Joint Defra / Environment Agency Flood and Coastal Erosion Risk Management R&D Programme

Provision of flood warning information-Observations and Recommendations

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Environment Agency

defra
Department for Environment
Food and Rural Affairs
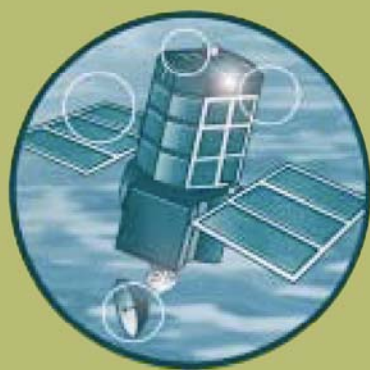
The Environment Agency is the leading public body protecting and improving the environment in England and Wales.

It's our job to make sure that air, land and water are looked after by everyone in today's society, so that tomorrow's generations inherit a cleaner, healthier world.

Our work includes tackling flooding and pollution incidents, reducing industry's impacts on the environment, cleaning up rivers, coastal waters and contaminated land, and improving wildlife habitats.

This report is the result of research commissioned and funded by the Environment Agency's Science Programme.

Environment Agency

Science underpins the work of the Environment Agency. It provides an up-to-date understanding of the world about us and helps us to develop monitoring tools and techniques to manage our environment as efficiently and effectively as possible.

The work of the Environment Agency's Science Department is a key ingredient in the partnership between research, policy and operations that enables the Environment Agency to protect and restore our environment.

The science programme focuses on five main areas of activity:

- **Setting the agenda**, by identifying where strategic science can inform our evidence-based policies, advisory and regulatory roles;

- **Funding science**, by supporting programmes, projects and people in response to long-term strategic needs, medium-term policy priorities and shorter-term operational requirements;

- **Managing science**, by ensuring that our programmes and projects are fit for purpose and executed according to international scientific standards;

- **Carrying out science**, by undertaking research – either by contracting it out to research organisations and consultancies or by doing it ourselves;

- **Delivering information, advice, tools and techniques**, by making appropriate products available to our policy and operations staff.

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1 Introduction

1.1 Background

The Environment Agency is the leading public body for protecting and improving the environment in England and Wales.

During 2005, the Environment Agency concluded a scoping study, technology assessment and field study to assess the needs for future technologies in the dissemination of flood warnings. The results of the study failed to establish a meaningful solution moving forward. The aim of this original project was to demonstrate the reliability, resilience and practicality of a chosen method of warning dissemination in a trial community.

Given the uncertain results garnered from the 2005 project, the Environment Agency wishes to ascertain which technologies are viable for consideration taking into account the practical findings of the initial engagement.

1.2 Objectives

The objectives of this document are to:

- Provide the Environment Agency with a brief appraisal of the current solutions in use.
- Identify the potential technologies of value in flood warnings, identifying where possible the benefits and weaknesses.
- Present an overview of technologies on the horizon that merit future consideration.
- Provide actionable recommendations for the Environment Agency including:
    → Identification of an appropriate solution for immediate contemplation.

2 Solutions, potential technologies and horizon technologies

2.1 Solutions in Use

The solutions presented in Table 1 are fundamental to flood warnings. Each solution is mature and beneficial in its own right and critical to a diverse approach to flood warnings. The recommendations provided in Section 3 are provided in addition to these traditional solutions. The recommendations provided in this report should not be viewed as a replacement.

Table 1 – Solutions in use for flood warning dissemination

Solution	Benefits	Issues / Challenges
Voice Messaging	• Multiple recipients receive same information in short space of time. • Cheaper than continuous mail-shots. • Delivery receipts can be measured. • Can listen for responses via telephone keypad e.g., press 1 to confirm you have heard this message. • Can detect answer machines and voicemail and retry if required.	• Running costs. • Unknown number of messages received if no response. • Unknown if message is understood by recipient. • In severe flood events telephone lines may be impacted.
Loud Hailers	• Ease of use. • Audible (visual) confirmation at site of flood. • Warning messages can be read and adapted in situ. • Flexibility to changing conditions at event. • Mobility. • Low cost.	• Range of loud hailer. • Operation may require power and/or human involvement.
Sirens	• Ease of use. • Audible (visual) confirmation at site of flood. • Flexible to changing conditions at event. • Mobility. • Low cost.	• Range. • Operation may require power and/or human involvement.

Solution	Benefits	Issues / Challenges
Fax Broadcast	• Confirmation in addition to other methods. • Targeted broadcasts to at risk areas buildings. • Typically, always on. • Fax to email conversions (no need for fax to fax communication). • Cheap transmission (pence per send). • Mature technology.	• Declining technology. • Number of fax machines in consumer dwellings. • Non-energy efficient (use of paper, use of energy). • Received documents not legible.
Broadcast Media	• Public reach (60m TV's, 500+ TV channels, 800+ radio stations, 1500+ newspapers, 1900+ magazines, 25m+ vehicles fitted with radios). • Suitable for deaf (subtitles/signing) and blind (audible). • Efficient. • Speed.	• Not 100% ubiquitous (e.g., circa 600k-800k UK homes do not have a TV). • Power loss in severe flooding events. • Control over message.
Flood Wardens	• Dedicated individuals in situ. • Central information point for community. • Knowledgeable respondent to community queries and questions.	• Illness. • Availability of wardens in multiple areas. • Resource intensive.
Internet	• 15m + homes connected to the Internet. • Links with other media especially broadcast media. • Low cost. • Accessible in public areas e.g., libraries, airports, cafes. • Real time updates.	• Not totally ubiquitous especially to some demographics and social groups. • Network availability. • Server errors (downtime). • Relies on recipients being online.
Teletext & Interactive Digital TV	• Back up information service to broadcast TV media – most homes connected to either digital TV (75% of all homes now access digital services) or analogue teletext services.	• Not totally ubiquitous. • Usability – consumer education required.
Signage	• Low cost. • Can be tactically placed in high risk areas. • Advanced 'electronic' signage can be controlled by Environment Agency and updated regularly.	• Vandalism. • Theft. • Weather. • Ongoing cost of replacement signage.

2.2 Potential Technologies

A number of potential technologies are worth consideration for the Environment Agency with regard to flood warning. The technologies highlighted in Table 2, below, could feature in forthcoming community trials.

Table 2 – Potential technologies for flood warning dissemination

Technology	Benefits	Weaknesses
SMS Messaging	• 75 million mobile subscriptions in the UK. • Personal (95% of active UK mobile users cannot go through a day without using their phone). • Mostly always-on technology. • 95% plus of SMS are read (unlike email). • Inclusive for hearing impaired and other members of society. • Easy to manage. • Can link directly into Environment Agency systems. • Delivery receipting. • Interactive messaging. • Automated SMS alerts/warnings. • Dynamic headers facilitate legitimate messaging. • Guaranteed message delivery for working mobile numbers via UK Operators. • Reliability – 99.99% uptime. • Low cost (pence per message). • SMS to email conversions possible. • Concise & Succinct messages. • Several examples of SMS messaging being used in flood warning are noted: Shah Alam Malaysia, Department of Irrigation and Drainage (DID) Malaysia, Oxford C.C UK, Sichuan Province China, Gujarat State India.	• Not totally ubiquitous. • Availability of mobile phone numbers. • Privacy issues (getting end users to opt in to the service). • Messages being misinterpreted. • Network resilience.

Solution	Benefits	Issues / Challenges
GPS	• Ability to locate devices in a given place. • GPS can also identify the speed and direction a device is moving. • Map delivery based upon a users location (suitable in high risk areas). • Gather timely & accurate information for Environment Agency from registered users to a specific service. • Identify registered users in high risk areas. • Alternative to traditional fixed and mobile networks. • Device manufacturer, Garmin, now provide United States county storm and flood warnings to subscribers on their GPS devices. • Anticipate maturity in the next 18 months. The location ecosystem has benefited from standard application interfaces on a wide range of wireless devices e.g., Tom Tom or Garmin.	• Access to GPS devices. • Education of users with GPS devices. • Satellite responsiveness sometimes slow (out of sight). • Ease of use. • Integrity of information received from GPS devices. • Cost. • Management of GPS services.
Mobile Internet Portals	• WAP technology has improved markedly over the past few years. • Mobile internet portals offer a real opportunity to disseminate info. • Consumer education with mobile internet portals moving fast. • Link with SMS and internet campaigns. • Growth of mobile internet – July 2006, 12.5 million subscribers. February 2008, > 17 million mobile subscribers accessed the mobile internet. • Gather consumer data (opt-in information). • Promote other Environment Agency services re: Waste, Water, Recreation. • Easy to manage. • Real time updates. • Additional communication channel. • There is currently little being done in this area. Opportunity exists for the Agency to develop a pioneering mobile internet portal to provide critical information.	• Pervasiveness of mobile internet ready handsets. • Consumer education. • Mobile internet portals require development (as opposed to transcoded websites). • Network availability. • Connection speeds. • Limitations of small screen.

Solution	Benefits	Issues / Challenges
Email Broadcasts	• Coverage. • Mature technology. • Easy to manage. • Reliability. • Reporting and analysis. • Real time campaign management possible. • Personal. • Opt-in lists are highly likely to read warning emails. • Low cost. • Gather feedback from high risk recipients. • Examples include; Chiang Mai Thailand, Pennsylvania Emergency Management Agency, Australian Government Bureau of Meteorology.	• Not all email is read. • Some email treated as spam. • Non-delivery to unrecognized or inactive/out-of-use email addresses. • Accurate email addresses required. • Not inclusive of all UK citizens. • No longer the preferred means of personal communication.
RDS Radio	• Ideal for audio alerts (users can choose to switch radio channel to receive flood warnings). • Can be digitally coded to avoid mal-treatment of service. • Suitable for sight impaired. • Low cost. • RDS features an Emergency Warning System (EWS). • Fast & cost-efficient warning of flood events.	• Potential to be replaced by DAB in the long-term (10 years+). • Not ubiquitous. • Unsuitable for hearing impaired.

Solution	Benefits	Issues / Challenges
DAB Radio	• Quality of sound (higher data rates than RDS radio). • Broadcast media. • Flexibility. • Suitable for sight impaired. • Multiple radio stations in the UK are now broadcasting flood warnings.	• Restricted coverage until 2009 and beyond. • Not ubiquitous technology. • Access to DAB radio devices. • Unsuitable for hearing impaired.
SMS Cell Broadcast	• No knowledge of telephone numbers required. • Messages can be restricted to a geographical area. • Cell broadcast is low cost and low loading on a mobile network – this overcomes problems of mobile networks failing in a disaster event. • An example of this deployment is observed on DHI Water & Environment in Denmark.	• Possible in the UK but restricted in use by mobile network operators. • No delivery receipting possible. • Legal provision an issue – who is responsible for the service. • Lack of public faith in the service. • Network operators unwilling to be liable for inaccurate information sent out to the public. • Capacity and coverage of given cell is dynamic in nature – always changing. • Additional generations of mobile technology (3G) add complexity to the structure of a cell which is already layered with overlapping cells of different sizes e.g., umbrella, overlaid, macro, micro and pico cells. • Mobile Network resistance of allowing a 'flood warden' i.e. member of the public to distribute a cell broadcast would be excessively high.
LBS	• Possibility for location based 'flood warning' information to be delivered direct to the mobile handset or device – potential to combine information with maps showing high risk flooding areas. • Low cost. • Will reach maturity over the next 18 months.	• Privacy issues. • User education with LBS services. • Accuracy of information could be insufficient in floods that are very localized (generally accepted radius of 500m). • Not available for use with 3 network or Virgin Media (approx 7% of UK subscribers).

Solution	Benefits	Issues / Challenges
Bluetooth	• Potential for Bluetooth information points to be placed in high risk areas or deployment of sensors at flood prone sites. • Mobile users can pick up warning information from Bluetooth enabled kiosks. • Data from sensors can be processed using spatial or point based prediction algorithms, the results of which can be used to issue flood warnings. • Can be included in a Bluetooth/WiFi/GPRS solution – network types change when water submersion is predicted. • Secure and reliable. • Real time updates. • Information can be localized. • Bluetooth is less than two years away from mass market adoption in a number of different applications.	• Installation costs; expensive. • Maintenance of Bluetooth equipment. • Open to vandalism. • Privacy. • Area of broadcast coverage very localized (sub 100 metres).
ZigBee (802.15.4)	• Potential for ZigBee information points to be placed in high risk areas or mesh networks to forecast flood events. • Mobile users can pick up warning information from ZigBee enabled kiosks. • Secure and reliable. • Real time updates. • Information can be localized. • Low power requirement. • Low data rates. • Mesh sensor network – every node is a router for its neighbours (vs. WiFi star network (central hub) orientation) – ZigBee could connect to a GPRS GSM concentrator and broadcast messaging (200-500m apart). • Able to react to rainfall occurrences. • Currently in use for in-building networks, environmental sensors (changes in temperature, humidity, water levels, soil moisture – flood forecasting), and energy efficiency. • We're currently 12 months to 3 years away from seeing the maturity of ZigBee.	• Installation costs; could be expensive. • Maintenance of ZigBee equipment. • Open to vandalism. • Privacy.

Solution	Benefits	Issues / Challenges
Satellite Messenger Handsets	• Ideal for emergency situations. • Satellite messenger handsets can send an information message and exact location (linked to Google Maps with full aerial and birds eye views) to a given application or contact emergency services if required. • Repeats message every 5 minutes to Coast Guard, RNLI, Emergency Teams. • Easy to use. • Small lightweight devices. • Waterproof. • Could potentially be partially funded for the <2.5 million homes located in high risk flood areas for England and Wales. • Overcomes issue of unavailable mobile networks and GPS navigation systems in an actual disaster.	• Access to Satellite Messenger Handsets. • Consumer education. • Satellite responsiveness sometimes slow (out of sight). • Integrity of information received from satellite messenger devices (open to misuse). • Battery life may be an issue, handsets operate on AA batteries.

2.3 Horizon Technologies

The following technologies are currently out of reach as potential solutions. These technologies have been discussed in 'next wave' forums for some time – stretching back to 2000. The technologies included in this section are provided for awareness only. Hence, the brevity of information provided. Providing indicative costs is difficult to achieve as many of these technologies are in trial or not deployed widely.

Table 3 – Horizon technologies for flood warning dissemination

Technology	Description
Location Aware Applications	Over the next five years, an array of location aware applications will prevail on GPS enabled devices. This will mainly be to support field force management and fleet management, although potential exists to extend the use of these location aware applications into the consumer world and especially flood warnings where location is important. Reconsideration of GPS devices is recommended during the next two to five years and these applications on enhanced devices prevail.
4G	The next generation of mobile technology providing a comprehensive IP solution for voice, data and multimedia. The development of 4G will emerge as wired and wireless networks converge. The networks will operate seamlessly at high data rates both in building and outdoors. The notion of 4G has been in existence since the turn of this century. The ultimate goal of the next generation of mobile technology is to support applications such as multimedia messaging service (MMS), high definition TV (HDTV) and Digital Video Broadcasting. The focus will be streaming services providing 'anytime-anywhere' applications to consumers and enterprises alike. The real impact of 4G will begin to be realised in earnest in 2010 as a wider number of operators roll out services in the UK. Global trials have begun in 2007 and are ramping up in 2008. Examples include NTT DoCoMo (Japan), Sprint (USA) and Digiweb (Ireland). Expect 4G to be mainstream before 2015.
Push To Talk	During the next two to five years, push to talk services over mobile is highly likely to proliferate. A variety of multimedia messages including photos, videos, email and text will converge into a single application. A high profile service is already deployed in the UK by Leicestershire Police who uses Orange's service as a back up to their TETRA radio network.

Technology	Description
Ad Hoc Networks	Sometimes referred to as 'Sensor Mesh Networks', self configuring networks able to operate on a standalone basis or connected to the larger Internet. They are meshes of peer nodes containing simple networking, computing and sensing capabilities. Low power operation and multi year battery life are key features of this horizon technology allowing for self organizing networks capable of transmitting small data transmissions (such as flood warnings). This is a very immature market and characteristically fragmented. A great deal of propaganda has surrounded this technology. In truth, mainstream adoption could be ten or more years away as early implementations are likely to become obsolete and refined very quickly.
UWB & Personal Area Networks	High bandwidth communication network operating a low energy levels (by using a larger amount of radio spectrum) suitable for short range and indoor applications. This could be suitable in flood risk areas throughout the UK. The technology can be used in conjunction with location systems and, more importantly, real time location systems. This is particularly important as personal area networks (PANs) evolve. PANs will network computers, telephones and mobile devices close to one person utilising WiFi, Bluetooth, ZigBee and UWB technologies. These networks are evolving and during the next two to five years will become more pervasive amongst consumers making it easier for flood warning information to reach an individual regardless of their location.
Software Defined Radio (SDR)	A radio communication system implemented using software as opposed to hardware. In the longer term, SDR is likely to become the dominant technology in radio communications due to its flexibility, although timescales are still unclear.

3 Conclusions and Recommendations

3.1 Conclusions

A number of technologies exist that may have a significant role to play in flood warning dissemination as well as for members of the public in different environments and situations. Each technology has its major strengths and could be considered viable in different environments. It should be recognised that it could be practically, logistically and economically unrealistic to capture all technologies in a generic solution. However, a combination of a 'few' pervasive technologies can be harnessed to deliver a powerful solution that is simple (from a citizen perspective), cost effective and efficient.

This section includes recommended technologies and overall proposed solution for the Environment Agency. This recommendation is based upon a review of all the available technologies, a high level assessment of the practical use of these technologies in at risk communities and real world experience with technologies that can be utilised for most impact.

3.2 Recommendations

Proposed Solution

From the wide range of technologies that are readily available today, a powerful solution exists by combining the technologies outlined below:

- Response to flooding events – *incidents*
- Provision of flood *alerts*
- Dissemination of flood warning *information*

The proposed solution would allow for citizen initiated warnings via SMS and then subsequent alerting to groups by the same method. Other proposed elements of the solution would allow for a converged mobile solution providing access to more detailed information relating to areas at risk, registration and group management. This would be via voice calls and the use of mobile internet.

The proposed solution contains some existing elements of the Environment Agency's Flood Warnings Direct but should be seen as an enhanced solution to the current service.

Table 4 – Provisional solution for the Environment Agency

Technology Components & Role in Solution

Core component	Technology Recommendation	Solution
Incidents	• SMS • Mobile Internet (WAP) • Inbound Voice IVR using Text to Speech & Speech Recognition • LBS (Location Based Services)	• SMS inbound messages from citizens to initiate an incident report using their mobile handset. • Mobile Internet portal to allow for incident reporting using full media rich service. • Inbound telephony IVR to allow for reporting and recording of incidents. • All the above to utilise LBS as an identifier of incident and/or to reduce data set required to identify the radius of incident. This would create a subset of 'citizens' who would then require notifying of an alert.
Alerts	• SMS • Voice Messaging	• System initiated SMS and voice messaging (Landline & Mobile) to user groups based on incident alerts provided via 'flood warden' and/or automatic reception of an 'Incident'.
Information	• Mobile Internet (WAP) • Internet	• Citizen: Handset/Device Mobile Internet Portal and traditional Internet site to allow for specific information to current and/or expected alerts. Also provides for • Flood Warden: Ability to create and manage groups of 'local' subscribers. Create and send alerts.

Assumptions:
- All available data sources, links and communications are provided for between the solution provider and the Environment Agency
- Reporting is provided for all management information as part of the solution
- Multi tiered access rights are provided for
- User identification and verification is provided for by using appropriate Agency procedures – such as Government Gateway.

3.3 Costs

Where possible standard application components should be used to negate costs but bespoke development of mobile internet and traditional internet services would be required. For a detailed costing to be provided for – further information on the appropriate services required would need to be agreed.

The headline areas which will require a detailed cost breakdown are:

- Consultancy
- Project Management
- Development
- Testing
- Implementation
- Hosting
- User Training
- Marketing.

It is suggested that a fuller functional study be prepared to determine actual costs but at this stage a suggested high level breakdown would be:

Description	Man Days	Cost
Consultancy	5	£3,750
Project Management	5	£3,750
Application Development	25	£18,750
Testing	10	£7,500
Training	20	£15,000
Total	**65**	**£48,750**

The above excludes any marketing associated with the launch of the service. It also provides for a current nominal sum for user training. At this stage the audience and exact number have not been identified, but an assumption of 1% of a target population (10,000 citizens) would require a maximum of one days training. Hosting and use of mobile short codes are excluded from the above. The former would be determined by the overall solution and the latter is available via standard industry costs.

3.4 Audience

The intention would be to provide a solution that would be inclusive to as many members of society as possible with the defined technology. The technology suggested principally SMS and voice is as close to 100 percent inclusive of the UK population as possible. Handset penetration in the UK is in excess of 90 percent. The priority would be to deliver an application that allows for easy reporting and dissemination of messages to the user audience. This would need to encompass both registration of subscribers and the management of those groups.

Specific user reference would need to be made to allow for simple adoption of the service by Environment Agency selected members of the public. This would be achieved by effective development of the UI and UE. The suggested approach is to provide a simple web user access to allow for group management and sending of alerts.

3.5 Coverage

The solution will be scalable and provide for greater adoption by other communities if required. A valid user of the service would have to have either a mobile telephone or a landline telephone. This would accommodate the highest majority of the population (adult 18+).

List of abbreviations

MI   Management Information
UI   User Interface
UE   User Experience

Glossary

3G   Third Generation Mobile

3G refers to the third generation of developments in wireless technology, especially mobile communications. 3G includes capabilities and features such as:

- Enhanced multimedia (voice, data, video, and remote control).
- Usability on all popular modes (cellular telephone, e-mail, paging, fax, videoconferencing, and web browsing).
- Broad bandwidth and high speed (upwards of 2 Mbps).
- Roaming capability throughout Europe, Japan, and North America.

4G   Fourth Generation Mobile

4G is the short term for fourth-generation wireless, the stage of broadband mobile communications that will supersede the third generation (3G). End-to-end IP and high-quality streaming video will be among 4G's distinguishing features.

DAB   Digital Audio Broadcast

Digital radio technology for broadcasting radio stations. Benefits include more stations, less piracy interference, reception quality, variable bandwidth, improved end user features such as radio text.

GPS   Global Positioning Service

GPS is a fully functional Global Navigation Satellite System (GNSS). GPS uses 24 Medium Earth Orbit (MEO) satellites transmitting precise microwave signals, the system enables a GPS receiver located within a device to determine location, speed, direction, and time.

IVR   Interactive Voice Response

IVR is a phone technology allowing a computer to detect voice and touch tones using a normal phone call. IVR systems can respond with pre-recorded or dynamically generated audio to further direct callers on how to proceed.

LBS   Location Based Services

LBS information services are accessible with mobile devices through mobile networks. The service has the ability to make use of the location of the mobile device. For example, by sending location sensitive information to the handset or device.

RDS   Radio Data System

RDS is a European Broadcasting standard for sending small amounts of digital information using conventional FM radio broadcasts. The RDS system standardises several types of information transmitted, including time, track/artist info and station identification.

SMS   **Short Message Service**

SMS is a communications protocol allowing the exchange of short messages between mobile devices.

UWB   **Ultra Wideband**

High bandwidth communication network operating a low energy levels (by using a larger amount of radio spectrum) suitable for short range and indoor applications.

WAP   **Wireless Application Protocol**

WAP enables access to the internet via a mobile phone or device.

We are The Environment Agency. It's our job to look after your environment and make it **a better place** – for you, and for future generations.

Your environment is the air you breathe, the water you drink and the ground you walk on. Working with business, Government and society as a whole, we are making your environment cleaner and healthier.

The Environment Agency. Out there, making your environment a better place.