THE CHICHESTER FLOOD, JANUARY 1994

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Flooding is a familiar phenomenon in the United Kingdom and communities tend to adjust, albeit imperfectly, to the short term disturbance associated with the relatively rapid rise, and subsequent fall, of river levels during a flood event. However, when the principal causative factors are sustained rainfall and exceptionally high groundwater levels flooding can be very protracted and the associated problems outside recent experience. The 1993/94 inundation at Chichester was a remarkable hydrological event which provided a graphic demonstration of the role groundwater can play in generating and sustaining flood conditions. As the spring-fed River Lavant remained above previous maximum levels for an extended period, mitigation of the flood's impact constituted a considerable challenge. This report on the flood, and the response to it, is based upon a paper presented at the British Hydrological Society's Fifth National Hydrological Symposium.[1].

Introduction

Sussex is no stranger to both tidal and river flooding with its long low lying coastline and many flashy rivers. However, what made the 1993/94 event and the response different was that flooding and communication disruption continued in major urban areas for over a month. Consequently, the response of the National Rivers Authority (NRA), Local Authorities and Emergency Services required careful management and coordination over several weeks.

The Catchment

The River Lavant is a small West Sussex Chalk stream which flows through the centre of the County City of Chichester. The Lavant rises in the folds of the South Downs to the north east of the city with its normal winter spring head somewhere between the villages of Singleton and Charlton. Its initial course is from east to west, it then swings towards the south below Singleton and flows between the villages of Mid and East Lavant. It then drops onto the coastal plain, turning through a further right angle bend in the Westhampnett area to flow west through the city to the sea at Fishbourne. This somewhat tortuous route, controlled partly by geology and partly by man, can be seen in Figure 1.

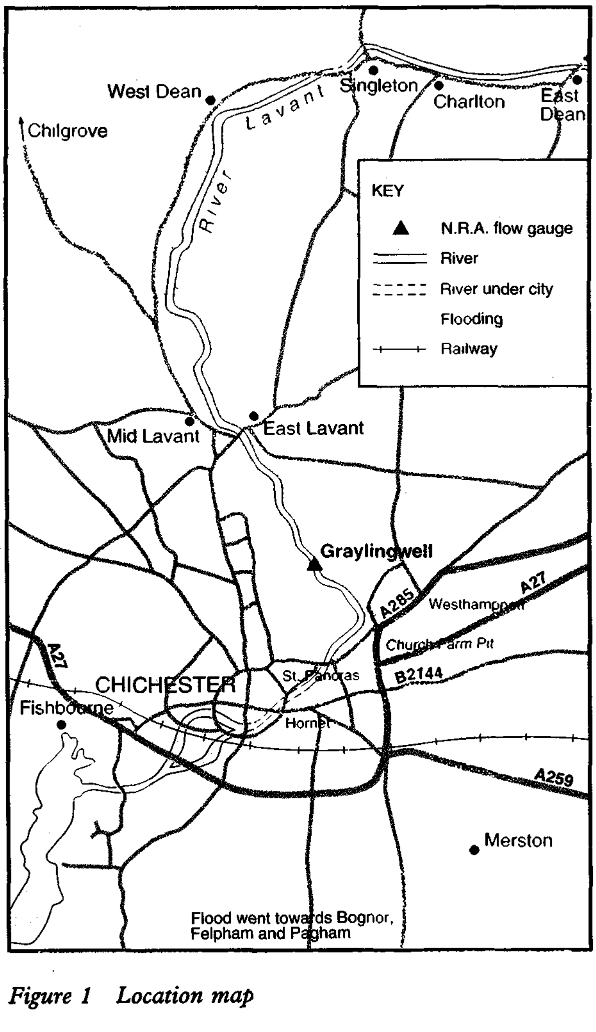

Figure 1 Location map

Although the Lavant is a Chalk stream, just under half of its course on the coastal plain lies over younger Tertiary strata. The catchment drains about one-third of the outcrop of the Chichester Chalk block which is bounded by the Rivers Arun, Ems, the South Downs scarp and the coast. Most of the outcrop in the upper catchment comprises Upper Chalk but the Middle and Lower Chalk is exposed in some locations. The Chalk has a shallow southward dip associated with the Wealden anticline, but the Lavant is particularly affected by the minor features of the Singleton anticline and the Chichester syncline. These east to west trending folds govern the upper river course and result in the thick sequence of Lower London Tertiaries which confine the Chalk in the lower valley below East Lavant. Of equal importance in the lower valley are the superficial deposits which take the form of two raised beaches and an extensive alluvial fan derived from the Lavant and on which Chichester sits. These gravels vary from some 10 m in depth in the Westhampnett area to around 2 m on the southern edge of the fan, (British Geological Survey[2]). The catchment is unique in that the longest continuous Chalk groundwater record in the country (records back to 1836) is located at Chilgrove House in the upper catchment.

Throughout its upper reaches the Lavant flow is governed by the hydrogeology. Although the normal winter spring head lies just above Singleton, following wet winters the spring head may migrate well upstream of the village of East Dean. Conversely, following dry winters the Lavant may disappear altogether; indeed during the period of 1989–93 much of the river was dry. Rainfall records have been collected in the valley from 1834 (again at Chilgrove House), but flow records are available only from 1971. The flows are recorded at Graylingwell gauging station, the location of which can be seen in Figure 1. Normal winter flows average around 2 m^3s^{-1}.

Winter 1993–94

In October, at the beginning of the 1993/94 winter half-year, groundwater levels in the Chalk Downs were reasonably low (see page 153). However, from then onwards to the end of January the weather was much wetter than average. The monthly areal rainfalls for the Lavant catchment are given in Table 1. The total for the October to January period was some 610 mm against an average of 379 mm (1961–90). Of particular note are the heavy rainfalls in late December and early/mid January where daily totals on one occasion reached almost 50 mm (December 30th) in the lower Lavant valley. Between the 29th September and the 13th October 1993, a period of heavy rainfall totalled 175 mm. This overcame the summer soil moisture deficit, groundwater levels responded rapidly and a small but sustained flow of about 0.1 m^3s^{-1} appeared in the Lavant by late October. This was followed by a relatively dry spell until the end of November in which groundwater levels declined slightly, but the flow in the Lavant increased slowly up to around 0.25 m^3s^{-1} during this period. From the 28th November until mid-January the area was swept by a series of vigorous depressions which resulted in more than 350 mm of rainfall. 40% of this fell on six days in late December and early January. As a result, groundwater levels rose rapidly, between mid-December and Christmas Day the Chilgrove level rose some 16–18 metres above the December average. On the 7th January the well became artesian and remained so for some 18 days (see Plate 1). This is the longest recorded period of artesian overflow. Consequently river flows also rose rapidly from 0.3 m^3s^{-1} in mid-December to 1.7 m^3s^{-1} on the 29th and peaking at around 8.1 m^3s^{-1} on the 10th January. Whilst these are not 'large' flows, in a flat bottomed Chalk valley with a channel adjusted to flows of around 2 m^3s^{-1} plus a flat impermeable tide-locked coastal plain, the potential for flooding is easy to imagine. The resultant hydrograph from Graylingwell can be seen in Figure 2. (The spot gauged peak exceeds the flow over the weir which was bypassed by out-of-bank flows).

TABLE 1 WINTER RAINFALL IN THE LAVANT CATCHMENT OCTOBER 1993 TO JANUARY 1994

Month	1961-90 Average (mm)	Actual (mm)
October	90	140
November	90	80
December	100	200
January	99	190
Total	379	610

Plate 1 Chilgrove House borehole overflowing, January 1994
Photo: Phillip Turton

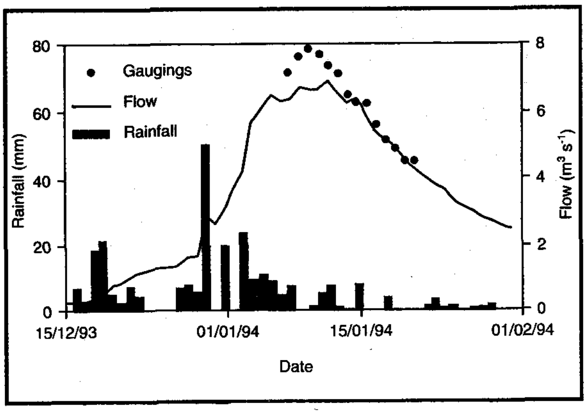

Figure 2 Flows at Graylingwell (River Lavant) and daily rainfall totals at West Dean

Of great interest is the change in response to rainfall of the catchment over the mid-December to January period. Prior to mid-December the Lavant behaved as a normal Chalk stream with delayed response of river flow and groundwater levels to rainfall. After mid-December this began to change and until late January the response of flow to rainfall was extremely rapid and the catchment became almost flashy. Later analysis by Posford Duvivier[3], who were contracted to investigate the floods, identified a critical groundwater level at Chilgrove well of 69.5 m aOD. Once this threshold level is reached then the response of the catchment appears to switch from a baseflow dominated flow regime to a more rainfall responsive regime. It has been postulated that this level marks the movement into a zone of much more fissured Chalk which enables a more rapid response to rainfall.

This, plus the fact that by the time this level is reached the whole catchment and valley bottom is saturated, possibly leads to rapid runoff. The full reasons for this phenomenon still remain to be explored, but other independently obtained hydrogeological data may provide additional evidence. Packer testing was carried out on a site some two kilometres to the east of Chilgrove, which indicated a marked change in transmissivity at or around 70 m aOD.

Event Magnitude

Estimation of the flood return period is difficult, even though there are long period rainfall and groundwater level records available. Whilst the event was characterised by an extremely high flow, it is difficult to determine the significance of short and long term rainfall and of groundwater level. In many respects it is the combined probability of intense rainfall on top of a generally wet winter causing high groundwater levels, which produced the flood. In order to assess the impact of rainfall on groundwater storage, various durations of daily totals were examined. Single daily totals, whilst quite large, do not produce results which explain the flood conditions. Although the impact of a >25 mm storm on an already saturated catchment produces a worsening of the conditions, indications are that all groundwater storage must be exhausted first. This produces the two stage catchment response described earlier.

TABLE 2 FREQUENCY OF RAINFALL EVENTS - SEPTEMBER 1993 TO JANUARY 1994

Rainfall Duration (days)	Dates of rainfall	Rainfall (mm)	Return Period (years)
1	01/10/93	33.4	2.1
1	30/12/93	25.7	1.3
5	30/12/93-03/01/94	78.9	2.7
5	28/09/93-03/10/94	79.0	2.7
10	28/12/93-06/01/94	132.3	5.7
40	06/12/93-14/01/94	335.0	38.6
90	03/11/93-31/01/94	455.6	6.3

Source: Ref. 3.

TABLE 3 RELATIVE RANKINGS OF 40- AND 45-DAY CUMULATIVE RAINFALL TOTALS (TOP 10 YEARS 1921 TO 1995) FOR CHILGROVE WITH CORRESPONDING PEAK FLOWS (FROM 1971)

Rank	40-Day	Total (mm)	45-Day	Total (mm)	Peak Q* (cumecs)
1	1930	353	1961	375	-
2	1994	345	1994	373	8.1
3	1961	341	1930	368	-
4	1935	319	1977	339	-
5	1995	315	1935	339	4.4
6	1977	308	1995	332	2.2
7	1971	307	1950	326	0.9
8	1988	306	1928	322	3.9
9	1950	304	1988	321	-
10	1987	298	1971	313	1.2

* Associated with year in 40-day ranking

Examining a 6-month period (October-March) for rainfall totals, the return period appears to be around 30–60 years. The return period assessment for various durations peak at around the 40–50 day timeframe. (See Table 2.) By taking cumulative 40- and 45-day rainfall totals from Chilgrove House, a ranked list of events is obtained. Extending from 40 to 45 days does not change the years involved in 9 out of 10 cases, although the rank position does alter. This can be seen in Table 3. This gives 1993/94 a return period of about 1 in 45 for a 40 day period. For 45 days 1994 increases to 1 in 55. These cumulative rainfall totals perhaps suggest that >300 mm (40 days) or >320 mm (45 days) is required before more major problems may occur. At somewhere over 300 mm of rainfall Chalk groundwater storage must be at or around capacity and any storms of significance (>20 mm) cause an instant peaky flow response. This possibly explains the increased flooding from individual storms in 1993/94.

A variety of return periods have been postulated using combinations of hydrometeorological variables. The results vary from 1 in 17 for the total winter rainfall, through 1 in 100 for the Graylingwell flow, to approaching 400 years for groundwater levels and combined probability analyses. Possibly the best estimate, assuming a stable climate, is that the return period exceeds the 1 in 100 year event.

Previous Records

Searching carefully through the archives it appears that "flood" events have happened in the past every 30 years or so. Undoubtedly the areas of urban flooding were greater in the past, but flows were probably less. The last major event occurred in 1960/61. This was certainly a very severe flood, although no river flow records exist. Much of the flood protection built after 1961 withstood the flood waters of 1994, although the impact of flooding was different. In the case of 1960/61 water was diverted from the Lavant into gravel workings, subsequently infilled. The site is now occupied by a Sainsbury's superstore, which had burnt down in December 1993! Flooding in the upper valley in particular was exacerbated by the Chalk stream character of the land. Small channels, low banks and low capacity bridges all played a part. Towards the city itself, man's activities on the coastal plain played an even greater part in the events. In the relatively recent past it is almost certain that the Lavant has been diverted from its original path to the sea at the mouth of Pagham Harbour. This accounts for the westward course of the river from Westhampnett through the city to Chichester Harbour. Diversion possibly occurred in Roman times (contemporary rumour). The normally placid or dry nature of the summer Lavant would aid this. Certainly early maps of the city[4] show the Lavant forming part of the city defence and, presumably, water supply. As time went on the city expanded and a large section of the Lavant source within the city became culverted. The majority of the present culverts date back to Victorian times.

The 1993/94 Flood

First evidence of the flood problems to come surfaced in the Westhampnett area around the 20th of December 1993. Here flooding caused by excessive groundwater discharge began to occur in a low-lying industrial estate set amongst old gravel workings (Church Farm Pit). By the beginning of January springs were appearing throughout the valley and in several locations in the upper Lavant valley the channel could no longer cope with the flow. As the road was the next lowest conduit this began to become a subsidiary channel (see Plate 2). Attendant traffic wash then began to affect adjacent properties. The first widespread flooding occurred on the 4th when the Lavant began to overtop right along the channel length. The most serious occurrences were at Westhampnett where the river burst its banks and flowed off towards the Pagham Rife, and in The Hornet/St Pancras area of the city, where demolition of a building appears to have affected the flood wall. Here serious overtopping occurred. Within the Hornet around twenty properties and business premises were inundated by the overtopping (Plate 3). Around this time the city centre culverts became surcharged. They remained in this state until virtually the end of January.

Meanwhile, in the Westhampnett area overflow from the Lavant had been channelled down the B2141 and across the A285, closing them to traffic, before entering the Church Farm Pit. The industrial estate around the Pit was already flooded with groundwater and the Lavant overflow of around 1.25 m^3s^{-1} simply added to the depth of inundation. Within 24 hours the available storage in the Pit was used up and the flood of combined groundwater/surface water overflow crossed the A27 (T) and closed it. Next the floodwater closed the B2144, passed under the railway line (where small culverts throttled back the flow) and by the 9th January the flood closed the A259 on its flow path towards Pagham Harbour. Supplemented by groundwater the 1.25 m^3s^{-1} flood to the south reached well over 3 m^3s^{-1} within a kilometre. Thankfully the number of properties severely flooded was relatively small, less than 50. However, the disruption to commerce and communications (see Cover) was tremendous. At one point the most secure route between Southampton and Brighton by road was via London and the M3, M25 and M23. All the main South Coast roads were closed and on the main South Coast railway line, trains passed through the flood area at walking pace with water passing through the ballast. Road traffic around the city was only reinstated with the provision of military Bailey bridges at key points.

Whilst this major overtopping was occurring every village along the Lavant was suffering widespread flooding and road closures. In The Hornet area of the city the river was periodically rising with rainfall

Plate 2 Floodwater on the B2141, near Chilgrove, in January 1994
Photo: NRA, Southern Region

Plate 3 Flooding in The Hornet, Chichester City Centre
Photo: NRA, Southern Region

causing culvert surcharging and overtopping. There was no respite from the flooding for almost a month.

The city centre Victorian culverts were giving cause for increasing concern. The most constricted section has a normal capacity of around 4.5 m^3s^{-1}. Peak flow at Graylingwell was around 8.1 m^3s^{-1} and although around 1.25 m^3s^{-1} was out of bank around the city some 5–6 m^3s^{-1} was at times passing through the culvert. The culvert was itself in dubious structural condition and at times a spray mist could be seen through fine cracks in the floor of buildings along the culvert line.

During periods of rainfall the river rose, the culvert surcharged and water spilled out upstream of the culvert into the city. Fortunately a combination of relays of 'green goddess' fire appliances and Maine Coastal Pollution Unit pumps kept the city centre flood water confined to a restricted area. Throughout most of January there was an ever present fear of culvert collapse. Had this happened some 1200 properties would have been inundated within 30 minutes, around 10,000 people would have required evacuation and all roads/railways to the east would have been closed. As a result Operation Badminton was conceived by the Emergency Committee. Initially alternative flood water routes both around and through the city were investigated, but gradients and services prevented this. Sandbag channels were planned through the city but they would have virtually isolated the centre. Consequently, evacuation procedures using public service vehicles and fully fitted reception centres in Hampshire were set up. Military, NRA, County/District and Emergency Service staff were available on a 24 hour basis and strategic sandbag stores were located through the city. Had the need arisen the sandbags, plus selected buildings, would have formed the new channel. Whilst precautions were in place the vast majority of city and commercial life continued as normal.

Discussion

Although the areas flooded are low lying and have a history of inundation, there have been no problems since the early 1960s. In the intervening period residents have changed and many properties have been renovated. During past floods it appears possessions were moved upstairs and the residents waited for the water to abate. It is difficult to do this with central heating systems, fitted furniture/carpets and sophisticated electrical equipment, even if warning is given. The question was raised "why did they not stop it?", as attempts were made to apportion blame and impute negligence. This was particularly so where the flooding was associated with sewer surcharging and contaminated water.

Associated with the direct public response is management of the media. January is traditionally a quiet month for news, Chichester is in easy reach of London for media crews, the imagery of pumps, floods and fire engines is newsworthy and the length of the event in 'commuter land' led to intense media interest. Whilst the Lavant and Chichester event of 1993–1994 was caused by exceptional weather it did not flood a large number of individual properties. However, it was distinguished by its longevity, media interest and disruption to communications.

Response to the event was hindered by the arcane state of Flood Defence and Land Drainage law. Flooding is no respecter of the limits of NRA main river and riparian responsibility. Interestingly, if flooding occurs naturally then there is no liability. If water is diverted from a river and flooding damage subsequently occurs then there is potential for liability and claims of negligence.

NRA investigations are underway to decide upon the optimum route for a Chichester flood alleviation scheme. Three proposals are being given detailed consideration and a decision on the preferred option is expected early in 1996.

References

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