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TC7769F3.ags	05/07/2016	11:09:42	193,173	Final Log data and laboratory test data.
tc7769g3.txt	05/07/2016	11:09:53	610	gINT checker report
tc7769k3.txt	05/07/2016	11:10:16	334	KeyAGS checker report

Unless otherwise stated, this submission supersedes any and all previous submissions.

Checked			SOIL ENGINEERING
redacted 11(2)			
Form No. SE-AGS-F-001	Revision No. 1.03	Issue Date 30/10/2012	Part of the Bachy Soletanche Group

FOVERAN CULVERT CAPACITY CHECK
Determination of Flood Flows

Table 6.1 of HA107/04 recomments a design upon flood return period of 1 in 100 years for village (overflow floods Foveran Village)
Paragraph 6.6 of HA107/04 recommends use of FEH method where catchments are greater than 50ha

Catchment size estimated at 120 ha

Inflow from Catchment determined via link below:

http://geoservergisweb2.hrwallingford.co.uk/uksd/greenfieldrunoff.aspx

Unable to verfiy variables used do determine flows as no access documentation.
However noted that soil parameters inparticular have very significant effect on runoff.

1 in 100 year Flood storm determined as	297.6	l/s	from above link
	0.3	cumec/s	rounding up

Maximum permissible headwater		
Upstream soffit level	101.445	m
Freeboard	0.2	m
	101.245	m

Normal Depth (y)		0.38	By trial and error
Channel Width		0.5	
Area (A)		0.19	
Wetted Perimeter (P)		1.26	
Hydraulic Radius ®		0.150794	
slope (So)	1 in 20		
	as deciminal	0.05	
Assumed Manning (n)		0.04	

Q=	0.301287925	cumec
V=	1.585725923	m/s
Downstream Invert	100	m
Total Head of Tailwater(Htw)	100.5082	m
Water Level of tailwater (WLt)	100.38	m

Discharge estimate 0.388 cumec/s

Water Depth (y)	0.4	(0.6 less 0.2 freeboard)
Channel Width	0.6	
Area (A)	0.24	
Wetted Perimeter (P)	1.4	
Hydraulic Radius ®	0.171429	

V=	1.616666667	m/s
Culvert Ler	15	m
Hhoc	101.2462875	m

Capacities Ignoring inlet/outlet controls

Capacity of Upstream channel		
Water Depth (y)		0.7
Channel Width		0.8
Area (A)		0.56
Wetted Perimeter (P)		2.2
Hydraulic Radius ®		0.254545
slope (So)	1 in 100	
	as deciminal	0.01
Assumed Manning (n)		0.04

Q=	0.562817712	cumec
V=	1.005031628	m/s

Capacity of 600diameter concrete at 1 in 20			1.54 cumec/s
From hydraulic tables			

Capacity of Downstream channel		
Water Depth (y)		0.5
Channel Width		0.6
Area (A)		0.3
Wetted Perimeter (P)		1.6
Hydraulic Radius ®		0.1875
slope (So)	1 in 20	
	as deciminal	0.05
Assumed Manning (n)		0.04

Q=	0.550003069	cumec
V=	1.833343563	m/s

Capacity of Culvert (allowing fo 0.2m freeboard)		
Water Depth (y)		0.4
Channel Width		0.6
Area (A)		0.24
Wetted Perimeter (P)		1.4
Hydraulic Radius ®		0.171429
slope (So)	1 in 20	
	as deciminal	0.05
Assumed Manning (n)		0.04

Q=	0.414510626	cumec
V=	1.727127607	m/s

North East Trunk Road Unit

B0609804 A90 Culvert Assessment: Foveran, Aberdeenshire

July 2014

Prepared for BEAR Scotland by

experience that delivers

DOCUMENT CONTROL SHEET

Document Title	A90 Culvert Assessment: Foveran, Aberdeenshire
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1 Introduction

Ongoing flooding issues are reported along a section of the A90 carriageway at Foveran, located between Aberdeen and Ellon (Figure 1).

An unnamed watercourse takes the surface water runoff from agricultural lands surrounding Overhill to a 0.55m wide by 0.6m deep box culvert under the A90. Downstream of the A90 the box culvert discharges into an open ditch before entering a 0.6m diameter concrete carrier drain which runs adjacent to the eastern road embankment. The carrier drain outfalls to the Foveran Burn approximately 205m north of the box culvert outlet on the western side of the A90 (see Figure 2).

During storm conditions the box culvert is unable to take the flow in the watercourse. Water backs up in the channel, eventually overtopping the banks and flowing in a northerly direction along the western boundary of the A90, inundating residential properties and gardens, before discharging into Foveran Burn upstream of the road.

It is believed that the existing box culvert under the A90 may be undersized and not have sufficient capacity to pass the necessary flows. Site inspections also indicate that overgrown vegetation within the channel and around the inlet headwall to the box culvert may also contribute to flooding.

A proposal by Cala Homes (East) Ltd. to develop 28No. homes on a 1.83 hectare site to the west of Foveran was approved by Aberdeenshire Council on 15 March 2012. The proposed development needs to be considered in any assessment of culvert capacity, as an upstream development will have the potential to exacerbate the existing flooding problem. The location of the approved development is shown on Figure 2. Surface water from the proposed development is to be discharged at the greenfield run-off rate to the unnamed watercourse identified above. As can be seen from Figure 2 the footprint of the development will marginally increase the natural catchment area discharging into the watercourse. In more extreme storm events, exceeding the design standard for the developments drainage, the additional run-off will discharge directly into the watercourse. A post-development assessment is included in Section 3.

Figure 1 - Topographical map showing the A90 and the location of the Foveran site.

Contains Ordnance Survey data © Crown copyright and database right [2014]

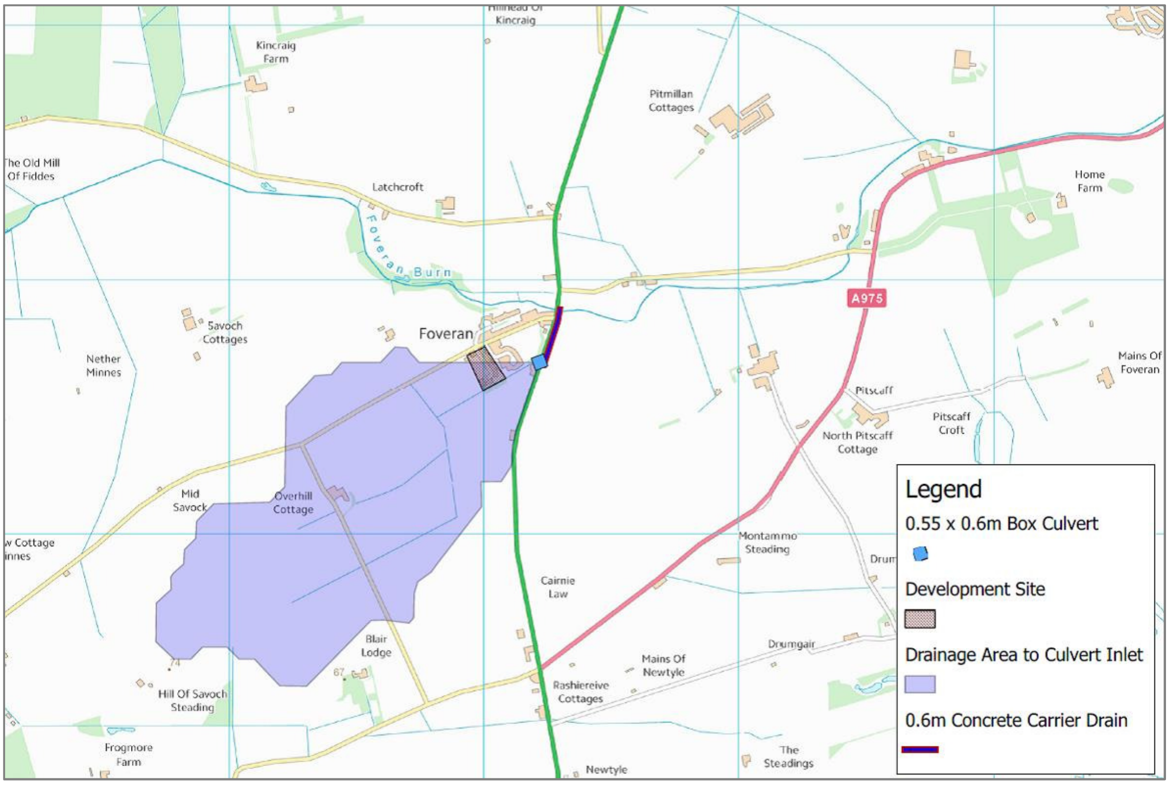

Figure 2 - Existing site drainage and location of development site.

Contains Ordnance Survey data © Crown copyright and database right [2014]

1.1 Catchment Description

A general description of the catchment (Figure 2) is given in Table 1.

Attribute	Description
Catchment Area	1.1km² to inlet of culvert passing under the A90.
Topography	Catchment topography is generally flat, ranging from a maximum elevation of 75mAOD to 35mAOD.
Urban Areas	The catchment is essentially rural URBEXT2000 = 0.
Land use	Catchment land use is predominantly arable agricultural.
Average Annual Rainfall	759mm
Reservoir\Lake	No attenuation of flows resulting from the presence of lochs or reservoirs FARL = 1.0.
Soils\Geology	The underlying geology is composed wholly of Dalradian quartzose-mica schist. Soil type within the catchment consists primarily of Brown Forest Earths BFIHOST = 0.46 SPRHOST = 32

Table 1 - General description of the catchment.

2 Data Available and Methodology

A Topographical Survey of the Foveran site, including a survey of invert levels of existing on-site drainage, was undertaken in early 2014. Survey data obtained has been used to inform a technical study of the site.

The technical study has included a hydrological analysis of the catchment in order to estimate design peak flood flows and a hydraulic assessment of existing culvert capacity. The methodologies applied to the hydrological analysis and hydraulic assessment are described below.

2.1 Hydrological Analysis

Design flows at the study site have been estimated from FEH catchment descriptors using the revised QMED equation reported in Science Report SC050050[1] and standard application of the FEH statistical pooling group method to determine flood growth curves (up to the 200-year event).

It should be noted that FEH guidance on the degree of uncertainty associated with QMED estimates from catchment descriptors alone is ± 55%. While no formal quantification of the Q-Tyr uncertainty is provided in the FEH, it is likely to be at least in the order of the QMED uncertainty and in some circumstance will be appreciably larger.

2.2 Hydraulic Analysis

The hydraulic assessment has included both an assessment of the existing culvert capacity and the design requirements for replacing the culvert. The assessment of culvert hydraulic performance has been undertaken in accordance with guidance given in CIRIA C689[2].

[1] Improving the FEH statistical procedures for flood frequency estimation, Science Report: SC050050, Environment Agency – June 2008

[2] Culvert design and operation guide: Balkham, M., Fosbeary, C., Kitchen, A., Rickard, C. CIRIA C689 RP901 © CIRIA 2010

3 Design Flows

In accordance with recent DEFRA research, SEPA recommends that an uplift of +20% be used to make allowance for the likely effects of climate change by the 2050s[3]. Design flows presented in Table 2 show estimated design flows for both the current period and with an allowance for Climate Change **(bold)**.

Table 2 presents the final estimated design flows

Return Period	Annual Exceedence Probability (AEP)	Growth Factor	Foveran A90 Culvert	
(Year)	(%)	(GL)	*Design Flows (m3/s)	
2	50	1.00	0.39	**0.47**
5	20	1.44	0.56	**0.67**
10	10	1.79	0.69	**0.83**
25	4	2.35	0.91	**1.10**
50	2	2.89	1.12	**1.34**
100	1	3.54	1.37	**1.65**
200	0.5	4.34	1.68	**2.02**

Table 2 - Estimated peak flood flows.

3.1 Post Development Design Flows

The approved development to the west of Foveran comprises 28No. houses on a 1.83 hectare plot. The marginal increase in impermeable (paved) area within the catchment does not show a significant increase on the estimated design flows presented in Table 2. For the estimated 200-year design flow, including a 20% allowance made for Climate Change the estimated peak flow was found to increase by 0.006m³/s.

[3] SEPA; Technical Flood Risk Guidance for Stakeholders (Version 3). Undated.

4 Hydraulic Assessment of Culvert Performance

Table 3 reports capacity of the existing culverts in both volume of water (m^3/s) and design flood event (T(yr)).

Crossing	Culvert Width	Culvert Depth	Length	Culvert Capacity	
	(m)	(m)	(m)	Q (m^3/s)	T(yr)
A90 Culvert @ Foveran	0.55	0.60	21	~0.40	~2

Table 3 - Existing culvert capacity.

Table 3 shows that the existing box culvert under the A90 lacks the capacity to convey the 2-year (50% AEP) flood event. For flows greater than the 2-year flood event; water levels will exceed the Maximum Permissible Headwater Level (HWLmax).

HWLmax has been taken as the sum of the u/s bed level (mAOD) plus culvert depth. The assessment seeks to find the maximum free flowing hydraulic capacity to convey the design flows shown in Table 2.

A suite of indicative replacement scenarios have been assessed to give a feel for the capacity requirements of a replacement culvert under the A90 at Foveran. Tables 4 - 6 summarise the hydraulic performance of various widths of box culvert (0.6m, 0.8m and 1.0m deep) under the estimated 200-year and the 200-year plus a 20% allowance for Climate Change (**bold**) flows shown in Figure 2.

The following assumptions have been made:

1. Inlet invert level (31.42mAOD) and gradient/fall of the concrete carrier drain remains unchanged.

2. Road elevation is taken to be 33.84mAOD (lowest elevation surveyed along western boundary of A90 carriageway - within immediate proximity to culvert).

3. The minimum level of the left bank adjacent to the upstream headwall of the A90 box culvert has been surveyed as 33.51mAOD (adjacent to the masonry wall). Above this level surcharged water will pass along the western edge of the A90 and have the potential to flood adjoining properties.

4.1 Results

	0.55m x 0.60m	1.5m x 0.60m	1.8m x 0.60m	2.1m x 0.60m
Invert Level (mAOD)	32.50	32.50	32.50	32.50
Soffit Level (mAOD)	33.07	33.07	33.07	33.07
Road Level (mAOD)	33.84	33.84	33.84	33.84
Calculated Water Level (mAOD)	35.65 **(36.82)**	33.92 **(34.31)**	33.92 **(34.31)**	33.92 **(34.31)**

Table 4 - Summary of results of culvert hydraulic performance (0.6m Depth).

	1.2m x 0.80m	1.5m x 0.80m	1.8m x 0.80m	2.1m x 0.80m
Invert Level (mAOD)	32.30	32.30	32.30	32.30
Soffit Level (mAOD)	33.10	33.10	33.10	33.10
Road Level (mAOD)	33.84	33.84	33.84	33.84
Calculated Water Level (mAOD)	33.33 **(33.62)**	33.33 **(33.61)**	33.31 **(33.60)**	33.31 **(33.60)**

Table 5 - Summary of results of culvert hydraulic performance (0.8m Depth).

	1.2m x 1.0m	1.5m x 1.0m	1.8m x 1.0m	2.1m x 1.0m
Invert Level (mAOD)	32.10	32.10	32.10	32.10
Soffit Level (mAOD)	33.10	33.10	33.10	33.10
Road Level (mAOD)	33.84	33.84	33.84	33.84
Calculated Water Level (mAOD)	33.12 **(33.40)**	33.10 **(33.39)**	33.10 **(33.38)**	33.09 **(33.38)**

Table 6 - Summary of results of culvert hydraulic performance (1.0m Depth).

4.2 Discussion

Table 4 presents the results from an assessment of culvert performance under the existing drainage scenario (0.55m x 0.6m box culvert) and three potential design scenarios for 0.6m deep box culverts.

Under the existing scenario it is observed that the 0.55m x 0.6m deep box culvert has insufficient capacity to convey the 200-year design flow. With a free flowing hydraulic capacity of ~0.40 m^3/s (Table 3), surcharging is likely to occur during flood events greater than the 2-year event and will most certainly be highly surcharged during a 200-year event.

A number of design scenarios were investigated (Tables 4 - 6) to find the required capacity for conveying the estimated 200-year design flow to the carrier drain on the eastern side of the carriageway.

Table 4 shows that an internal culvert depth of 0.6m is insufficient for conveying the 200-year design flow irrespective of increasing the culvert width (culvert widths up to 2.1m were assessed). In each case, predicted water levels are shown to be above both soffit and road elevation.

Table 5 shows the results from increasing internal culvert depth to 0.8m. While all scenarios result in predicted water levels which are greater than culvert soffit level (i.e. the culvert is surcharged) in both the present and future design scenarios, water levels are below the adopted road elevation of 33.84mAOD. In the 200-year flood event water levels upstream of the A90 box culvert are predicted to reach 33.31mAOD to 33.33mAOD, which is retained in-bank (top of left bank at a minimum level of 33.51mAOD). However in the 200-year plus Climate Change scenario the upstream water levels are predicted to reach 33.60mAOD to 33.62mAOD. Localised ground raising within the western verge of the A90, by approximately 150mm, could resolve this issue and prevent flood water from the watercourse flowing down the western boundary of the A90 carriageway.

Table 6 shows the results for an internal culvert depth of 1.0m. In all of the 4No. width scenarios the 200-year and 200-year plus Climate Change flood levels upstream of the A90 box culvert would be retained within the existing bank levels. However, an internal depth of 1.0m would result in the invert of the culvert outlet (31.32mAOD) being lower than the invert of the downstream carrier drain (31.42mAOD). This back-fall in the channel would not be acceptable and hence the adoption of a 1m deep culvert would either require the reprofiling of the downstream carrier drain or the localised raising of the carriageway.

4.3 Summary

In summary, the results from the hydraulic assessment show:

- The existing 0.55m x 0.6m culvert has insufficient capacity to convey the flood flows from a 2-year flood event or greater.
- The proposed Cala Homes (East) Ltd residential development upstream of the A90 will have a minimal impact on food risk.
- An internal culvert depth of 0.6m is insufficient for conveying the 200-year design flow (tested up to a 2.1m width of box culvert).
- Table 5 demonstrates that the suite of culvert scenarios with an internal depth of 0.8m will retain the upstream water level within bank in a 200-year event. Minor reprofiling of the ground levels adjacent to the left bank of the upstream headwall would enable a 0.8m deep culvert to pass the 200-year plus Climate Change event.
- A 1m deep culvert, whilst having the capacity to pass the 200-year and 200-year plus Climate Change events, is impractical as it would require either the downstream receiving channel and carrier drain or the carriageway level in the vicinity of the culvert to be reprofiled.

Greenfield Runoff Estimation for Sites

Site name: A90 Foveran
Site location: Foveran Culvert
Site coordinates
Latitude: 57.30385 deg N
Longitude: 2.04762 deg W

Reference: 1364378960677
Date: 27/3/2013

This is an estimation of the greenfield runoff rate limits that are needed to meet normal best practice criteria in line with Environment Agency guidance "Preliminary rainfall runoff management for developments" (2005), W5-074/A/TR1/1 rev. D and the CIRIA SUDS Manual (2007). It is not to be used for detailed design of drainage systems. It is recommended that detailed design of any drainage scheme uses hydraulic modelling software to finalise runoff requirements before construction takes place.

- **Site Characteristics:**

Total site area	120	ha
Significant public open space		ha
Area positively drained	120	ha

- **Methodology:**

Greenfield runoff method	FEH

• **Hydrological Characteristics:**	**Automatic values**	**Editable values**	
HOST	1	1	
SPRHOST	0.02	0.02	
BFIHOST	1.034	1.034	
Qmed	0.028	0.028	m^3/s
Qbar/Qmed conversion factor	0.9	0.9	
SAAR	738	738	mm
M5-60 Rainfall Depth	14	14	mm
'r' Ratio M5-60/M5-2 day	0.3	0.3	
FEH/FSR conversion factor	1.06	1.06	
Hydrological region	1	1	
Growth curve factor: 1 year	0.85	0.85	
Growth curve factor: 30 year	1.95	1.95	
Growth curve factor: 100 year	2.48	2.48	

- **Greenfield Runoff Rates:**

Qbar	**25.64**	**25.64**	l/s
1 in 1 year	**102**	**102**	l/s
1 in 30 years	**234**	**234**	l/s
1 in 100 years	**297.6**	**297.6**	l/s

Please note that a minimum flow of 5 l/s applies to any site

HR Wallingford Ltd, the Environment Agency and any local authority are not liable for the performance of a drainage scheme which is based upon the output of this report.

Greenfield Runoff Estimation for Sites

Site name: A90 Foveran
Site location: Foveran Culvert
Site coordinates
Latitude: 57.30385 deg N
Longitude: 2.04762 deg W

Reference: 1364379086661
Date: 27/3/2013

This is an estimation of the greenfield runoff rate limits that are needed to meet normal best practice criteria in line with Environment Agency guidance "Preliminary rainfall runoff management for developments" (2005), W5-074/A/TR1/1 rev. D and the CIRIA SUDS Manual (2007). It is not to be used for detailed design of drainage systems. It is recommended that detailed design of any drainage scheme uses hydraulic modelling software to finalise runoff requirements before construction takes place.

- **Site Characteristics:**

Total site area	120	ha
Significant public open space		ha
Area positively drained	120	ha

- **Methodology:**

Greenfield runoff method	IH 124

• **Hydrological Characteristics:**	**Automatic values**	**Editable values**	
Soil Type (Based on FSR)	3	3	
SPR	0.37	0.37	
SAAR	738	738	mm
M5-60 Rainfall Depth	14	14	mm
'r' Ratio M5-60/M5-2 day	0.3	0.3	
FEH/FSR conversion factor	1.06	1.06	
Hydrological region	1	1	
Growth curve factor: 1 year	0.85	0.85	
Growth curve factor: 30 year	1.95	1.95	
Growth curve factor: 100 year	2.48	2.48	

- **Greenfield Runoff Rates:**

Qbar	**333.06**	**333.06**	l/s
1 in 1 year	**283.1**	**283.1**	l/s
1 in 30 years	**649.46**	**649.46**	l/s
1 in 100 years	**825.98**	**825.98**	l/s

Please note that a minimum flow of 5 l/s applies to any site