The 1952 Flood Disaster in Context
Exmoor National Park Authority

Introduction

The small coastal town of Lynmouth became known throughout the world for the disaster that struck in August 1952. On the night of the 15th, after continuous rain throughout the day, the East and West Lyn Rivers rose suddenly and filled with the waters from their Exmoor catchment. Large boulders and rocks were carried in the flow towards the village, destroying houses, roads and bridges. Many lost their lives during that dark and terrifying night. The whole of Exmoor was affected and considerable damage was caused on the Barle, Exe, Heddon and Bray but the worst effects were at Lynmouth. This is because the water draining from most of the northern side of Exmoor ends up in the East and West Lyn Rivers, which join at Lynmouth. Hundreds of thousands of years ago these rivers used to run to the sea much further to the west but during the Ice Age the side of their valley was eroded by the sea and, as a result, they fell to the sea along a much shorter and steeper course. This makes the waters descending on Lynmouth particularly fast and erosive.

Although not the biggest flood Britain has had, it was one of the most spectacular and most studied. Interest was shown in the small scale as well as the larger effects on the landscape. Green studied the effects on river courses, erosion and deposition and Gifford and Kidson studied land-slipping and its causes in the upper reaches of the Exe. Whilst it is still possible to see landforms created by the flood and to calculate its flow from remaining flood channels, most of the evidence of the flood has now disappeared, although parts of the West Lyn - the Glen Lyn gorge and part of the headwaters near Woolhanger - are now a geological Site of Special Scientific Interest for the evidence they show of the flood. At first it seemed that the flood confirmed the theory that most of the shaping of our landscape occurred during such violent events that were perhaps hundreds of years apart. However, work by Anderson and Calver on how the great scars and piles of boulders left by the flood have largely been removed by commonplace fluvial activity has changed our view of the shaping of landscape. Few now remember the disaster but its study has had far reaching effects upon our understanding of erosion and the way we deal with floods.

Evidence of Previous Floods

Observations made following the disaster suggested that past floods had occurred at greater magnitudes, although their dates, numbers and frequencies are unknown. The alluvial deposits of banded loam, gravel and boulders all around Lynmouth are indicators of past floods. The 1952 flood had caused erosion of the river bed and exposed in the banks boulders of huge size, whose outline gave proof that they had been rolled there by a larger volume of water. Until erosion had exposed them they had rested under layers of smaller debris and a cover of soil and vegetation including old oak trees. The age of the covering was no doubt considerable, pointing to long recurrence intervals between these heavy floods (Dobbie and Wolf, 1953; Green, 1955). There was an account of a devastating flood in 1770, when it was written:

"The river at Lynmouth by the late rain rose to such a degree as was never known by the memory of any man now living, which brought down great rocks of several tons each, and choked up the harbour. And also carried away the foundation under the Kay on that side of the river six foot down and ninety foot long, and some places two foot under the Kay, which stands now in great danger of falling."

It is possible that this flood was responsible for the deposit of boulders mentioned above. An even more devastating flood was mentioned in 1607 but this appears to have been more of a tidal surge or tsunami than a river flood. Further flooding has been reported numerous times since 1952. In 1978 Watersmeet was evacuated. In 1982 snow melt and heavy rains caused the boulders of the West Lyn to start moving again, and heavy rains in 1990 caused further concerns. Bad flooding has occurred in Barbrook four times since 1952.

The Passage of the Waters

The following is an account from writer S H Burton:

"Lynmouth. The vast downpour that descended on the Chains was refused by the waterlogged, impervious land. Down every gully and natural depression, down the channels dug by John Knight, down the northwards running combes, the thousands of tons of water flowed into the East and West Lyn rivers. Farley Water and Hoaroak Water joined the already swollen East Lyn at Watersmeet. Half a dozen streams converging at the head waters of the West Lyn brought the deluge from the western Chains, and at Barbrook Mill another influx from Woolhanger Common joined the raging torrent, sweeping bridges and houses away before starting the last deadly descent into Lynmouth", (Burton, 1952. 335).

Much has been written on the human impact of the flood and this can be researched at the Flood Memorial Hall and Glen Lyn Gorge at Lynmouth. The damage and loss of life was at the time the subject of the media, for which the national impact from such a tragic occurrence aroused extraordinary interest. In his article 'Unparalleled Scene of Destruction, A. J. Butcher wrote in The Western Morning News the following Monday:

"*Superlatives are too puny to describe the calamity, which has befallen Lynmouth and Barbrook. Deaths on a wartime scale, destruction at Barbrook worse than in the heaviest blitz, hundreds of residents and visitors personally ruined and destitute - the story stuns the human mind*".

The Sunday Express also reported the incident and published eye witness accounts from guests staying in the Lyndale Hotel, Mr H. L. Watson of Catford who was staying in the hotel with his wife and family said:

"*From seven o'clock last night the waters rose rapidly and at nine o'clock it was just like an avalanche coming through our hotel, bringing down boulders from the hills and breaking down walls, doors and windows. Within half an hour the guests had* *evacuated the ground floor. In another ten minutes the second floor was covered, and then we made for the top floor where we spent the night*".

Arthur Brooks of Croydon was also staying in the Lyndale hotel and reported:

"We were looking out when we saw three people being washed out to sea. We managed to get a hold of them and brought them through the window. By the morning boulders were piled 20ft high outside that window".

After the Rains had stopped

Once the flood had subsided the full extent of damage, both erosional and depositional, could be assessed. Trees stripped of their bark were intermingled with enormous piles of boulders and occasionally interspersed was the wreckage of human habitation and property. River banks had been ripped out, exposing dangling roots; walls and hedges were left with gaps torn through; potholes had been gauged out of the ground leaving bewildered trout swimming in them (Green, 1955).

The river course had been altered, shortening the length by cutting through meanders. In places flood water was forced out of the constricted river bed and cut back from the banks where it re-entered the channel until the blocked channel was completely bypassed. Following the constrictions where the valley opened out and the gradient slackened, boulder deposits were found. Yet on most of the rivers the gradient was so high and the flood plains so narrow that minimal storage could be achieved. The size of the individual boulders shifted depended upon the availability of boulder material and the water velocity to shift them. The largest moved was of some 350 cu. ft. found in the West Lyn, while the East Lyn produced smaller and more rounded material. Peat was eroded from the headwaters of the valley as the waters undercut the already saturated ground, causing land slips of peat up to 40 ft. by 18 ft. by 5 ft. thick to be carried floating or rolling several hundreds of yards downstream. Gouging of the ground downstream from breaches in stone walls resulted in pits of between 2 and 8 feet deep. Similar gouging caused the undermining of bridges on their upstream side, as waters were forced down and underneath the arches removing the drift material supporting the bridge piers. Potholes caused by trenching measured to depths of 12 ft. as surface water moved downwards in sheets, entrenching itself in ruts and then rapidly down cutting. Slipping occurred in the drift deposits overlying the Devonian rock, as water ran over the impermeable layer, sweeping away up to two foot of the saturated drift and further inducing slumping. The two small reservoirs at Woolhanger and North Furzehill, both on West Lyn tributaries, burst. Suggestions that these may have been an important contribution to the flood disaster have been discredited as all the debris from the burst was deposited some 200 yards downstream with little damage to the valley below (Green, 1955).

During the period that followed the flood disaster it became noticeable that rainfall of unusual intensity caused a very rapid rise in the river levels. This immediate increase in run-off level prior to the flood was originally attributed to the effects of exhaustion of water retention within the soils. Subsequently it became evident that this situation was more permanent in that there had been an improvement in the discharge pattern of the whole catchment basin with scouring of new tributaries and widening of the channel (Dobbie and Wolf, 1953). The flood's devastating effects upon buildings and bridges occurred in two ways:

Firstly, direct battery was accomplished by the sheer weight of the flood waters and its load of trees and boulders pounding against the artificial structures. The main street of Lynmouth was damaged in this way, as was the bridge at Glebe House, Malmsmead, where both its piers were based on the solid Devonian rock and could stand the weight of debris and water behind. There the bridge broke at its weakest point, the junction of the span and the sides.

The second way of property destruction was the undermining of structures that were built on easily erodible drift deposits. Most of the ruination of houses and bridges was due to this undermining action (Green, 1955).

The following examples given by Green illustrate this point:

Lyn Bridge (West Lyn River) A packhorse bridge of traditional construction. The archway of 75 sq. ft. opening was obviously inadequate to take the water flow of about 750 sq. ft. cross section area, and the parts based on the solid Lynton Beds held but those based on drift were destroyed.

Hillsford Bridge (Farley Water) The bridge was completely inadequate to take the great volume of water, trees and boulders but the foundations based on solid rock resisted erosion whilst those based on drift were swept away.

Barbrook (West Lyn) Houses built on drift were undercut and fell into the river.

Countisbury Hill Bridge (East Lyn) The retaining wall on the downstream side of the bridge was removed and on the upstream side was weakened by the washing out of its support from behind through a small break in it.

The damage at Lynmouth itself was predominately to the newer constructions, built during the Victorian era when the area grew in popularity. Due to the restricted nature of the site, many buildings were built out into the former course of the Lyn, which was diverted into a confined channel. During the flood the river attempted to revert to its former, more direct, course and widen its channel, resulting in the destruction of houses and bridges. Although a large amount of debris was carried out to sea, a considerable amount was deposited on the river beds, which were raised from 6ft to 10ft above their original levels (Carnegie, 1956). The bridge over the West Lyn, an immensely solid structure based on the Lynton Beds, did not give way to the waters. Instead, the area below filled with flood debris and thereafter acted as an obstacle, diverting the West Lyn and its debris load down the main street of Lynmouth. Meanwhile, the East Lyn had removed the easily erodible alluvial deposits at its bankside, undermining the cottages of Middleham and depositing them into the flow (Green, 1955).

"*The valley form of the lower reaches is a V-shaped gorge, so narrow at the bottom that there is no room for a road beside the river. The valley sides are too steep for cultivation and are clothed with oak woods, with here and there a cliff of naked rock. There is no room in these valleys for a village and no call for one because the arable land lies several hundred feet above the their floor. The single exception is Lynmouth which originated as a fishing village and developed as a resort. But even here, at the river mouth, there has only been room to build on the river bed itself, as has been proved by the flood which washed away so many houses merely by claiming for itself* *again the boulder beds on which they had been built". (Scott Simpson, 1953, cited in Dobbie and Wolf, 1953)*".

Contributing Factors

Moorland Vegetation and Soils

The catchment area of the Lyn rivers totals 39.2 sq. miles, much of which is plateau drained by steep sided combes. The plateau is covered in parts by moorland grasses growing from wet, peaty ground and in others by heather and bracken on well drained soils. These soils do not extend much further than 4 feet deep (Wolf 1953). S.H Burton, author of 'Exmoor', wrote in the journal 'Weather' in 1952:

"*The Chains is the name given to the north-west plateau of Exmoor. This plateau lies above the 1,500 foot contour, its higher point such as Chapman Barrows, Wood Barrow and Chains Barrow being nearly up to the 1,600 foot line. It is the watershed between the rivers flowing south and west - the Barle and the Exe and their tributaries, and the rivers flowing to the north - Farley Water and Hoaroak Water, the main tributaries of the East Lyn, and the West Lyn with its numerous feeders*”

The soil of Exmoor is of two kinds. The dry land soil is loamy on top and clayed below and drains rapidly. It is to be found mainly in the valleys of Exmoor and, though it is deficient in lime, heavy dressing makes it fertile. The wet land soil is peaty. Just below the surface a thin ironstone pan occurs which prevents drainage until the pan is cracked by subsoil ploughing" (Burton, 1952. 334).

During the 19th century the Knight family had tried to drain the northern plateau by ineffectually digging gutters to carry the water to the rivers. Not until Frederic Knight used the steam plough to penetrate the hard pan did thousands of acres of Exmoor become good pasture land. Yet he did not successfully drain the Chains, which, according to Burton, "remain to this day the wettest and wildest region of the moor". S.H Burton continues with:

"*To reach the Chains from Lynmouth involves a climb of fifteen hundred feet in four miles, and that is not the worse part of the journey...Even in a good summer the route is wet, and for yards at a time the walker must stride or jump from tussock to tussock to avoid the bogs where black water oozes sluggishly over sphagnum moss and under the white heads of cotton grass*" (Burton, 1952. 335).

Despite the wetness of the Chains, the amount of peat and its capacity to hold water has been reduced over the last century and a half by peat cutting, grazing and burning. In addition there has been much reclamation of surrounding moor and heath in the 19th and early 20th centuries. Since 1947 there have been government grants for agricultural drainage and there is evidence that runoff is more rapid now than before that time. This rapid runoff has been blamed for the apparent increase in flash flooding.

The Weather

Before examining the weather over Exmoor during 15th August 1952, it is relevant to assess the situation prior to the event. Drought had effected most of southern England during the second half of July of that year. Conditions broke down at the beginning of August to be followed by a period of changeable weather over the whole country. Maximum temperatures of 80° F were reported on only three days. Thunderstorms occurred daily in the country with the centre of activity changing from place to place. This led to an irregular distribution of the monthly rainfall. During the evening of the 6th there were severe thunderstorms over London and the Home Counties. A record daily fall of 4.83 inches was recorded at Boreham Wood, and rainfalls of "very rare" intensity were recorded in parts of North London. Further heavy falls and flooding were reported in Belfast, Cumberland and parts of Argyllshire on the 9th and 10th of August. Rain continued to fall in North Devon and West Somerset on all but two of the fourteen days prior; although there were no outstanding heavy falls, these were not small amounts (R.S.R, 1952).

A depression had formed at about 12.00 G.M.T in the mid-Atlantic three days prior to the 15th, at about 47 N., 34 W at a central pressure of 1016 mb and then subsequently moved east-south-east to 43 N., 19 W at 00.00 hours of the 14th at 1007 mb. Afterwards, it rounded an upper trough and then moved slowly north-east, parallel to the general thermal gradient and the 500 mb contours (Bleasdale and Douglas, 1952, 360). Although this depression had no frontal structure, warm air from France was drawn into the circulation as it approached Brittany. Large moisture contents in the air around southern England combined with the warm thundery air from France indicated a high possibility of thunderstorms breaking out anywhere near the track of the depression, which in fact they did in most parts of south and south-east England. Continuous rain began at the Scilly Isles in the early hours of the morning and spread to all parts of Devon, Cornwall and Somerset by midday. The nearest synoptic reporting station to Lynmouth, at Chivenor, reported incessant rain for almost 18 hours. The largest falls of rain were located on the left-hand side of the low track, as expected, (Marshall 1952) but, as Marshall explains:

"*This was not merely a case of orthodox rainfall distribution around a frontal depression on high ground. It was complicated by thunderstorms all over the area of heavy rain, and one set of storms seems to have come up from Brittany in the south south-east wind which was observed at 700 mb over Brest at 300 GMT on the 15th*"(Marshall 1952 , 341).

Cold, moist and unstable air ascending up the northward facing slopes of Exmoor introduced more moisture into the already heavy raining area. This may well have been decisive in producing the excessive rainfall in the Lyn catchments (Marshall 1952). In a rain gauge on Longstone Barrow on the ridge running from west to east at approximately five miles south of the coast, a voluntary observer, Mr C.H. Archer of Wootton Courtenay, measured 9.00 inches of rainfall for the 24 hour period beginning at 9.00 G.M.T on the 15th. Two other measurements were made with standard gauges, these were 7.58 inches at Challacombe, and 7.35 inches Honeymead near Simonsbath. Both of these were on lower ground within a few miles of Longstone Barrow. Unfortunately, there were no rain gauges in the heart of

Exmoor: only those of Wootton Courtenay in the east and Chivenor at some 14 miles west-south-west of Longstone Barrow. These were carefully analysed using intervals of 6 minutes along the time scale.

Despite the distance between the two stations there is agreement in the timing of the most intense peaks of the day, where the difference is only a matter of a few minutes. A composite picture of the storm incorporating the information from both Wootton Courtenay and Chivenor would divulge that the rain started some time during the morning at approximately 11.00 to 12.00 G.M.T. Heavy periods occurred during the afternoon with brighter intervals. The first exceptional downpour occurred after a darkening of the sky and peculiar colour effects between 15.30 and 17.30 G.M.T and thereafter easing. Although reports vary, torrential rain occurred during 18.30 and 22.30 G.M.T, easing off to rain of little importance in most places at approximately 02.00 G.M.T on the 16th. There were some reports of rain continuing throughout the night and into the next morning (Bleasdale and Douglas, 1952).

At the time, the rainfall over Exmoor produced one of the three heaviest falls in 24 hours ever recorded in the British Isles from records dating back to 1862. These were at Bruton on the 28th of June 1917 of 9.56 inches, and Cannington on the 18th August 1924 of 9.40 inches. As Bleasdale and Douglas point out, it is rather strange that these cases both occurred in Somerset, and now third highest to be added to the list is in Devon some half a mile from the Somerset border.

River Maintenance

During the 1930's economic recession, there was little maintenance carried out to the valley sides as these were held in private ownership. As a result large trees of sycamore, birch and ash were growing in the river bed and among shoals and shattered rock at the side (Harris, 1992). Since the flood this situation has changed as various government agencies have taken responsibility for flood prevention and river maintenance. As the waters cascaded into the narrow steep sided valleys of the East and West Lyn, the rushing waters became torrents bearing uprooted trees, boulders and other debris that acted as battering rams dislodging other material and blocking culverts and bridges in a remorseless flood towards the sea (Binding, 1997; Dobbie and Wolf, 1953). According to Einstein, a velocity of 15 feet per second will move a rock measuring 3 feet cubed, although super-critical velocities of 20-30 feet per second are common and may account for a boulder weighing 7.5 tons that was found in the basement of a Lynmouth hotel (Dobbie and Wolf, 1953).

The Landscape

As a great deal of rain had fallen on the catchment during the previous two weeks and the evaporation during the day of the flood was negligible, the permeability of the surface of the area was minimal. The storage capacity of the vegetation, peat or soil and rocks was taken up by the rain which fell prior to the 15th, leaving no opportunity for infiltration to occur. On the smooth, convex hills there were few storage dips and ponds, and this capacity would have quickly filled after the first rains (Dobbie and Wolf, 1953). When the soil profile becomes completely suffused, saturation excess develops into overland flow or surface runoff (Burt, 1986). On the high moors this would have been consistent with the movement of a sheet of water only hindered by the closely grown thick stemmed plants and the artificial channels cut during the nineteenth century. These being inadequate during normal times, could carry only a small portion of this exceptional rainfall. While the average velocity of flow may have only been a few inches per second over the summit, by the time it had travelled hundreds of feet before reaching a stream or the edge of the moor it would now be travelling at 10 to 20 feet per second and at a depth of several inches. This may well have taken as long as two hours. As the water passed over the valley edge and down the sides the velocity increased to several feet per second. Reaching the streams, this then increased again to 5 to 10 feet per second. At the height of the flood the time of flow from the head waters of the West Lyn down to the sea was less than one hour (Dobbie and Wolf, 1953).

As the valleys were narrow and deeply incised there was little room for flood storage, the result being that the waters were confined to the narrow river channel (Harris, 1992). The Devonian sandstones break up into boulders of all sizes, including smaller fragments and sand. Transportation is minimal during normal flow conditions, yet during flood conditions much material can be moved and the valley sides are loosened up, allowing this material to be carried away by the following floods (Dobbie and Wolf, 1953). Additionally, long, low intensity rainstorms can wet slopes to the point of failure but cannot produce flood peaks to damage the actual channel. Storms of high intensity that produce rapid slope runoff for a short period of time, are capable of devastating small order channels and transporting large quantities of material to the lowland reaches. The Lynmouth flood was remarkable for being both a slope flood and channel flood, in all terms a "rarity" (Newson, 1989).

It is rare that both the East and West Lyn peak at the same point, for the West Lyn rises first if the rains come in from the south-west. The East Lyn rises first with a easterly or south-easterly wind direction (Keene and Elsom, 1990). On the night of the 15th both the rivers peaked together, causing competition for the limited space at the confluence of the two rivers.

The Flood Investigation

Before reconstruction could take place the flood had to be investigated so that the new Lynmouth could accommodate such flooding without a repeat of the disaster. The floods were investigated as soon as possible and before any evidence could be destroyed. The assessment of the peak flow in each part of the Lyn river system was the first hydraulic investigation to be carried out a fortnight after the occurrence. As there were no gauging sites, walking surveys of the river bed were undertaken by engineers of the Ministry of Agriculture and the River Boards. From this information gauging sites were selected and surveyed with a cross section of the channel, the gradient and the measurement of the wrack line. Wrack lines indicate the peak flow where vegetation and loose material have visibly been removed. These may well have been washed down by side flow or alternatively had only indicated a transient surge. Eye-witnesses had emphasised the occurrence of frightening flood waves or surges in the Lyn rivers, which were no doubt caused by recurring ponding and subsequent release of flood waters from temporary reservoirs formed by the jamming of trees and boulders. The high water mark may thus have indicated discharges of short duration only (Dobbie and Wolf, 1953).

Flood Modelling

Sites were selected for their uniformity in cross section, their straightness and their ease of access. The Mannings formula was adopted as being easiest for calculation and as being the standard for both the Ministry of Agriculture and the United States Department of Agriculture. The coefficient value is of paramount importance, making a large difference to the results. For the Lyn river system, values of 0.045 to 0.08 were used (Dobbie and Wolf, 1953). Using four cross sections of each part of the main river and tributaries with clearly defined wrack lines and where there was no doubt about the channel change during the flooding, the rate of flow could be calculated using the well established Mannings formula:

Q = (AR 1/3 S 1/2) / n

Whereby Q = Rate of flow; A = Wetted area; R = Hydraulic radius; S = Water surface slope; n = A variable coefficient dependant on the roughness of the channel. While A,R and S are physical measurements, the value of "n" depends largely upon an experienced judgement, although published guides are available. In these circumstances n = 0.045 in tributaries, 0.06 in heavy wooded sections, 0.08 in rock filled gorges.

Without the very necessary run-off figures it would have been impossible to design with confidence any river improvements. Dobbie recognised the importance of assessing the river flow by two independent methods. Upon discovery of a natural gauging site, Dobbie constructed a 1/48 scale model of a rocky cleft situated 600 yards up the West Lyn from Lynmouth in the Hydraulic laboratory of the Imperial College London. The flow at the site was confined in a steep sided channel of remarkable regularity where the solid rock would have insignificant erosion during the event. Turning in quick succession of two right angles, the flow then emerges over a series of waterfalls. All boulders reaching this channel were quickly moved through this stretch (Dobbie & Wolfe,1953). Flood water had clearly scoured moss from the rock faces, giving a clear indicator of the maximum depth. The wax model reproduced the gorge, waterfall and 350 ft. of the approach channel. Tests made using the model showed that the peak flow in the West Lyn had been 8,000 cusecs (226.4 cumecs) compared with 8,630 cusecs (244.2 cumecs) as calculated by the Mannings formula. It was felt that both figures were significantly close to indicate that the combination of the "n' figure used on both the East and West Lyn had produced a reasonably accurate figure for both, (Harris, 1992, 22).

Although felt to be less reliable than the above methods, the Met. Office isohyetal map was used to calculate that the maximum rate of runoff from the combined East and West Lyn, and was calculated as 22,000 cusecs (622.6 cumecs), (Harris, 1992). Dobbie's report built upon information of flood volume and velocity, recommended to the Council the main concerns with the rebuilding and reconstruction of the town.

These were Dobbie's recommendations:

- The proposed span and cross-sectional area of all bridges.
- The width and depth of the rivers East and West Lyn, particularly near Lynmouth, Hillsford, Barbrook and Parracombe.
- The construction of dams to trap boulders on the East and West Lyn near Lynmouth.
- The construction of an overflow channel across the Manor House grounds to the sea from the confluence of the Rivers East and West Lyn.

Many of Dobbie's recommendations were rejected by the Roads and Rivers Committees. The construction of boulder dams was felt to be unnecessary as the delta was to be cleared of all obstructions, which, in the event of such a repetition, would supply adequate space to receive further debris. Also deleted was the flood relief channel. It was felt that, should a return event ever exceed the capacity of the widened channel, then the right bank nearest the Manor House should be constructed so that it could breach as happened during the flood, and carry flood water over the Manor House grounds to the sea, preventing damage to village side. The width of the river and bridge spans were completed to the recommendations of the Dobbie Report (Carnegie, 1956).

The Reconstruction

Reconstruction took several years. Plans were drawn up and a model produced, which was used for public debate. The opportunity was used not only to reconstruct but to plan for Lynton and Lynmouth's future as a tourist resort and to cater for the motor car. Roads were widened and new car parks created in both settlements.

It was necessary to completely rebuild the harbour wall. This was undertaken by Devon County Council and Lynton Urban District Council with the engagement of Dobbie as consultant engineer. The harbour wall, as with the new Riverside wall and

Tors wall, were constructed over sheet steel toe piles driven into the ground to prevent any possibility of scouring. These were then constructed of concrete faced with local stone washed down in the flood. It was also necessary to rebuild the Rhenish Tower and a new river training wall was added to divert the river from scouring out the harbour, giving shelter to the anchored boats in times of sea storms and river floods (Carnegie, 1956).

Many roads had been damaged during the flood. A number of these had to be completely re-made including road foundations, embankments and surfacing. The opportunity was taken to modernise, allowing for the requirements of modern traffic. The new Riverside Road was constructed to a width of 22ft. Tors Road was reconstructed to 16ft wide and both main approaches to Lynmouth from Watersmeet and from Countisbury were widened (Carnegie, 1956).

During the temporary phase of reconstruction a large amount of debris was excavated from the rivers to restore their flow. This, along with further material derived from channel widening, had to be removed from Lynmouth. Suggestions were made that the material should be hauled up Countisbury Hill, where it would be tipped over the cliff into the sea. Another suggestion was to deposit it out of sight somewhere on Exmoor. Both suggestions were considered too expensive. Instead it was agreed to tip the 70,000 cubic yards of excavated material at the extreme western end of the Esplanade, where it would make a useful extension to the car park (Carnegie, 1956).

The new channels in Lynmouth were designed and constructed to accommodate flood discharges of 15,000 cubic feet per second for the East Lyn and 9,000 cubic feet per second for the West Lyn, and a total of 23,000 cubic feet per second for the River Lyn below the confluence, these being the peak flow estimations for the flood estimated by Dobbie. It will be noticed that the flow of the River Lyn is less than the total of both the East and West Lyn. The reason for this is the unlikely chance of maximum discharge of the two rivers occurring at the same time, since both have different times of concentration. Additionally, it had proved difficult in designing for a 23,000 cubic feet per second discharge on the River Lyn due to the threshold levels of shops and houses. The parapet wall against the riverside road forms part of this defence and all openings are non-return flap valves (Carnegie, 1956).

Special treatment was given to the Manor Grounds bank, where a two stage channel was created for the combined rivers. The bed was stepped on two levels to avoid the appearance of an empty channel: the lower 60 ft. wide channel conveying the water during dry times of the year and the higher to be available for the higher flow levels on extreme occasions. The 12ft wide terrace was cobbled on a concrete bed. From here to the river is a 1 in 3.5 slope of reinforced concrete bed, and from the terrace to the Manor Grounds a further 1 in 1 slope, giving a total width of 100ft - a vast increase from the original 35 ft. (Carnegie, 1956; Harris,1992).

During the flood, the Lynmouth Street Bridge over the West Lyn was completely destroyed without a trace. Lyndale bridge over the East Lyn was underscoured and the Prospect Corner Bridge was undamaged but filled to the roof with debris. In response to the Dobbie report the Lyndale bridge was reconstructed to give a clear span of 80 ft., and the new road over the West Lyn had a clear span of 50 ft. These were constructed from pre-stressed concrete beams on mass concrete abutments faced with local stone and of sufficient widths not to be blocked by trees and debris (Carnegie, 1956). Further upstream, a different design of bridge was used. The alternative to the expensive concrete structures was the relatively cheap, low wooden bridges which are deliberately built to fail in the event of a flood. In such times the wooden structure will simply lift off the stone base and be swept away ensuring that they do not become dammed (Keene and Elsom, 1990). Further measures taken to ensure future safety were to install flood markers further up stream where, during excessive rain periods, close studies can be kept and warnings could be issued if so required.

Conclusions

The slope of rivers running towards Lynmouth and the high rainfall in their catchment determines high possibility of flooding there and the likelihood of severe erosion. The deep, incised valleys and smooth contours provided little storage for excess waters. The poor maintenance of the river had left previous flood debris and trees in the flood's passage. Further restrictions were placed upon the river with the encroachment of properties upon the river banks. The saturated soils could retain little of the precipitation that had fallen on Exmoor over the previous days. The water table was already high and all the water had to travel into the river system.

The presence of low pressure convinced weather men that this was an explainable scenario, although rather unusual. Thunderstorms had played a major part of the British weather throughout the country, where observation had been remarked at the rarity of such events. Further remarks used such terms as 'unorthodox', which, when later combined with Whitehall officials' admittance that rain making experiments had sometime been conducted over Lynmouth, fuelled the belief of government responsibility. Official declassified files were later obtained by The Sunday Times and provided the first evidence that during the height of the Cold War the MoD was trying to develop techniques to flood enemy trenches, paralyse forces and bog down tanks in the event of a Soviet invasion. This experiments involved the dispersal of silver iodide or dry ice particles from small aircraft into clouds to induce rain in a technique called cloud-seeding (Brennan, 1997). The records show that ministers authorised rainmaking experiments across Britain from 1949 to 1957. However, a connection with the disaster has not been demonstrated and there is no evidence of success of or co-incidence of experiments over Lynmouth. The only experiments taking place anywhere near the time of the flood were in East Anglia and the flood was caused by a depression moving eastward from the Atlantic and drawing in moist air from France and Wales.

The ascending warm moist air up and over Exmoor played another additional key role in the flood explanation. For the peaking of both rivers concurrently is rare. The usual time lag between the rivers means that the West Lyn peaks prior to the East, unless there are two sources of rainfall. The moisture release from the local uprise of air over Exmoor produced the second source, which was sufficient to bolster the East Lyn and advance it by adequate time to peak at the same time as the West Lyn.

Lynmouth was prone to floods and was ready for a once in two centuries flood such as the 1952 flood. By examining the physical environment the inevitability of such an occurrence was very real. All that Lynmouth was waiting for was the rains, and, like so many communities that live in potential risk areas, this was only a matter of time.

The measures undertaken to secure the safety of the village have continued to work. The major undertakings of channel clearance and widening have ensured an adequate area for the water to travel through unhindered. Reconstruction of bridges and the removal of bank side houses have further warranted against the damming and blocking of the rivers. Early warning systems have been put into place to alert those who may be in danger. To date several warnings have been given when the river level has climbed. Localised flooding has occurred around the Barbrook area but nothing in resemblance to that of 1952. Some say that Lynmouth's charm has been lost but it has emerged in a resurrected and changed form, attractive, picturesque and, hopefully, safe.

Summary

WHY DID THE FLOOD HAPPEN?

Exceptionally heavy rain occurred at a time when the ground was already saturated.
Drainage and steepness of the valleys contributed to rapid run-off. The rivers are ‘spate’ rivers where floods are commonplace.
The Lyn Rivers include a large area of high, wet moorland in their catchments and the rivers meet at Lynmouth, where all of the water from this large area is concentrated.
The rivers at Lynmouth have been ‘rejuvenated’, resulting in narrow valleys and confined channels unusual for rivers at the end of their courses.

WHY WAS THERE SO MUCH DAMAGE?

There had been much building on the flood plains of rivers.
Development had diverted rivers from their flood courses and confined them in unnaturally narrow channels.
Exmoor’s north-flowing rivers descend to the sea very steeply, giving them much speed and power to erode.
Obstacles to flooding had not been cleared.

WHY WAS THERE SO MUCH LOSS OF LIFE?

The flood occurred in complete darkness and it was difficult to assess the amount of danger or safe means of escape.
It was the peak of the holiday season and the population was swelled with tourists.
Local people were used to flooding and did not evacuate their homes because they underestimated the danger from this exceptional flood.
Houses and holiday accommodation were built close to the rivers.

Some of the dead had been staying in tents, caravans or insubstantial buildings that had not been able to withstand the flooding.

WHAT HAS BEEN DONE TO ENSURE THAT THE DISASTER IS NOT REPEATED?

Floods of this magnitude have occurred roughly once every two centuries and are likely to occur again. They cannot be prevented, only contained.
A flood warning system has been installed.
Building on flood plains has been restricted. Buildings have been removed to ensure that flood waters are no longer confined.
River channels and bridges over them have been widened to accommodate a flood of similar proportions. A larger flood would still cause damage but within the settlement of Lynmouth the river channel has been designed so that flood water would mostly spill over the Manor Green on the eastern side of the river, away from the main settlement.

Acknowledgements

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