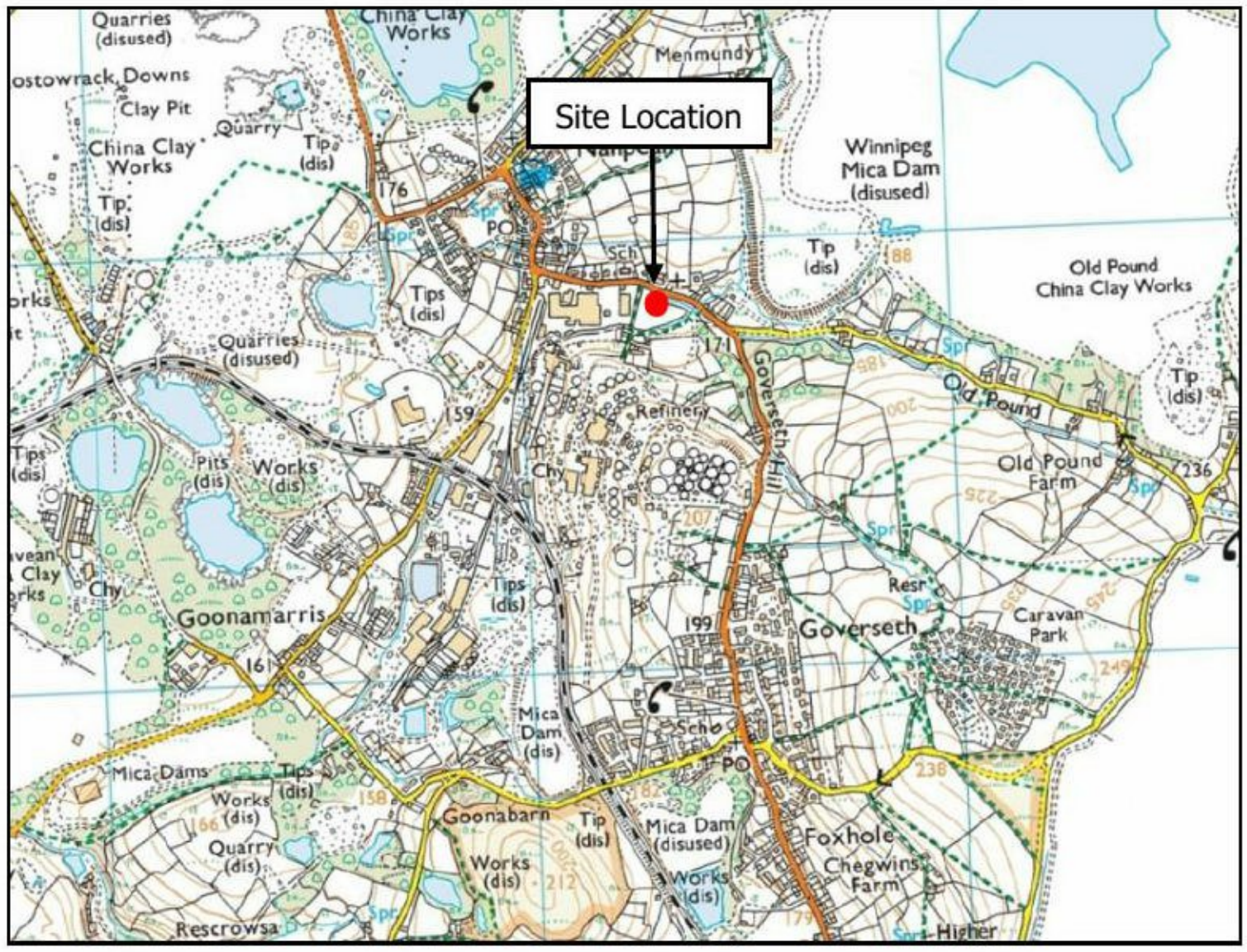

Figure 1 – Location Plan

Figure 2 – Site Boundary

The total area of the site is approximately 0.72 ha. Reference to the Environment Agency (EA) indicative mapping shows the site to be located within Flood Zone's 1 (Low Risk) 2 (medium risk) and 3 (High Risk). As part of the site is located in flood zone's 2 and 3, then the development will require a Flood Risk Assessment (FRA) in accordance with the National Policy Framework on Planning and Flood Risk.

The primary aim of the FRA will be to investigate the extent of the floodplain on the site for a range of return period events and flood scenarios. This should allow any vulnerable development to be located in areas which are not at risk of flooding.

In order to address this requirement, Engineering and Development Solutions (EDS) have been commissioned to prepare an FRA for the proposed development, in accordance with the best practice principles of the National Planning Policy Framework (NPPF), Drainage Guidance for Cornwall (DGfC) and Planning Practice Guidance (PPG). The report details the findings of this study

2.0 SITE LOCATION AND DESCRIPTION

- **Site Location**

The site comprises an existing large commercial plot located on the eastern site of the village of Drinnick in Mid Cornwall. The site takes the form of a rough triangle shape with principal dimensions of about 95m wide by 135m long. The Ordnance Survey Grid Reference for the site is SW 96311 55841. The site covers an area of approximately 0.72ha.

The site located within the catchment of the Gwindra Stream which runs along the southern boundary of the site.

The northern boundary abuts the main B3279 road serving the village. To the west the site abuts another large industrial plot.

The topographic survey, included as **Appendix A**, indicates that the site falls generally from the east to the west at a typically gradient of about 1 in 50. The highest point on the site is set at an approximate elevation of 167.25 mAOD on the eastern border and the lowest point is at an elevation of about 165.70 mAOD at the western corner of the site.

In the wider topography, the site is situated on elevated ground to the north west of St Austell and is surrounded by undulating hilly ground.

- **Existing Usage**

The site is currently a large open area used as a builders yard for the storage of equipment and materials.

- **Proposed Usage**

A new large industrial building is proposed to compliment the sites existing use as a builders yard.

3.0 FLOOD MECHANISMS

Existing Hydrology

Analysis of the Environment Agency indicative flood map shows that the site is located within Flood Zone's 1,2 and 3., indicating that it is at little or no risk from tidal or fluvial flooding and therefore suitable for all types of development. However, the lower area of the site is within flood zone 3 (high risk).

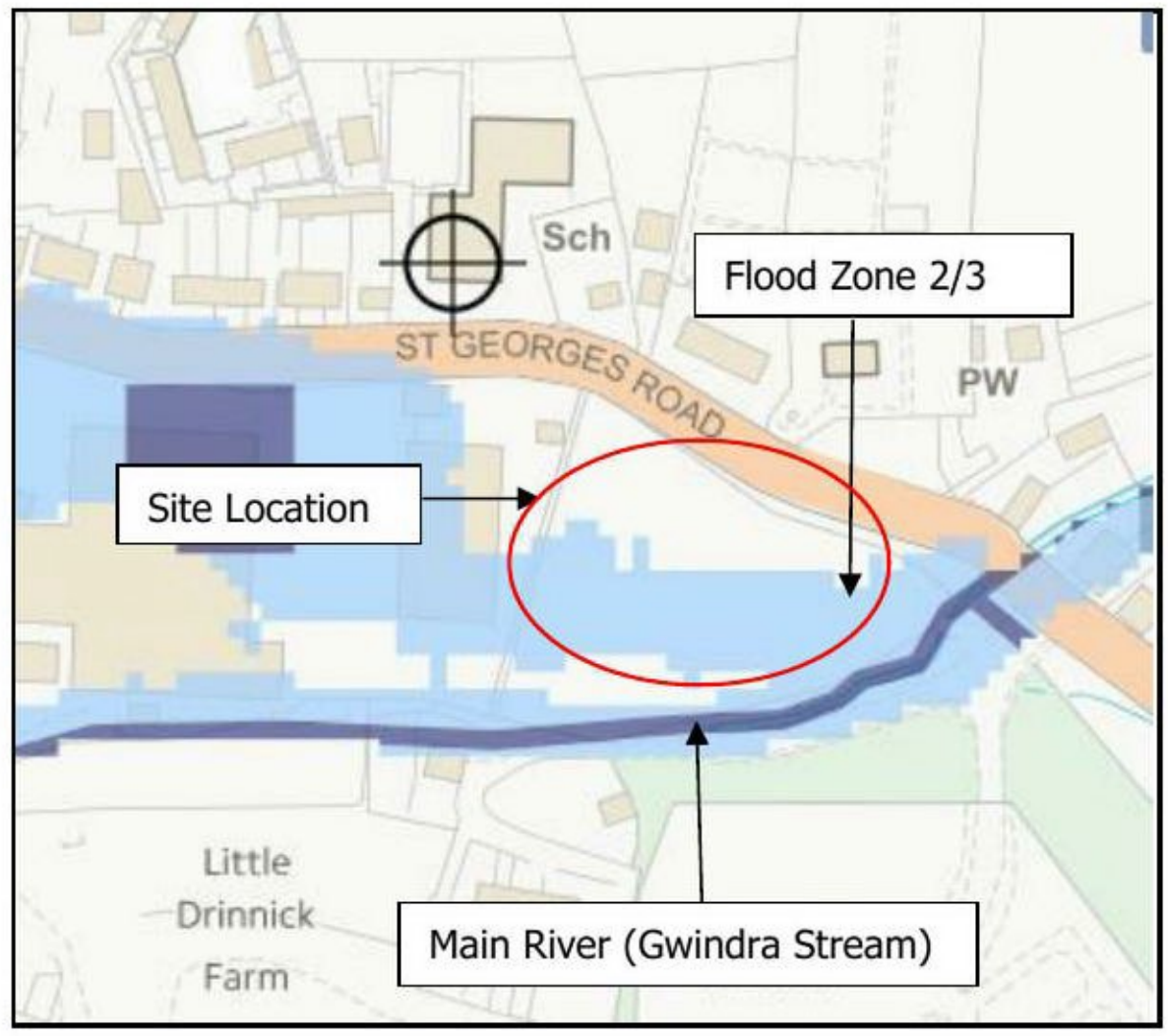

Figure 3 Environment Agency Indicative Flood Map

Several possible flooding mechanisms have been considered at the site, and are discussed below.

- **Groundwater Flooding**

The site is located on sloping topography which falls towards the Stream. It is expected that the nearby watercourses will act as a sump that will drain groundwater away from the site.

Given the above, it is considered that ground water flooding does not pose a significant risk to the development site and will not be considered further within this report.

- **Overland Sheet Flow**

Overland flows from the south of the site would fall into the stream and as such would not affect the site itself. Flow from the north would be intercepted by the highway and its drainage network and would divert flows away from the yard.

Given this scenario the risk of overland flow affecting the site is considered minimal and is not considered further in this report.

- **Fluvial (River) Flooding**

The Environment Agency indicative flood mapping (Figure 3) shows that the site includes an area of flood zone 2 and 3. As such this is investigated in more detail in section 4 and 5 of this report.

- **Tidal Flooding**

The site is well outside of any areas of tidal influence, located at a minimum elevation of around 165.70 m AOD. Given the nature of the site, and surrounding topography, tidal flooding has not been considered further within this report.

- **Flooding as a Result of Development**

The development site is currently entirely hard paved. The proposed building will be situated over an area of existing hard paving. As such the rate of runoff from the site will not change as a result of this development.

The site is not within a critical drainage area, as defined in 'Drainage Guidance for Cornwall' and as such no special drainage requirement apply. However the proposed building should still be served with a surface water drainage system that complied with 'Drainage Guidance for Cornwall' as well as part H of the Building Regulations.

4.0 FLOOD FLOW ESTIMATION

Flood flow estimates have been derived for a variety of return period events. The catchment descriptors for the site were obtained from the FEH web service.

- **Catchment**

The catchment at this site encompasses an area of 4.41km^2 according to FEH web service catchment descriptors. An extract of the catchment area and catchment descriptors is shown below in Figure 4. The upstream catchment of the site is largely undeveloped but incorporates large areas of former china clay workings.

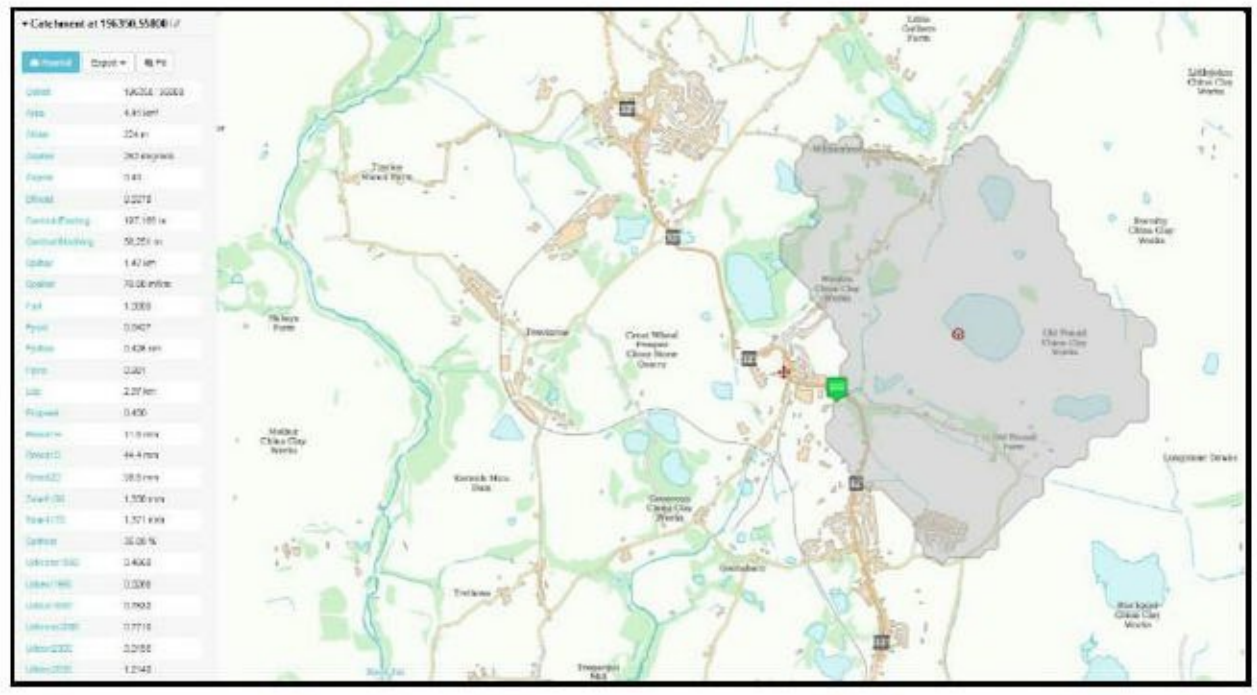

Figure 4 – Catchment Boundary

- **Methodology**

The ReFH2 rainfall runoff method was used to determine flood flows using the software created by the Centre for Ecology & Hydrology version 2.1.

The ReFH2 method is the most up-to-date method and is currently the industry standard recognised by the Environment Agency.

The catchment descriptors for the site (see figure 4) were entered; this resulted in an essentially rural area, which is accurate for the upstream catchment area.

A time step of 15 minutes and duration of 3 hours and 15 minutes were used for calculating the design rainfall as recommended as part of the ReFH2 software.

The table below shows the calculated flows for various return period events:

Return Period	**Constantine Stream (m^3/s) Peak Flow**
30 yr	4.69
100 yr	6.45

100 yr + CC (+40%)	9.03
1,000 yr	13.28

Table 5 ReFH2 Flow Estimates

- **Summary**

The predicted flows have been calculated using the industry approved ReFH2 Rainfall Run-off Method. Full details of the flow calculations are included in **Appendix B**.

5.0 HEC-RAS HYDRAULIC MODELLING

Steady state flood modelling of the on-site watercourse has been carried out to assess the extent of the flood zones on the site, using HEC-RAS Version 4.1.0 released in January 2010 developed by the U.S. Army Corps of Engineers, Hydrologic Engineering Centre. The modelling has been carried out in order to assess the likely extents, depths and velocities of flood water within the site.

- **HEC-RAS Data Inputs**

The model has been created using topographic sections which were surveyed for this study by CE Surveys Ltd. A total of 5 no. cross sections were entered in the model. Further interpolated cross sections were then added to give a total of 10 sections on the site itself.

The flood flow estimates defined in Section 4 of this report have been entered into the model at the most upstream cross section, number 5.

Flow Boundary Conditions – All Watercourses

Upstream: Normal Depth, Gradient of Channel 0.014.

Downstream: Normal Depth, Gradient of Channel 0.014.

Geometric Data

Manning's n values: Conservative n values were used to represent the worst case scenario of heavy vegetation cover within the channel, and un-kept floodplain areas. Values were taken from the HEC-RAS manual as follows.

- Channel – Clean, winding, some pools and shoals – 0.055
- Left bank – Rough asphalt – 0.016
- Right bank – Rough asphalt – 0.016

The HEC-RAS files for this project are available upon request.

- **Modelling Assumptions & Methodology**

The aim of this modelling study is to seek a quantifiable demonstration of the flood risk at the subject site. Rather than providing outputs for all return periods this modelling study focuses principally upon the 1 in 100-year flood event including a 40% allowance for climate change and the 1 in 1,000-year flood event. Therefore, flood zone extents will be indicative of Flood Zones 2 & 3 as defined in the Planning Practice Guidance (PPG). Value for an 85% climate change scenario are included in **Appendix B**.

For the 1 in 100 year + 40% climate change and 1 in 1,000 year flood events the fluvial floodplain extent has been exported onto the topographical survey plan. The floodplains have been plotted by translating flood levels at each cross section onto the survey, with areas between sections interpolated by examination of ground levels and falls.

Flood levels and velocities for each cross section have been extracted directly from the model. Flood levels, depths and flow velocities have been determined for each cross-section and interpolated cross-sections.

- **Bridge/Culverts**

There is a culvert downstream of the site which could potentially impact on the flood flows for the area. The culvert is largely overgrown and as such is susceptible to blockage. As such the culvert has been excluded from the model. This is a conservative approach as this forces flows overland which is what would occur if the culvert were to become blocked.

Figure 6 below shows an overview of the model.

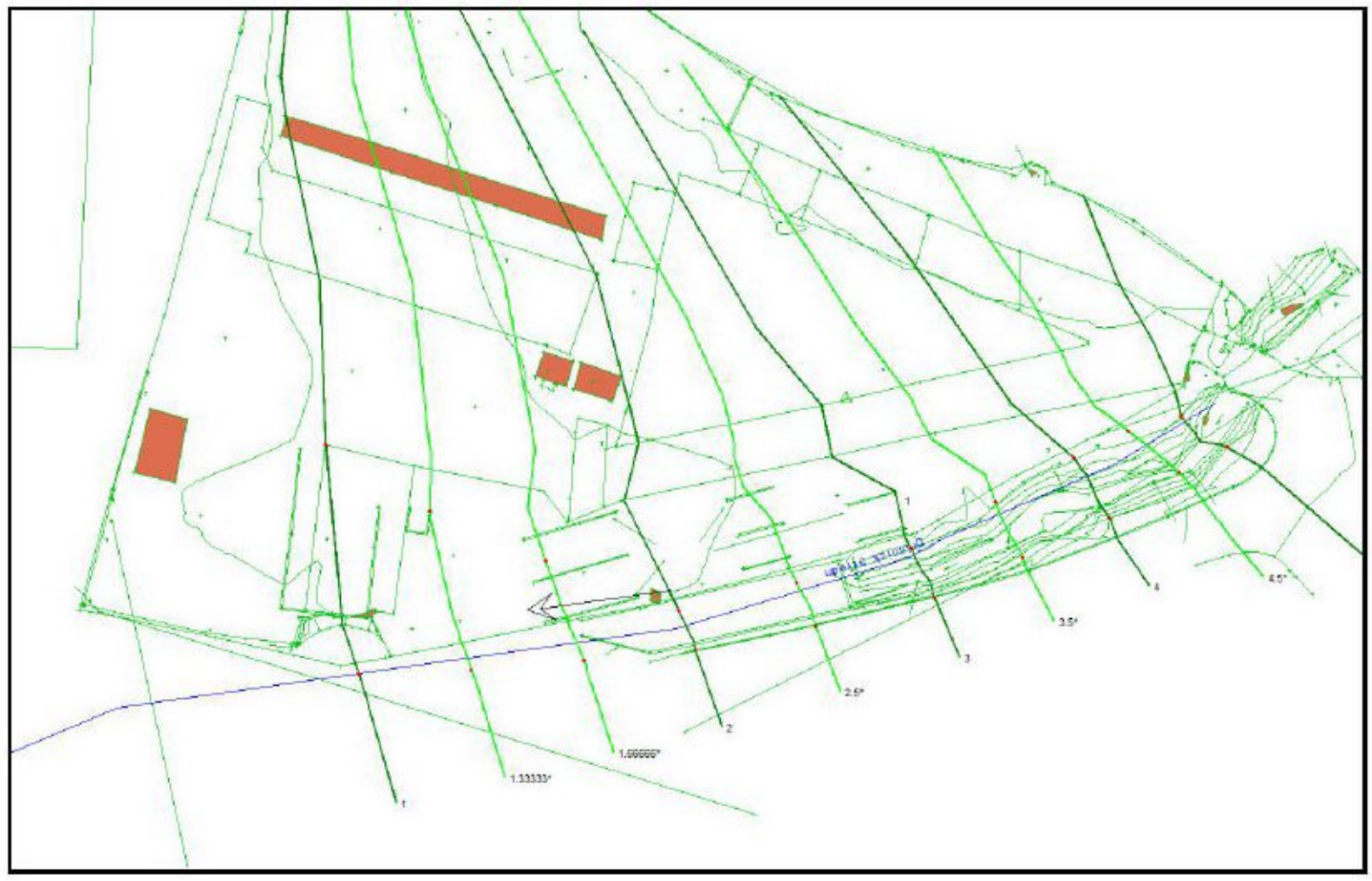

Figure 6 HEC-RAS Geometry Overview

- **Modelling Results**

The resulting floodplain drawing is included on Drawing 1010 in **Appendix A** which shows the 1 in 100-year with 40% climate change (CC) and the 1 in 1,000-year floodplains. Tabulated HEC-RAS results are included in **Appendix B**.

Floodplains across the proposed development site

A summary of the flood levels relating to the sections across the site from upstream to downstream is presented below in **Table 7**. The table lists the estimated flood levels at each section. Flow velocities calculated by the HEC-RAS model have also been listed.

HEC-RAS Plan: Plan 01 River: Drinnick Stream Reach: 1 Reload Da

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
1	5	100 yr	6.45	165.06	166.64	165.86	166.68	0.002764	0.89	7.21	6.97	0.28
1	5	100 yr + CC	9.03	165.06	166.72	166.02	166.79	0.004319	1.16	7.79	8.00	0.35
1	5	1000 yr	13.28	165.06	166.83	166.24	166.95	0.006658	1.53	8.76	9.98	0.44
1	4.5*	100 yr	6.45	164.83	166.63		166.66	0.002080	0.80	8.09	7.55	0.24
1	4.5*	100 yr + CC	9.03	164.83	166.70		166.76	0.003310	1.04	8.68	9.51	0.31
1	4.5*	1000 yr	13.28	164.83	166.80		166.90	0.005128	1.38	9.84	13.47	0.39
1	4	100 yr	6.45	164.61	166.62		166.65	0.001567	0.71	9.07	8.72	0.21
1	4	100 yr + CC	9.03	164.61	166.69		166.73	0.002570	0.94	9.67	10.14	0.28
1	4	1000 yr	13.28	164.61	166.79		166.86	0.003983	1.23	11.13	20.45	0.35
1	3.5*	100 yr	6.45	164.56	166.60		166.63	0.001593	0.74	8.73	9.14	0.22
1	3.5*	100 yr + CC	9.03	164.56	166.66		166.71	0.002640	0.99	9.24	10.45	0.28
1	3.5*	1000 yr	13.28	164.56	166.72		166.82	0.004615	1.35	10.14	20.92	0.38
1	3	100 yr	6.45	164.50	166.59		166.62	0.001433	0.74	8.84	11.28	0.20
1	3	100 yr + CC	9.03	164.50	166.63		166.68	0.002404	0.98	9.44	16.35	0.26
1	3	1000 yr	13.28	164.50	166.68		166.77	0.004220	1.33	10.39	22.14	0.35
1	2.5*	100 yr	6.45	164.40	166.57		166.60	0.001372	0.71	9.73	34.58	0.19
1	2.5*	100 yr + CC	9.03	164.40	166.61		166.65	0.002020	0.88	11.12	37.84	0.23
1	2.5*	1000 yr	13.28	164.40	166.65		166.71	0.003069	1.10	12.83	41.48	0.29
1	2	100 yr	6.45	166.25	166.50	166.50	166.56	0.004252	0.41	6.82	55.27	0.29
1	2	100 yr + CC	9.03	166.25	166.54	166.54	166.61	0.004139	0.44	8.80	63.23	0.29
1	2	1000 yr	13.28	166.25	166.58	166.58	166.66	0.003944	0.49	11.90	74.01	0.29
1	1.66666*	100 yr	6.45	166.24	166.37	166.40	166.48	0.009401	0.47	5.46	55.62	0.47
1	1.66666*	100 yr + CC	9.03	166.24	166.39	166.44	166.53	0.009550	0.56	7.04	65.36	0.49
1	1.66666*	1000 yr	13.28	166.24	166.42	166.48	166.58	0.009868	0.66	9.44	80.75	0.52
1	1.33333*	100 yr	6.45	166.10	166.24	166.28	166.35	0.011117	0.71	5.49	54.76	0.67
1	1.33333*	100 yr + CC	9.03	166.10	166.26	166.31	166.40	0.011699	0.82	7.08	86.85	0.71
1	1.33333*	1000 yr	13.28	166.10	166.29	166.34	166.44	0.012430	0.95	9.77	113.68	0.75
1	1	100 yr	6.45	165.91	166.09	166.12	166.18	0.016150	1.15	5.32	80.20	1.12
1	1	100 yr + CC	9.03	165.91	166.10	166.14	166.22	0.017232	1.29	6.75	93.36	1.18
1	1	1000 yr	13.28	165.91	166.13	166.17	166.26	0.016645	1.42	8.98	100.53	1.19

Table 7 Summary of HEC-RAS Results

The full set of results is included in **Appendix B**.

- **Sensitivity Analysis**

A sensitivity analysis has been undertaken for the site. The Manning 'n' values have been increased globally across the model by 0.01. This resulted in an increase in flood levels of around 0.0-0.2m across the model.

- **Summary**

In all the events considered the western area of the site is inundated with shallow flood water of typically 100-200mm total depth. The velocity of the flood water on site is in the order of 1 m/s. The full flood duration from baseflow to peak and back to baseflow is 3.15 hours. Therefore flooding will only occurring on the site at peak flows for around 1 to 2 hours at most.

6.0 MITIGATION MEASURES

The following mitigation measures are recommended for the proposed development. The proposed building is located on cross sections 1 to 1.33. At section 1.33 the highest flood level was found to be 166.29m AOD. Based on this the following mitigation measures are recommended.

- The highest flood level on the site at section 1.33 in the blocked culvert scenario is 166.29m AOD. As such finished floor levels for the building should be set at a level not lower than 166.4m AOD or higher. As the building requires level access from the adjacent yard levels high than 166.40m AOD are unlikely to be practical.

- A SuDS system should be implemented for the development to limit runoff rates from the site. This should be designed to the standards outlined in 'Drainage Guidance for Cornwall'. Infiltration drainage should be utilised as a first choice, subject to successful percolation testing. If percolation tests fail than an attenuated discharge to the stream should be used.

- It is advised that the site owner ensure the stream on the southern boundary of the site and downstream culvert entrance is kept well maintained and clear of debris.

- The building will be a typical portal frame commercial unit and as such is unlikely to be resistant to water ingress. So flooding could be expected up to 200mm deep within the building. Therefore any internal building works up to say 400mm should be carried out using flood resilient construction.

- As the building will not be designed to withstand flooding there will be no loss of floodplain storage as a result of the development.

7.0 ACCESS/EGRESS

The sites established access is via a gate and road at the sites eastern corner. This access point would be susceptible to flooding in an extreme flood event. Providing an alternative access route is unlikely to be viable given the boundary constraints of the site.

The site has a separate access gate in the northern fence line. This access should be retained and could be used as a safe dry access route for users of the site in the event of a flood.

8.0 FLOOD RISK POLICY SUMMARY

Based on the findings of this study, the site has been found to lie within Flood Zones 1, 2 and 3 as defined in NPPF.

The site is currently used as a builders yard, which would be classified as 'Less Vulnerable' as a flood risk vulnerability. Commercial Buildings are also considered to be 'Less Vulnerable' according to the Planning Practice Guidance (PPG) Table 2.

Given the above situation the proposal does not increase the flood vulnerability of the site.

Referring to Table 3 of PPG shown in Figure 8 below, the proposed development, is deemed appropriate in flood zones 1, 2, and 3.

Flood risk vulnerability classification (see table 2)		Essential infrastructure	Water compatible	Highly vulnerable	More vulnerable	Less vulnerable
Flood zone (see table 1)	Zone 1	✓	✓	✓	✓	✓
	Zone 2	✓	✓	Exception Test required	✓	✓
	Zone 3a	Exception Test required	✓	×	Exception Test required	✓
	Zone 3b functional floodplain	Exception Test required	✓	×	×	×

Key: ✓ Development is appropriate.
× Development should not be permitted.

Figure 8 Extract from PPG - Flood risk vulnerability and flood zone 'compatibility'

The sequential test should be applied to all developments in flood zone 2 and 3. This development is associated with the current site usage as a builder's yard. As such the consideration of alternative sites is not considered appropriate as the building could not be delivered on another site and meet the aims of this development proposal.

9.0 SUMMARY

A number of flood mechanisms have been investigated for the site, which is found to be at low risk of flooding from all sources, other than fluvial flooding. Given the proximity of the watercourses to the site, further investigation into fluvial flood risks has been undertaken.

A HEC-RAS model has been constructed with a view to quantifying the risk of fluvial flooding to the site.

Flood flow estimates have been undertaken for the 100yr, 100yr + 40% CC and 1,000yr events using the industry standard and most up-to-date method - ReFH2, the estimated flows are outlined in Section 4.

The data from the model has been used to produce a floodplain plan for both the 100 year with 40% allowance for climate change and 1,000 year flood events at the site. These have been extracted from the model and added to Drawing 1010 found in **Appendix A**. Flood levels and water velocities have also been extracted for the channel and both banks. The full set of HEC-RAS results are included in **Appendix B**.

During all events considered the extent of inundation is similar showing shallow flooding over around two thirds of the site. This is in line with the Environment Agency indicative floodplain extent for the site. Figure 9 below shows the flood extent at section 2.5 for this event.

Typical flood depths on the site are in the region of 100-200mm deep, at a velocity of 1 m/s.

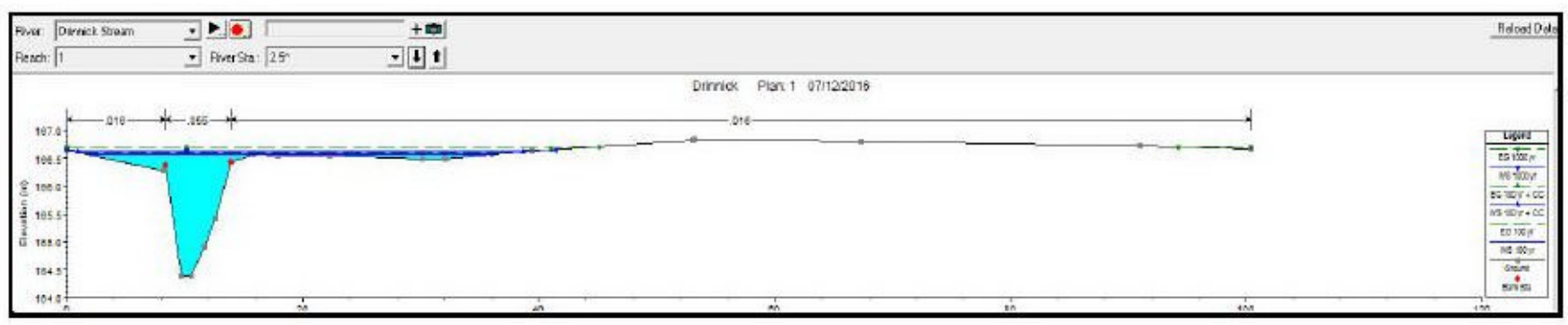

Figure 9 Flood Extent at Section 2.5.

The current and proposed site use are both classified as 'less vulnerable' to flooding and as such the development does not increase the flood vulnerability of the site.

The proposal is for a commercial building to compliment the sites current use. As such the consideration of alternative sites as part of a sequential test is not thought to be appropriate.

Table 3 of the planning practice guidance indicates that this type of development is appropriate in flood zones 1, 2 and 3. As such it is considered that the development is entirely appropriate in this location given the guidance outlined in NPPF and the associated planning guidance.

APPENDIX A SITE SURVEY SHOWING FLOODPLAIN EXTENTS

NOTES

1. This drawing is copyright. Refer to details above.
2. This drawing is only to be used for the purposes described in the status box below.
   Work to figured dimensions only, do not scale.
3. This drawing is to be read in conjunction with all other drawings, details and specifications pertaining to the work described.
4. Materials and workmanship shall comply to the appropriate British Standards and Codes of Practice unless otherwise stated.
5. The activities required to construct the work, shown on drawings clearly marked FOR CONSTRUCTION, may be subject to the provisions of the Construction (Design & Management) Regulations 2015. The Contractor and Client must ensure that they are adequately conversant with these regulations and that the appropriate procedures required under the regulations are observed at all times.
6. Design Risk Assessment

   A risk assessment relating to potential hazards associated with the construction, operation and demolition of the work described within this drawing, in so far as it has been designed by EDS, has been undertaken. Risks so identified have been eliminated by design wherever practicable. The situation with regard to residual risks is as follows.

   Planning stage – to be risk assessed at detail design stage.

DATE.	DRWN.	CHKD.	REV.	NOTES.
07:12:16	JC	JC	A	PRELIMINARY ISSUE

PROJECT MANAGER:-	JAN CLARK
DRAWN DATE -	DEC 2016
SCALE & SHEET SIZE:-	1:250 @ A1

PRELIMINARY

EDS
Engineering & Development Solutions
• Flood Risk Assessment • Highway Design
• SuDS and Surface Water • Civil Engineering
• Foul and Sewage Treatment • Statutory Approvals
EDS, Unit 10, Penstraze Business Centre, Truro, Cornwall. TR4 8PN Phone (01872) 306311 Mob 07973816457
Email: jan@edsolutions.co.uk
www.edsolutions.co.uk

CLIENT
MR MIKE TREGUNNA

PROJECT
PROPOSED DEVELOPMENT AT YARD OFF ST GEORGES ROAD, NANPEAN.

DRAWING TITLE
SITE FLOOD PLAN

PROJECT No.	DRAWING No.	REV.
J-056	1010	A

FLOOD ZONE 3
1 in 100 YEAR FLOOD

FLOOD ZONE 2
1 in 1000 YEAR FLOOD

APPENDIX B CALCULATIONS

UK Design Flood Estimation

Generated on Tuesday, December 06, 2016 11:01:38 AM by Jan Clark
Printed from the ReFH Flood Modelling software package, version 2.2.6029.28099

Summary of estimate using the Flood Estimation Handbook revitalised flood hydrograph method (ReFH)

Site details Checksum: A760-B1DB

Site name: Drinnick

Easting: 196350

Northing: 55800

Country: England, Wales or Northern Ireland

Catchment Area (km^2): 4.41

Using plot scale calculations: No

Site description: None

Model run: 100 year

Summary of results

Rainfall - FEH 2013 (mm):	66.08	Total runoff (ML):	65.25
Total Rainfall (mm):	50.31	Total flow (ML):	158.41
Peak Rainfall (mm):	9.81	Peak flow (m^3/s):	6.45

Parameters

Where the user has overriden a system-generated value, this original value is shown in square brackets after the value used.
** Indicates that the user locked the duration/timestep*

Rainfall parameters (Rainfall - FEH 2013 model)

Name	Value	User-defined?
Duration (hh:mm:ss)	03:15:00	No
Timestep (hh:mm:ss)	00:15:00	No
SCF (Seasonal correction factor)	0.8	No
ARF (Areal reduction factor)	0.96	No
Seasonality	Winter	n/a

Loss model parameters

Name	Value	User-defined?
Cini (mm)	97.96	No
Cmax (mm)	423.87	No
Use alpha correction factor	No	No
Alpha correction factor	n/a	No

Routing model parameters

Name	Value	User-defined?
Tp (hr)	1.49	No
Up	0.65	No
Uk	0.8	No

Baseflow model parameters

Name	Value	User-defined?
BF0 (m^3/s)	0.26	No
BL (hr)	33.35	No
BR	1.49	No

Urbanisation parameters

Name	Value	User-defined?
Urban area (km^2)	0.14	No
Urbext 2000	0.02	No
Impervious runoff factor	0.7	No
Imperviousness factor	0.3	No
Tp scaling factor	0.5	No
Sewered area (km^2)	0.00	Yes
Sewer capacity (m^3/s)	0.00	Yes

Time series data

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
00:00:00	0.895	0.000	0.212	0.000	0.261	0.261
00:15:00	1.386	0.000	0.332	0.011	0.259	0.270
00:30:00	2.139	0.000	0.520	0.050	0.257	0.307
00:45:00	3.286	0.000	0.820	0.132	0.256	0.388
01:00:00	5.011	0.000	1.300	0.280	0.256	0.536
01:15:00	7.531	0.000	2.064	0.529	0.258	0.787
01:30:00	9.809	0.000	2.886	0.938	0.263	1.201
01:45:00	7.531	0.000	2.369	1.565	0.273	1.838
02:00:00	5.011	0.000	1.650	2.393	0.291	2.684
02:15:00	3.286	0.000	1.114	3.324	0.317	3.641
02:30:00	2.139	0.000	0.739	4.243	0.352	4.595
02:45:00	1.386	0.000	0.484	5.050	0.397	5.448
03:00:00	0.895	0.000	0.315	5.650	0.450	6.100
03:15:00	0.000	0.000	0.000	5.934	0.508	6.442
03:30:00	0.000	0.000	0.000	5.881	0.567	6.448
03:45:00	0.000	0.000	0.000	5.570	0.624	6.195
04:00:00	0.000	0.000	0.000	5.096	0.678	5.774
04:15:00	0.000	0.000	0.000	4.538	0.725	5.263
04:30:00	0.000	0.000	0.000	3.959	0.766	4.726
04:45:00	0.000	0.000	0.000	3.410	0.801	4.211
05:00:00	0.000	0.000	0.000	2.921	0.830	3.751
05:15:00	0.000	0.000	0.000	2.490	0.854	3.345
05:30:00	0.000	0.000	0.000	2.102	0.873	2.975
05:45:00	0.000	0.000	0.000	1.744	0.888	2.633
06:00:00	0.000	0.000	0.000	1.413	0.899	2.312
06:15:00	0.000	0.000	0.000	1.105	0.907	2.011
06:30:00	0.000	0.000	0.000	0.820	0.910	1.730
06:45:00	0.000	0.000	0.000	0.566	0.911	1.477
07:00:00	0.000	0.000	0.000	0.359	0.910	1.268
07:15:00	0.000	0.000	0.000	0.212	0.906	1.119
07:30:00	0.000	0.000	0.000	0.118	0.901	1.019
07:45:00	0.000	0.000	0.000	0.059	0.895	0.955
08:00:00	0.000	0.000	0.000	0.025	0.889	0.914
08:15:00	0.000	0.000	0.000	0.008	0.883	0.890
08:30:00	0.000	0.000	0.000	0.001	0.876	0.877

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
08:45:00	0.000	0.000	0.000	0.000	0.870	0.870
09:00:00	0.000	0.000	0.000	0.000	0.863	0.863
09:15:00	0.000	0.000	0.000	0.000	0.857	0.857
09:30:00	0.000	0.000	0.000	0.000	0.850	0.850
09:45:00	0.000	0.000	0.000	0.000	0.844	0.844
10:00:00	0.000	0.000	0.000	0.000	0.838	0.838
10:15:00	0.000	0.000	0.000	0.000	0.831	0.831
10:30:00	0.000	0.000	0.000	0.000	0.825	0.825
10:45:00	0.000	0.000	0.000	0.000	0.819	0.819
11:00:00	0.000	0.000	0.000	0.000	0.813	0.813
11:15:00	0.000	0.000	0.000	0.000	0.807	0.807
11:30:00	0.000	0.000	0.000	0.000	0.801	0.801
11:45:00	0.000	0.000	0.000	0.000	0.795	0.795
12:00:00	0.000	0.000	0.000	0.000	0.789	0.789
12:15:00	0.000	0.000	0.000	0.000	0.783	0.783
12:30:00	0.000	0.000	0.000	0.000	0.777	0.777
12:45:00	0.000	0.000	0.000	0.000	0.771	0.771
13:00:00	0.000	0.000	0.000	0.000	0.766	0.766
13:15:00	0.000	0.000	0.000	0.000	0.760	0.760
13:30:00	0.000	0.000	0.000	0.000	0.754	0.754
13:45:00	0.000	0.000	0.000	0.000	0.749	0.749
14:00:00	0.000	0.000	0.000	0.000	0.743	0.743
14:15:00	0.000	0.000	0.000	0.000	0.737	0.737
14:30:00	0.000	0.000	0.000	0.000	0.732	0.732
14:45:00	0.000	0.000	0.000	0.000	0.727	0.727
15:00:00	0.000	0.000	0.000	0.000	0.721	0.721
15:15:00	0.000	0.000	0.000	0.000	0.716	0.716
15:30:00	0.000	0.000	0.000	0.000	0.710	0.710
15:45:00	0.000	0.000	0.000	0.000	0.705	0.705
16:00:00	0.000	0.000	0.000	0.000	0.700	0.700
16:15:00	0.000	0.000	0.000	0.000	0.695	0.695
16:30:00	0.000	0.000	0.000	0.000	0.689	0.689
16:45:00	0.000	0.000	0.000	0.000	0.684	0.684
17:00:00	0.000	0.000	0.000	0.000	0.679	0.679
17:15:00	0.000	0.000	0.000	0.000	0.674	0.674
17:30:00	0.000	0.000	0.000	0.000	0.669	0.669

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
17:45:00	0.000	0.000	0.000	0.000	0.664	0.664
18:00:00	0.000	0.000	0.000	0.000	0.659	0.659
18:15:00	0.000	0.000	0.000	0.000	0.654	0.654
18:30:00	0.000	0.000	0.000	0.000	0.649	0.649
18:45:00	0.000	0.000	0.000	0.000	0.644	0.644
19:00:00	0.000	0.000	0.000	0.000	0.640	0.640
19:15:00	0.000	0.000	0.000	0.000	0.635	0.635
19:30:00	0.000	0.000	0.000	0.000	0.630	0.630
19:45:00	0.000	0.000	0.000	0.000	0.625	0.625
20:00:00	0.000	0.000	0.000	0.000	0.621	0.621
20:15:00	0.000	0.000	0.000	0.000	0.616	0.616
20:30:00	0.000	0.000	0.000	0.000	0.611	0.611
20:45:00	0.000	0.000	0.000	0.000	0.607	0.607
21:00:00	0.000	0.000	0.000	0.000	0.602	0.602
21:15:00	0.000	0.000	0.000	0.000	0.598	0.598
21:30:00	0.000	0.000	0.000	0.000	0.593	0.593
21:45:00	0.000	0.000	0.000	0.000	0.589	0.589
22:00:00	0.000	0.000	0.000	0.000	0.585	0.585
22:15:00	0.000	0.000	0.000	0.000	0.580	0.580
22:30:00	0.000	0.000	0.000	0.000	0.576	0.576
22:45:00	0.000	0.000	0.000	0.000	0.572	0.572
23:00:00	0.000	0.000	0.000	0.000	0.567	0.567
23:15:00	0.000	0.000	0.000	0.000	0.563	0.563
23:30:00	0.000	0.000	0.000	0.000	0.559	0.559
23:45:00	0.000	0.000	0.000	0.000	0.555	0.555
24:00:00	0.000	0.000	0.000	0.000	0.551	0.551
24:15:00	0.000	0.000	0.000	0.000	0.546	0.546
24:30:00	0.000	0.000	0.000	0.000	0.542	0.542
24:45:00	0.000	0.000	0.000	0.000	0.538	0.538
25:00:00	0.000	0.000	0.000	0.000	0.534	0.534
25:15:00	0.000	0.000	0.000	0.000	0.530	0.530
25:30:00	0.000	0.000	0.000	0.000	0.526	0.526
25:45:00	0.000	0.000	0.000	0.000	0.522	0.522
26:00:00	0.000	0.000	0.000	0.000	0.519	0.519
26:15:00	0.000	0.000	0.000	0.000	0.515	0.515
26:30:00	0.000	0.000	0.000	0.000	0.511	0.511

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
26:45:00	0.000	0.000	0.000	0.000	0.507	0.507
27:00:00	0.000	0.000	0.000	0.000	0.503	0.503
27:15:00	0.000	0.000	0.000	0.000	0.499	0.499
27:30:00	0.000	0.000	0.000	0.000	0.496	0.496
27:45:00	0.000	0.000	0.000	0.000	0.492	0.492
28:00:00	0.000	0.000	0.000	0.000	0.488	0.488
28:15:00	0.000	0.000	0.000	0.000	0.485	0.485
28:30:00	0.000	0.000	0.000	0.000	0.481	0.481
28:45:00	0.000	0.000	0.000	0.000	0.477	0.477
29:00:00	0.000	0.000	0.000	0.000	0.474	0.474
29:15:00	0.000	0.000	0.000	0.000	0.470	0.470
29:30:00	0.000	0.000	0.000	0.000	0.467	0.467
29:45:00	0.000	0.000	0.000	0.000	0.463	0.463
30:00:00	0.000	0.000	0.000	0.000	0.460	0.460
30:15:00	0.000	0.000	0.000	0.000	0.456	0.456
30:30:00	0.000	0.000	0.000	0.000	0.453	0.453
30:45:00	0.000	0.000	0.000	0.000	0.450	0.450
31:00:00	0.000	0.000	0.000	0.000	0.446	0.446
31:15:00	0.000	0.000	0.000	0.000	0.443	0.443
31:30:00	0.000	0.000	0.000	0.000	0.440	0.440
31:45:00	0.000	0.000	0.000	0.000	0.436	0.436
32:00:00	0.000	0.000	0.000	0.000	0.433	0.433
32:15:00	0.000	0.000	0.000	0.000	0.430	0.430
32:30:00	0.000	0.000	0.000	0.000	0.427	0.427
32:45:00	0.000	0.000	0.000	0.000	0.424	0.424
33:00:00	0.000	0.000	0.000	0.000	0.420	0.420
33:15:00	0.000	0.000	0.000	0.000	0.417	0.417
33:30:00	0.000	0.000	0.000	0.000	0.414	0.414
33:45:00	0.000	0.000	0.000	0.000	0.411	0.411
34:00:00	0.000	0.000	0.000	0.000	0.408	0.408
34:15:00	0.000	0.000	0.000	0.000	0.405	0.405
34:30:00	0.000	0.000	0.000	0.000	0.402	0.402
34:45:00	0.000	0.000	0.000	0.000	0.399	0.399
35:00:00	0.000	0.000	0.000	0.000	0.396	0.396
35:15:00	0.000	0.000	0.000	0.000	0.393	0.393
35:30:00	0.000	0.000	0.000	0.000	0.390	0.390

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
35:45:00	0.000	0.000	0.000	0.000	0.387	0.387
36:00:00	0.000	0.000	0.000	0.000	0.384	0.384
36:15:00	0.000	0.000	0.000	0.000	0.381	0.381
36:30:00	0.000	0.000	0.000	0.000	0.378	0.378
36:45:00	0.000	0.000	0.000	0.000	0.376	0.376
37:00:00	0.000	0.000	0.000	0.000	0.373	0.373
37:15:00	0.000	0.000	0.000	0.000	0.370	0.370
37:30:00	0.000	0.000	0.000	0.000	0.367	0.367
37:45:00	0.000	0.000	0.000	0.000	0.365	0.365
38:00:00	0.000	0.000	0.000	0.000	0.362	0.362
38:15:00	0.000	0.000	0.000	0.000	0.359	0.359
38:30:00	0.000	0.000	0.000	0.000	0.356	0.356
38:45:00	0.000	0.000	0.000	0.000	0.354	0.354
39:00:00	0.000	0.000	0.000	0.000	0.351	0.351
39:15:00	0.000	0.000	0.000	0.000	0.349	0.349
39:30:00	0.000	0.000	0.000	0.000	0.346	0.346
39:45:00	0.000	0.000	0.000	0.000	0.343	0.343
40:00:00	0.000	0.000	0.000	0.000	0.341	0.341
40:15:00	0.000	0.000	0.000	0.000	0.338	0.338
40:30:00	0.000	0.000	0.000	0.000	0.336	0.336
40:45:00	0.000	0.000	0.000	0.000	0.333	0.333
41:00:00	0.000	0.000	0.000	0.000	0.331	0.331
41:15:00	0.000	0.000	0.000	0.000	0.328	0.328
41:30:00	0.000	0.000	0.000	0.000	0.326	0.326
41:45:00	0.000	0.000	0.000	0.000	0.323	0.323
42:00:00	0.000	0.000	0.000	0.000	0.321	0.321
42:15:00	0.000	0.000	0.000	0.000	0.319	0.319
42:30:00	0.000	0.000	0.000	0.000	0.316	0.316
42:45:00	0.000	0.000	0.000	0.000	0.314	0.314
43:00:00	0.000	0.000	0.000	0.000	0.311	0.311
43:15:00	0.000	0.000	0.000	0.000	0.309	0.309
43:30:00	0.000	0.000	0.000	0.000	0.307	0.307
43:45:00	0.000	0.000	0.000	0.000	0.305	0.305
44:00:00	0.000	0.000	0.000	0.000	0.302	0.302
44:15:00	0.000	0.000	0.000	0.000	0.300	0.300
44:30:00	0.000	0.000	0.000	0.000	0.298	0.298

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (mm)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
44:45:00	0.000	0.000	0.000	0.000	0.296	0.296
45:00:00	0.000	0.000	0.000	0.000	0.293	0.293
45:15:00	0.000	0.000	0.000	0.000	0.291	0.291
45:30:00	0.000	0.000	0.000	0.000	0.289	0.289
45:45:00	0.000	0.000	0.000	0.000	0.287	0.287
46:00:00	0.000	0.000	0.000	0.000	0.285	0.285
46:15:00	0.000	0.000	0.000	0.000	0.283	0.283
46:30:00	0.000	0.000	0.000	0.000	0.280	0.280
46:45:00	0.000	0.000	0.000	0.000	0.278	0.278
47:00:00	0.000	0.000	0.000	0.000	0.276	0.276
47:15:00	0.000	0.000	0.000	0.000	0.274	0.274
47:30:00	0.000	0.000	0.000	0.000	0.272	0.272
47:45:00	0.000	0.000	0.000	0.000	0.270	0.270
48:00:00	0.000	0.000	0.000	0.000	0.268	0.268
48:15:00	0.000	0.000	0.000	0.000	0.266	0.266
48:30:00	0.000	0.000	0.000	0.000	0.264	0.264
48:45:00	0.000	0.000	0.000	0.000	0.262	0.262

Appendix

Catchment descriptors

Name	Value	User-defined value used?
Area (km²)	4.41	No
ALTBAR	224	No
ASPBAR	262	No
ASPVAR	0.43	No
BFIHOST	0.54	No
DPLBAR (km)	1.47	No
DPSBAR (mkm-¹)	78	No
FARL	1	No
LDP	2.97	No
PROPWET (mm)	0.45	No
RMED1H	11.9	No
RMED1D	44.4	No
RMED2D	59.9	No
SAAR (mm)	1330	No
SAAR4170 (mm)	1371	No
SPRHOST	35.08	No
Urbext2000	0.02	No
Urbext1990	0.03	No
URBCONC	0.77	No
URBLOC	1.21	No
Urban Area (km²)	0.14	No
DDF parameter C	-0.03	No
DDF parameter D1	0.46	No
DDF parameter D2	0.35	No
DDF parameter D3	0.34	No
DDF parameter E	0.29	No
DDF parameter F	2.51	No
DDF parameter C (1km grid value)	-0.03	No
DDF parameter D1 (1km grid value)	0.46	No
DDF parameter D2 (1km grid value)	0.35	No
DDF parameter D3 (1km grid value)	0.33	No
DDF parameter E (1km grid value)	0.29	No
DDF parameter F (1km grid value)	2.5	No

HEC-RAS Plan: 1 River: Drinnick Stream Reach: 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
1	5	100 yr	6.45	165.06	166.64	165.86	166.68	0.002764	0.89	7.21	6.97	0.28
1	5	100 yr + CC	9.03	165.06	166.72	166.02	166.79	0.004319	1.16	7.79	8.00	0.35
1	5	1000 yr	13.28	165.06	166.83	166.24	166.95	0.006658	1.53	8.76	9.98	0.44
1	4.5*	100 yr	6.45	164.83	166.63		166.66	0.002080	0.80	8.09	7.55	0.24
1	4.5*	100 yr + CC	9.03	164.83	166.70		166.76	0.003310	1.04	8.68	9.51	0.31
1	4.5*	1000 yr	13.28	164.83	166.80		166.90	0.005128	1.38	9.84	13.47	0.39
1	4	100 yr	6.45	164.61	166.62		166.65	0.001567	0.71	9.07	8.72	0.21
1	4	100 yr + CC	9.03	164.61	166.69		166.73	0.002570	0.94	9.67	10.14	0.28
1	4	1000 yr	13.28	164.61	166.79		166.86	0.003983	1.23	11.13	20.45	0.35
1	3.5*	100 yr	6.45	164.56	166.60		166.63	0.001593	0.74	8.73	9.14	0.22
1	3.5*	100 yr + CC	9.03	164.56	166.66		166.71	0.002640	0.99	9.24	10.45	0.28
1	3.5*	1000 yr	13.28	164.56	166.72		166.82	0.004615	1.35	10.14	20.92	0.38
1	3	100 yr	6.45	164.50	166.59		166.62	0.001433	0.74	8.84	11.28	0.20
1	3	100 yr + CC	9.03	164.50	166.63		166.68	0.002404	0.98	9.44	16.35	0.26
1	3	1000 yr	13.28	164.50	166.68		166.77	0.004220	1.33	10.39	22.14	0.35
1	2.5*	100 yr	6.45	164.40	166.57		166.60	0.001372	0.71	9.73	34.58	0.19
1	2.5*	100 yr + CC	9.03	164.40	166.61		166.65	0.002020	0.88	11.12	37.84	0.23
1	2.5*	1000 yr	13.28	164.40	166.65		166.71	0.003069	1.10	12.83	41.48	0.29
1	2	100 yr	6.45	166.25	166.50	166.50	166.56	0.004252	0.41	6.82	55.27	0.29
1	2	100 yr + CC	9.03	166.25	166.54	166.54	166.61	0.004139	0.44	8.80	63.23	0.29
1	2	1000 yr	13.28	166.25	166.58	166.58	166.66	0.003944	0.49	11.90	74.01	0.29
1	1.66666*	100 yr	6.45	166.24	166.37	166.40	166.48	0.009401	0.47	5.46	55.62	0.47
1	1.66666*	100 yr + CC	9.03	166.24	166.39	166.44	166.53	0.009550	0.56	7.04	65.36	0.49
1	1.66666*	1000 yr	13.28	166.24	166.42	166.48	166.58	0.009868	0.66	9.44	80.75	0.52
1	1.33333*	100 yr	6.45	166.10	166.24	166.28	166.35	0.011117	0.71	5.49	54.76	0.67
1	1.33333*	100 yr + CC	9.03	166.10	166.26	166.31	166.40	0.011699	0.82	7.08	86.85	0.71
1	1.33333*	1000 yr	13.28	166.10	166.29	166.34	166.44	0.012430	0.95	9.77	113.68	0.75
1	1	100 yr	6.45	165.91	166.09	166.12	166.18	0.016150	1.15	5.32	80.20	1.12
1	1	100 yr + CC	9.03	165.91	166.10	166.14	166.22	0.017232	1.29	6.75	93.36	1.18
1	1	1000 yr	13.28	165.91	166.13	166.17	166.26	0.016645	1.42	8.98	100.53	1.19

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