Historic Tides Study: Devon Area
Study findings and reporting

Environment Agency

21st April 2011
Final Report
9W3164
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- Reference spreadsheet
1 ACKNOWLEDGMENTS

Royal Haskoning wish to thank and acknowledge the contributions of the following people involved in this study:

- Iain Baines of the Environment Agency,
- Alison Bethel, Systems Information Researcher,
- Daniel Conley, Reader in Coastal Dynamic Modelling Plymouth University
- Plymouth University Undergraduate students; John Atkinson, Nathaniel Booth, Terran Gilda, Richard Glover, Chris Hall, and Ian Kirby.

2 INTRODUCTION

Royal Haskoning was commissioned by the Environment Agency in September 2010 to undertake an investigation into historic flood events around the coast and estuaries of Devon Area, with a specific aim of data collection in relation to historical extreme tidal water levels. The study was commissioned under the Strategic Flood Risk Management Framework to be completed within the 2010/11 financial year.

3 AIMS AND OBJECTIVES

The aim of the study was to gather data on the frequency and magnitude of past extreme tidal water levels and associated flood events for the north and south coasts of Devon Area, including estuary locations, over the past 200 to 500 years (and further back if possible). This was to also include records of coastal change where these may have affected extreme tide levels.

The study objective was to bring together the relevant information and data from a wide range of sources, and for the first time record it in a consistent format to ensure that it can be used in the future. This comprehensive historic search was to make use of newly accessible digital data as well as examining written records, often pre-dating newspapers.

By understanding historic events and estimating water levels from these events it is anticipated that these data could be applied to improve present day extreme tide level predictions and inform future management of coastal flooding. Learning from historic events has the potential to strongly influence the way in which present day communities live with and adapt to coastal flood risk and specifically to assist the Environment Agency in many aspects of their work; from consultation to scheme development and flood warning services.

4 METHOD

4.1 Overarching approach

The overarching approach proposed for this study was to undertake a collaborative exercise with the Environment Agency, Royal Haskoning, a qualified Systems Information Researcher and Plymouth University. The immediate benefits of this approach were to combine the engineering and coastal expertise of the Environment
Agency and Royal Haskoning with the systematic and auditable research skills of a qualified researcher, along with the enthusiasm and time of students undertaking related project work for their undergraduate degree, with the aim to obtain well researched and confident study outputs.

The other benefits of this approach were identified as follows:

- Environment Agency benefit from established links of Royal Haskoning with Plymouth University
- Direct contact for undergraduate students with the environmental regulator and industry
- Longevity of the research intent with future collaborations a possibility.

The project brief was deliberately flexible from the Environment Agency, refined through the submission of a costed proposal from Royal Haskoning and a finalised at an Inception Meeting of 30th September 2010.

The approach agreed at the Inception Meeting was captured using a software tool called C Map.

4.1.1 Collaboration

Collaboration with Plymouth University was facilitated through long established links held between Royal Haskoning and individual academics at the university. The university runs an undergraduate Resilience of Communities programme, coordinated through Course Leaders Dominic Reeve, Andrew Fox and Daniel Conley (Reader in Coastal Dynamic Modelling). The opportunity to link up with their programme by providing this research study as a choice for students undertaking an independent research topic module was an ideal opportunity to meet the needs of this study, whilst also providing students with a study topic to contribute towards their academic study and the opportunity to significantly contribute to industry knowledge.

Collaboration with our Information Systems Researcher, Alison Bethel, was again facilitated through established links between Royal Haskoning and Alison. Alison is a qualified librarian with much experience of desk based research and archive and data systems. As a former employee of the Environment Agency, including at the Southwest Regional Office library, Alison was ideally placed not only to undertake desk based and local research but also understand the Environment Agency data sources and processes.

4.1.2 Coordination

This approach has required a substantial level of coordination, with the Royal Haskoning and Environment Agency Project Managers working closely together to ensure that all research has been undertaken within a clear process framework agreed, reviewed and amended throughout the project as required.

The research has required a focussed direction in terms of guidance on data to record and seek, and iteration into the search process as results began to emerge. It has also required some travel around the county and this has required setting up financial arrangements with Plymouth University to cover students travel expenses.
Close liaison between the project team throughout the commission has been based on the facilitation provided by the Royal Haskoning and Environment Agency Project Managers to ensure an integrated approach in terms of:

- engineering and technical support - so that the researchers knew what to look for, could query the importance of information identified and remain targeted
- organisational support
- source identification
- establishing data recording conventions which compliment those already used by the Environment Agency
- Project reporting, conclusions, source/information signposting and recommendations.

4.1.3 Process

The research process envisaged at the outset of the study has largely been followed, with some modifications as the study has progressed. Figure 3.1 sets out the approach proposed at the outset of the study.

![Figure 3.1 Research process initially proposed](image)

Figure 3.1 shows how the approach envisaged was to use Royal Haskoning expertise on historic tidal research and data sources to direct desk based research to be undertaken by Alison Bethel to identify historic tidal events. It was then anticipated that Plymouth University Undergraduate students would then select which historic events to follow up in more detail, with the intention to travel the county to physically access locally held records with the ultimate aim of obtaining flood extent and level data for as many events as possible.
It was envisaged that the desk based research and more detailed follow up research would have an element of feedback between them, as for example findings from local records triggered fresh dates or new searches for fresh desk based enquires at other locations. It was also thought that a systematic approach to covering the large geographical area of the north and south coasts and estuaries of Devon may be appropriate, particularly for the detailed follow up work on the ground.

Consistent record keeping between the desk based and ground level research was also identified as extremely important, with an agreed data quality coding system to be established to identify confidence in data sources. The agreed data quality suffix codes are presented below in Table 3.1.

**Table 3.1 Data Quality suffix codes agreed for the study**

<table>
<thead>
<tr>
<th>Data Quality Suffix and description</th>
<th>Example and application</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Best of breed</td>
<td>Gauge/wrack mark</td>
</tr>
<tr>
<td>B Known deficiencies</td>
<td>Photo/good report</td>
</tr>
<tr>
<td>C Gross assumptions</td>
<td>Inference</td>
</tr>
<tr>
<td>D Heroic assumptions</td>
<td>Anecdotal</td>
</tr>
</tbody>
</table>

The record keeping approach was required to be compatible with the Environment Agency’s Flood Reconnaissance Information System (FRIS) which is used to record all reported flood incidents in Devon Area. This is in database format and difficult to access outside of the Environment Agency systems and so the Environment Agency Project Manager created a spreadsheet in MS Excel for use in the project which contained all the required fields for future upload into FRIS.

The information required for FRIS, as shown in Table 3.2, was entered into the spreadsheet for each flood event identified through the research by both Alison and the students. This was combined into one final spreadsheet at the end of the commission, which is presented in Appendix A and named Full Reference Spreadsheet.

**Table 3.2 Event information required for FRIS**

<table>
<thead>
<tr>
<th>Unique ID</th>
<th>Estimated Number of Properties flooded</th>
<th>NGR Easting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start day</td>
<td>Cause</td>
<td>NGR Northing</td>
</tr>
<tr>
<td>Start month</td>
<td>Action Taken</td>
<td>Information Source</td>
</tr>
<tr>
<td>Start year</td>
<td>Event Frequency</td>
<td>Information Reference</td>
</tr>
<tr>
<td>Detail (of event)</td>
<td>National Grid Reference</td>
<td></td>
</tr>
</tbody>
</table>

Additional fields were also added to this spreadsheet by Alison for specific record keeping relevant to this project (see Section 3.2.5 for details).

Reporting, with mapped based illustrations where appropriate were also identified as important to the study to enable sharing of findings, data and lessons learnt throughout the Environment Agency and more widely. The opportunity for future papers and
conference presentations was also proposed as a vehicle to disseminate the outcomes from this research study.

4.1.4 Approach modifications

During the course of the study a number of modifications to the research approach were made through necessity and pragmatism and agreed within the project team. These modifications are listed below and reflected in the research method reporting from the undergraduate students below (Sections 3.2 and 3.3):

- Alison Bethel undertook more follow up work than envisaged through visits to the Local Studies Library in Exeter to flesh out online searches and seek level data.
- The undergraduate students did not wait for dates to be identified for follow up work; they undertook their own desk top research to obtain dates with follow up work undertaken at the Local Studies Library in Plymouth and Barnstaple.
- Initial contact made by the students to locally based organisations was reportedly not fruitful and as a consequence no visits were made to obtain locally held records.
- Initial difficulty in working with the University to facilitate payment of expenses to students did not enable students to travel as widely as envisaged for the project, although visits were made to Barnstaple Local Studies Library and the Met Office library in Exeter.
- There was no feedback from detailed follow-up work back into further desk top / online searches.

4.1.5 Communications

Communications have been vital to the successful outcome of this research study. From the outset both Royal Haskoning and the Environment Agency understood the importance of engaging our Systems Information Researcher and undergraduate students with the project straight away.

A start-up meeting was held with the Environment Agency Project Manager, our Systems Information Researcher and the Royal Haskoning Project Manager and Director at the outset of the commission. This was a useful meeting as it meant that all present felt engaged and that they were contributing equally to the research study. This meeting did not involve the undergraduate students.

Communication between the Royal Haskoning Project Manager and Daniel Conley, the course tutor, ensured a joint understanding of the Environment Agency’s aims of the study and the requirements of the undergraduate course. A separate meeting was held with the undergraduate students during their early tutor contact sessions for their topic. A presentation was jointly prepared Royal Haskoning and Environment Agency to engage and interest the students in the topic, provide information on the Environment Agency’s aims and objectives for the study and to offer ideas of how the students could make the topic work for their undergraduate course requirements whilst also meeting the needs of the Environment Agency. Throughout the duration of the study the group of six undergraduate students were tutored by Daniel Conley with frequent contact time.
From this stage onwards, general communication between all parties was frequent, timely and constructive. Communications were through telephone, email and meetings.

As part of the link with the undergraduates, both Environment Agency and Royal Haskoning Project Managers undertook a review of the undergraduate’s joint reporting on their project which is presented in Appendix B (the conclusions of which were not available to review at the time and are not supported by Royal Haskoning or the Environment Agency). The project team also attended the poster presentation session of the topic by the students in March 2011, which contributes, along with their report to their grade for the course.

4.2 Research method – Information Systems Research

Desk top research was carried out using relevant databases and catalogues. The results were entered in to the Full Reference Spreadsheet specially prepared for this study.

4.2.1 Sources

The places to search were identified through previous research experience and sources identified by Royal Haskoning and the Environment Agency. The sources were graded according to which ones would provide the most and best results, with priority given to searching these sources first. The sources accessed during the study are listed as follows:

- **Times Archive, 1785-1985**
  
  http://archive.timesonline.co.uk/tol/archive/
  
  A fully searchable database of The Times newspaper.
  
  This source was not as fruitful as expected. It is not recommended that this source is used to find the initial dates. It could be used after dates have been obtained by checking the newspaper on the day, or two days, after the event to find out if anything was mentioned in relation to a similar event happening either in the same location, or another.

- **Web of Science**
  
  A citation and journal database for academic users, available to employees of the Environment Agency
  
  One relevant paper which does have an excellent reference list which would be useful to go through (Historic tsunami in Britain since AD 1000: a review. Haslett, SK & Bryant, EA. Natural Hazards and Earth Systems Science. 8, 587-601. 2008).

- **British Library British Newspapers 1800-1900 database**
  
  http://newspapers.bl.uk/blcs/
  
  Contains millions of articles from 49 London, national and regional newspaper titles from the period.
  
  This was a very valuable source of information. The Devon newspaper digitized in this database was Trewman's Exeter Flying Post.
• **Meteorological Office online catalogue**
  http://library.metoffice.gov.uk/
  Only one reference which might be useful to follow up. A more thorough search may provide a few more dates, detail or perhaps some further information on the meteorological conditions at the time of the events.

• **Devon Records Office online catalogue**
  http://app-calmview.devon.gov.uk/CalmView/
  No further information obtained.
- Westcountry Local Studies Library online catalogue
  http://www.devon.gov.uk/localstudies/100173/1.html
  Had some useful documents about very specific locations, no levels, only
description but did provide a couple of additional dates.

- Zong, Y and Tooley, MJ. A historical record of coastal floods in Britain:
  This academic research paper provided a very valuable source of dates for
  historic tidal events in the UK between 1789 and 1994.

- Research by Ivan Haigh http://www.ivanhaigh.com/Sea-Level/Home.html
  Royal Haskoning obtained a list of dates from research carried out on high water
  events in the Solent. This provided a very valuable list of dates from the 20th
  Century, which although outside of the study area could point to flooding events
  in Devon Area.

- Environment Agency Flood Reconnaissance Information System
  The Environment Agency Flood Reconnaissance Information System was used
  by the Environment Agency Project Manager to extract a list of tidal event dates
  already contained in this database for possible follow up.

- River Exe list of historic flood events
  This was a list of dates of flooding incidents on the estuary identified during the
  course of a recent Environment Agency Strategy study on the River Exe,
  provided by the Environment Agency Project Manager (EEFCRMS Baseline
  FRCM report i1 App A working draft).

4.2.2 Searches

Of all the sources of data accessed, source 1.1.3, the online British Library Newspapers
1800-1900 database was identified very early on to be the most useful source of data in
terms of providing previously unidentified dates of flood events and was therefore
prioritised for searching within the desk top phase of work.

The searches were undertaken using key words and deliberately kept very basic and
wide within the context of costal/tidal flooding in order to maximise the opportunity for
identifying flood events.

The key words searched upon were as follows:
- flood
- coast
- wave
- cliff
- breach
- sea
- tide
- storm
- hurricane
- gale
Other wider based sources (such as Times online) were narrowed down by using a place name for example Devon or Sidmouth.

Newspaper reporting of flood events at the time were found to be very descriptive and often contained information relating to weather conditions, sea state, locations affected (street names, assets and properties) and depth of flooding. The accuracy of the reporting is unknown however could be assumed to be largely factual with some subjectivity in terms of general description and depth estimates. A number of extracts from some typical newspaper articles about flooding in Exmouth found in the Trewman’s Flying Post are listed below.

“all the houses in the lower part of the town and those on the quays were filled with water...the sea making a clean sweep of gardens, walls, partitions” (1)  
Date: 24th Oct 1859

“..the waves...destroyed upward of 100 feet of the inner wall of the promenade and swamped three adjoining fields, the waves dashing over Beach Cottage at the corner of Temple road” (2) Date: 31st Jan 1869

“…the sea wall was a good deal shaken and the road from the docks to the lifeboat house much washed up” (3). Date: 13th Nov 1875

“…sea flooded … Clinton Terrace and part of Ferry Rd” (4). Date: 17th Oct 1875

“…the sea dashed with terrific fury over the sea wall completely enveloping Beach (alias Cats) Castle in a sea of spray” (5). Date: 3rd Dec 1876

4.2.3 Follow up research

In order to follow up events from the online search of the British Library Newspapers 1800-1900 database, a number of visits to the Local Records Library in Exeter were undertaken to obtain more detailed descriptions of the flood events. During the course of these visits a number of tithe map and estate records were discovered. The discovery of drainage maps dating from 1840’s for the Rolle Estate which at the time covered much of east Devon was particularly exciting. This source was investigated further to attempt to extract flood levels for Exmouth and Teignmouth.

4.2.4 Qualitative to quantitative

Using tithe maps and the drainage records for the Rolle Estate obtaining flood level information for a number of historic tidal events was attempted for Exmouth and Teignmouth. An example of a tithe map and drainage map for Exmouth is shown below from photographs taken of the original canvas plans.
There were a number of difficulties encountered during this process:

- The form of measurement for the tithe maps were in ‘chains’. It was difficult to read this from the mapping and relate it to present day metric measurement.
Road names quoted in the newspaper articles did not match or could not be identified on the tithe maps
The tithe maps contain no information on elevation. Without another source of elevation data or local knowledge this meant that interpretation of where flooding as described in the newspaper articles may have occurred was difficult.

Result documentation

The search results were documented in the Full Reference Spreadsheet format spreadsheet to capture the information for future upload to FRIS. In addition to the FRIS dataset requirements, the following further data was captured within the spreadsheet for record keeping specific to the needs of the research project as shown in Table 3.3.

Table 3.3 further data capture undertaken for this study

<table>
<thead>
<tr>
<th>Incident location</th>
<th>Source details</th>
<th>Follow up instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Quality Suffix</td>
<td>Article title</td>
<td>Action Taken</td>
</tr>
<tr>
<td>Document reference</td>
<td>Tertiary source</td>
<td>Unique ID</td>
</tr>
<tr>
<td>Source title</td>
<td>Priority</td>
<td>Data/Reference</td>
</tr>
</tbody>
</table>

All newspaper articles accessed and other documentation has been scanned as pdf format documents with a unique reference identification which can be linked to the data in the Full Reference Spreadsheet for future access to the document. The scanned articles are presented in Appendix A.

An example scanned newspaper article from the North Devon Advertiser, dating from 26th February 1833 and describing a flood at Barnstaple is shown in Figure 3.4.

Figure 3.4 North Devon Advertiser article 1833 – example of an identified flood event and the scanned document for future reference.
4.3 Research method – Plymouth University undergraduate students

The undergraduate students undertook their research in order to meet the needs of their topic brief set by their course tutor. In liaison with Royal Haskoning and the Environment Agency the topic brief was established in order to contribute to the needs of the research study and determined as follows:

“The Environment Agency (EA) needs to understand coastal flooding risk from extreme sea levels. The past contains information for the future so they are developing knowledge about historic sea levels around North and South Devon coasts including the major estuaries. Particular interest is on the period from 50 to 500 years before present. Your group is being asked to undertake focused research to collect as much historic tide level data as possible by visiting coastal locations to follow up documentary evidence. You will work to create a dataset recording extreme events and compare the observations with more contemporary records. Your report will conclude with an analysis of what your information says about future potential for coastal flooding around the Devon coast”.

The work undertaken by the students has been documented in their topic paper titled “Historic Flood Levels” and which is provided in an appendix to this report (Appendix B). With permission from the students, we have summarised their methodology and findings for the purposes of the research study reporting.

4.3.1 Desk top research

The students chose to undertake their own desk top research to find flooding events predating the 1960s with a location, date and an indication of severity which could be further researched.

Online searches identified previous academic studies of which Zong and Tooley (2003) was found to contain the most expansive list of coastal flooding events. Other sources were also identified such as local history and personal internet pages however events discovered were not pursued.

Once the Full Reference Spreadsheet and initial results from Alison were sent through to the undergraduate students they were used in collaboration with their own desk top research findings to provide a more comprehensive list of events to base follow up research on.

4.3.2 Follow up research

The follow up research was first implemented by identifying and then contacting a number of possible local data sources in relation to specific flood events and areas. This included harbour masters, life boat stations, museums, studies centres, historic hotels, country houses and local historians within the study area. The students report that these contacts provided a limited amount of positive response, with much of the organisations having little or no resources regarding historic flood levels and where data was provided its context or relevancy was inadequate and did not coincide with the key aims of the study.
The focus of follow up research therefore was redirected to obtaining greater details on specific events from historic archived newspapers provided within a number of local studies centres. This began with the Plymouth Local Studies Centre found within the Plymouth Central Library, which contained the national newspaper “The Times” available from 1604 and the regional newspapers “The Western Morning News” (1810) and “The Evening Herald” (1815) all in microfiche film format.

For each of the identified flood events each corresponding newspaper was searched from the day of the flooding event for seven days. Where articles were found, the following data (where available) was recorded:

- Published article date
- Locations within the geographical domain affected
- Qualitative data regarding the flood, this was generally vast covering a range of impacts:
  - Social
  - Economical/structural: “Destroying a number of boat houses”
  - Meteorological descriptions: “A strong gale approached from the North West around midnight”
  - Tidal states: “Coinciding with the highest spring tide in living memory”
- Possible quantitative flooding levels which could be expanded or researched upon: “The whole main street up to Harris the Grocers is now only accessible by boat”.

This first newspaper investigation provided a number of outcomes:

- A number of previously established flooding events were expanded in both qualitative and quantitative data.
- A spreadsheet for these events with details on flooding was devised (Appendix B)
- Some potential flooding events were not covered within any of the newspapers. Especially linked with the north coast. This was down to local papers available in Plymouth being dominantly Southern Devon news and showed the need to visit north coast study centres with a visit to the Barnstaple Local Studies Centre subsequently undertaken.

### 4.3.3 Qualitative to quantitative data

After expanding the database through qualitative data, a range of data and techniques were used to establish quantitative data for the confirmed flooding events. The students report that this involved:

- Calculated tidal levels obtained from Easy Tide for each of the flooding events. This provided data regarding the modelled elevation of the sea not due to atmospheric influence, as well as allowing an understanding of the tide cycle (i.e. Spring Neap Cycle, Ebb/flood, high/low times).
- Pressure charts and meteorological observations obtained from the Met Office library, in order to link and describe the cause of flooding events in relation to meteorological forcing.
- Obtaining Light Detection and Ranging (LiDAR) digital terrain data (produced between 2007-2010 and based on mAOD Newlyn) from Plymouth Coastal
Observatory (freely available) to convert qualitative data obtained from newspaper articles to quantitative flood heights.

- Use of Google Earth to obtain spatial coordinates for the descriptions of flooding described in the newspaper articles.
- Obtaining a height from the LiDAR for the coordinates to obtain a level of possible flooding.
- Use of historical maps as close the date of the flood event as possible obtained online from the Ordnance Survey (freely available) to confirm the validity of the location in respect to street names.

Noting that the LiDAR data operates to a height accuracy of +/-0.4m and a spatial resolution of 1m² in order to ensure that the produced height through the LiDAR system was indicative to the actual ground level, a topographic map was produced to confirm height readings taken at street level and the coordinates in were accurate to those converted from the Latitudinal and Longitudinal coordinates identified in Google Earth.

Figure 3.5 shows a topographic map of Barnstaple produced from LiDAR by the undergraduate students to confirm elevation readings from the LiDAR have been taken at street level.

![Figure 3.5 Topographic map produced from LiDAR](image)

4.3.4 Result documentation

The search results were documented in the Full Reference Spreadsheet to capture the information for future upload to FRIS. Some newspaper articles accessed were scanned into .pdf format to enable them to be linked into the FRIS database, but unfortunately the majority were not.
5 FINDINGS

5.1 General

The study has identified at least 124 separate incidents of historic flooding at the coast and estuaries in Devon Area between the years of 1811 and 1960.

This study has also identified a previously unknown source of data which lists the top 100 high water levels recorded at a tidal gauge in Southampton during the 20th Century. This source should be followed up to identify if flooding was recorded in Devon Area for any of these instances.

These dates have been identified through a search of the sources listed in Section 3.2.1 for dates of tidal flood events in Devon Area. These sources are presented in Table 4.1 indicating where it is considered that these sources have been exhausted for flood event dates in this geographic study area or where further searches are required in order to avoid repetitive searches in the future.

Table 4.1 Accessed sources of data for events in Devon area

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Accessed by</th>
<th>Source Exhausted</th>
<th>Further search recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td>Times Archive, 1785-1985 <a href="http://archive.timesonline.co.uk/tol/archive/">http://archive.timesonline.co.uk/tol/archive/</a></td>
<td>Alison Bethel</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Web of Science</td>
<td>Alison Bethel</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>A citation and journal database for academic users, available to employees of the Environment Agency</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>British Library British Newspapers 1800-1900 database <a href="http://newspapers.bl.uk/blcs/">http://newspapers.bl.uk/blcs/</a></td>
<td>Alison Bethel</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Meteorological Office online catalogue <a href="http://library.metoffice.gov.uk/">http://library.metoffice.gov.uk/</a></td>
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<td>Alison Bethel</td>
<td>Yes</td>
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<td>Zong, Y and Tooley, MJ. A historical record of coastal floods in Britain: frequencies and associated storm tracks. Natural Hazards, 29, 13-26. 2003</td>
<td>Alison Bethel and undergraduates</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
5.1.1 Limitations on records of flood events

Although we have attempted to identify those sources historic flood events exhausted through this research study, this does not mean that the identification of historic flood events has been exhausted for the time periods covered by this commission.

The use of the online British Library Newspapers database 1800-1900 as the major source of dates and information on past flood events mean that this study has focussed on identifying flood events from this period that were considered newsworthy at the time. Newsworthiness is a factor which would have depended on a number of factors including:

- Other news items of the day
- Whether the reporting was at a local, regional or national scale
- The scale of the event in relation to previous events and dependent on the reporters viewpoint
- The damage caused in relation to previous events and dependent on the reporters viewpoint.

This final bullet point also relates to the fact that where historic extreme tide levels have occurred where no infrastructure or property was present and or damaged it is unlikely that any consideration would have been made to recording such a natural event or even that it would have been witnessed.

5.1.2 Event follow up

A number of events with the best descriptive information have been followed up during the course of this research study to obtain estimates of flood levels achieved (Section 4.2). There are a number of events however which have not been able to be followed up through this study and specific actions have been suggested in order to find out more about these events in the future. This includes the list of dates from Ivan Haigh’s research into 20th Century events in the Solent, as well as any further books, pamphlets
or references obtained from a reliable source. These are identified in the Full Reference Spreadsheet as priority 1 actions.

Priority 2 follow up actions have been identified for a number of events where less information has been obtained from the reference but it would be worth using the dates to carry out further investigation.

In addition, whilst undertaking the research, a number of events were encountered relating to coastal flooding outside of Devon Area which may be of interest to the wider Environment Agency. Also a number of solely fluvial events or combination tidal and fluvial events were identified within Devon Area which may be of interest for future follow up work.

5.1.3 The Great flood of 1607

During the course of this study various references to the great flood of 1607, which affected the Bristol Channel have been encountered on which there have been many papers produced. These have not been specifically followed up in this study because this event is so well documented elsewhere. However, it is worth noting the 2007 paper 1607 Bristol Channel Floods: 400-Year Retrospective written by Risk Management Solutions (RMS) which states that

“It is considered that the southwestern extent of known flooding was at the town of Barnstaple in north Devon “where the lowe Marshes and fenny groundes... were overflowne.” In detailed accounts, it is reported that three people were killed and £2,000 worth of goods were lost.”

The RMS (2007) paper also quotes Haslett and Bryant (2004) in stating that in Barnstaple, the height of the flooding was 6.15 ± 0.25 m above Ordnance Datum (AOD), as recently reconstructed from detailed accounts of the streets and quayside locations that were flooded in 1607.

The paper references the following titles which have not been accessed during this study but are listed here for future information:

- Lost Chronicle of Barnstaple as compiled by Dr. Todd Gray of Exeter University in 1998 from records written between 1586 and 1611 by the Barnstaple town clerk, Adam Wyatt (Gray, 1998).

5.2 Flood Levels

One of the main aims of this research study was to identify quantitative data in the form of flood levels and extents caused by historic flood events. The events identified with the most descriptive information which could be related to the present day environment have been followed up by the undergraduate students and Royal Haskoning using broadly the same approaches as documented in Sections 3.2.4 and 3.3.3 above.
A number of recorded flood events at separate locations have been investigated in order to obtain an estimate of the level flood waters may have reached. This information is presented Appendix B (Plymouth University) and Appendix C (Royal Haskoning) with a flag that level information is available recorded in the ‘Action Taken’ field in the Full Reference Spreadsheet provided in Appendix A.

Investigations have been undertaken to understand the influence of surge, waves and wind on the flood levels obtained through this study for a small number these events by Plymouth University. It is recommended that this work is undertaken for a wider range of events in order to identify the tide levels and associated weather conditions which have resulted in flooding in the past.

5.2.1 Flood level estimation limitations

The confidence levels assigned to the flood level estimations relate to the limitations in data or description which may have a bearing on any flood level estimated during this study.

The main limitations are as follows:

- Description of the flood: affected features may be mentioned, for example a road, but a depth of flooding is not and so in this case any level produced may be on the lower side of what was achieved.
- Conversely, the identified features, such as roads may still be present in the same location as at the time of the flood (checked through comparing historic mapping with present day mapping) but the level at which that feature now stands may be different. In the case of roads it is likely that road heights will have increased through modern surfacing methods.
- Description of the flood: depths, if mentioned in the description are provided in anecdotal form with no measurement undertaken at the time and rounded to provide an estimate in feet. Converting this into metric may give a false impression of accuracy which was never attributed at the time of the event.
- Use of local datum on maps: an exercise is required to convert local levels to metres above ordnance datum Newlyn in order to make levels meaningful and comparable to other locations. In some cases it may not be possible to identify specific features still present in order to undertake this.

6 RECOMMENDATIONS

Within the context of the findings of this research study for Devon Area the following recommendations can be made with reference to the Full Reference Spreadsheet provided in Appendix A:

1. The FRIS database is updated to include all relevant entries and cross reference is made to the Plymouth University Reference Spreadsheet and the Royal Haskoning Reference Spreadsheet to insert flood level information as appropriate.
2. Exhausted searches for historic tidal events in Devon Area (as identified in Table 4.1) are noted and closed from future research to avoid duplication of effort.
3. Un-exhausted searches for Devon Area (as identified in Table 4.1) are
considered for follow up.
4. Priority 1 follow up actions are undertaken with the aim of identifying flood level
and extent data.
5. Priority 2 and 3 follow up actions are recorded and noted for future reference
and use as appropriate.
6. Level data for historic events estimated through this study is compared against
more recent datasets of recorded flood events to improve confidence in the
estimated levels through comparison with recent records of levels or affected
features.
7. The use of the online British Library Newspapers database 1800-1900 as the
major source of dates and information on past flood events, means that this
study has focussed on identifying flood events from this period. It is therefore
recommended that further research is undertaken to investigate local sources of
data with the aim to go beyond 200 years into the past.

Within the context of the wider application of the findings from this research study the
following recommendations can be made:

- Following a validation exercise (recommendation 5 above) those flood levels
with good confidence should be fed into appropriate datasets to inform the
application flood level information for industry and regulator use. This could
include the local application of extreme flood levels in the context of :
  o Flood Risk and Development Planning
  o Scheme design
  o Strategic flood risk mapping and Shoreline Management Plans etc.

- The use of desk top research followed up by more detailed analysis to obtain
more details and apply current and historic data sets to obtain flood level
estimations has been demonstrated as a successful approach to obtaining
extent and level information on historic flood events. It is recommended that this
approach can be applied more widely to increase our knowledge on the
qualitative and quantitative scale and impacts of historic tidal events using the
research process flow chart in Figure 5.1.

- Application of this process could be applied to both tidal historical events on a
wider geographical basis or to fluvial events, again on a wide geographical
basis. The use of this approach for fluvial events however should consider that
rivers are geomorphologically active and significant change in position and level
of the channel and floodplain may have occurred historically which would make
relating flood events to the present day situation more challenging and less
confident.
Figure 5.1 Research process flow chart
7 LESSONS LEARNT

As expected, this research study has benefited from the approach of linking a flood risk management consultancy with qualified Information Systems Researcher. This has ensured focused research and documentation in an efficient and robust manner, minimising the need for future repeat work and maximising the opportunities to follow up leads both through this study and as recommendations for future work.

Working with undergraduate students from Plymouth University has offered an alternative approach to the task, with the students and their course tutor demonstrating great buy-in to the study. The students were given the freedom to report their results with their own conclusions in a Topic Report submitted to contribute to their final degree result (Appendix B). The conclusions of the Topic Report are not supported by Royal Haskoning or the Environment Agency; however the flood event and meteorological research undertaken by the students is a valuable contribution to this study. Furthermore, this study has developed the undergraduates approach to desk based research, their interest in extreme flooding and enabled them direct contact with both industry and regulator which they report is invaluable to their learning.

The idea of utilising the students time to travel the county in pursuit of locally held flood event records did not happen during this study for a number of reasons:

- Limited positive response to initial enquiries by the students from various local organisations.
- Competing time commitments of the third year students.
- Delay in organising the administration of expenses payments for students.

The delay on organising expenses administration has also been cited as a reason by the undergraduates for limited scans or copies of newspapers articles accessed as reference material.

Future collaborations of this kind may benefit from linking with Postgraduate students who may be able to commit more time, have better means of transport for such activities and have greater research experience.

Open communication between the three parties involved in this study has been vital to a successful conclusion, with the Royal Haskoning and Environment Agency Project Managers facilitating this throughout the duration of the study.

8 CONCLUSIONS

There are a wide range of data in a variety of formats and accessibility relating to historic tidal events for the Devon Area. For this first time this research study has enabled a focussed capture of this data for the period 1811 to 1960 into one consistent format to be held centrally by the Environment Agency in the FRIS database.

This process has identified at least 124 incidents of flooding at the coast to be added to the FRIS database with much valuable descriptive information supplied and links to the original source data provided.
In a small number of cases, flood level and extent data has been obtained for these events which is it hoped will be of sufficient confidence (through future validation work) to contribute to local and national datasets.

Established links between Royal Haskoning and Plymouth University have been used to maximise the scope of this study making good use of time and resources. The undergraduate students involved in this study have benefited from working with both regulator and industry in a common field of interest and have made a valuable contribution to the research through the identification of historic flood events and flood level estimation.

The study has benefited enormously from the research and archivist expertise of our Information Systems Researcher, Alison Bethel, who has ensured a systematic approach to the research, minimising the need for future repeat work and maximising the opportunities to follow up leads both through this study and as recommendations for future work.

9 REFERENCES

1607 *Bristol Channel Floods: 400-Year Retrospective* Risk Management Solutions (2007)