ENVIRONMENT AGENCY
NORTH EAST REGION

SECTION 105 - C30/92 SURVEYS

RIVER WEAR AT DURHAM

JUNE 1998

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THE ENVIRONMENT AGENCY, NORTH EAST REGION, NORTHUMBRIA AREA
SECTION 105, CIRCULAR 30/92 FLOOD PLAIN MAPS
SUMMARY
RIVER WEAR AT DURHAM

June 1998

This summary is to be read in conjunction with map reference:

- C1395/FPM/01/020

Study Reach

The study includes a 5.8km reach of the River Wear between Shinclife Bridge at NGR NZ287 410 and Barkers Haugh at NGR NZ281 434.

Existing and Predicted Problems

Locations that are predicted to flood and the areas at risk during a 100 year event are as follows:

• Left bank between Shincliffe and Baths Bridge	Properties and recreational land
• Left bank between Baths Bridge and Kingsgate Bridge	Properties and car park
• Right bank between Elvet Bridge and Kingsgate Bridge	Properties
• Right bank between Kingsgate Bridge and Prebends Bridge	Riverside open space
• Left bank downstream of Museum Weir	Old Filling Mill
• Left bank at Framwellgate Offices	Road, car park and depot
• Right bank at Milburngate and the sands	Factory, ice rink and recreational land

The existing flooding problems on this reach are covered in the "Report on Survey of Flooding Problems Volume 1 March 1997" Posford Duvivier

CONTENTS

1.0 INTRODUCTION

1.1 Section 105 Surveys Circular 30/92 Surveys

Section 105 – C30/92 surveys will be the Environment Agency's main input to the preparation of the Local Planning Authority (LPA) development plans. The surveys have been instigated by the Department of the Environment Circular 30/92 and are carried out by the Agency under the powers granted by section 105(2) of the Water Resources Act 1991.

Surveys within the Agency's Northeast Region encompass three elements:

- Indicative flood plain mapping.
- Surveys of flooding problems.
- Catchment drainage studies

1.2 Scope of this Study

The Section 105 – C30/92 Surveys reported here covers a 5.8km reach of the River Wear passing through Durham. The River Wear was modelled between the downstream face of Shincliffe Bridge at NGR NZ287410 and Barkers Haugh at NGR NZ281434 (downstream extent of study).

The associated catchment contributing to the River Wear between Shincliffe Bridge and Barkers Haugh has a total area of 62.4km². The River Wear upstream of Shincliffe Bridge has a much larger catchment area. The catchment contributing to the reach studied is principally drained by 3 watercourses, the River Wear, Old Durham Beck and Barkers Haugh Tributary.

The River Wear drains the central part of the catchment which is approximately 12% of the total area. The eastern extent of the catchment is drained by the Old Durham Beck which joins the River Wear at NGR NZ285420; this watercourse is responsible for the drainage of 86% of the total catchment area. The northern area of the catchment is drained by Barkers Haugh tributary which enters the River Wear at the downstream end of the study reach, and is responsible for the drainage of the remaining 2% of the catchment. The 5.8km reach modelled has a typical bed gradient of 1 in 1000. A location plan is given as Figure 1.1.

1.3 Purpose of this Report

This report describes the work carried out for the Flood Plain Mapping and Catchment Drainage Studies. It provides the details required by the Agency's Survey Brief. It should be read in conjunction with the Report on Survey of Flooding Problems Volume 1, March 1997 and the following 1:10,000 scale map:

- C1395/FPM/01/020

and 1:2,500 scale map:

- C1395/DM/01/020

2.0 DATA COLLECTION

2.1 Environment Agency Area Offices

Visits were made to the Newcastle office of the Agency in to gain survey and flow data that would assist in the building of the model. The Agency's Liaison Officer, Mr David Bassett, gave guidance during the visit as to where useful data could be found. Topographical surveys of the reach had been undertaken in 1968, 1971 and 1975. Cross-section data available from these surveys was obtained from the Agency and used to establish the hydraulic model.

The Project Identification FD100 Appraisal of the River Wear at Milburngate, Durham was also collected. The report produced by the then National Rivers Authority, Northumbria and Yorkshire Region identified two flooding events occurring in 1963 and 1967 and gave flood heights and return periods for these events. The report also identified properties at risk from flooding.

A long-section showing the flood levels between Baths Bridge and the downstream extent of the model during the 1967 event was obtained from the Agency. A flooded area map and occasional flood levels between Shincliffe Bridge and Milburngate Bridge during the January 1995 event was also available. The data available for these two events has been used to assess the models reliability.

Sunderland Bridge Gauging Station is located approximately 8km upstream of the study reach on the River Wear. One kilometre downstream of this gauge is the confluence of the River Browney and the River Wear. Burn Hall Gauging Station is located on the River Browney close to the confluence. Peaks over threshold data was obtained for these gauging stations.

2.2 Site Visits

During site visits to the catchment an assessment of the main hydraulic and hydrological features, to be included in the required model of the River Wear reach was made. Each of the hydraulically significant structures on the water course was visited and a series of photographs were taken during the visit.

3.0 INDICATIVE FLOOD PLAIN MAPPING (Brief 3.1)

3.1 Flow Estimation

The flow throughout the catchment was estimated using the gauging station data and methods identified in the Flood Studies Report and the subsequent Flood Studies Supplementary Reports. The Flood Studies Report was published by the Natural Environment Research Council in 1975. The document provides methods of flood estimation for use in engineering design. FSR was recognised in the brief as being an acceptable method of flow estimation.

There are fundamentally two types of flood prediction technique recommended in the Flood Studies Report. These are statistical methods (eg. frequency analysis) and unit hydrograph methods. The purpose of the statistical analysis is to derive a relationship between flood magnitude and return period. The simplest form of frequency analysis is the annual maxima series where the largest flood event from each year is abstracted. In general the procedure for the unit hydrograph method is rather more complex than for the statistical methods. The unit hydrograph should be derived if possible from rainfall run off records but may be estimated from catchment characteristics if no records exist. The accuracy of each method depends on the amount and quality of data available. Estimates from gauged catchments are more accurate than those from un-gauged catchments.

Micro-FSR is a computer package produced by the Institute of Hydrology. Micro-FSR, enables the estimation of design flood hygrographs and flood peaks using the methods contained in the Flood Studies Report. It requires the catchment characteristics to be input.

To estimate the flow entering the reach, the catchment upstream of Shincliffe Bridge was studied. The flows associated with events having return periods of 5, 10, 20 and 50 and 100 years were estimated for the two gauging stations. This was achieved by analysis of the supplied data. An estimate of the flow was made for the catchment upstream of Shincliffe Bridge, but downstream of the two gauging stations, using the unit hydrograph method in Micro FSR. This catchment is predominantly drained by Croxdale and Tursdale Beck. These two Becks drain the right bank of the Wear. The Tursdale Beck flows into the Croxdale Beck which flows into the River Wear approximately 1km downstream of the Sunderland Bridge gauging station. The three sets of flow data were combined to estimate the flow at Shincliffe Bridge. To achieve a conservative flood estimate, the peak flows for the three sets of data were added together for each return period.

The flow from the old Durham Beck and the flow draining to the reach from the rest of the catchment was estimated using the unit hydrograph method in Micro FSR. These flows were added to the flow at Shincliffe Bridge to estimate the increase in flow through the reach.

The characteristics estimated for each sub-catchment which are necessary inputs into Micro FSR are shown in Table 3.1 below. A description of each characteristic has also been included.

Table 3.1

Catchment Characteristics

Characteristic/ Parameters	**Upstream of Shincliffe Bridge, Downstream of Sunderland Bridge and Burn Hall Gauging Stations**	**Old Durham Beck**	**Upstream of Barkers Haugh, downstream of Sunderland Bridge and Burn Hall gauging stations, excluding Old Durham Beck**
Area	54.33km^2	52.52km^2	64.20km^2
Urban Fraction	6%	7%	12%
Main Stream Length (MSL)	21.1km	14.1km	26.7km
Stream Slope (S1085)	4.76m/km	6.61m/km	3.45m/km
Soil Index	0.45	0.45	0.42
Annual Rainfall (SAAR)	680mm	690mm	670mm
M5-2 Day Rainfall	52mm	54mm	52mm
Ratio M5-60 min Rainfall/M5-2 Day Rainfall	0.34	0.34	0.34
Effective mean SMD	10.5mm	11.0mm	10.5mm

Characteristic/Parameter Description

Area	-	The area draining to a site
Urban Fraction	-	An index of urban development
Main Stream Length	-	The longest stream length measured upstream of a station
Stream Slope	-	Mainstream Slope between the 10 and 85 percentiles of mainstream length
Soil Index	-	Determined from the fractions of five classes of soil which are based on their winter rain acceptance potential
Annual Rainfall	-	Standard average annual rainfall
M5-2 Day Rainfall	-	2 day rainfall of 5 year return period
Ratio M5-60min/M5-2 day	-	The ratio of the 60 minute rainfall of 5 year return period to the 2 day rainfall of 5 year return period
Effective mean SMD	-	Effective mean soil moisture deficit

The Soil Index, Annual Rainfall, M5-2 Day Rainfall, ratio of M5-60min rainfall to M5-2 day rainfall and the Effective Mean Soil Moisture Deficit values for the catchment were determined using the maps included in Volume V of the Flood Studies Report. The Soil Index is derived from the fractions of the catchment occupied by various soil classes. Five classes of soil, based on their winter rain acceptance potential, are shown on the map. The soil index for a catchment is derived by measuring the fractions of the catchment within each soil class, and adopting a weighted mean of these soil fractions.

The remaining values were derived from maps showing contours of each characteristic. Catchment average values are required and these were obtained by weighted areas.

The rainfall run-off method within Micro-FSR was used. This produces a flow peak for a flood of a particular return period and also has the option of producing flood hygrographs. The revised estimation equations summarised in Flood Studies Supplementary Report number 16 (FSSR 16) were used.

Table 3.2 shows the estimated flows from the gauging station data and the Micro-FSR output for flood events with return periods of 5, 10, 20, 50 and 100 years.

Table 3.2
Estimated Flows

Return Period	Upstream of Barkers Haugh Tributary (m^3/s)	Upstream of New Elvet Bridge (m^3/s)	Upstream of the Confluence of Old Durham Beck and the River Wear (m^3/s)
5 year	340	339	317
10 year	399	398	371
20 year	461	460	428
50 year	531	530	492
100 year	589	587	543

The flows predicted from the gauging station data and the Micro FSR output were used to calculate the flows entered into the river model. The flow estimates were used in the model on the reaches immediately upstream of the location where each flow estimate was made. This ensured that the flow and, consequently, the water level were not underpredicted.

3.2 HEC-RAS Modelling

HEC-RAS River Analysis System is a one dimensional study state model produced by the US Army Corps of Engineers. HEC-RAS has the ability to assess water levels and velocities in open channel river systems. It can model steady flow water surface profiles, branched channel networks, supercritical, subcritical or mixed flow regimes and a variety of structures. These features make it suitable for modelling this reach.

The initial step involved ascertaining the number and location of river cross-sections that would be required in order to provide realistic geometric characteristics to input into the model.

Significant locations where cross-section data was input into the model were as follows:-

- Bridges
- Weirs
- Variations in channel width
- Variations in channel bed features
- Variations in channel alignment
- Variations in channel roughness

As the cross-section data was not all derived from the same initial source it was necessary to relate all cross-sections to the same reference point. For this study Barkers Haugh was assigned a chainage of 0m; cross-section chainages increasing positively as progressing upstream. Upon entering each cross-section's geometry data into the interface it was possible to make an allowance for the channel alignment. The maximum distance between any cross-sections within the reach was just over 300 metres.

As the cross-section data set available was not complete for the stretch of the river under consideration it was necessary to generate extra cross-sections to infill any gaps. The basic process used to create the new cross-sections was as follows:-

i) choose the cross-section either from immediately upstream or immediately downstream of the gap which most resembles the known river characteristics (i.e. width, bank type etc.) within the gap;

ii) calculate the average bed elevation both immediately upstream and immediately downstream of the gap; hence the gradient between the two known cross-sections may be calculated;

iii) the elevations of the stations with infill cross-section may then be directly adjusted in proportion to their distance relative to the bounding cross-sections.

Interpolation was required to generate the cross-sections indicated in the table below:

Table 3.3

Cross-Sections Generated Through Interpolation

Chainage of Bounding Cross-Section Upstream /m	Chainage of Bounding Cross-Section Downstream /m	Number of Cross-Sections Generated /No.
5789	5309	3
5309	4409	6
2562*	2273	2
1251	824	2

Note: * Indicates that cross-section at this chainage was not used in model.

Bridges were only modelled when it was anticipated that they would have an impact on the channel's flow regime. Bridges which had decks greatly separated from the channel and/or piers situated outside of the main channel were not modelled.

For the purpose of this study the following bridges were modelled:-

Elvet Bridge	@ chainage 324m
Prebends Bridge	@ chainage 2205m
Framwelgate Bridge	@ chainage 1626m

At each bridge location it was necessary to input four cross-sections; one at both immediately upstream and immediately downstream of the structure and the remaining two sufficiently upstream and downstream from the bridge so that the flow was not affected by the structure. These extra cross-sections were generated in a similar method as was previously described.

Two long-based, broad-crested weirs were situated within the study reach. The first weir (known as the Museum weir) beginning at chainage 2034m was straight and approximately 90 metres in length, lying at an angle across the channel. The second weir (know as Framwelgate Dam) was slightly curved, approximately 230 metres in length, and once again lying skewed across the channel.

HEC-RAS version 1.2 does not facilitate the modelling of weirs and it recommends that the bridge modelling interface is used instead. This is done by inputting the underside of the bridge deck with the same levels as the bed of the channel and the top of the bridge deck at the same level as the crest of the weir. The flow is forced over the top of the bridge deck and the head of water is calculated using the standard weir equation. At both weirs cross-section data was input at the upstream and downstream ends. Additionally a cross-section was input the full length of each of the downstream and upstream faces of the two weirs The four cross-sections at each weir were aligned to represent the actual weir in plan.

Upon initially running the model it was seen that in some locations the 100 year return period water level was greater than the highest point of the provided cross-section data. The banks were therefore extended beyond the limit of the data available with the use of Ordnance Survey Pathfinder Map Number 572. The 5m interval contours were traced on the 1:25,000 scale map and hence the boundaries of the model's cross-sections could readily be extended to intersect these points when necessary.

3.3 Model Parameters

Several types of coefficient are utilised by HECRAS to evaluate energy losses. They are:

(1) Mannings n values for friction loss due to the roughness of the channel section material
(2) Contraction and expansion coefficients to evaluate transition losses.
(3) Bridge and culvert coefficients to evaluate losses related to weir shape, pier configuration, pressure flow and entrance and exit conditions.

A Mannings value of 0.020 was used for parts of the channel which were bound by concrete (e.g. concrete retaining walls). Where wooded slopes or trees and undergrowth were indicated it was decided to use a Mannings value of 0.040. In all other cases a value of 0.030 was adopted.

All cross-sections had an expansion coefficient of 0.3 and contraction coefficient of 0.1, except for those immediately upstream and downstream of the three bridges. These cross-sections had an expansion coefficient of 0.5 and contraction coefficient of 0.3. These parameters are those suggested when the changes in the river cross-section are small and for typical bridge sections. HECRAS models the overtopping of bridge decks by considering them as a weir. A weir coefficient of 1.7 was used on all three bridges. This is the suggested value for weir flow over bridges.

There are several choices available when selecting methods for computing surface water profiles through a bridge. Low flows (water surface below underside of deck) through the bridges were computed using both the Momentum and Yarnell methods and the technique that computed the greatest energy loss was used. Water levels approaching the elevation of the bridge decks were not achieved so no consideration was given to the calculation of high flows.

The model was run using a subcritical flow regime. The water level at the downstream boundary was equal to the normal depth.

3.4 Areas Predicted to Flood

The model shows significant flooding along both banks during the 100 year event. Between the upstream extent of the model at Shincliffe Bridge and Baths Bridge (ch. 3550) flooding occurs to the left bank. The properties at risk from this flooding include a sports hall, a boat house, a sports pavilion and Hilton cottage. Various other areas including playing fields, tennis courts and a bowling green would be flooded

Out of bank flow occurs over the right bank at the upstream end of the catchment. There are no properties affected by this.

Flooding occurs to the left bank between Baths Bridge and Kingsgate Bridge. The properties on the Elvet Waterside in the vicinity of Durham Baths are at risk and also a University building and car park downstream of Elvet Bridge. On the right-bank, the waterfront properties downstream of Elvet Bridge in the area of Browns Boathouse are also predicted to flood.

Between Kingsgate Bridge and Prebends Bridge the river side open space on the right bank is predicted to flood.

Flooding occurs immediately downstream of the Museum weir to the Old Fulling Mill. The predicted water level is approximately 1m above the existing defences for a 100m length.

At the lower end of the reach flooding occurs over approximately 500m of the left bank and 1100m of the right bank. On the left bank flooding occurs to an area known as Framwelgate Offices, to a road, car park and to a depot.

On the right bank downstream of Framwelgate Bridge flooding is predicted in the area of Millburngate, to a factory and to an ice rink. Downstream of the ice rink an area known as the Sands is at risk.

4.0 SURVEY OF FLOODING PROBLEMS (Brief 3.2)

4.1 Identified Flooding Problems

During the Catchment Drainage Study a drainage problem was identified on the left bank on the Elvet Waterside. It is thought that some flooding to the Durham Baths and other properties in the vicinity is caused by a drain outfall being impeded during flood flows.

4.2 Other Problem Areas

Other flooding problems on this reach not associated with fluvial inundation are covered in the "Report on Survey of Flooding Problems Volume 1 March 1997" Posford Duvivier. This report includes the responses and information gathered through consultation with councils.

5.0 CATCHMENT DRAINAGE STUDIES (Brief 3.3)

5.1 Development Proposals

The brief identifies two areas of proposed development, Leazes Bowl on the right bank between the new and old Elvet Bridges and Riverside on the right bank immediately downstream of Milburngate Bridge.

The City of Durham is in the process of submitting a bid to the Millennium commission to raise funds for a scheme entitled the Walkergate Initiative. If the proposal is granted funding the new facilities would be constructed on the eastern side or the River Wear, just north of Millburngate road bridge. New facilities would be likely to comprise the following:

- Millennium Hall
- Library
- Visitor Centre
- Car Park
- Cinema
- Swimming Pool and other leisure facilities.

Originally, the scheme incorporated a new road bridge. This proposal has been replaced with the plan to build a footbridge from Framwelgate Waterside (downstream of Millburngate Bridge on the left bank) to the Walkergate.

There are plans also for a walkway to be constructed above the sewer, that is sited on piers within the river, between Framwelgate Bridge and the Ice Rink. Drawings of this construction were obtained from the Agency.

5.2 Effects of Proposals on Flood Flows and Water Levels

It is unknown as to whether the proposal for the walkway has been granted funding, however if the scheme was constructed effects on flood flows and hence water levels would be negligible. Therefore, no allowance for the proposal was made within the model.

As the project would involve the redevelopment of an existing site surface run-off flows would be similar to present. Demolition of the ice rink would provide a more efficiently draining area and hence would theoretically reduce flood levels, albeit minimally.

It would be unlikely that the proposed bridge would greatly impair river flow as the Environment Agency impose the restriction that any new bridges erected would require the soffit level to be at minimum 600mm above design flood level (1 in 100 year return period).

5.3 Mitigation Works

To afford enhanced flood defences along the 2.2km length of bank between Shincliffe Bridge and Baths Bridge (ch. 3550) the most suitable construction option is likely to be an earth embankment. Its height would be on average approximately 1.2m. The cost of this would be approximately £385,000.

On the reaches between Baths Bridge and Kingsgate Bridge the limited space along the banks indicate that flood defence walls would be a suitable option. Approximately 450m of the left bank would require defending to an average height of approximately 1.0m and approximately 150m of the right-bank require defence to an average height of approximately 1.5m. A broad-brush estimate for this work would be in the region of £140,000.

Immediately downstream of the weir that is closest to Prebends Bridge, work would involve the construction of a 1m high flood defence wall. A broad-brush estimate of cost for this work is approximately £15,000.

At the lower end of the reach defences to an average height of 0.75m would be required to alleviate the problem. If the construction were a flood defence wall then the cost of the work would be approximately £240,000.

At the Sands there would be sufficient room to construct a flood defence bank. with an average height of approximately 0.5m and a length of 700m the estimated cost is £70,000. The cost of a 1.0m high, 400m long flood defence wall in the Millburngate area would be in the region of £60,000.

A fully detailed investigation into the alternative options at each location would be required to progress and scheme. A detailed assessment of the benefits would be needed followed by a MAFF PAGN cost benefit analysis. Initial assessment of benefits indicates that some areas will not provide positive benefit cost ratios.

5.4 Flood Warning Recommendations

The existing Flood Warning Dissemination Plan has been reviewed in the light of the findings of this study. All areas identified as being at risk in the Plan are still predicted to flood. It is recommended however, that the following locations be studied in order to make the Plan comprehensive:

- Maiden Castle Sports Centre
- Sports Pavillion and Bowling Club on University playing fields
- Hilton Cottage

These areas are not listed in the existing plan but are within the limits of the 100 year floodplain. A detailed survey of the threshold levels of these properties is required.

6.0 RESULTS AND CONCLUSIONS

6.1 Accuracy of Modelling Techniques

An indication of the accuracy of the models output (MicroFSR and HECRAS) and the accuracy of the analysis using the gauging station records can be achieved by comparing the predicted water levels and historical levels.

Data from two events is available. Flood levels between Baths Bridge and the downstream extent of the model had been plotted on a long section for the 1967 event. A flood plain map with occasional flood levels produced by Rust Consulting Ltd had been produced for the January 1995 event.

During the 1995 event the peak flow at Sunderland Bridge Gauging Station was equivalent to a 1 in 36 year event. At Chester le Street Gauging Station, which is downstream of the Study reach, the maximum recorded flow was equivalent to a 1 in 7 year event. This suggested that the flow through Durham would have a return period somewhere between these two values.

The recorded levels upstream of Prebends Bridge during the 1995 event, when compared to the levels predicted by the model can be given a return period of between 7 and 8 years. Downstream of Prebends Bridge the predicted water levels are typically lower, relative to the levels recorded during the flood. This results in the recorded levels being equal to those predicted for flows with 40 year return periods or even higher. The consistency in the levels predicted by the model relative to the recorded levels also decreases over the reach downstream of Prebends Bridge.

During the 1967 event the peak flow recorded at Sunderland Bridge Gauging Station was attributed a return period greater than 1 in 100 years. The FD 100 Appraisal suggests that the flood in Durham had an estimated return period of 1 in 25 years. This decrease in return period for the event between Sunderland Bridge and Durham is similar to the decrease identified for the 1995 event. This also suggests that the analysis of the Sunderland Bridge gauging data is wrong. A more detailed analysis of the data from this gauge would be worthwhile.

The modelling predictions also show a similar trend when compared to the recorded 1967 levels as they did when compared to the 1995 levels. Upstream of Prebends Bridge the predicted flood levels indicate that recorded levels can be associated with an event of approximately 20 years return period. Downstream of Prebends, the model appears to underpredict the flood level for the flows studied. This results in the recorded levels falling between those levels predicted which are associated with return periods of 50 years and 100 years.

The results show that the modelling of the reach upstream of Prebends Bridge is relatively accurate. It may possibly be suggested that the model is predicting water levels that are too high. Without more accurate flow estimates, more reliable data relating to the return period of a particular flow at Sunderland Bridge and more knowledge of the changes in return period of events between Sunderland Bridge and Durham, this suggestion cannot be concluded .

The model predicts levels that are too low downstream of Prebends Bridge. Inaccuracies are evident in the vicinity of the two weirs, Framwelgate Dam and the Museum Weir. Both structures are complex in terms of hydraulic modelling. The Museum Weir is angled across the river. The Framwellgate Dam is curved and is also tiered. Alternative methods of modelling the weirs are available but are not within the scope of this project at this time. In addition to any errors created by the complexities of the weirs, the topographical data should be checked. The accuracy of bed levels and weir levels should be looked at in detail.

6.2 Discussion of Results

From the one in one hundred year event flood plain map the following observations have been made.

Between the upstream end of the reach (chainage 5789) and chainage 4007 out of bank flow (right bank) has been predicted, but fortunately it appears that few assets exist in this zone. As can be seen from the map an extensive area of flooding is anticipated between Shincliffe Bridge (chainage 5789) and chainage 4900 (left hand bank); it would be likely that the Sports Hall would be significantly damaged in this extreme event.

From chainage 4900 to chainage 3550 (left-hand bank) the modelling has predicted a large flooded area, but once again a great percentage of this land is sports ground. There are, however, a number of buildings within this zone.

It is expected that the 100-year event would cause flooding reaching two hundred metres to both the upstream and the downstream sides of Elvet Bridge. This flooding would breach the left-hand bank and effect a number of buildings. Downstream of Kingsgate Bridge out of bank flow flooding the riverside open space could be expected on the right side of the channel, down as far as the Museum Weir. Between the Museum Weir and Framwelgate Bridge flooding is anticipated to the waterfront on the left bank.

Downstream of Framwelgate Bridge to chainage 1251 (approximately a 375 metre stretch) a significant out of bank flow could be expected to either side of the river. Flooding would cause damage to property on the left bank including the Framwelgate Waterside and Milburngate. On the opposing bank, the ice rink and planned Walkergate Development are within the flooded area.

From chainage 1251 to 458 an out of bank flow (to right of channel) is predicted, however, this area has been developed little, composed predominantly of open space.

Within bank flows are anticipated between chainage 458 and the downstream extent of the study reach.

6.3 Conclusion

The predictions made for the 100-year water level have a reasonable level of confidence. The reason for this is because of the quality of the data sets used. The flow data, because it had been collected from a gauging station, is comparatively reliable although some accuracy would have been lost by adjusting the estimated flows using Flood Studies methods to allow for the distance between the gauging station and study reach. There is some uncertainty as to whether flood data for the historic period or the gauged period (1957 onwards) should be used for frequency analysis. The length of the historic period over which data is analysed is also critical. The report "Improvements in Flood estimates using Historical Flood Information on the River Wear at Durham" by D Archer 1987 highlights these variations. Within the discussion of this report Archer comments that the 1967 flood is assigned a return period of 18 years for the historic series compared to 60 years for the gauged series.

The flood estimates made in the work using the gauged data and making an allowance for the catchment contributing to the reach downstream of the gauging stations closely matches the estimates made by Archer for the Historic Period 1900 to 1986.

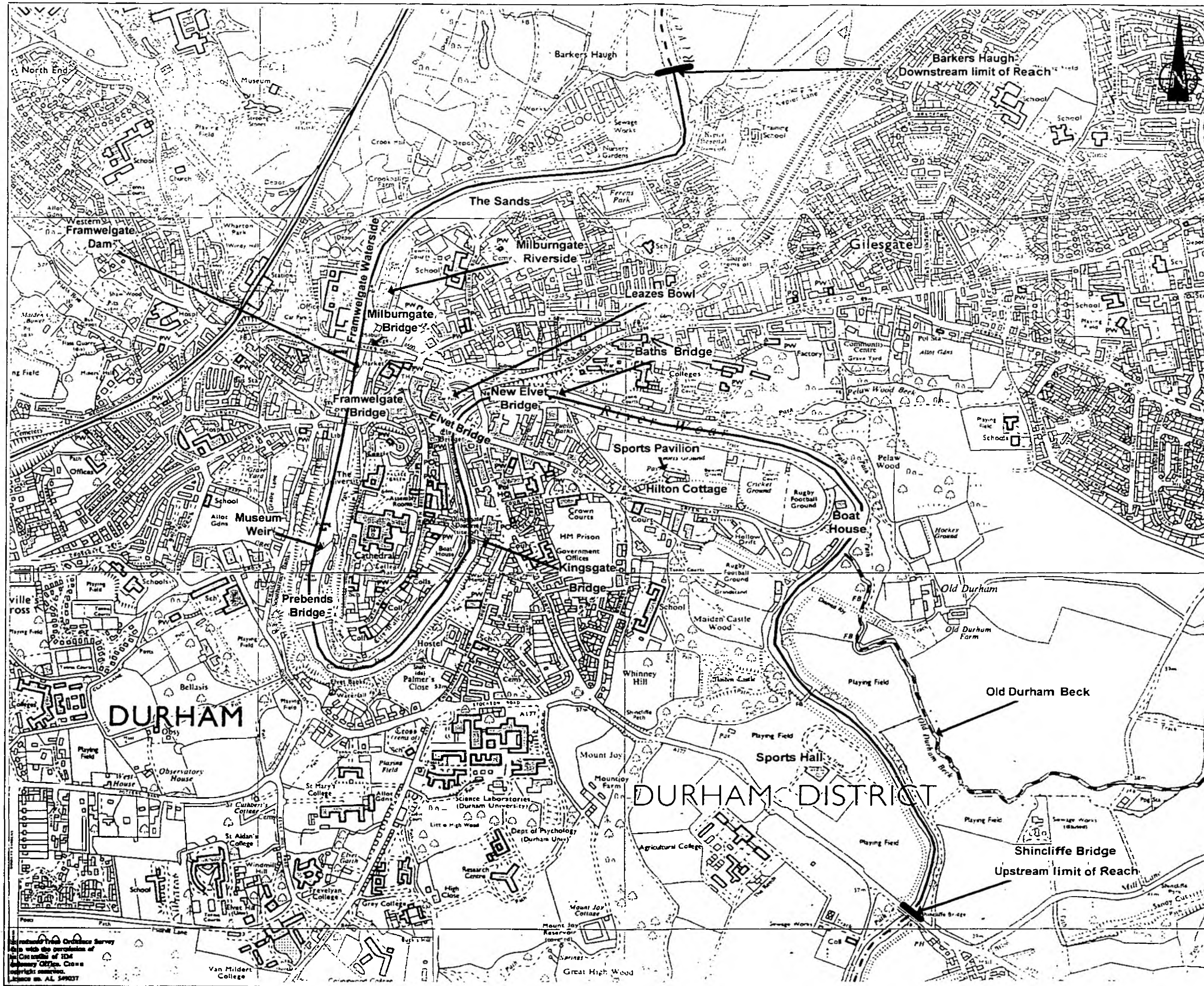
The available topographical information was reasonably comprehensive although if there had been more detail then greater confidence could have been achieved. Having cross-sections that extend further across the flood plain would give the greatest benefit as the need to interpolate using 5m contours would be eliminated. However, it is unlikely that having a greater number of cross-sections would influence the predicted water levels but it would assist in identifying the areas where out of bank flow occur. Using a more recent survey of the water course would have the benefit of identifying any development on the river banks since the date of the survey. This would assist in the identification of flooded property. The parameters discussed in Section 3.3 would help in increasing confidence in the predicted results.

To enhance the model predictions the following work should be considered.

- Extend the width of survey at cross-sections where the existing survey does not extend to a level equal to the 100 year water level.
- Survey bank levels in areas where flooding has been known to occur so the extent of the out of bank flow can be estimated.
- Establish a two dimensional model of the river which includes the Museum Weir and Framwellgate Dam.
- Calibrate the model so that the parameters discussed in Section 3.3 can be accurately predicted.

It should also be noted that there are confidence limits on any modelling exercise and that no amount of additional data will produce a 100% accurate answer.

Sensitivity testing at this stage would have limited benefit. Although it would give an indication to the impact that a parameter has on the flood levels, it is not possible to determine whether the change to the variable has given a better prediction.



POSFORD DUVIVIER
CONSULTING ENGINEERS

ENVIRONMENT AGENCY
North East Region

Project

Section 105 - C30/92

Surveys

Title

Northumbria Area

River Wear

Barkers Haugh to Shincliffe

LOCATION PLAN

Date: 19/03/98	Scale: 1 : 10,000
Drawn MDWP	Chkd. TE
Drg. No.	Figure 1.1

APPENDIX A
PHOTOGRAPHS

Photograph 1 – Looking upstream at Baths Bridge (ch 3550m)

Photograph 2 – Looking upstream at Elvet Bridge from Kingsgate Bridge (ch 3224m)

Photograph 3 – Looking downstream from Kingsgate Bridge (ch 2940m)

Photograph 4 – Looking downstream at the Museum Weir (ch 2034m)

Photograph 5 – Looking upstream at the Museum Weir and Prebends Bridge (ch 2034m)

Photograph 6 – Looking downstream at Framwelgate Waterside (ch 1327m)

APPENDIX B
MODEL OUTPUT

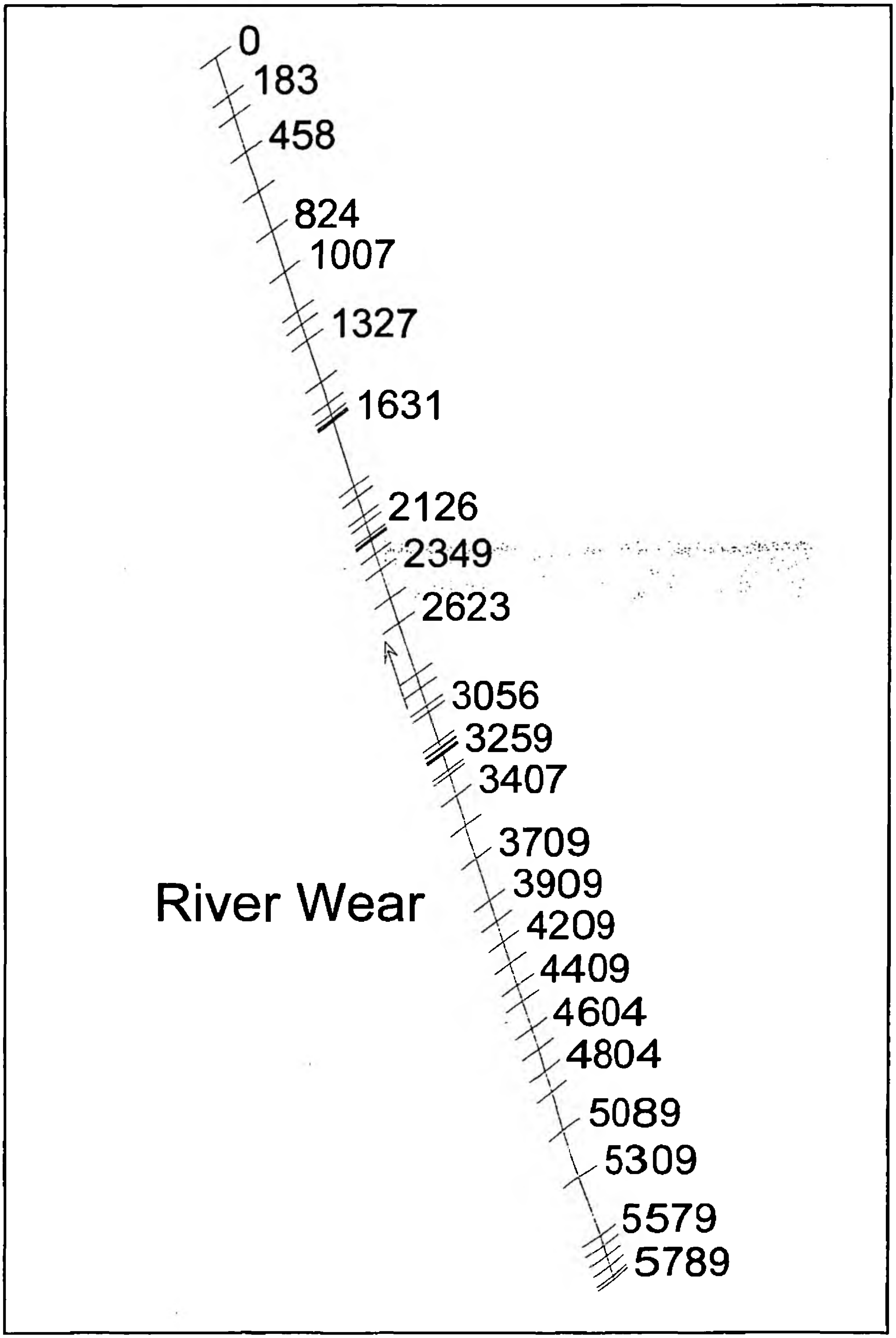
APPENDIX B

MODEL OUTPUT

Appendix B contains a selection of the output generated by HECRAS. The model run shown used the flows predicted for the catchment that included proposed development. The table lists each river station and the reaches that they are on. For each river station the total flow, water surface elevation, top width of the flow and the velocity within the channel has been given for flows with return periods of 100 years, 50 years, 20 years, 10 years and 5 years. For each river station, the results for the largest event are given first with the following result representing the next largest return periods. The model includes a total of five significant structures, three bridges and two weirs. The schematic drawing included in Appendix B shows the relative locations of River Stations.

The attached disc contains the files of all data used including cross-sections that can be output in hard copy as required.

Final Geometry File	Wear 3.GO1
100,50,20,10,5 year Flow File	Wear 3.FO2


0
183
458
824
1007
1327
1631
2126
2349
2623
3056
3259
3407
3709
3909
4209
4409
4604
4804
5089
5309
5579
5789
River Wear

HEC-RAS Plan: EXISTING Reach: wear1 3/2/98

River Sta	Q Total	W.S. Elev	Top Width	Vel Chnl
	(m3/s)	(m)	(m)	(m/s)
5789	543.00	37.33	178.93	2.05
5789	492.00	37.18	134.86	1.95
5789	428.00	36.98	73.41	1.79
5789	371.00	36.78	60.32	1.63
5789	317.00	36.53	57.54	1.49
5773	543.00	37.32	180.93	2.04
5773	492.00	37.17	137.39	1.94
5773	428.00	36.97	76.55	1.78
5773	371.00	36.77	60.46	1.63
5773	317.00	36.53	57.68	1.48
5724.5*	543.00	37.23	242.52	2.36
5724.5*	492.00	37.06	197.18	2.30
5724.5*	428.00	36.86	140.92	2.17
5724.5*	371.00	36.67	89.58	2.00
5724.5*	317.00	36.44	52.95	1.83
5676.*	543.00	37.18	301.92	2.45
5676.*	492.00	36.97	246.23	2.53
5676.*	428.00	36.73	182.52	2.51
5676.*	371.00	36.53	130.79	2.39
5676.*	317.00	36.31	86.25	2.23
5627.5*	543.00	37.19	362.66	2.23
5627.5*	492.00	36.96	303.83	2.40
5627.5*	428.00	36.69	233.86	2.52
5627.5*	371.00	36.45	174.74	2.53
5627.5*	317.00	36.19	121.67	2.50
5579	543.00	37.20	417.04	1.89
5579	492.00	36.98	358.63	2.06
5579	428.00	36.70	290.31	2.20
5579	371.00	36.46	228.66	2.27
5579	317.00	36.17	158.61	2.34
5309	543.00	37.07	425.16	1.68
5309	492.00	36.82	369.81	1.84
5309	428.00	36.48	294.46	2.07
5309	371.00	36.17	225.90	2.23
5309	317.00	35.77	143.75	2.47
5089	543.00	36.99	415.17	1.54
5089	492.00	36.71	363.03	1.69
5089	428.00	36.34	292.17	1.92
5089	371.00	35.97	222.31	2.13

HEC-RAS Plan: EXISTING Reach: wear1 3/2/98 (continued)

River Sta	Q Total	W.S. Elev	Top Width	Vel Chnl
	(m3/s)	(m)	(m)	(m/s)
5089	317.00	35.43	127.33	2.53
4909	543.00	36.66	124.47	2.42
4909	492.00	36.38	104.68	2.41
4909	428.00	36.04	81.73	2.32
4909	371.00	35.72	59.50	2.23
4909	317.00	35.28	40.53	2.16
4804	543.00	36.63	197.38	2.20
4804	492.00	36.32	160.47	2.26
4804	428.00	35.97	118.39	2.25
4804	371.00	35.63	78.60	2.18
4804	317.00	35.20	41.36	2.12
4704	543.00	36.63	396.77	1.82
4704	492.00	36.29	309.26	2.01
4704	428.00	35.90	208.26	2.14
4704	371.00	35.54	116.39	2.14
4704	317.00	35.12	42.07	2.08
4604	587.00	36.46	191.74	2.30
4604	530.00	36.12	156.71	2.38
4604	460.00	35.75	118.14	2.36
4604	398.00	35.41	82.00	2.30
4604	339.00	35.01	42.37	2.21
4479	587.00	36.59	692.41	0.83
4479	530.00	36.26	683.85	0.96
4479	460.00	35.87	673.68	1.18
4479	398.00	35.44	662.59	1.61
4479	339.00	34.90	44.47	2.17
4409	587.00	36.27	119.23	2.54
4409	530.00	35.93	102.64	2.52
4409	460.00	35.57	84.57	2.42
4409	398.00	35.22	67.02	2.30
4409	339.00	34.84	47.40	2.17
4309	587.00	36.28	149.67	2.11
4309	530.00	35.94	134.46	2.13
4309	460.00	35.56	117.70	2.09
4309	398.00	35.19	101.26	2.04
4309	339.00	34.79	47.10	1.96
4209	587.00	36.28	212.87	1.82
4209	530.00	35.92	211.93	1.95

HEC-RAS Plan: EXISTING Reach: wear1 3/2/98 (continued)

River Sta	Q Total	W.S. Elev	Top Width	Vel Chnl
	(m3/s)	(m)	(m)	(m/s)
4209	460.00	35.52	177.41	2.00
4209	398.00	35.14	134.57	2.00
4209	339.00	34.73	89.27	1.94
4009	587.00	36.23	156.66	1.83
4009	530.00	35.88	154.29	1.89
4009	460.00	35.48	151.63	1.92
4009	398.00	35.08	149.03	1.94
4009	339.00	34.68	48.69	1.89
3909	587.00	36.21	178.52	1.66
3909	530.00	35.85	177.18	1.74
3909	460.00	35.44	175.67	1.79
3909	398.00	35.04	66.10	1.83
3909	339.00	34.64	59.53	1.75
3709	587.00	36.19	221.88	1.42
3709	530.00	35.81	215.34	1.49
3709	460.00	35.39	207.94	1.55
3709	398.00	34.96	86.87	1.66
3709	339.00	34.57	58.40	1.57
3550	587.00	35.83	49.28	2.61
3550	530.00	35.49	44.33	2.54
3550	460.00	35.12	42.41	2.39
3550	398.00	34.74	41.84	2.25
3550	339.00	34.37	41.05	2.10
3407	587.00	35.72	75.64	2.59
3407	530.00	35.37	57.24	2.53
3407	460.00	35.00	42.43	2.38
3407	398.00	34.64	39.96	2.23
3407	339.00	34.28	39.54	2.07
3303	589.00	35.67	75.75	2.38
3303	531.00	35.31	59.09	2.34
3303	461.00	34.94	55.85	2.24
3303	399.00	34.57	53.64	2.15
3303	340.00	34.21	45.00	2.03
3282	589.00	35.68	61.27	2.25
3282	531.00	35.32	59.95	2.20
3282	461.00	34.95	58.57	2.10
3282	399.00	34.58	57.21	2.01
3282	340.00	34.22	55.86	1.90

HEC-RAS Plan: EXISTING Reach: wear1 3/2/98 (continued)

River Sta	Q Total	W.S. Elev	Top Width	Vel Chnl
	(m3/s)	(m)	(m)	(m/s)
3259	589.00	35.71	153.12	1.79
3259	531.00	35.34	126.49	1.80
3259	461.00	34.96	105.87	1.74
3259	399.00	34.58	86.82	1.68
3259	340.00	34.22	63.78	1.59
3254	589.00	35.47	134.01	2.75
3254	531.00	35.10	113.93	2.75
3254	461.00	34.73	94.83	2.66
3254	399.00	34.37	74.69	2.58
3254	340.00	34.02	62.19	2.45
3253	589.00	35.47		
3253	531.00	35.10		
3253	461.00	34.73		
3253	399.00	34.37		
3253	340.00	34.02		
3247	589.00	35.31	125.82	2.86
3247	531.00	34.95	107.05	2.85
3247	461.00	34.62	89.95	2.74
3247	399.00	34.28	70.08	2.63
3247	340.00	33.95	61.76	2.49
3229	589.00	35.39	116.69	2.08
3229	531.00	35.04	103.13	2.07
3229	461.00	34.69	89.79	1.97
3229	399.00	34.35	76.54	1.88
3229	340.00	34.01	55.66	1.76
3224	589.00	35.40	142.76	1.97
3224	531.00	35.05	122.52	1.99
3224	461.00	34.70	102.61	1.92
3224	399.00	34.35	82.86	1.85
3224	340.00	34.01	55.68	1.75
3196	589.00	35.28	98.97	2.43
3196	531.00	34.92	87.84	2.42
3196	461.00	34.59	77.21	2.31
3196	399.00	34.25	66.62	2.20
3196	340.00	33.93	56.28	2.06
3056	589.00	34.97	45.45	2.93
3056	531.00	34.64	45.45	2.86
3056	461.00	34.33	45.45	2.68
3056	399.00	34.02	45.45	2.53

HEC-RAS Plan: EXISTING Reach: wear1 3/2/98 (continued)

River Sta	Q Total	W.S. Elev	Top Width	Vel Chnl
	(m3/s)	(m)	(m)	(m/s)
3056	340.00	33.71	45.45	2.37
3026	589.00	34.92	46.36	2.98
3026	531.00	34.58	46.36	2.92
3026	461.00	34.28	46.36	2.75
3026	399.00	33.96	46.27	2.60
3026	340.00	33.65	45.64	2.45
2940	589.00	34.91	63.89	2.50
2940	531.00	34.55	60.90	2.48
2940	461.00	34.24	58.28	2.36
2940	399.00	33.92	55.58	2.26
2940	340.00	33.60	53.85	2.14
2873	589.00	34.72	70.34	2.84
2873	531.00	34.30	69.69	2.98
2873	461.00	33.96	61.83	2.97
2873	399.00	33.64	49.38	2.91
2873	340.00	33.35	43.12	2.73
2623	589.00	34.47	61.44	2.46
2623	531.00	33.98	60.15	2.53
2623	461.00	33.65	59.28	2.43
2623	399.00	33.36	58.52	2.31
2623	340.00	33.10	56.44	2.15
2495	589.00	34.34	61.99	2.48
2495	531.00	33.81	60.00	2.59
2495	461.00	33.48	58.74	2.49
2495	399.00	33.19	57.65	2.36
2495	340.00	32.95	56.75	2.19
2349	589.00	34.19	64.67	2.50
2349	531.00	33.61	58.94	2.67
2349	461.00	33.27	57.29	2.58
2349	399.00	32.98	55.91	2.45
2349	340.00	32.76	54.84	2.26
2273	589.00	34.10	64.38	2.55
2273	531.00	33.47	58.46	2.76
2273	461.00	33.13	56.78	2.67
2273	399.00	32.85	55.41	2.54
2273	340.00	32.64	54.42	2.33
2209	589.00	34.10	77.43	2.19
2209	531.00	33.45	75.18	2.42

HEC-RAS Plan: EXISTING Reach: wear1 3/2/98 (continued)

River Sta	Q Total	W.S. Elev	Top Width	Vel Chnl
	(m3/s)	(m)	(m)	(m/s)
2209	461.00	33.08	73.90	2.40
2209	399.00	32.78	67.86	2.36
2209	340.00	32.58	66.74	2.18
2205	589.00	33.94	76.86	2.75
2205	531.00	33.22	74.38	3.12
2205	461.00	32.83	68.10	3.17
2205	399.00	32.56	66.62	3.06
2205	340.00	32.40	66.16	2.80
2204	589.00	33.94		
2204	531.00	33.22		
2204	461.00	32.83		
2204	399.00	32.56		
2204	340.00	32.40		
2199	589.00	33.93	76.84	2.76
2199	531.00	33.20	74.28	3.16
2199	461.00	32.81	67.93	3.21
2199	399.00	32.53	66.45	3.10
2199	340.00	32.38	66.11	2.83
2184	589.00	33.98	76.94	2.28
2184	531.00	33.25	74.40	2.62
2184	461.00	32.85	68.12	2.67
2184	399.00	32.57	66.58	2.60
2184	340.00	32.41	66.13	2.38
2126	589.00	33.93	82.44	2.21
2126	531.00	33.14	79.91	2.63
2126	461.00	32.70	76.86	2.75
2126	399.00	32.37	70.93	2.79
2126	340.00	32.24	66.51	2.54
2034	589.00	33.89	82.35	2.29
2034	531.00	33.08	80.34	2.67
2034	461.00	32.64	74.74	2.71
2034	399.00	32.32	61.86	2.64
2034	340.00	32.20	57.44	2.36
1999	589.00	33.98	156.07	1.19
1999	531.00	33.17	153.86	1.44
1999	461.00	32.70	152.42	1.56
1999	399.00	32.33	144.49	1.65
1999	340.00	32.20	138.07	1.53

HEC-RAS Plan: EXISTING Reach: wear1 3/2/98 (continued)

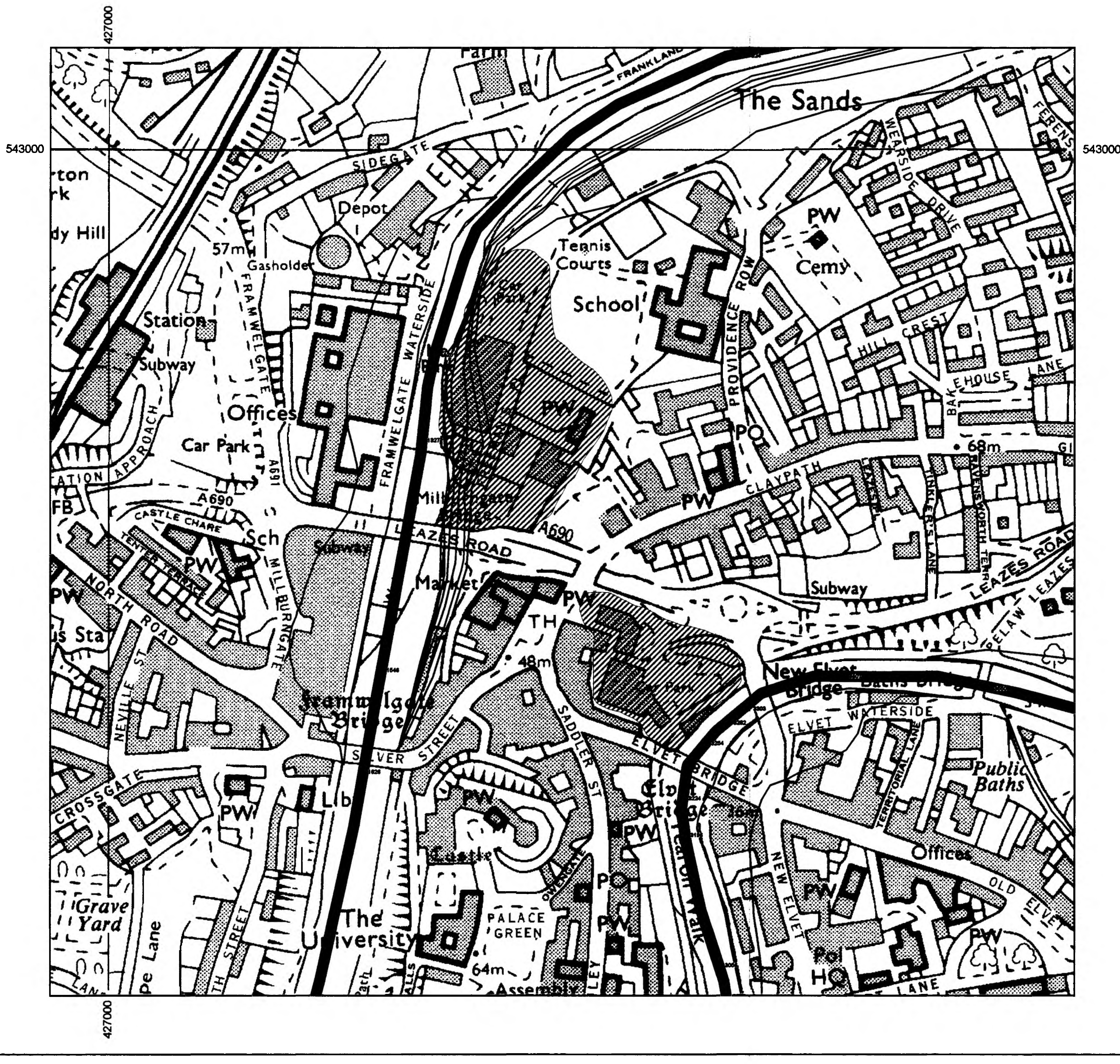
River Sta.	Q Total	W.S. Elev	Top Width	Vel Chnl
	(m3/s)	(m)	(m)	(m/s)
1998.9	589.00	33.98		
1998.9	531.00	33.17		
1998.9	461.00	32.70		
1998.9	399.00	32.33		
1998.9	340.00	32.20		
1998.4	589.00	33.00	153.39	1.63
1998.4	531.00	32.73	152.92	1.66
1998.4	461.00	32.42	148.28	1.70
1998.4	399.00	32.09	136.46	1.77
1998.4	340.00	31.82	133.29	1.80
1945	589.00	32.84	85.80	2.22
1945	531.00	32.59	84.45	2.16
1945	461.00	32.29	82.76	2.07
1945	399.00	31.98	81.01	2.00
1945	340.00	31.74	79.64	1.88
1631	589.00	32.38	62.86	2.74
1631	531.00	32.12	61.87	2.66
1631	461.00	31.84	60.77	2.53
1631	399.00	31.52	59.52	2.44
1631	340.00	31.31	58.52	2.24
1626	589.00	32.21	62.20	3.24
1626	531.00	31.96	61.25	3.14
1626	461.00	31.69	60.22	2.97
1626	399.00	31.38	58.90	2.87
1626	340.00	31.20	57.95	2.62
1625	589.00	32.21		
1625	531.00	31.96		
1625	461.00	31.69		
1625	399.00	31.38		
1625	340.00	31.20		
1617	589.00	32.20	68.05	3.22
1617	531.00	31.96	65.87	3.13
1617	461.00	31.67	63.29	2.99
1617	399.00	31.35	60.30	2.90
1617	340.00	31.17	58.46	2.65
1597	589.00	32.23	68.38	2.83
1597	531.00	31.98	66.16	2.75
1597	461.00	31.68	63.52	2.64
1597	399.00	31.36	60.52	2.56

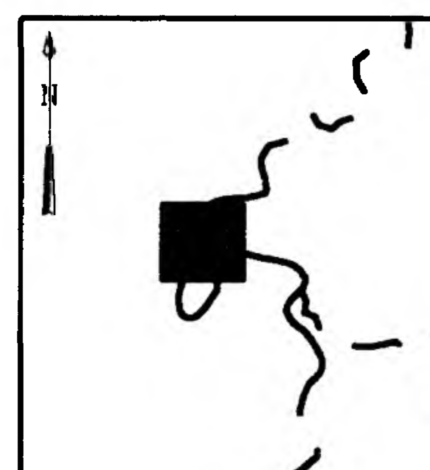
HEC-RAS Plan: EXISTING Reach: wear1 3/2/98 (continued)

River Sta	Q Total	W.S. Elev	Top Width	Vel Chnl
	(m3/s)	(m)	(m)	(m/s)
1597	340.00	31.17	58.63	2.35
1546	589.00	32.20	97.21	2.67
1546	531.00	31.94	84.30	2.62
1546	461.00	31.64	65.58	2.50
1546	399.00	31.30	59.39	2.43
1546	340.00	31.13	56.12	2.20
1342	589.00	32.41	404.36	0.69
1342	531.00	32.14	369.27	0.70
1342	461.00	31.81	336.59	0.70
1342	399.00	31.46	305.97	0.72
1342	340.00	31.25	216.05	0.70
1341.9	589.00	32.41		
1341.9	531.00	32.14		
1341.9	461.00	31.81		
1341.9	399.00	31.46		
1341.9	340.00	31.25		
1341.4	589.00	32.38	398.98	0.78
1341.4	531.00	32.10	361.73	0.82
1341.4	461.00	31.76	328.77	0.85
1341.4	399.00	31.42	299.57	0.90
1341.4	340.00	31.04	213.00	1.00
1327	589.00	32.12	137.81	2.07
1327	531.00	31.82	130.04	2.12
1327	461.00	31.44	119.48	2.16
1327	399.00	31.07	97.00	2.19
1327	340.00	30.70	59.44	2.07
1251	589.00	31.68	72.81	3.29
1251	531.00	31.38	66.65	3.28
1251	461.00	31.04	59.89	3.18
1251	399.00	30.72	37.84	3.05
1251	340.00	30.39	37.08	2.87
1190	589.00	31.56	70.59	3.35
1190	531.00	31.25	64.84	3.35
1190	461.00	30.90	58.47	3.26
1190	399.00	30.59	37.70	3.10
1190	340.00	30.27	36.95	2.91
1007	589.00	31.39	93.96	2.79
1007	531.00	31.07	56.22	2.76

HEC-RAS Plan: EXISTING Reach: wear1 3/2/98 (continued)

River Sta	Q Total	W.S. Elev	Top Width	Vel Chnl
	(m3/s)	(m)	(m)	(m/s)
1007	461.00	30.73	51.75	2.64
1007	399.00	30.41	50.54	2.53
1007	340.00	30.07	49.26	2.41
824	589.00	31.10	86.27	2.85
824	531.00	30.80	53.77	2.80
824	461.00	30.47	51.57	2.68
824	399.00	30.14	50.34	2.57
824	340.00	29.79	49.03	2.47
641	589.00	30.84	80.85	2.87
641	531.00	30.54	62.32	2.81
641	461.00	30.21	49.36	2.67
641	399.00	29.89	47.30	2.54
641	340.00	29.55	43.29	2.40
458	589.00	30.57	49.78	2.94
458	531.00	30.26	48.87	2.87
458	461.00	29.95	47.95	2.71
458	399.00	29.63	47.01	2.58
458	340.00	29.31	44.81	2.43
275	589.00	30.34	48.44	2.96
275	531.00	30.05	42.02	2.87
275	461.00	29.76	40.98	2.67
275	399.00	29.46	39.90	2.48
275	340.00	29.16	38.84	2.28
183	589.00	30.17	56.06	3.05
183	531.00	29.90	48.27	2.97
183	461.00	29.61	47.97	2.79
183	399.00	29.30	47.65	2.65
183	340.00	29.00	47.46	2.49
0	589.00	29.52	48.78	3.70
0	531.00	29.30	48.21	3.56
0	461.00	29.03	47.50	3.39
0	399.00	28.72	44.61	3.28
0	340.00	28.44	43.43	3.11





KEY:

Development Site	
Main river, hydraulic model node and cross section	154
Non-main river, hydraulic model node and cross section	154
Culvert / Tunnel main river	
Culvert / Tunnel non-main river	
Weir	
Indicative 100 year flood event	
Indicative 50 year flood event	
Indicative 20 year flood event	
Indicative 10 year flood event	
Indicative 5 year flood event	

List of revisions

ENVIRONMENT AGENCY
NORTH EAST REGION

PROJECT TITLE

SECTION 105 - C30/92 SURVEYS IDENTIFICATION OF DEVELOPMENT AT RISK FROM FLOODING

DRAWING TITLE

NORTHUMBRIA AREA BARKERS HAUGH TO SHINCLIFFE (SHEET 1 OF 1)

USER NOTE

This plan has been produced with the requirements of Department of the Environment Circular 30/92. Because the information is indicative rather than specific, local planning authorities will nevertheless need to consult the Environment Agency on individual applications. Flood plain extent is based on data available at the time of survey. Amendments will be required in future to account for information gathered subsequently eg. changes in hydrological river response or observations following flood events.

It should be noted that locations adjacent to rivers not included in this stage of the survey may be at risk of flooding. When in doubt the Environment Agency should be consulted.

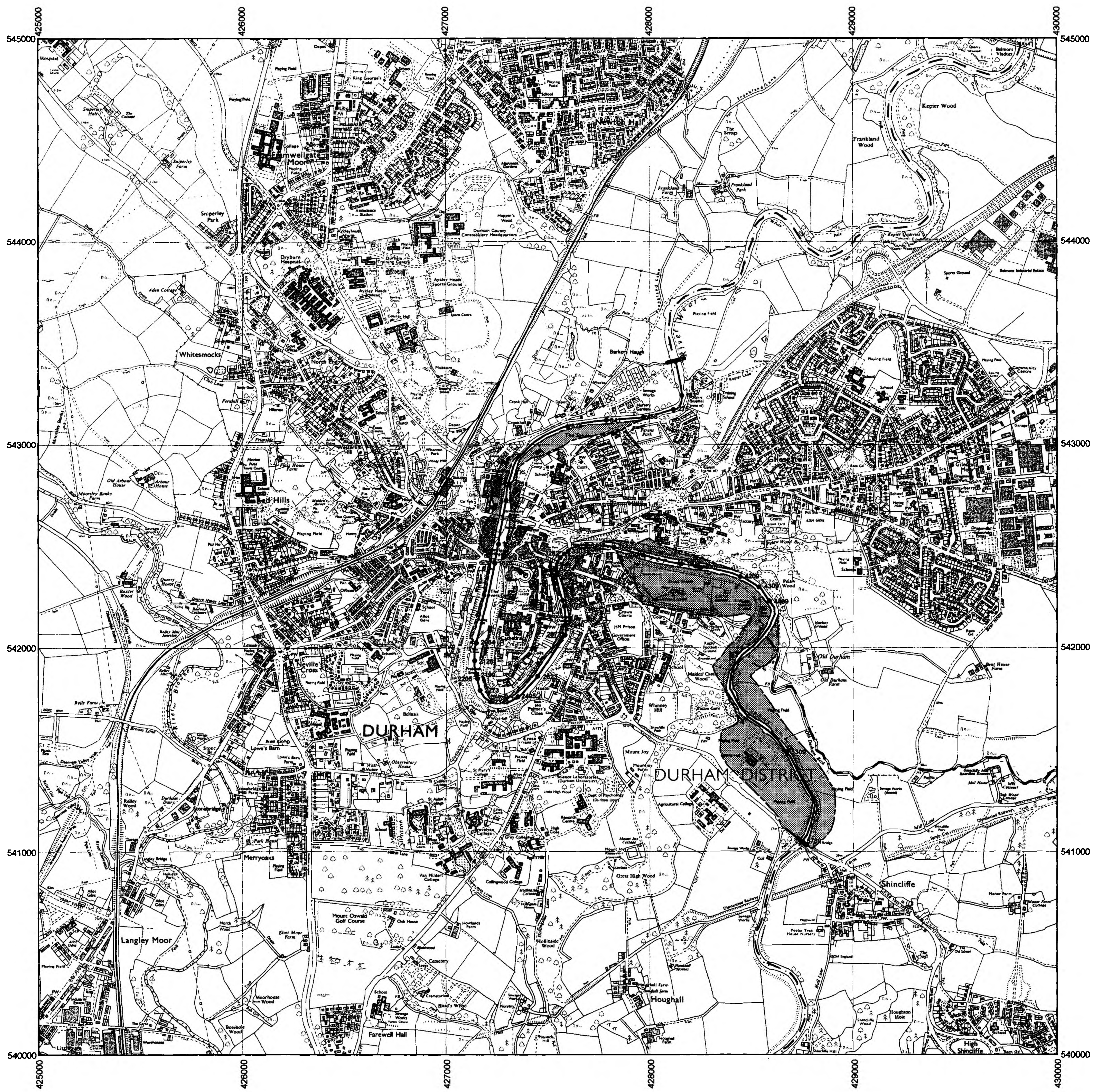
ORIGINATED BY	DRAWN BY	CHECKED BY	APPROVED BY
SPT	TH-R	TJS	
DATE	DATE	DATE	DATE

SCALE 1 : 2,500

PROJECT NO. / DRAWING NO. / REV C1395/DM/01/020

POSFORD DUVIVIER

09/10/1997



Key:

Symbol	
Fluvial Floodplain (100yr unless noted otherwise)	
Tidal Floodplain (200 yr unless noted otherwise)	
Washland	
Controlled Washland	
Limit of reach	
Floodplain extent (High confidence)	
Floodplain extent (Medium confidence)	
Floodplain extent (Low confidence)	
Known event line with estimated return period	eg 150 yr
Main river included in survey	
Ordinary watercourse included in survey	
Main river excluded from survey	
Ordinary watercourse excluded from survey	
Culvert / tunnel	
Model node Point	2883

Note :- for clarity only indicative model node points have been included on this plan. For full listing please refer to model output

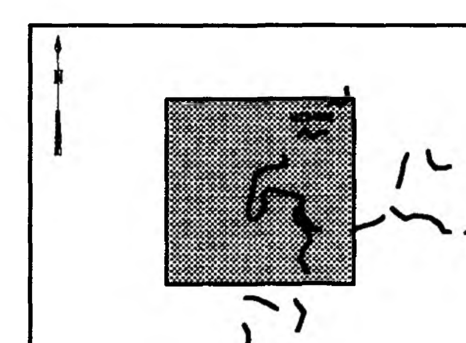
Originated	Date	Details
Drawn By	Date	
Checked	Date	

List of revisions

ENVIRONMENT AGENCY
NORTH EAST REGION

PROJECT TITLE

SECTION 105 - C30/92 SURVEYS
FLOOD PLAIN IDENTIFICATION
1 IN 100 YEAR EVENT



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DRAWING TITLE

NORTHUMBRIA AREA
RIVER WEAR
BARKERS HAUGH
TO SHINCLIFFE

ORIGINATED BY	DRAWN BY	CHECKED BY	APPROVED BY
SPT	TH-R	TJS	
DATE	DATE	DATE	DATE

SCALE 1:10,000

PROJECT NO. / DRAWING NO. / REV
C1395/FPM/01/020

POSFORD DUVIVIER

19-05-98