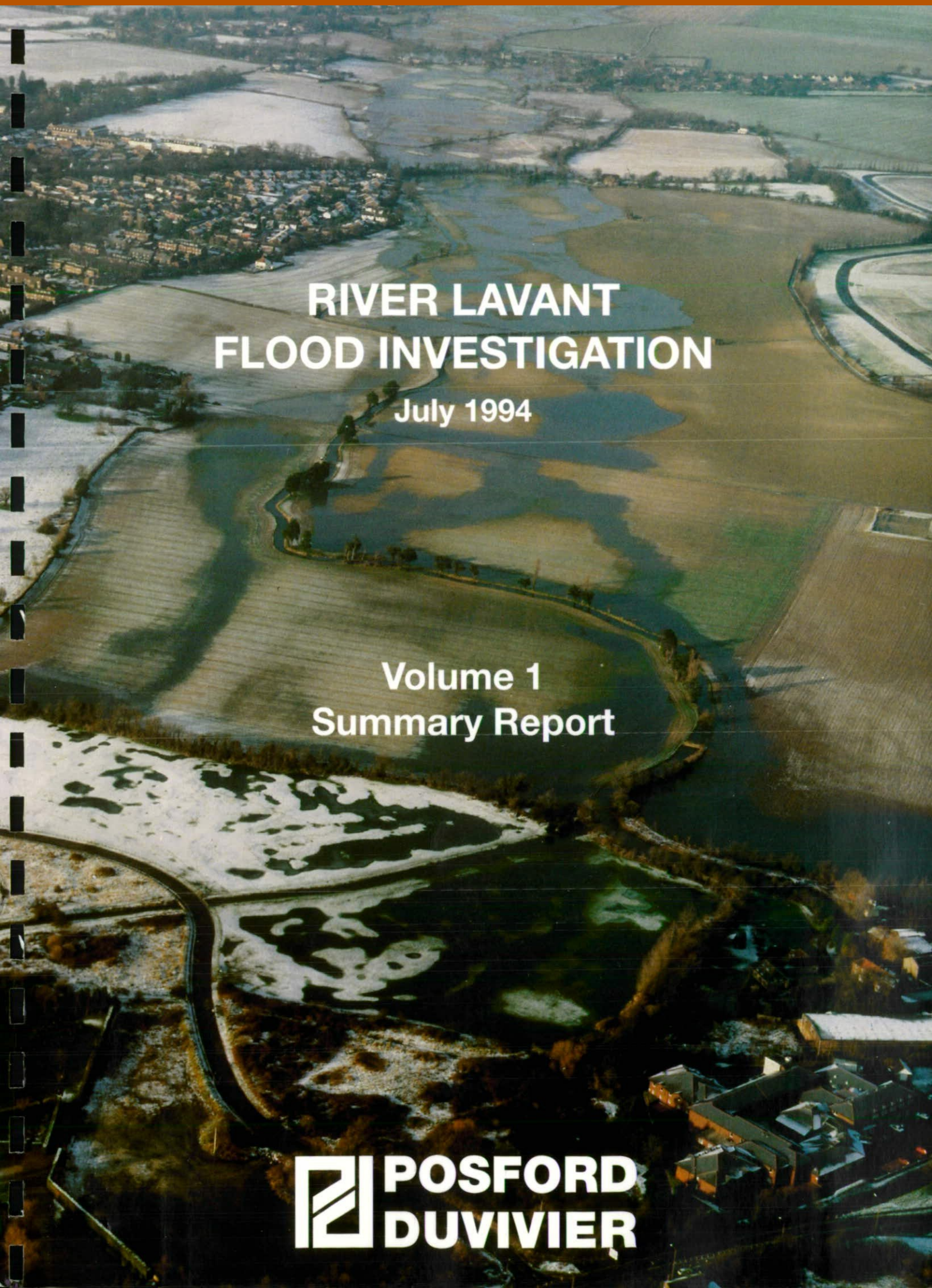

RIVER LAVANT FLOOD INVESTIGATION

July 1994

Volume 1
Summary Report

POSFORD DUVIVIER

IN ARCHIVE.

RIVER LAVANT FLOOD INVESTIGATION

JULY 1994

VOLUME 1
SUMMARY REPORT

Revision	Date	Prepared	Checked	Approved	Status
Original	26 May 1994	M.J. Newman	B.E. Waters	B.E. Waters	Draft
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FOREWORD

This report was commissioned by the National Rivers Authority (NRA) as an independent assessment of the causes of the flooding associated with the River Lavant in and around Chichester early in 1994 and the consequences thereof. It does not address the remedial measures open to the NRA and others, which will be considered separately.

The mechanism of flooding is shown to be complex, with numbers of inter-dependent variables. Furthermore, estimates of return periods, for instance, (which are statistical means and not predictions) are based of necessity on data which may itself be a matter of interpretation.

It is important therefore to consider the report in its entirety. Individual extracts, perhaps out of context, may be misleading. The summary report has been prepared, with this problem in mind, to provide an overview.

Finally, all at Posford Duvivier would like to thank the many dozens of contributors of background information, both historical and current.

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1.0 SUMMARY REPORT

1.1 Introduction

Following flooding of the River Lavant in the Chichester area in January 1994, National Rivers Authority (NRA) Southern Region, appointed Posford Duvivier to investigate and report on the flood event.

1.2 River Lavant Catchment

1.2.1 The River Lavant has a catchment of around 90km^2 which is divided into an upper steep chalk catchment on the South Downs above Westhampnett *(Figure 1.1)* and an essentially flat, ill defined gravel plain lower catchment below this point, much of which drains separately to the sea via "Rifes" *(Figure 1.2)*. Flow in the river is mostly influenced by ground water levels, and frequently in times of low ground water level, the channel is dry.

1.2.2 The upper catchment is mostly rural and predominantly used for arable farming, although over a third of the catchment is woodland. The length of channel in the upper catchment is 12.4km with an average gradient of 4.3m/km. The bed is generally gravel and there is therefore a good hydraulic connection to the underlying chalk.

1.2.3 The lower catchment is far more developed, and a significant area is occupied by the City of Chichester and the outlying retail and commercial developments. The area to the east and south of Chichester has undergone large scale gravel extraction over the past 50 years; leaving many worked out pits now either filled in and developed, or open and water filled. Gravel extraction is continuing with further pits being developed.

1.2.4 There is much evidence to suggest that in Medieval or Roman times, the course of the Lavant was artificially diverted at Westhampnett Mill to flow through the City. Prior to this the river continued south to connect with either the Pagham or Aldingbourne Rife.

1.2.5 Through Chichester, the Lavant flows in channels and for two considerable lengths has been contained in irregular culverts *(Figure 1.3)*. These culverts date at least from the last century and act to restrict the volume of flow which can pass through the City before the Lavant discharges into the Fishbourne Channel. However, even through Chichester the river bed is still predominantly gravel allowing a free movement of ground water both into and out of the channel

1.2.6 There is a single gauging station on the Lavant, located just upstream of Westhampnett Mill at Graylingwell. The gauge has been operational since January 1971 and records flows at 15 minutes intervals up to a maximum of 8.0m^3/sec. Prior to the recent flood event, the highest previously recorded flow was 4.2m^3/sec in 1988, at which time no flooding occurred. For considerable periods, the Lavant has been dry and no flow has been recorded. During the January 1994 flood event, the gauge recorded a maximum of 7.1m^3/sec, but was being by-passed by out-of-bank flows.

1.2.7 Flow in the Lavant is predominantly ground water in origin rather than surface run-off. This is evidenced by the very clear water recorded during times of high flow. The upper Lavant catchment is predominantly in the upper chalk, which is a major aquifer in the region, with a catchment extending beyond the topographically defined boundaries of the Lavant catchment. Although the chalk itself is relatively impermeable, there are nevertheless extensive fissures in the material which provide considerable storage for ground water. The distribution of fissures is not uniform, and therefore the transmissivity of the chalk (its property of allowing the passage of ground water) is similarly non-uniform, varying with both depth and location.

Chichester, on the lower catchment is situated on extensive fan gravel deposits derived from the River Lavant. Under normal circumstances the ground water from the upper catchment flows through these gravels to discharge to the sea. However, the natural ground water regime has been greatly disturbed by gravel workings, with both open waterfilled and backfilled pits forming areas of lower transmissivity.

1.2.8 Ground water levels within the chalk respond relatively rapidly to precipitation and there is a regular seasonal variation. There are two major telemetering ground water level recording stations in the area, at Chilgrove in the Lavant catchment and at Compton 6.5km to the west in the Ems catchment. There is a very good correlation between the levels recorded at the two locations. At Chilgrove there are records extending back to January 1836 and at Compton the records began in February 1893. Chilgrove is unable to record ground water levels above 77.18mOD at which point the well becomes artesian. Levels above this figure can be estimated using the very good correlation with Compton which does not suffer this drawback.

During the January 1994 event, the Chilgrove well was artesian for 18 days, and the well at Compton recorded a peak ground water level of 68.75mOD; nearly 4m higher than previously recorded since records began 101 years ago.

1.2.9 Rainfall data are available for 23 stations in the Chichester area; eight of which lie within the Lavant catchment. Furthermore, Meteorological Office Rainfall and Evaporation Calculation System (MORECS) data are available for the area. Long term data used in this study were obtained for Chilgrove, where data records extend back to April 1834. MORECS data were obtained from January 1961.

Over the 32 year period of available MORECS data, water year 1993 (October '92 to September '93) ranks third in terms of effective precipitation, being exceeded only by 1982 and 1976.

1.2.10 The previous major flood event on the Lavant occurred in 1960, when East Dean and Lavant were flooded as well as the St. Pancras area of Chichester. This flood was associated with a ground water level at Chilgrove of 76.4m. but no contemporary gauging records exist for flows in the Lavant; this event being some 10 years before construction of the Graylingwell gauge.

There is a long history of flooding of the River Lavant, with some 10 events (including January 1994) occurring in the 158 years since ground water level records began at Chilgrove. Details of the extent of flooding which occurred are sketchy, particularly of the earlier events. However, it is apparent that the majority of these resulted in significant urban flooding, notably in the St. Pancras and Hornet areas of Chichester.

1.3 Flood Event of January 1994

1.3.1 Hydrological Conditions in the Upper Lavant Catchment Prior to Flood Event

The aquifer had become depleted in the late 1980's resulting in the lowest recorded level of 33.79m OD at Chilgrove. However during the early 1990's the aquifer was fully recharged and was close to a long-term average position by late September 1993.

Heavy rain during early and late Autumn 1993 resulted in a Chilgrove level of 69m OD by late December, some 18m above the average. A further period of intense rainfall from 30 December raised the levels further and the well became artesian for a period of 18 days. The estimated peak level based upon correlation with Compton was 79.15m OD.

Flow in the Lavant was not significant until mid-December, but rose rapidly from 1.7m^3/sec at the end of December reaching a peak of approximately 7.9m^3/sec on 11 January and dropping rapidly thereafter to about 2.5m^3/sec by the end of January.

1.3.2 Ground Water Levels in the Lower Catchment

Church Farm Pit, a water filled worked out gravel pit near Westhampnett Mill, is a good indicator of general ground water levels in the lower catchment, although it has frequently been influenced by pumping in connection with both the recent A27 Westhampnett By-pass construction and by Mitre Properties, managers of the Dares Estate on Rutland Way. It has been demonstrated that there is a good hydraulic connection between this pit and the River Lavant. From an artificial low brought about by by-pass construction, de-watered levels in Church Farm Pit began rising in September 1993 in conjunction with the on-set of significant flow in the Lavant. The level rose steadily through the Autumn to reach the highest recorded peak of 16.86mOD on 12 January. However, from 4 January out-of-bank Lavant flows were entering the pit in the south west corner, and this undoubtedly influenced levels recorded.

1.3.3 Development of Flood

Flooding within the Lavant catchment was first recorded in late December 1993 in the Church Farm Pit area of Westhampnett. More widespread flooding occurred from 3 January 1994 including the Hornet area of the City, East Lavant, Singleton and the A27. By the evening of the 5th, flooding was more extensive and the Church Farm Pit had overtopped and flooded the east bound carriageway of the new A27 Westhampnett By-pass. By the following day, the westbound carriageway was also under threat and it was in fact closed on 7 January.

On 8 January further flooding was reported in the upper catchment villages of East Dean, Charlton, Singleton and Lavant. A dangerous gable wall was threatening to collapse and block the upstream city culvert near Kwikfit and a decision was later taken to demolish it.

Floodwater overflowing from the A27 Westhampnett By-pass overtopped the Tarmac Coach Road Pit on 8th and flowed south across country to cause flooding of Shopwhyke, as well as closing the A259, and flooding Merston to the south.

Over the next few days flow in the Lavant increased and out-of-bank flows intensified causing more widespread flooding both in the City and the surrounding villages.

1.3.4 River Flows

The Graylingwell gauge continued to monitor Lavant flows during the event, although it was outflanked by out-of-bank flows. In addition, flow measurements were taken of both the Lavant, and the out-of-bank flows at a number of points during the flood event, including St. Pancras, Madgewick Lane, the A27 Westhampnett By-pass and at the Chichester culverts.

The peak flow recorded at Graylingwell on 12 January was 7.1m^3/sec and the maximum flow through the City culverts was 5.3m^3/sec on the 11th. The maximum estimated Graylingwell flow, including the unrecorded out-of-bank flows was 7.9m^3/sec on the 10th.

1.3.5 Extent of Flooding

Some 45 properties were flooded in East Dean, Charlton, West Dean and Lavant, as well as extensive flooding of farmland and local roads. Downstream of Westhampnett Mill in the lower catchment, flooding was more extensive with the newly opened A27 Westhampnett By-pass, the A259 and several more minor roads closed for considerable periods. Industrial and commercial properties to the east of Chichester were affected and about 45 houses were flooded in the Hornet and St. Pancras areas of the City. South of Chichester, there was flooding in the villages of Oving and Merston, where out-of-bank Lavant flows entered the already swollen Pagham, Forebridge and Aldingbourne Rifes. Trains were operated at a reduced speed when floodwaters were impounded behind the railway embankment threatening its stability and causing flooding of farmland. Further farmland was flooded south of the railway as far as Pagham Harbour.

1.3.6 Damage to River Structures

Little significant damage occurred to river structures during the flood, other than localized erosion caused by the high flows. Preliminary examination by divers of the culverts through Chichester has shown them to be in fair condition but a detailed examination is needed as soon as flow conditions permit.

1.3.7 Emergency Measures

West Sussex County Council activated its normal procedures for control of an emergency from their control room at County Hall on 30 December and co-ordination of the emergency response to the flood event was exercised from there until 21 January. NRA's normal response to flooding in the region is to increase the staffing of the emergency flood control room in Worthing but from 6 January, they participated together with many other authorities including District Councils, Police, Fire Brigade and utilities in the central control of the emergency from County Hall.

During the period of the emergency a group comprising representatives of all bodies then involved met twice daily to review the current situation and plan future actions. The emergency measures directed in this way included:

- Flood alleviation measures both in the form of temporary defences and overpumping to relieve flows in the worst affected areas.
- Evacuation of threatened areas and planning for a major evacuation in the event of a culvert collapse.
- Measures to alleviate the effects of flooding, such as temporary bridges over flood affected roads.
- Assistance and advice to flood affected people and businesses.
- Public information

1.4 Factors Affecting Long Term Catchment Regime

1.4.1 Agricultural

There have been changes in agricultural practice over the past 50 years which have the potential for increasing run-off. However, the chalk of the upper catchment allows rapid soak away of rainfall and flows in the Lavant are influenced mostly by ground water rather than run-off. It is not considered likely that agricultural changes have significantly changed the catchment hydrology.

1.4.2 Gravel Extraction

There has been extensive extraction of the river fan gravels present in the channel of the Lavant to the east and south of Chichester. The natural fan gravels are very permeable and form a drainage path for much of the water derived from the chalk of the upper catchment. Worked out pits, be they infilled by silt and/or domestic waste, or left open and water filled, are far less permeable and the transmissivity of ground water is reduced as a consequence. There is therefore the possibility that ground water levels have been raised in the lower

catchment by gravel extraction, as bulk flow is constricted to the narrow corridors between former workings. There is little available data to prove this; any available ground water level data being subject to the effects of local pumping and water transfer regularly undertaken as part of the gravel extraction process.

Previous ground water model studies of the Westhampnett area indicate that Church Farm Pit is significant in the local ground water regime.

1.4.3 Abstraction from the Aquifer

The major ground water abstractor from the two main boreholes in the Lavant catchment is Portsmouth Water Co. Records of abstraction since 1973 have been reviewed for these and a further four borehole sources in the adjacent catchments. Although the records indicate a recent reduction in total abstraction of some 28%, it is not considered that this will have had any significant effect on the winter season ground water regime, and hence the River Lavant flows.

1.4.4 Development within the Catchment

There has been little significant development in the upper catchment of the Lavant, whereas in the lower catchment some 29 hectares of housing and light industrial development has occurred since 1960. However the great majority is drained to soakaways in the river gravels and as a result there has been little noticeable change in the drainage regime.

There has been a local perception that the recently completed A27 Westhampnett By-pass was a contributory factor to the recent flooding, and indeed it has been shown that the adjacent Church Farm Pit plays a major role in the local ground water regime. The Department of Transport in recognition of this, commissioned a study of the likely impact of the by-pass on water levels in Church Farm Pit. The report concluded that the road may indeed result in increased water levels and recommended that specific measures be taken to mitigate this effect. Accordingly special design considerations were included in the new road to minimize potential impact on local ground water levels. These included construction of the road formation in permeable chalk where infilling of part of Church Farm Pit was required so as to minimize loss of available storage volume, and provision of two 300mm culverts to allow drainage of the pit to soakaway in the natural gravels south of the new road alignment. However, these culverts have not been commissioned due to difficulties experienced by DTp in reaching agreement for their discharge onto land now being developed as a further gravel pit. Both culverts were sealed at the time of the flood event, and indeed remain so, and it is believed that no alternative arrangements have been made to deal with the flows they otherwise would have accommodated.

1.4.5 Planning Policy

Chichester District Council is the Planning Authority for residential and business developments and consult routinely with NRA regarding flooding risk. A new Local Plan consultation draft is currently being circulated.

West Sussex County Council is responsible for planning control of mineral extraction and are similarly in consultation for the forthcoming publishing of a Mineral Extraction Plan. There are currently several potential sites under consideration for further gravel extraction workings and WSCC are aware of their potential for disturbance of the current ground water regime.

1.4.6 Deterioration in River Channel and Culverts

It has not been possible to identify specific deterioration which may have had a long-term untoward effect on the catchment regime. However general ageing of the culverts and river adjacent structures through Chichester has certainly increased the risk of a potentially disastrous collapse and blockage of the channel in an area where access and working space is at a premium.

1.5 Assessment of Return Period of January Event

1.5.1 Single Variable Return Period

The return period of the event has been calculated in a number of ways using the following single variables:

a. Average Daily Flow in the Lavant

Only a 17 year period of continuous data is available from the Graylingwell gauge and the average daily flow recorded in January 1994 was over 50% higher than previously recorded, giving a very skewed record. Whilst the return period calculated from this data is 110 years, this is not considered definitive in view of the shortness of the available data set.

b. Rainfall

Using the long data set for Chilgrove, estimates of the return period of the rainfall vary depending upon the rainfall duration considered. A return period of over 38 years has been determined for rainfall over 40 days; that being the duration of heavy rainfall during December 1993 and January 1994. This is not truly representative as a short period of intense rain is considered more likely to produce flooding, particularly when occurring in conjunction with high ground water levels.

c. Effective Precipitation

A 32 years record of MORECS data shows the effective precipitation in water year 1993 to have a return period of 18 years but again this does not represent the event itself, being of too general a nature.

d. Ground Water Level

Using the two long data sets for Chilgrove and Compton, it can be shown that ground water levels in January 1994 were truly exceptional. The level recorded at Compton was 3.8m higher than recorded during the preceding 101 years, and has a return period estimated at 384 years.

Chilgrove

1.5.2 Return Period Based upon Combined Probability Analysis

Extreme flows are generated by a combination of events and it has been shown that flooding is probable when a significant period of rainfall occurs when the ground water level at Chilgrove is at or above 69.5m OD. For the recent event this was 190.3mm of rain in the 17 day period between 20 December and 12 January and the joint probability of these two variables if considered as statistically independent, is in the order of 400 years.

1.5.3 Event Return Period

There is a good correlation between the return period calculated from ground water levels alone and return period derived from the combined probability of exceptional rainfall with a high ground water level. Both indicate a return period of the order of 400 years. However there is insufficient data to be certain that the January 1994 Lavant river flows could not recur more frequently. The return period of the event is therefore considered to be in excess of 100 years.

1.6 Adequacy of Present Arrangements

1.6.1 River Lavant Flow Capacity

The adequacy of the Lavant to accept unusually high flows is restricted by the various structures in its channel. Throughout Chichester, the capacity is limited to that which can pass through the culverts and although a maximum flow of 5.3m^3/sec was measured during the recent event, this was achieved only by significant surcharging and at the expense of localized flooding. A maximum capacity without flooding or surcharge is estimated to be 4.3m^3/sec.

Upstream of Westhampnett Mill the capacity is limited by a number of over bridges to an estimated 5.3m^3/sec without flooding.

1.6.2 Standard of Service

The indicative standards of protection given by the Ministry of Agriculture, Fisheries and Food (in their Project Appraisal Guidance Note) for non-tidal flooding are 100 years for high density urban areas such as Chichester and 25 years for the low density rural communities of the upper catchment.

When assessed on the no-flooding capacity of the Lavant in these areas, the present standards of service are 25 years in the city area, and 45 years upstream of Westhampnett Mill. Clearly the standard of service pertaining in the City is inadequate on this basis.

1.7 Estimated Flood Damages

1.7.1 January 1994 Event

The cost of the damage and emergency measures taken during the recent flooding has been assessed based not only upon the direct costs incurred by WSCC, NRA, local commerce and industry, but also upon assessed flood costs using conventional benefit assessment methods. The total cost estimated in this manner is in the order of £6.0 million.

1.7.2 Potential Damages Resulting from Culvert Blockage

During the January event it was soon realized that there was the potential for a major urban flood should the channel or culverts through Chichester be blocked or suffer collapse, and contingency plans were made to evacuate up to 2000 properties then thought to be at risk. A more considered assessment of the area potentially at risk from such flooding indicated a somewhat lesser number of properties. Nevertheless, with potential flood damages when assessed by conventional benefit methods of over £16.3m, such minimum damages could result from 1 in 25 years flows in the river, or possibly less.

1.8 Conclusions and Recommendations

1.8.1 The main conclusions are:

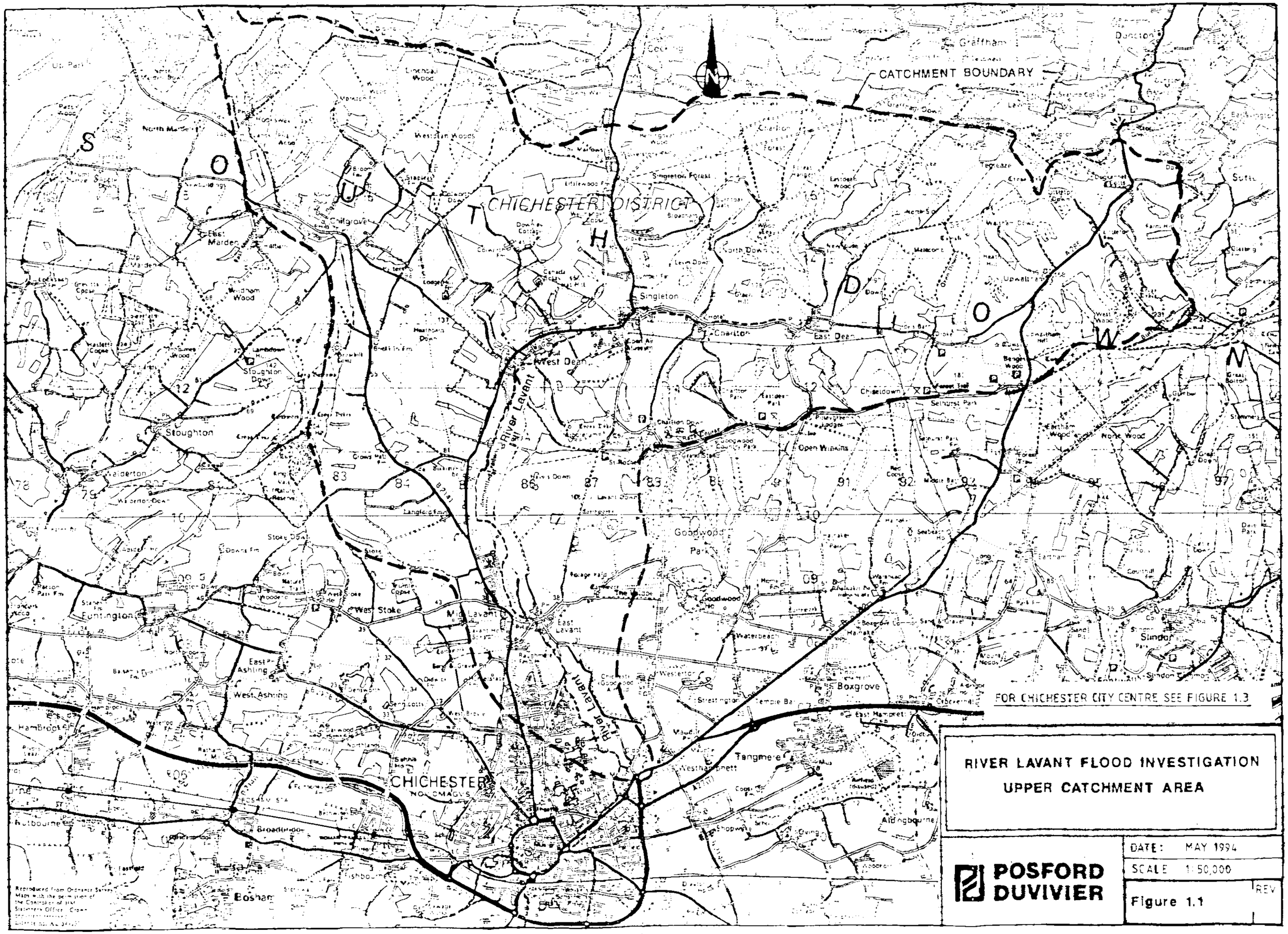
- The primary cause of the flood event was unusually heavy rain on the catchment
- The January 1994 flood was an extremely severe event with a return period estimated to be in excess of 100 years
- The present standard of flood defence service provided by the River Lavant in Chichester is 25 years; well below the indicative 100 year standard for such an area.
- The damages resulting from the recent event were about £6.0M. However there is the potential for more serious flooding in the event of a culvert blockage. At least £16.3M damages could quickly be sustained during comparatively modest events.

- Flooding resulted from one or more of the following:
  - Ground water
  - River Lavant channel and structures being overwhelmed by the flood flow
  - Out-of-bank flows
  - Out-of bank flows entering the adjacent Pagham and Forebridge Rife catchments and overwhelming their channel capacities
- Significant flow in the River Lavant is likely when heavy rainfall occurs on the Lavant catchment following the achievement of 69.5m OD ground water level at Chilgrove.
- The recently completed A27 Westhampnett bypass was not a primary factor in the January flooding.
- Culverts identified as necessary to mitigate the effect of the bypass on Church Farm Pit water levels had not been commissioned.
- The unavailability of the culverts had no material effect on the severity of flooding at any location, although it is likely that the duration of flooding in the Church Farm Pit and Maudlin Farm area would have been shorter, had they been operational.
- Natural gravels in the lower catchment are an important part of the Lavant system and their progressive extraction has most probably resulted in rising ground water levels locally. Worked out pits, be they infilled, or left water filled, have a significantly reduced transmissivity. This effect is significant only in the extent and duration of flooding in the area local to the pit infilling and was not a primary factor in the recent flood event.
- Recent development and land use changes within the catchment have been examined and have not had any appreciable effect on the Lavant flows.
- No hydraulic connection has so far been found between the River Lavant culverts in Chichester and the canal basin.
- It is not possible to deal with the extreme flows in the Lavant through Chichester by the use of temporary pumps. Pumping of this nature, such as was employed as an emergency measure during the January flood, can do no more than deal with a small proportion of peak flows and ease local problems.

1.8.2 The main recommendations are:

- A flood alleviation scheme for Chichester be investigated.

- To alleviate flooding in the upper catchment, consideration should be given to removal of obstructions in the river channel.
- An emergency plan should be developed to deal with a culvert blockage in the interim before any flood alleviation scheme is commissioned.
- A flood warning system is developed based upon the Chilgrove "trigger" ground water level of 69.5m OD.
- Future development in the lower catchment which has the potential to affect ground water levels be carefully studied before it is sanctioned.
- Measures to control ground water level changes in Church Farm Pit which are associated with the A27 Westhampnett By-pass should be brought into operation.



RIVER LAVANT FLOOD INVESTIGATION
UPPER CATCHMENT AREA

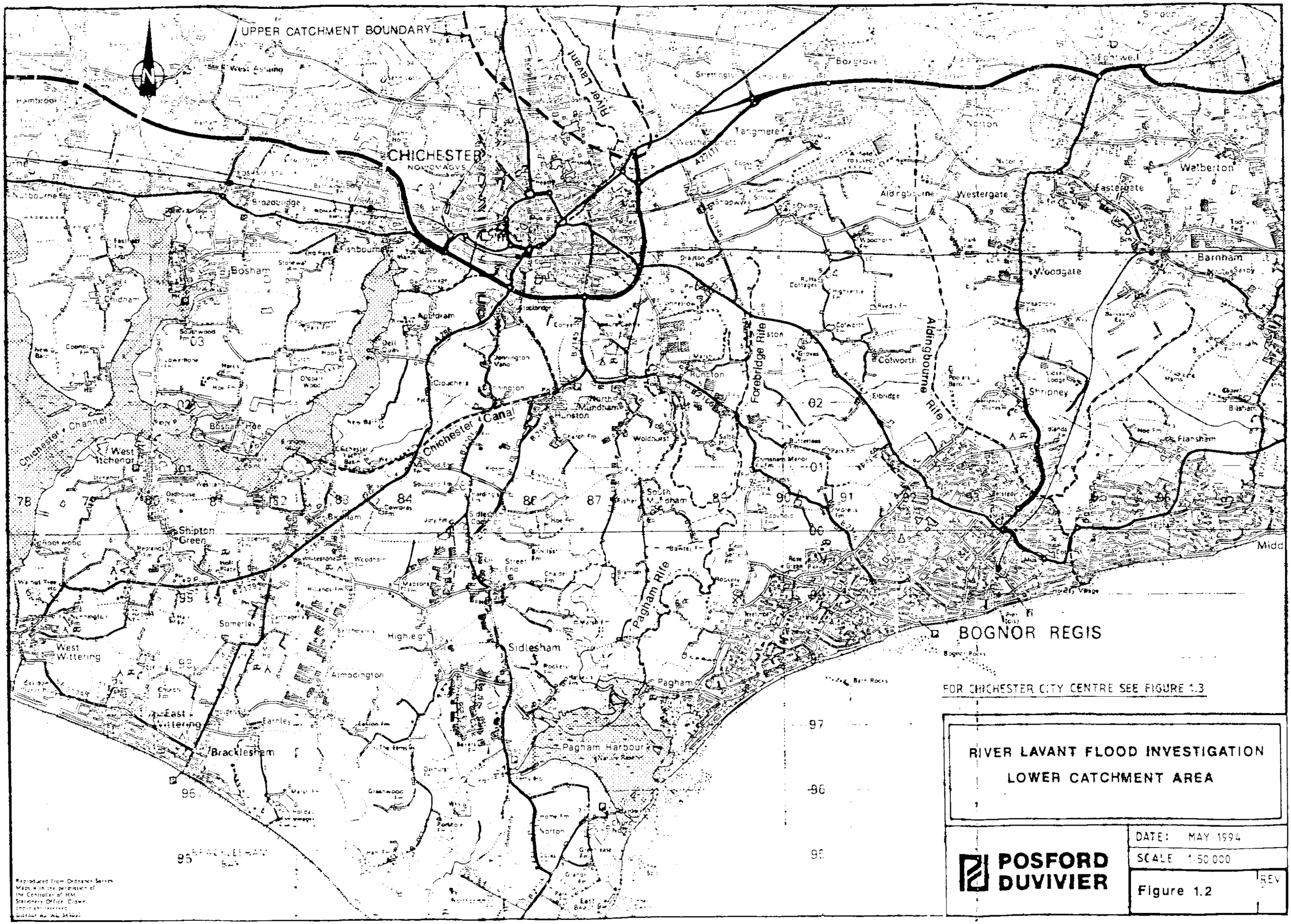
POSFORD DUVIVIER

DATE: MAY 1994

SCALE 1:50,000

Figure 1.1

REV



RIVER LAVANT FLOOD INVESTIGATION
LOWER CATCHMENT AREA

POSFORD DUVIVIER

DATE: MAY 1994
SCALE 1:50 000
Figure 1.2
REV

LEGEND AND NOTES

Open Channel

Upstream and Downstream City Culverts

Ref.	Revision	Date	By

RIVER LAVANT FLOOD INVESTIGATION

CHICHESTER STREET PLAN

POSFORD DUVIVIER

DATE: MAY 1994

SCALE: As shown

Figure 1.3

REV

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