Halcrow Water
Windsor House Queensgate Britannia Road Waltham Cross Hertfordshire EN8 7NX
Tel +44 (0)1992 707100 Fax +44 (0)1992 760594
www.halcrow.com

Technical note

Project	Project: Dacorum Level 2 SFRA	**Date**	Date: 01 Feb 2008
Note	Note: River Gade Hydraulic Modelling	**Ref**	Ref: WN/CBAD/21/D4661
Author	Author: Phebion Mudoti		

1 Hydraulic Modelling

1.1 Overview

The River Gade is a dip slope stream draining the Chiltern Hills (from Dagnell to Hemel Hempstead) with a predominantly rural catchment area of approximately 48km². The catchment forms part of the River Colne which drains into the River Thames at Staines. Immediately downstream of Hemel Hempstead the River Gade flows into the Grand Union Canal (note: there are spills from the Canal into the River Bulbourne to the south forming part of a water transfer system). The underlying geology is Chalk with some tertiary deposits and extensive boulder clay cover, and as a result the catchment is considered relatively permeable.

1.2 Modelling Approach

The ISIS 1D modelling software package (Version 3.0) was used to construct the model, which comprises the River Gade reach running through Hemel Hempstead. The upstream limit of the model is at Charter House, along the A4146 road (Gadebridge Park) – (Grid reference 505271, 207812) and the downstream end is at the confluence of River Gade with the Grand Union Canal at Heat Park.

The modelling methodology involved building a 1-D ISIS model with recently surveyed data of hydraulically significant channel sections and control structures along the River Gade. Additional infill channel sections were derived from photogrammetry data and bed levels adjusted using interpolation from surveyed sections.

1.3 Survey Data Used

The survey data that has been used in the development of the new ISIS hydrodynamic model of the River Gade in Hemel Hempstead (see **Appendix B**). Location of survey cross-sections and structures is based on the walkover survey carried out on 30 October 2007. Key structures and minimum representative cross-sections of the River Gade have been selected in order to construct the new ISIS hydrodynamic model. In certain places where the detail to which channel reaches were surveyed was not thought sufficiently representative of channel geometry (i.e. distance between surveyed cross sections was thought to be too great), additional infill sections were generated from photogrammetry data to increase the accuracy with which these certain river reaches have been represented.

1.4 Labelling Convention

The naming convention for river cross sections in ISIS is limited to 12 characters. For this study, the naming convention is broken down as follows – e.g. GD005su. The first two characters are derived from the River Gade. The next three figures, **005, are the cross section positions in the original survey. The last figures, *****su, are an optional reference used to define additional nodes at structures. The system used for the River Gade model is as follows:

- ‘u’ the upstream node at a structure or junction (e.g. GD002u)
- ‘d’ the downstream node at a structure or junction (e.g. GD002d)
- ‘b’ to represent bridge structures (e.g. GD002bu or GD002bd)
- ‘w’ to represent weir structures (e.g. GD005wu or GD005wd)
- ‘s’ to represent spills for flow over and around structures (e.g. GD007su or GD007sd)

Halcrow Water

Windsor House Queensgate Britannia Road Waltham Cross Hertfordshire EN8 7NX

Tel +44 (0)1992 707100 Fax +44 (0)1992 760594

www.halcrow.com

Technical note

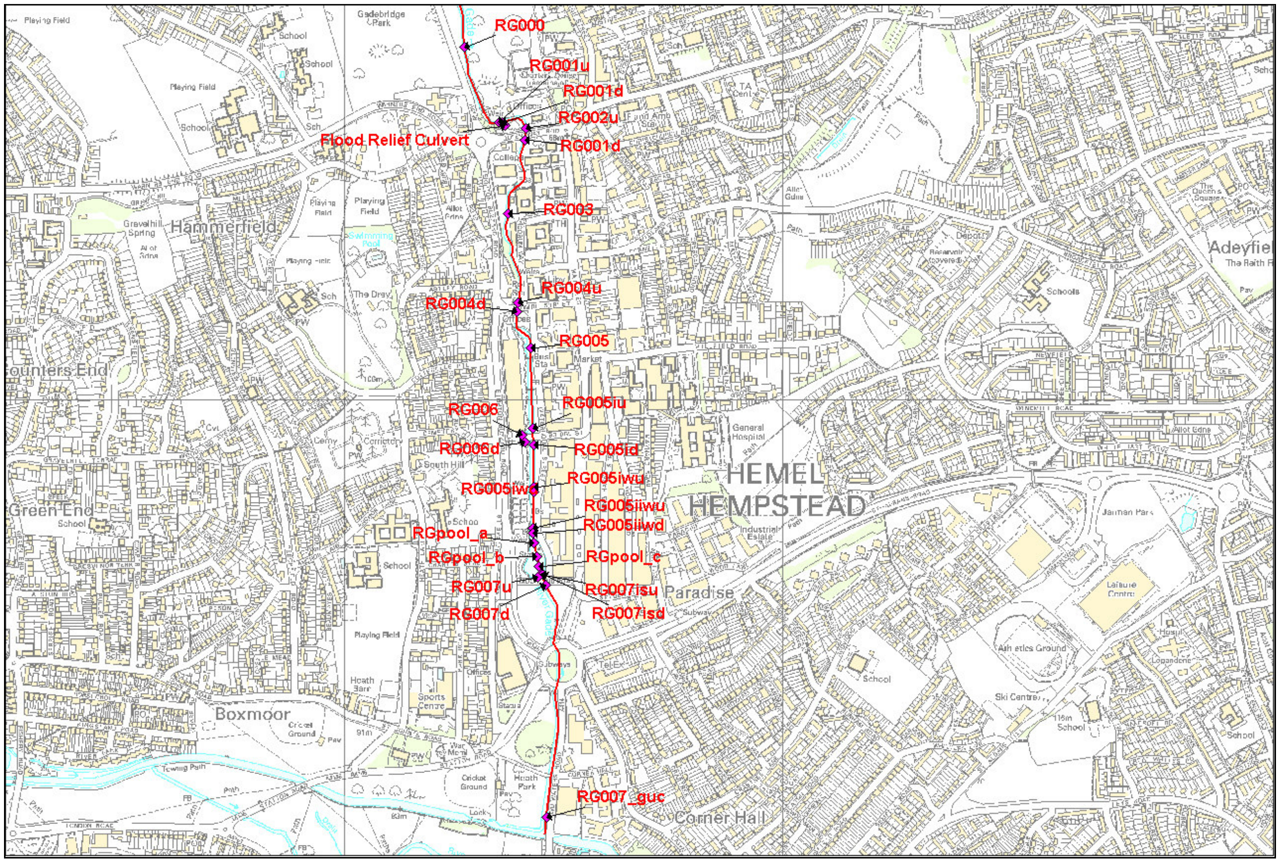

Figure 1: River Gade ISIS nodes

1.5 Manning's 'n' Parameterisation

One-dimensional models calculate conveyance in each section as a function of the roughness and energy loss characteristics of the channel. This is represented by Manning's 'n', a dimensionless indication of the degree of energy loss that the channel surface and geometry induces on the body of water, and resultant attenuating effect.

Channel roughness parameters, specified as Manning's 'n', were derived for each model cross section based on observations during site visits and comparison of survey photographs with published values (e.g. Chow, 1959). Chow (1959) contains reference tables to match observed bed conditions with a value for Manning's 'n'. These reference tables are the most widely used method in one dimensional hydraulic modelling study.

A description of the river reaches characterised by similar floodplain and channel bank roughness conditions is provided in ***Table 1*** below.

Cross Section References	Manning's n value	Description
 in-bank	0.04	Clean, straight, full, no rifts or deep pools
 floodplain	0.06	Scattered brush and weeds; light brush and trees in winter

Table 1: Manning's 'n' roughness

1.6 Modelled Scenarios

For the purposes of this study, a 75% blockage of the Hemel Hempstead flood relief culvert was modelled. This was achieved by raising the spill levels into the flood relief culvert by 400mm. Simulations were runs for 20 year, 100 year, 1000 year and 100 year plus climate change.

2 *Model Results*

2.1 Maximum Water Level

The model was run for 1 in 20 year, 1 in 100 year, 1 in 100 year plus climate change and 1 in 1000 year flood flow (hydrological details is given in Appendix A). The maximum water levels are shown in ***Table 2***.

	Maximum Water Levels (mAOD)			
Node Label	**020yr**	**100yr**	**100yr+CC**	**1000yr**
RG000	85.69	85.76	85.83	85.90
RG001u	84.99	85.04	85.09	85.15
RG001d	84.99	85.04	85.08	85.13
RG002u	84.75	84.81	84.86	84.91
RG002d	84.73	84.77	84.80	84.83
RG003	83.97	84.00	84.03	84.06
RG004u	82.83	82.88	82.91	82.94
RG004d	82.82	82.86	82.88	82.91
RG005	82.32	82.44	82.51	82.53
RG005iu	82.13	82.31	82.39	82.42
RG005id	82.01	82.10	82.14	82.15
RG005iwu	81.99	82.06	82.10	82.10
RG005iwd	81.74	81.86	81.91	81.92
RG005iiwu	81.70	81.79	81.83	81.84
RG005iiwd	81.42	81.54	81.59	81.60
RG006	82.12	82.29	82.38	82.40
RGpool_a	81.42	81.54	81.59	81.60
RGpool_b	81.42	81.54	81.59	81.60
RGpool_c	81.42	81.54	81.59	81.60
RG007u	80.86	81.01	81.08	81.09
RG007d	80.85	81.00	81.07	81.08
RG007_guc	80.22	80.22	80.22	80.22

Table 2: Maximum Water Level

3 *Sensitivity Analysis*

Sensitivity analysis investigates the sensitivity of model results to the assumed model parameters. This provides an indication of how important individual model parameters are in determining model behaviour and the extent of flood inundation. The scope and tabulated results for each sensitivity analysis are outlined below.

3.1 Manning's "n" Roughness Coefficient

An assessment of sensitivity to the choice of Manning's n was made by carrying out two additional runs on the 100 year return period event. The first run applied a uniform 20% increase in Manning's n value, while the second applied a 20% decrease.

Increase in Manning's n by 20%

Table 3 contains the results of simulations of the 100 year flood event, with Manning's n values increased by 20% for all channel cross sections.

1 in 100 yr event		**Max. Water Level**		**Difference [mm]**
Location	**ISIS Node**	**Standard Run [mAOD]**	**Increase in roughness by 20% [mAOD]**	
	RG001u	84.893	84.923	30
	RG001d	84.891	84.921	30
Queensway Rd	RG002u	84.489	84.475	-14
Queensway Rd	RG002d	84.487	84.474	-13
	RG003	83.713	83.693	-20
Combe St	RG004u	82.622	82.609	-13
Combe St	RG004d	82.622	82.609	-13
Bus Station	RG005	82.249	82.260	11
	RG006	82.061	82.051	-10
Moor End Rd	RG007u	80.901	80.948	47
Moor End Rd	RG007d	80.891	80.940	49
Grand Union Canal	RG007_guc	80.219	80.219	0

Table 3: Sensitivity analyses following an increase in Manning's n

Decrease in Manning's n by 20%

Table 4 contains the results of simulations of the 100 year flood event, with Manning's n values decreased by 20% for all channel cross sections.

1 in 100 yr event		**Max. Water Level**		**Difference [mm]**
Location	**ISIS Node**	**Standard Run [mAOD]**	**Decrease in roughness by 20% [mAOD]**	
	RG001u	84.893	84.851	-42
	RG001d	84.891	84.851	-40
Queensway Rd	RG002u	84.489	84.501	12
Queensway Rd	RG002d	84.487	84.498	11
	RG003	83.713	83.736	23

1 in 100 yr event		Max. Water Level		Difference [mm]
Location	ISIS Node	Standard Run [mAOD]	Decrease in roughness by 20% [mAOD]	
Combe St	RG004u	82.622	82.632	10
Combe St	RG004d	82.622	82.631	9
Bus Station	RG005	82.249	82.24	-9
	RG006	82.061	82.078	17
Moor End Rd	RG007u	80.901	80.853	-48
Moor End Rd	RG007d	80.891	80.838	-53
Grand Union Canal	RG007_guc	80.219	80.219	0

Table 4: Sensitivity analyses following a decrease in Manning's n

Conclusion

A variance in Manning's n of +/-20% showed corresponding changes in maximum water levels of +/-55mm showing that the model is relatively insensitive to channel and floodplain seasonal changes in roughness.

3.2 Inflow and climate change effects

To test model sensitivity to inflow, and as an estimate of the effect of climate change, the 100 year return period event was run with flows increased by 30%.

Increase in inflow by 30%

Table 5 contains the results of simulations of the 100 year flood event, with a 30% increase in inflows.

1 in 100 yr event		Max. Water Level		Difference [mm]
Location	ISIS Node	Standard Run [mAOD]	Increase in inflows by 30% [mAOD]	
	RG001u	84.893	84.963	70
	RG001d	84.891	84.959	68
Queensway Rd	RG002u	84.489	84.54	51
Queensway Rd	RG002d	84.487	84.537	50
	RG003	83.713	83.767	54
Combe St	RG004u	82.622	82.666	44
Combe St	RG004d	82.622	82.665	43
Bus Station	RG005	82.249	82.311	62
	RG006	82.061	82.141	80
Moor End Rd	RG007u	80.901	80.989	88
Moor End Rd	RG007d	80.891	80.978	87

1 in 100 yr event		Max. Water Level		Difference [mm]
Location	ISIS Node	Standard Run [mAOD]	Increase in inflows by 30% [mAOD]	
Grand Union Canal	RG007_guc	80.219	80.219	0

Table 5: Sensitivity analyses following an increase in inflow

Decrease in inflow by 30%

Table 6 contains the results of simulations of the 100 year flood event, with a 30% decrease in inflows.

1 in 100 yr event		Max. Water Level		Difference [mm]
Location	ISIS Node	Standard Run [mAOD]	Decrease in inflows by 30% [mAOD]	
	RG001u	84.893	84.815	-78
	RG001d	84.891	84.813	-78
Queensway Rd	RG002u	84.489	84.436	-53
Queensway Rd	RG002d	84.487	84.435	-52
	RG003	83.713	83.657	-56
Combe St	RG004u	82.622	82.574	-48
Combe St	RG004d	82.622	82.574	-48
Bus Station	RG005	82.249	82.191	-58
	RG006	82.061	81.983	-78
Moor End Rd	RG007u	80.901	80.804	-97
Moor End Rd	RG007d	80.891	80.796	-95
Grand Union Canal	RG007_guc	80.219	80.219	0

Table 6: Sensitivity analyses following a decrease in inflow

Conclusion

Increasing inflows has the expected effect of increasing maximum water levels observed from the model and the inverse is true for decreased inflows. A variance in inflows of +/-30% showed corresponding changes in maximum water levels of +/-100mm showing that the model is relatively insensitive to changes in inflows.

3.3 Weir Coefficients

An assessment of sensitivity to the choice of weir coefficients was made by carrying out additional runs on the 100 year return period event.

Increase in weir coefficients by 20%

Table 7 contains the results of simulations of the 100 year flood event, with a 20% increase in weir coefficients.

1 in 100 yr event		Max. Water Level		Difference [mm]
Location	**ISIS Node**	**Standard Run [mAOD]**	**Increase in weir coefficients by 20% [mAOD]**	
	RG001u	84.893	84.887	-6
	RG001d	84.891	84.884	-7
Queensway Rd	RG002u	84.489	84.458	-31
Queensway Rd	RG002d	84.487	84.457	-30
	RG003	83.713	83.678	-35
Combe St	RG004u	82.622	82.594	-28
Combe St	RG004d	82.622	82.594	-28
Bus Station	RG005	82.249	82.231	-18
	RG006	82.061	82.027	-34
Moor End Rd	RG007u	80.901	80.894	-7
Moor End Rd	RG007d	80.891	80.883	-8
Grand Union Canal	RG007_guc	80.219	80.219	0

Table 7: Sensitivity analyses following an increase in weir coefficients

Decrease in weir coefficients by 20%

Table 8 contains the results of simulations of the 100 year flood event, with a 20% decrease in weir coefficients.

1 in 100 yr event		Max. Water Level		Difference [mm]
Location	**ISIS Node**	**Standard Run [mAOD]**	**Decrease in weir coefficients by 20% [mAOD]**	
	RG001u	84.893	84.904	11
	RG001d	84.891	84.901	10
Queensway Rd	RG002u	84.489	84.527	38
Queensway Rd	RG002d	84.487	84.524	37
	RG003	83.713	83.757	44
Combe St	RG004u	82.622	82.655	33
Combe St	RG004d	82.622	82.654	32
Bus Station	RG005	82.249	82.276	27
	RG006	82.061	82.108	47
Moor End Rd	RG007u	80.901	80.91	9
Moor End Rd	RG007d	80.891	80.9	9
Grand Union Canal	RG007_guc	80.219	80.219	0

Table 8: Sensitivity analyses following a decrease in weir coefficients

Conclusion

The River Gade model outputs are not sensitive to changes in weir coefficients, with a variance of +/-20% in weir coefficients resulting in a +/-50mm change in maximum water levels.

3.4 Model Uncertainty and Level of Confidence Summary

Based on the sensitivity analysis and uncertainty in model schematisation (not including blockage analysis), the model uncertainty for the Hemel Hempstead reach of the River Gade is summarised in ***Table 9***.

Reach	Sensitivity variation (m)	Factors in model uncertainty
River Gade (Hemel Hempstead)	+/-0.1	Climate change effects on inflows, Seasonal variation in Manning's *n*
Reach	**Level of Confidence**	**Comments**
River Gade (Hemel Hempstead)	MEDIUM	River Gade model insensitive to changes in model parameters, Recent good quality survey, but lacking good calibration data.
River Gade (downstream of Moor End Road to confluence with Grand Union Canal)	LOW	Lack of good quality survey plus lack of calibration data

Table 9: Confidence in model results

4 *Mapping Methodology*

- ISIS Mapper, a tool for mapping and processing spatially and temporally varying data and developed by Halcrow Group Ltd, was used to map the results from the River Gade 1-D ISIS model.

- ISIS cross sections are used to generate a set of points at each cross section location. A TIN (Triangulation) is generated by connecting all the river cross section points to form a triangular network of surfaces.

- The Digital Terrain Model (in this case, photogrammetry data to give ground levels) was loaded onto ISIS Mapper together with the River Gade TIN. ISIS results in the form of maximuam water levels are loaded onto the TIN to create a surface of maximum water levels.

- A flood calculator within is then used to calculate water depths by comparing water surface elevations with ground levels and produce final flood extent maps (see **Appendix D**).