Public Document Pack

Hampstead Heath, Highgate Wood and Queen's Park Committee

Date: **THURSDAY, 9 MAY 2013**

Time: **11.00 am**

Venue: **COMMITTEE ROOMS, 2ND FLOOR, WEST WING, GUILDHALL**

Members:
Deputy John Barker
Dennis Cotgrove
Karina Dostalova
Revd Dr Martin Dudley
Clare James
Professor John Lumley
Barbara Newman
Deputy John Owen-Ward
Virginia Rounding
Jeremy Simons
Tom Sleigh
Deputy Michael Welbank
Alderman Bob Hall (Ex-officio)

For Consideration of Business Relating to Hampstead Heath Only:

Councillor Melvin Cohen - (London Borough of Barnet)
Councillor Sally Gimson - (London Borough of Camden)
Charlotte Kemp - (English Heritage)
Tony Ghilchik - (Heath & Hampstead Society)
Maija Roberts - (Ramblers Association/Open Spaces Society)
Martyn Foster - (RSPB)

Enquiries: **Jacky Compton**
tel.no.: 020 7332 1174
jacky.compton@cityoflondon.gov.uk

Lunch will be served in the Guildhall Club at 1pm

John Barradell
Town Clerk and Chief Executive

AGENDA

Part 1 - Public Agenda

1. **APOLOGIES**

2. **MEMBERS DECLARATIONS UNDER THE CODE OF CONDUCT IN RESPECT OF ITEMS ON THIS AGENDA**

3. **ORDERS OF THE COURT OF COMMON COUNCIL, 25 APRIL 2013**

   Orders, Court of Common Council, 25 April 2013:-

   (i) appointing the Committee;

   (ii) approving the Committee's Terms of Reference (copy attached).

   For Decision
   (Pages 1 - 2)

4. **ELECTION OF CHAIRMAN**

   To elect a Chairman pursuant to Standing Order 29.

   For Decision

5. **ELECTION OF DEPUTY CHAIRMAN**

   To elect a Deputy Chairman pursuant to Standing Order 30.

   For Decision

6. **MINUTES**

   To agree the public minutes and summary of the meeting held on 15 April 2013 (copy attached).

   For Decision
   (Pages 3 - 10)

7. **2013/14 COMMITTEE APPOINTMENTS**

   Report of the Town Clerk (copy attached).

   For Decision
   (Pages 11 - 16)

Hampstead Heath

8. **HAMPSTEAD HEATH PONDS PROJECT - ASSESSMENT OF THE DESIGN FLOOD**

   Report of the Superintendent of Hampstead Heath (copy attached).

   For Decision
   (Pages 17 - 132)

9. **QUESTIONS ON MATTERS RELATING TO THE WORK OF THE COMMITTEE**

10. **ANY OTHER BUSINESS THAT THE CHAIRMAN CONSIDERS URGENT**

11. EXCLUSION OF THE PUBLIC

MOTION: That under Section 100A(4) of the Local Government Act 1972, the public be excluded from the meeting for the following items of business on the grounds that they involve the likely disclosure of exempt information as defined in Part I of Schedule 12A of the Local Government Act as follows:-

Item No.	Paragraphs in Schedule 12A
12-18	3

Part 2 - Non-Public Agenda

12. NON-PUBLIC MINUTES

To agree the non-public minutes of the meeting held on 15 April 2013 (copy attached).

For Decision
(Pages 133 - 134)

13. GOLDERS HILL PARK CAFE - LEASE RENEWAL

Report of the City Surveyor (copy attached).

For Decision
(Pages 135 - 138)

14. HIGHGATE WOOD CAFE - LEASE RENEWAL

Report of the City Surveyor (copy attached).

For Decision
(Pages 139 - 142)

15. PARLIAMENT HILL CAFE - LEASE RENEWAL

Report of the City Surveyor (copy attached).

For Decision
(Pages 143 - 146)

16. QUEEN'S PARK CAFE - LEASE RENEWAL

Report of the City Surveyor (copy attached).

For Decision
(Pages 147 - 150)

17. QUESTIONS ON MATTERS RELATING TO THE WORK OF THE COMMITTEE

18. ANY OTHER BUSINESS THAT THE CHAIRMAN CONSIDERS URGENT AND WHICH THE COMMITTEE AGREE SHOULD BE CONSIDERED WHILST THE PUBLIC ARE EXCLUDED

GIFFORD, Mayor	**RESOLVED:** That the Court of Common Council holden in the Guildhall of the City of London on Thursday 25th April 2013, doth hereby appoint the following Committee until the first meeting of the Court in April, 2014.

HAMPSTEAD HEATH, HIGHGATE WOOD & QUEEN'S PARK COMMITTEE

1. **Constitution**
A Non-Ward Committee appointed pursuant to the London Government Reorganisation (Hampstead Heath) Order 1989 consisting of not fewer than 18 Members in the following categories:-

- not fewer than 12 Members elected by the Court of Common Council, at least one of whom shall have fewer than five years' service on the Court at the time of their appointment
- the Chairman and Deputy Chairman of the Open Spaces, City Gardens & West Ham Park Committees (ex-officio)
- plus, for the consideration of business relating to Hampstead Heath only, at least six representatives who must not be Members of the Court of Common Council or employees of the City of London Corporation and at least six of whom are to be appointed as follows:-
    - one after consultation with the London Borough of Barnet
    - one after consultation with the London Borough of Camden
    - one after consultation with the owners of the Kenwood lands
    - three after consultation with bodies representing local, ecological, environmental or sporting interests

The Chairman of the Committee shall be elected from the City Corporation Members.

2. **Quorum**
A. For Hampstead Heath business the quorum consists of seven Members, at least one of whom must be a non-Common Council Member.

B. For Highgate Wood and Queen's Park business the quorum consists of three Members.

3. **Membership 2013/14**
14 (4) Dennis Cotgrove, B.A.
1 (1) Karina Helen Dostalova, *for one year*
8 (4) Michael Welbank, Deputy
3 (3) The Revd. Dr. Martin Dudley
3 (3) Clare James, M.A.
1 (1) Thomas Charles Christopher Sleigh, *for two years*
5 (2) Barbara Patricia Newman, C.B.E.
3 (2) Virginia Rounding
2 (2) John Richard Owen-Ward, M.B.E., Deputy
12 (1) John Alfred Barker, O.B.E., Deputy
8 (1) Jeremy Lewis Simons MSc.
1 (1) John Stuart Penton Lumley

Together with the ex-officio Members referred to in paragraph 1 above and the following representatives from outside organisations:-

Heath and Hampstead Society	-	Tony Ghilchik
English Heritage	-	Charlotte Kemp
Royal Society for the Protection of Birds	-	Martyn Foster
London Borough of Barnet	-	Councillor Melvin Cohen
London Borough of Camden	-	Councillor Sally Gimson
Ramblers' Association/Open Spaces Society	-	Maija Roberts

4. **Terms of Reference**
To be responsible, having regard to the overall policy laid down by the Open Spaces, City Gardens & West Ham Park Committees, for:-

Hampstead Heath

(a) devising and implementing the City of London Corporation's policies and programmes of work in relation to Hampstead Heath (registered charity no. 803392) (and, in fulfilling those purposes, to have regard to any representations made to it by the Hampstead Heath Consultative Committee) in accordance with the London Government Re-organisation (Hampstead Heath) Order 1989;

(b) exercising all the City of London Corporation's powers and duties relating to Hampstead Heath, including those set out in Regulation 5 of the London Government Re-organisation (Hampstead Heath) Order 1989, or in any Act or Statutory Instrument consolidating, amending or replacing the same;

Highgate Wood & Queen's Park

(c) devising and implementing the City of London Corporation's policies and programmes of work in relation to Highgate Wood and Queen's Park (registered charity no. 232986)) (and, in fulfilling those purposes, to have regard to any representations made to it by the Highgate Wood Joint Consultative Committee and the Queen's Park Joint Consultative Group) in accordance with the provisions of the Highgate Wood and Kilburn Open Spaces Act 1886;

Consultative Committees

(d) appointing such Consultative Committees as are considered necessary for the better performance of its duties including a,
Hampstead Heath Consultative Committee
Highgate Wood Joint Consultative Committee
Queen's Park Joint Consultative Group

Barradell.

HAMPSTEAD HEATH, HIGHGATE WOOD AND QUEEN'S PARK COMMITTEE
Monday, 15 April 2013

Minutes of the meeting of the Hampstead Heath, Highgate Wood and Queen's Park Committee held at Committee Room - 2nd Floor West Wing, Guildhall on Monday, 15 April 2013 at 1.45 pm

Present

Members:
Jeremy Simons (Chairman)
Deputy Michael Welbank (Deputy Chairman)
Deputy John Barker
Dennis Cotgrove
Revd Dr Martin Dudley
Clare James
Barbara Newman
Deputy John Owen-Ward
Virginia Rounding
Alderman Robert Hall (Ex-Officio Member)
Councillor Sally Gimson
Tony Ghilchik
Maija Roberts
Martyn Foster

Officers:

Jacky Compton	-	Committee & Member Services Officer
Esther Sumner	-	Policy Officer, Town Clerk's Department
Sue Ireland	-	Director of Open Spaces
Simon Lee	-	Superintendent of Hampstead Heath
Grace Rawnsley	-	Hampstead Heath Department
Alison Elam	-	Group Accountant, Chamberlain's Department
Edward Wood	-	Comptroller and City Solicitor's Department
Bob Meldrum	-	City Surveyor's Department

CHAIRMAN'S GOODBYE
The Chairman, on behalf of the Committee, wished to say farewell to a number of Members who were not re-elected and wished to thank them for their hard work and support on the Committee over the years.

The Chairman advised the Committee that he would write to those Members personally.

1. **APOLOGIES**
Apologies were received from Councillor Melvin Cohen and Charlotte Kemp.

2. **MEMBERS DECLARATIONS UNDER THE CODE OF CONDUCT IN RESPECT OF ITEMS ON THIS AGENDA**
There were none.

3. **MINUTES**
The public minutes and summary of the meeting held on 28 January 2013 were approved as a correct record.

Matters Arising
Dog Control Orders (page 2) – The Chairman advised that a report would be coming to the Committee in the autumn.

Postponement of SEAA Cross Country (page 3) – This event was **postponed** due to the spell of bad weather.

4. **HAMPSTEAD HEATH CONSULTATIVE COMMITTEE - MINUTES**
The draft public minutes of the meeting of the Hampstead Heath Consultative Committee meeting held on 11 March 2013 were received.

Matters Arising
Thanks to Bob Slowe (page 16) – The Chairman of the Open Spaces, City Gardens and West Ham Park Committee advised the Committee that Bob Slowe, a longstanding member of the Hampstead Heath Consultative Committee and Chairman of the Hampstead Heath Sports Advisory Forum had relinquished his post and the Chairman wished to place on record his thanks and appreciation for all the hard work that Bob Slowe had put into the Forum.

The Chairman stated that he would write to Bob Slowe on behalf of this Committee.

5. **OPEN SPACES DEPARTMENT BUSINESS PLAN 2013-2016 - KEY PROJECTS**
The Committee considered a report of the Director of Open Spaces relative to the Open Spaces Department Business Plan 2013-16 and outlining the Key Projects which will be included in the Plan.

RESOLVED: That Members note and agree the Key Projects for Hampstead Heath, Highgate Wood and Queen's Park, for inclusion in the Open Spaces Department Business Plan for 2013-16.

Hampstead Heath

6. **SUPERINTENDENT'S UPDATE**
The Superintendent was heard on matters relating to Hampstead Heath as follows:

National Grid Works
The Superintendent updated the meeting on the reinstatement works associated with the National Grid works. Inclement weather conditions had

resulted in delays to the programme of reinstatement but contractors were on site last week and Parliament Hill Fields site is ready for seeding.

Planning
An article published in the Observer on Sunday 14th April identified issues with major developments in the immediate environs of the Heath in the Fitzroy Farm area and their impact on Hampstead Heath.

The Superintendent advised that an objection had been lodged with Camden Council concerning an application for further development of The Garden House, a property on private Metropolitan Open Land.

In response to a question the Superintendent advised that he had sent a copy of the "Policies for the Fringes of the Heath" a former Camden planning document to the Chairman of the Highgate Neighbourhood Forum. He also advised that he and the Ponds Project Communication Officer had met with Members of the Highgate Neighbourhood Forum and walked the Highgate chain of ponds.

It was confirmed that Dartmouth Park were also likely to be designated a Neighbourhood Forum.

New Heath Diary
The superintendent referred to copies of the 2013 Heath diary that were laid around the table and thanked David Bentley his Communications Officer for leading the publication of this important document. Over 60,000 copies are distributed each year.

City Dip
The Superintendent was delighted to announce that the Parliament Hill Fields Lido was participating in the annual City Dip Lord Mayor's Charity appeal on the 7th and 8th June 2013. The Lord Mayor would be attending the event on the 8th June 2013.

Hampstead Heath Ponds Project
The Superintendent updated Committee on progress of the project in terms of further consultation with the wider community, including attending the local Highgate Area Action Forum chaired by Councillor Sally Gimson. A very useful visit to Abberton Reservoir a multi-million pound reservoir currently under construction had taken place with officers and members of the Ponds Project Stakeholder Group.

7. **HAMPSTEAD HEATH PONDS PROJECT - ASSESSMENT OF THE DESIGN FLOOD**

This report had been WITHDRAWN. The Chairman advised the Committee that this report would be considered at a special meeting of the Committee scheduled to take place shortly.

8. **HAMPSTEAD HEATH EDUCATION SERVICE - ANNUAL REPORT 2012**

The Committee received a report of the Superintendent of Hampstead Heath reporting the success and key achievements of the Hampstead Heath Education Service in 2012, including its work on formal and informal education, community education and partnership working.

RECEIVED.

9. **REVIEW OF HAMPSTEAD HEATH 2012 OLYMPIC AND PARALYMPIC GAMES - GREEN TO GOLD ACTIVITIES**

The Committee received a report of the Superintendent of Hampstead Heath relative to the success of the Green to Gold campaign and events held on Hampstead Heath in support of the London 2012 Olympic and Paralympic Games.

The Chairman, on behalf of the Committee, wished to thank Paul Maskell for all his hard work and contribution in arranging these events.

RECEIVED.

10. **REVIEW OF AFFORDABLE ART FAIR ON HAMPSTEAD HEATH IN 2012 AND PROPOSALS FOR 2013 AND BEYOND**

The Committee considered a report of the Superintendent of Hampstead Heath relative to reviewing the success of the Affordable Art Fair that was held at East Heath between 1st and 4th November 2012, that attracted 18,500 adult visitors over the course of four and a half days generating £2.8 million of art work sales by the 107 galleries exhibiting.

RESOLVED: That Members –

1) Note the success of the 2012 Affordable Art Fair in welcoming 18,500 (adult) visitors to the Heath and raising additional income to support management of the site;
2) Note the plans that are underway with regards the June 2013 event; and
3) Approve the principle of hosting another event on the back of the Affordable Art Fair in June 2014, subject to a further more detailed report later in 2013.

11. **REVIEW OF THE HAMPSTEAD HEATH SUMMER EVENTS PROGRAMME 2012**

The Committee received a report of the Superintendent of Hampstead Heath relative to the 2012 summer events programme at Hampstead Heath.

RECEIVED.

12. **PROVISIONAL ADDITIONAL WORKS PROGRAMME 2014/15**

The Committee considered a report of the Superintendent of Hampstead Heath setting out a provisional list of cyclical projects being considered for Hampstead Heath, Highgate Wood and Queen's Park in 2014/15 under the "additional works programme".

A Member enquired as to the future of the Athletics Track. The Superintendent advised that resources were currently unavailable within the organisation and that an investment would need to be sought for any improvement works to be undertaken.

RESOLVED: That the Committee's views be sought on the provisional list of works.

Highgate Wood and Queen's Park

13. **SUPERINTENDENT'S UPDATE**

The Superintendent was heard on matters relating to Highgate Wood and Queen's Park as follows:

Visit by Lord Mayor to Queen's Park

The Lord Mayor together with the Lady Mayoress and Chairman of the Management Committee visited Queen's Park on the 1st March 2013 and welcomed the Mayor of Brent and other guests. At the end of the tour of the park a tree was planted to celebrate the visit.

Conservation Management Plan

The first draft of a Conservation Management Plan for Queen's Park has been produced following consultation and workshops with local stakeholders. It is envisaged that this document will be discussed at the next meeting of the Queen's Park Joint Consultative Group.

Photovoltaic at Highgate Wood Machine Shed

The Superintendent advised Committee of further work being undertaken with the support of the City Surveyors Division to install photovoltaic cells on the roof of the machine shed in the Deport that would assist with reducing energy costs. A planning application for these works had been approved by Haringey Council.

14. **DECISION TAKEN UNDER DELEGATED AUTHORITY**

The Committee received a report of the Town Clerk providing details of action taken by the Town Clerk in consultation with the Chairman and Deputy Chairman of this Committee relative to the Highgate Wood Conservation Management Plan.

RECEIVED.

15. **QUESTIONS ON MATTERS RELATING TO THE WORK OF THE COMMITTEE**
There were no questions.

16. **ANY OTHER BUSINESS THAT THE CHAIRMAN CONSIDERS URGENT**
Oak Processionary Moth
The Director of Open Spaces updated the Committee on the latest situation with regards to Oak Processionary Moth. She advised that a bid had been submitted to DEFRA for the Forestry Commission to spend £5m on tackling the Oak Processionary Moth across London.

The Chairman of the Open Spaces Committee, on behalf of the Committee thanked the Director of Open Spaces for all her hard work on the subject and advising us of the problem.

17. **EXCLUSION OF THE PUBLIC**
RESOLVED: That under Section 100A(4) of the Local Government Act 1972, the public be excluded from the meeting for the following items of business on the grounds that they involve the likely disclosure of exempt information as defined in Part I of Schedule 12A of the Local Government Act as follows:-

Item No.	Paragraphs in Schedule 12A
18	3
19	3
20-21	-

18. **NON-PUBLIC MINUTES**
The Committee approved the non-public minutes of the meeting held on 28 January 2013 as a correct record.

19. **CITY OF LONDON PARKING SERVICE CONTRACTS**
The Committee considered a report of the Director of the Built Environment relative to the City of London Parking Service Contracts.

20. **QUESTIONS ON MATTERS RELATING TO THE WORK OF THE COMMITTEE**
There were no questions.

21. **ANY OTHER BUSINESS THAT THE CHAIRMAN CONSIDERS URGENT AND WHICH THE COMMITTEE AGREE SHOULD BE CONSIDERED WHILST THE PUBLIC ARE EXCLUDED**
There were no urgent items.

The meeting ended at 3pm

Chairman

Contact Officer: Jacky Compton
Tel No. 020 7332 1174
Jacky.Compton@cityoflondon.gov.uk

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Committee(s): Hampstead Heath Queen's Park & Highgate Wood Committee	Date(s): Monday 20 May 2013	Item no.
Subject: Committee appointments for 2013/2014		
Report of: Town Clerk	**Public** For Decision	
Ward (if appropriate):		

Summary

The Committee is asked to consider its appointments for the next twelve months. Appointments made to the various Consultative Committees and Joint Consultative Group during 2012/13 are explained in the attached appendix.

The appointment of the Committee's local representative to the Open Spaces and City Gardens Committee and West Ham Park Committee will also need to be confirmed.

Recommendation:

- That you consider the Committee's appointments to the Hampstead Heath and Highgate Wood Joint Consultative Committees as well as the Queen's Park Joint Consultative Group for 2013/2014; and
- That the Committee's local representative to the Open Spaces and City Gardens Committee and West Ham Park Committee for 2013/14 be ascertained;

Main Report

Background

1. The Committee makes a number of appointments to Consultative Committees and a Joint Consultative Group that fall within its remit. These are considered annually.

2. The constitution of the Hampstead Heath Consultative Committee provides that it shall consist of the Chairman of the Management Committee and not less than 19 other members of whom one shall be appointed from among the members of this Committee. Your customary practice has been to appoint your Chairman and Deputy Chairman for the time being.

3. The City membership of the Highgate Wood Joint Consultative Committee comprises the Chairman and Deputy Chairman for the time being and three other Members of this Committee.

4. The City membership of the Queen's Park Joint Consultative Group currently includes your Chairman and Deputy Chairman and three other Members of this Committee. The membership of the Queen's Park and Highgate Wood Consultative Groups is not as strictly determined as the Hampstead Heath Consultative Committee.

5. The arrangement whereby a local representative from the Management Committee attends the Open Spaces Committee was formalised in 2008. Following the Governance Review agreed in March 2011, a new Committee comprising the Open Spaces, City Gardens and West Ham Park Committee was formed in April of this year. At a recent Governance Review meeting in February 2013, two individual Committees were formed, the Open Spaces and City Gardens Committee and West Ham Park Committee. The Hampstead Heath Queen's Park & Highgate Wood Committee continues to have the right to appoint a local representative to serve as an observer on this Committee, but only in respect of its strategic open spaces capacity (and not for the City Gardens and West Ham Park parts of the agenda).

Options

6. That consideration be given to making the various appointments detailed in the report, from amongst the Committee membership.

Corporate & Strategic Implications

7. There are no Corporate & Strategic Implications.

Implications

8. By recommending a partnership and engagement approach, this report supports the City Together Theme: A World Class City, which supports our communities and the associated departmental strategic and improvement aims to work in partnership with communities and local authorities.

Conclusion

9. That consideration be made to making appointments to the various Consultative Committees and Joint Consultative Group detailed in the report.

Contact:
Jacky Compton
Jacky.Compton@cityoflondon.gov.uk | Tel: 020 7332 1174

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Appendix 1

2012/13 Appointments

Hampstead Heath Consultative Committee

City Members:
Jeremy Simons (Chairman)
Deputy Michael Welbank (Deputy Chairman)

Highgate Wood Joint Consultative Committee

City Members:
Jeremy Simons (Chairman)
Deputy Michael Welbank (Deputy Chairman)
Dennis Cotgrove
Barbara Newman
Dr Peter Hardwick *(no longer on the Court)*

Queen's Park Joint Consultative Group

City Members:
Jeremy Simons (Chairman)
Deputy Michael Welbank (Deputy Chairman)
Dennis Cotgrove
Barbara Newman
Virginia Rounding

Local representative to Open Spaces Committee

Tony Ghilchik

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Committee(s):	Date(s):
Hampstead Heath, Highgate Wood and Queen's Park Management Committee	9th May 2013
Subject: Hampstead Heath Ponds Project – Assessment of the Design Flood	**Public**
Report of: **Superintendent of Hampstead Heath**	**For Approval**

Summary

This report sets out the results on the first major task undertaken by the Design Team in relation to the Hampstead Heath Ponds Project. The City of London agreed that before any work commenced on preparing options and detailed design solutions the Design Team would undertake a Fundamental Review of the basis for the whole project. This work was deemed necessary by the City Corporation following the independent peer review of the original feasibility study and was also requested by the members of the Hampstead Heath Ponds Project Stakeholder Group.

The review utilises industry standards and software, ensuring that the work is in line with current industry best practice to determine "extreme rainfall events" and their impact on the earth dams across the Hampstead and Highgate chains of ponds. The work undertaken by Atkins follows the methodology set out in their Design Review Method Statement approved in December 2012.

The results show that, in adopting industry best practice and nationally derived data-sets, there remains an unacceptable risk from overtopping the dams. This could potentially result in their failure thereby releasing the stored water to inundate communities south of the Heath, with potential loss of life.

The new study has revealed that flood peaks are between 30-50% lower than those that were modelled by previous hydrologists, which used locally derived data-sets, as the basis to determine the maximum floods.

At this stage Atkins believes these results could reduce the overall impact on the Heath but that storage is still necessary, to help hold back water in major rainfall events, mitigating impacts on other ponds.

The results of this study have been considered by the Hampstead Heath Ponds Project Stakeholder Group and the Hampstead Heath Consultative Committee. Over the next few months utilising these results the Design Team, with support from the Stakeholder Group, will refine the long list of potential design solutions to arrive at two or three preferred schemes. These will then be subject to wide public consultation.

Recommendation

It is recommended that the Committee receive Design Flood Assessment Report and endorse it as the basis for the continuation of the Hampstead Heath Ponds Project and development of the preferred design options that will be subject to wide public consultation later in the year.

<u>Main Report</u>

Background

1. Approval was given by the Court of Common Council on 14 July 2011 for the project to upgrade the pond embankments on the Hampstead and Highgate chains. The aims of the project are to reduce the current risk of pond overtopping, embankment erosion, failure and potential loss of life downstream; ensure compliance with the existing requirements of the Reservoirs Act 1975 together with the additional expected requirements under the Flood and Water Management Act 2010 while meeting the obligations of the Hampstead Heath Act 1871; and improving water quality. At the same time it seeks to achieve other environmental gains through, for example, habitat creation.
2. In October 2012 the City of London Corporation appointed a Design Team to undertake the task of preparing designs, achieving planning permission and implementing works to meet its duty of care and mitigate its liabilities.

Current Position

3. The first major task undertaken by the Design Team in relation to the Hampstead Heath Ponds Project was to undertake a Fundamental Review of the basis for the whole project. This work was considered necessary by the City Corporation following the independent peer review of the original feasibility study that identified some concerns about deviation of methods from industry standards and also concerns from the Hampstead Heath Ponds Stakeholder Group. It was agreed that this work be undertaken before any proposals on design options and detailed solutions commenced.
4. The review utilises industry methods and software, ensuring that the work is in line with current industry best practice to determine "extreme rainfall events" and their impact on the earth dams across the Hampstead and Highgate chains of ponds.
5. The work undertaken by Atkins follows the methodology set out in their Design Review Method Statement approved in December 2012. The results of this study have shown there remains an unacceptable risk that in extreme rainfall events the Heath ponds will fill with water and overtop the dams, potentially resulting in their failure and thereby releasing the stored water in the ponds to inundate communities south of the Heath, putting people and property at risk.
6. The results, utilising nationally derived data-sets for rainfall estimation, percentage of run-off of water across the Heath and estimation of the size of a range of floods was then passed through a mathematical model (considered to be one of the most reliable packages in the reservoir industry). The results have shown that flood peaks are between 30-50% lower than the levels that

were modelled by previous hydrologists, who used locally derived data-sets as the basis to determine the maximum floods.

7. Given the complex and critical nature of this threshold stage of the design process, in addition to the detailed Technical Report, Atkins have also produced a Summary of their findings. Both papers are appended to this report (Appendix 1 Summary and Appendix 2 Technical Report).

Proposals

8. It is important to recognise that these results do not necessarily mean a 30 to 50% reduction in the mitigation requirements on site compared to the original feasibility ideas and concepts. Atkins have however stated that they believe these results could reduce the overall impact on the Heath, but that storage capacity is still necessary to help hold back water in major rainfall events and assist with mitigating impacts on other ponds across the Heath.

9. The next stage of the design process is for the Design Team to compile a list of all potential options. These will then be refined to those that are technically feasible. The Design Team have indicated that coarse modelling of one or two options for each chain of ponds where additional storage capacity could be considered would greatly assist in helping understand the impacts on other dams.

10. Continued involvement of the Ponds Project Stakeholder Group supported by the Strategic Landscape Architect at this stage of the project is essential. Time spent now in engaging this Group in the various iterations in refining the long list of options to those that are technically feasible and then in selecting the two or three preferred options will provide reassurance to the community that all possible measures are being taken to protect the Heath landscape.

Consultation

11. The Heath Ponds Project Stakeholder Group received a presentation from Dr Andy Hughes Panel Engineer on the Design Flood Assessment at its meeting on the 18th March 2013 (see notes of meeting appended to this report Appendix 3). The Group were able to seek clarification on a number of detailed technical issues arising from the study. Members were asked to submit in writing any further clarifications on the technical aspects of the report; these and the responses from Atkins and the City of London Corporation are included at Appendix 4.

12. The Hampstead Heath Consultative Committee held a special meeting on the 8th April 2013 to specifically consider this technical report, a copy of the draft minutes of that meeting are also appended to this report (Appendix 5).

13. Members of the Hampstead Heath Consultative Committee were also given an opportunity to seek further clarification on technical issues within the report and these have been included with the Stakeholder at Appendix 4.

14. Members of the Stakeholder Group at their next meeting on the 15th April 2013 requested further clarification on a number of the responses provided by Atkins. A specially convened meeting was held at Atkins Epsom offices on

Friday 19th April 2013, where three members representing the Heath & Hampstead Society, Fitzroy Farm Residents' Association and Elaine Grove & Oak Village Residents' Association were able to clarify a number of outstanding queries with members of Atkins design team. A copy of the notes of the meeting are also appended to this report (Appendix 6) to provide Members with the full picture of issues raised and responses from Atkins.

Corporate & Strategic Implications

15. The works support the strategic aim 'To provide valued services to London and the nation'. The scheme will improve community facilities, conserve/enhance landscape and biodiversity and contribute to a reduction in water pollution whilst meeting the City Corporation's legal obligations. The risk of any dam breach and serious downstream flooding of communities (and consequent harm to the City's reputation) is mitigated.

Implications

16. The risk of embankment failure at Hampstead Heath is assessed as a high risk on the City of London Corporations strategic risk register. In addition to the current measures to mitigate risks, there are other risks that also need to be considered, including the resources needed for on-going consultation and the potential threat of legal challenge that could still potentially delay the project.

Conclusion

17. Utilising industry based standards and adopting best practice, Atkins have undertaken a Fundamental Review of the basis for the project and have determined that whilst works are still essential to reduce the City of London's liability and meet its duty of care to communities south of the Heath, the size of potential floods in "extreme rainfall events" is less than those derived by previous hydrology consultants.

Appendices

- Appendix 1 and 2 – Hampstead Heath Ponds Project - Flood Design Assessment Summary & Detailed Technical Reports
- Appendix 3 – Notes of the Hampstead Heath Ponds Project Stakeholder meeting 18th March 2013.
- Appendix 4 Queries and Responses to Hampstead Heath Ponds Project Stakeholder Group and Consultative Committee from Atkins
- Appendix 5 – Draft Minutes of the Hampstead Heath Consultative Committee 8th April 2013

- Appendix 6 – Notes of Meeting held on the 19th April 2013 attended by Representatives of the Hampstead Heath Ponds Stakeholder Group and Atkins design Team

Simon Lee
Superintendent of Hampstead Heath

T: 020 7332 3322
E: simon.lee@cityoflondon.gov.uk

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Hampstead Heath Ponds Project
Assessment of Design Flood

Summary

March 2013

Introduction

Studies carried out by Haycock Associates in 2006 and 2010 suggested that during 'extreme rainfall events,' the earthen dams retaining the ponds on Hampstead Heath cannot be relied on to store the additional volume of water. Excess flood water would flow over the top and round the sides of the dams possibly leading to breach.

If the dams are breached the water normally stored in the ponds will also be released and combine with the flood water – very quickly and in a completely uncontrolled way – with risk to life and property downstream. The Haycock studies used bespoke methodologies raising concern that the results were not consistent with using accepted industry standard methods – for instance the magnitude of the floods could have been over-estimated.

To address these concerns Atkins has undertaken further detailed work as part of a fundamental review to assess the largest flood that the dams could face – known as the Probable Maximum Flood or PMF - and to check if the dams will withstand it.

This fundamental review of storm events and resulting flows through the ponds has been carried out using industry standard methods, based on established guidance from the Department for Environment, Food and Rural Affairs (Defra) and the Institution of Civil Engineers (ICE).

Atkins' new work shows flood peaks are generally 30% to 50% lower than those estimated by Haycock and there will be less water to deal with. However even at these smaller floods the dams will overtop and breaches are possible, with risk to life and property.

This means that works will need to be undertaken to make the dams safe. To reduce the risk to life and property downstream some work will need to be done to ensure the dams can pass the PMF safely.

This document provides a summary of the detailed analysis undertaken by Atkins as part of a fundamental review, its results and implications.

It explains:

- How Atkins determined the design flood
- Where results differ from those from earlier studies
- Computer modelled results of passing flows through each pond and the expected flows over and around the dams
- The expected effects of the overtopping flows on the dams.

The full technical report will be available on the City of London Corporation website.

Approach to the Hydrology Study

An early task for this new phase of work was a hydrology study to estimate the likely size of floods for a range of 'significant rainfall events'. Methods of deriving these estimates, that are recognised as industry best practice and have been developed over a number years. These methods were used for the fundamental review.

Primary sources included:

- Flood Estimation Handbook (FEH), 1999, Centre for Ecology and Hydrology.
- Flood Studies Report (FSR), 1975, and the supplementary report issued in 1985, Institute of Hydrology.
- Applicable guidance and updates to these as appropriate.

Hydrological studies provide the range of possible flood flows and their likelihood at the chosen location. Estimated flood flows are normally described as having a given return period (e.g. 1 in 1,000 years), or chance of occurrence in any given year (0.1% chance). The information obtained for each return period is shown as graphs of flow rates over time; as a storm builds, flows increase to a peak and then decrease to the conditions before the storm. These patterns of flow rates were used to check how water levels in the ponds would behave over the duration of each flood event.

This part of Atkins' study was followed by an assessment of how the ponds are likely to behave in response to these flood flows.

When rain falls on the Heath, although some water soaks into the ground and some runs off the surface of the ground and drains into the ponds. Rain falling over the surface of the pond also adds water directly to the pond. The extra water in the pond raises the water level until it starts to overflow through the pipes connecting each pond to the next pond downstream. When the rate of the water entering the ponds exceeds the rate it can flow out through the outlet pipe, the water level in the pond will continue to rise and will reach a stage where water flows over the top of the dam.

This behaviour can be described mathematically and a number of software packages are used routinely in industry to simulate it. The package Atkins used to simulate the performance of the ponds during floods for this study, InfoWorks RS, is considered to be one of the most reliable and is widely used in the industry. The package includes elements to closely represent the ponds and the surrounding land. The flow rate over time series for each pond was used in the model to simulate flows down the chain of reservoirs.

Future work will assess the volume of water that would be released if a breach occurred, and to examine options for reducing the risk of an uncontrolled release of such a large volume of water.

Flood Estimation

In Table 1-1 below, flood estimates derived by Haycock in 2010, using bespoke methods and those derived by Atkins in 2013, using standard methods and software in line with current industry best practice, show quite significant differences. The estimates prepared by Atkins, are 30% to 50% less than those from Haycock. Atkins' estimates included the contribution of the area around the grounds of Kenwood House.

It is important to understand why the estimates differ and the implications of these differences. Despite the reduced flow estimates the ponds are still likely to overflow, as shown later in Table 1-4 and work will be needed to improve safety for the downstream population.

Table 1–1 Comparison of Flood Estimates Haycock (2010) and Atkins (2013)

Pond Catchment	Maximum Flow (m^3/s)					
	1 in 100 year		1 in 10,000 year		Probable Maximum Flood (PMF)	
	Haycock	Atkins	Haycock	Atkins	Haycock	Atkins
Highgate Chain						
Stock	2.34	2.74	14.49	6.86	28.98	15.54
Ladies Bathing	2.85	3.63	18.15	9.10	36.30	20.35
Bird Sanctuary	3.76	5.82	24.14	14.53	48.28	31.88
Model Boating	4.15	6.15	31.23	15.65	62.46	33.71
Men's Bathing	4.48	6.57	34.13	17.02	68.26	36.48
Highgate No 1	4.79	7.02	36.84	18.44	73.68	39.10
Hampstead Chain						
Vale of Health	1.64	0.57	4.67	1.45	9.34	3.32
Viaduct	0.85	0.31	6.04	0.78	12.08	1.78
Mixed Bathing	2.49	2.46	22.80	6.31	45.60	14.15
Hampstead No 2	2.58	2.81	25.62	7.27	51.24	16.14
Hampstead No 1	2.78	3.34	26.30	8.49	52.60	18.82

The key factors that influence the estimates and that are explained more fully in the subsequent paragraphs below and include:

- The amount of rainfall that runs off the ground and enters the ponds i.e. percentage run-off
- The depth and the duration of the rainfall events i.e. how many millimetres fall during the storm and how long the storm lasts ie rainfall estimation
- The method used to convert rainfall to the rate of flow into the ponds ie conversion of rain to run-off
- The method used to determine the PMF.

Percentage Run-off

Key to estimating flood magnitude is the amount of rainfall that soaks into the ground and the amount of rainfall that drains off the surface of the ground into the watercourse. This is called 'run-off' and is expressed as a percentage of the total volume of rain that falls.

Atkins applied the method in the Flood Estimation Handbook (FEH) to estimate run-off. The information in the FEH required more detailed consideration when applied to Hampstead Heath because the footpaths and compacted soils nearby allow more rain to run-off during a storm. The more compacted the ground, the less the rainfall will soak into the ground. On the basis of the soils information provided by FEH, the distribution of soil types from the Heath soils map and an estimate of the area of compacted soil, Atkins used the FEH equations for run-off to derive an appropriate percentage run-off for floods from the Heath. The Atkins results and a comparison with the Haycock recommendations, which were based on a small number of infiltration tests, are shown below.

- Atkins percentage run-off for estimation of the Probable Maximum Flood 76%
- Atkins percentage run-off for estimation of the 100 year flood 53%
- Haycock recommendations (all events) 80% to 90%

In other words, appropriate application of the industry standard method yields lower percentage run-offs than recommended by Haycock leading directly to lower overall volumes of water going to the ponds for any given event.

Rainfall Estimation

Over the years, rainfall data for the UK has been gathered from many rain gauges around the country and statistically analysed to provide data for estimating floods with various probabilities of occurrence. The rainfall depths used for flood estimates for Hampstead Heath are shown in the table below.

Table 1–2 Hampstead Heath Design Rainfall depth and duration for varying events

Event	Rainfall Depth (mm) for varying storm durations			
	1.5 hours	2.5 hours	4.5 hours	9.5 hours
1 in 5	20.4	25.9	30.7	38.0
1 in 20	36.0	40.8	47.3	56.9
1 in 100	60.8	67.5	76.3	89.0
1 in 1,000	127.7	137.8	150.3	167.8
1 in 10,000	135.0	150.0	164.0	183.1
Probable Maximum Precipitation	Not required	187.9	208.5	235.0

The industry standard estimates are based on data from many rain gauges and were therefore used in preference to the data collected by the Hampstead Heath Scientific Society. While the Hampstead Heath data provided a useful record of rainfall over about 100 years, from a statistical perspective, it is not suitable to provide design rainfall depths for the 1 in 1000 period events up to the PMF needed for this study i.e. up to the 10,000 year flood, as this would involve significant extrapolation beyond the useful range of the rainfall data.

The rainfall data in Table 1–2 with other rainfall durations were used to establish the duration of the storm that produces the largest floods. This is termed the 'critical duration'. Atkins found that the critical duration varied from 1.9 hours to 3.9 hours for floods up the 10,000 year flood and was 9.5 hours for the Probable Maximum Flood. The critical duration for the PMF is longer ie 9.5 hours because the amount of rainfall that becomes runoff is much greater for longer PMF storms than for normal storms. The Haycock study adopted a 4.4 hour duration throughout.

Conversion of Rainfall into Run-off

The next step is to convert the estimated rainfall per event into run-off i.e. the amount of water which will run over the surface and drain into the ponds. The conversion of rainfall into run-off is called the "rainfall – run-off model". Atkins applied the latest standard rainfall – runoff model in the FEH.

Haycock developed a bespoke rainfall – run-off model for the Heath and applied a 90% run-off percentage. It is likely that use of the high percentage run-off was the main factor contributing to larger size floods proposed by Haycock.

Estimation of the Size of a Range of Floods

Atkins applied the appropriate rainfall distributions and durations described above, to arrive at a range of floods with return periods up to 10,000 years and PMF. Specific flow rate with time durations were developed for each flood. To derive the PMF, Atkins used the extreme rainfall information called the Probable Maximum Precipitation (PMP) available from the Flood Studies Report (FSR) and the appropriate rainfall run-off model as given in the FEH.

By comparison, Haycock estimated the 10,000year flood flow rate with time relationship using the bespoke model and scaled up the flows by a factor of 2. Haycock's application of this factor is strictly suitable for the 'rapid method' in Floods and Reservoir Safety (1996) only and is not applied when a detailed hydrological investigation has been carried out to estimate the PMF.

Although works will be required to cope safely with the PMF, as the Atkins estimates are 30% to 50% lower, the extent of the works required should be less than those proposed by Haycock.

Hydraulic Modelling

The InfoWorksRS models for the ponds on the Heath prepared by Atkins took into account that water could flow round the ends of the dams and out of the side of the ponds as well as over the crests. This better representation of real conditions was not available in the software package, STELLA, applied by Haycock.

The information provided by the InfoWorksRS hydraulic model included consideration of:

- How the flow over the crest of the dam varies over time
- How the water level varies over time as the floods pass through the reservoir systems.

This was used to estimate:

- The average frequency with which water will flow over the crest of the dams (see Table 1-3)
- The maximum depth of water flowing over the crest of the dams (see Table 1-5)
- The maximum speed of the water flowing down the outside face of the dam (See Table 1-5).

Table 1–3 Average Frequency of Flood Causing Water to Flow over the Dam Crests

Average Frequency Range	Pond Names
Up to 5 years	Stock Pond
5 years to 20 years	Ladies Bathing, Bird Sanctuary
20 to 50 years	Model Boating, Men's Bathing
50 years to 100 years	Highgate No 1, Mixed Bathing, Hampstead No 2
100 years to 1,000 years	Vale of Health, Viaduct
1000 to 10,000 years	Hampstead No 1

The following table, Table 1-4, shows the proportion of the PMF flood that can be stored before water starts to flow over the crest of the dams.

Table 1–4 Pond Storage Capacity with Respect to Probable Maximum Flood (PMF) Volume

Chain	Pond	Total PMF volume in (m^3) including spills from the upstream pond	Min. Crest Level (m AOD)	Top Water Level TWL (m AOD)	Pond Surface Area m^2	Available storage (m^3) above TWL	% of inflow PMF can be stored
Highgate	Stock	114,438	81.65	81.06	4,401	2,597	2
	Ladies Bathing	153,055	76.87	76.00	6,926	6,026	4
	Bird Sanctuary	171,407	72.57	71.95	7,694	4,770	3
	Model Boating	116,765	71.62*	71.35	16,280	4,379	4
	Men's Bathing	217,067	68.16	67.59	18,250	10,403	5
	Highgate No 1	275,972	63.50	62.45	13,660	14,343	5
Hampstead	Vale of Health	25,539	105.44	105.04	8,646	3,458	14
	Viaduct	13,444	89.97	89.50	3,329	1,565	12
	Mixed Bathing	67,020	75.46	74.95	7,148	3,645	5
	Hampstead No 2	89,542	74.91	74.39	10,910	5,673	6
	Hampstead No 1	117,819	70.91	69.39	15,190	23,089	20

* indicates the minimum level of the auxiliary spillway

Column 8 Table 1-4 shows Highgate No 1 can store a small amount (5%) whilst the other ponds can only store between 3% and 20%. This means much of the floodwater will overflow during the PMF, with the existing dams providing temporary storage for some rainwater that will eventually leave the Heath ponds as water levels subside. The volume of storage at the Kenwood ponds was investigated and judged to be insignificant.

The speed of the flow on the outside slope of the dams is used to assess the vulnerability of slope to erosion damage and possible breaching with loss of the entire contents of the pond. The estimated velocities for the design flood - PMF are summarised in Table 1-5 below. This information was not provided by Haycock.

Table 1–5 Estimated Depth of Overtopping and Speed of Water on Outside Slope of Dams

Chain	Pond	Peak overtopping discharge (m3/s)	Crest length (m)	Slope	Maximum depth of overtopping (m)	Peak velocity, over existing embankment (m/s)	Overtopping duration (hrs)
Highgate	Stock	10.95	43	0.30	0.45	5.07	9.25
	Ladies Bathing Left Bank	2.99	46	0.18	0.24	2.66	2.08
	Bird Sanctuary	17.01	100	0.17	0.45	3.73	6.75
	Model Boating	16.09	78	0.32	0.37	4.72	6.17
	Men’s Bathing	30.74	147	0.25	0.38	4.12	7.42
	Highgate No 1	32.18	100	0.24	0.62	5.42	8.75
Hampstead	Vale of Health	2.13	130	0.24	0.15	2.34	4.00
	Viaduct	1.40	55.5	0.44	0.12	2.75	3.75
	Mixed Bathing	7.28	44	0.22	0.31	3.38	4.92
	Hampstead No 2	9.13	100	0.22	0.27	3.15	3.83
	Hampstead No 1	7.60	112	0.31	0.19	3.07	3.33

At the speeds shown in Table 1-5, standard guidance suggests that the dam slopes would need reinforcement to prevent erosion that could lead to a breach of the dam. The velocities shown are based on a uniform surface; in reality the outer slopes are uneven with trees and other coarse vegetation which will contribute to locally greater speeds. In addition coarse vegetation is readily pulled out by flowing water. These factors will exacerbate erosion damage to the slope. Solutions will be investigated which will prevent water from flowing over dam crests by channelling the water around the dams as described below.

Atkins believes that there is the potential to limit the overall impact of the works on the Heath by limiting the number of dams on which work will be undertaken and to make use of ‘soft’ engineering solutions – based on reinforced grass. The flow of water around the dams, using spillways in areas out of the general view of the public will be the favoured approach.

In Conclusion

Floods estimated by Atkins were generally 30% to 50% lower than those estimated by Haycock. Even with reduced flood volumes water will still flow over the dam crests in events ranging from the 1 in 5 year to the PMF events**.** For example Stock Pond will overtop during the 1 in 5 year event while Hampstead 1 pond will start to overtop between the 1 in 1000 year flood and the 1 in 10,000 year flood. The speeds of the flows on the outer slope in conjunction with the uneven nature of the slopes with coarse vegetation are such that the dam embankments are likely to suffer erosion damage which in some cases could lead to a breach. This means that to reduce the risk of breaching, improvements will need to be made to some of the dams to enable them to cope with these floods, although the extent of the work needed should be less than that proposed by Haycock.

Hampstead Heath Ponds Project

Assessment of Design Flood

City of London Corporation

Final Draft

25 March 2013

Plan Design Enable

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Executive Summary

This document reports on the findings of the fundamental review and problem definition for Hampstead Heath Ponds Project. It is the first technical element of the project, as it is essential to defining the problem. The key output of this assessment is an estimation of the Probable Maximum Flood (PMF) and other design floods, and an assessment of the overtopping risk under these floods at each dam. The main aim of the assessment is to estimate the overtopping depth at each dam under the extreme floods (PMF, 10,000 year, 1,000 year), and to estimate the current standard of protection of each dam. A key feature of our assessment is the use of industry standard methods and software, ensuring that the work is in line with current industry best practice. This report has been prepared in line with the Design Review Method Statement approved under Hampstead Heath, Highgate Wood & Queens Park Committee, Delegated Decision – Standing Order No. 41 (B) signed by the Town Clerk on 18th December 2012.

Rainfall Depths

Design Rainfall Depth

The Flood Estimation Handbook (FEH) CD-ROM provides Depth-Duration-Frequency (DDF) curves for a 1km^2 grid covering the whole of the UK. Design rainfall depths were extracted for the four grid squares covering Hampstead Heath for a range of storm durations and rainfall events up to the 1 in 1,000 year. Rainfall depths for the 1 in 10,000 year and PMP events were extracted from the Flood Studies Report (FSR) as is recommended by Defra. A summary of the total rainfall depth for selected durations is shown in the table below.

Event	Rainfall Depth (mm) for varying storm durations			
	1.5 hours	2.5 hours	4.5 hours	9.5 hours
1 in 5	20.4	25.9	30.7	38.0
1 in 20	36.0	40.8	47.3	56.9
1 in 100	60.8	67.5	76.3	89.0
1 in 1,000	127.7	137.8	150.3	167.8
1 in 10,000	135.0	150.0	164.0	183.1
Probable Maximum Precipitation (PMP)	Not required	187.9	208.5	235.0

Percentage Run-off

The amount of rainfall that appears as run-off (percentage runoff) that has to be stored and / or passed through the chain of ponds was estimated using industry best practice. This was done using the Flood Estimation Handbook soils information taking into account that certain parts of the Heath might be compacted due to pedestrian traffic adjacent to the existing footpaths. The hard nature of the footpaths was also taken into account. The estimate also takes into account the soil conditions prior to the rainfall event and the magnitude of the rainfall event itself.

The percentage run-off estimated for Hampstead Heath was as follows:

- For estimation of the Probable Maximum Flood 76%
- For estimation of the 100 year flood 53%

The earlier work by Haycock, based on a small number of infiltration tests, suggested a value of 80% to 90%.

The percentage runoff of a catchment will vary from one event to the next depending on the soil moisture conditions prior to the event (that is, how wet the ground is at the start of the event) and the size of the event (very large events will have larger percentage runoff as less of the rain will be able to infiltrate). Hence it would be expected that the largest events are more likely to occur when initial soil moisture conditions are saturated, and rainfall will be less able to infiltrate the ground, particularly as the rainfall increases and uses up ground water storage as the event progresses.

Flood Estimates

On the basis of the above percentage run-off, using current Defra Guidance on extreme flood estimation and the Flood Estimation Handbook for return periods from 5 years to 100 years, the following peak flows were estimated.

Pond Catchment	Maximum Flow (m^3/s)					
	1 in 100 year		1 in 10,000 year		Probable Maximum Flood (PMF)	
	Haycock	Atkins	Haycock	Atkins	Haycock	Atkins
Highgate Chain						
Stock	2.34	2.74	14.49	6.86	28.98	15.54
Ladies Bathing	2.85	3.63	18.15	9.10	36.30	20.35
Bird Sanctuary	3.76	5.82	24.14	14.53	48.28	31.88
Model Boating	4.15	6.15	31.23	15.65	62.46	33.71
Men's Bathing	4.48	6.57	34.13	17.02	68.26	36.48
Highgate No 1	4.79	7.02	36.84	18.44	73.68	39.10
Hampstead Chain						
Vale of Health	1.64	0.57	4.67	1.45	9.34	3.32
Viaduct	0.85	0.31	6.04	0.78	12.08	1.78
Mixed Bathing	2.49	2.46	22.80	6.31	45.60	14.15
Hampstead No 2	2.58	2.81	25.62	7.27	51.24	16.14
Hampstead No 1	2.78	3.34	26.30	8.49	52.60	18.82

The Table above shows that the flood peaks estimated using current industry best practice are 30% to 50% of the flood peaks estimated by Haycock. However, the Table below also shows that current overflow arrangements are inadequate to pass the flood flows without overtopping the embankments.

Reasons for the differences between the Atkins and Haycock flood estimates

As can be seen from the table above, when the flood estimates derived by Haycock Associates in 2010, using methods incorporating bespoke elements and those by Atkins in 2013, using industry best practice are compared the estimates prepared by Atkins, are 30% to 50% less than those estimated by Haycock. The estimates in both studies included the contribution of the area around the grounds of Kenwood House.

However, it is important to understand why the estimates differ and the implications of these differences.

It is also important to understand that these conditions are still not acceptable in terms of reservoir safety and that therefore intervention measures will be needed to reduce the remaining breach risk.

The key factors that have influenced the estimates are:

- The amount of rainfall that runs off the ground and enters the ponds i.e. percent run-off

- The data and the duration of the rainfall events i.e. how many millimetres fall during the storm and how long the storm lasts
- The method adopted by Haycock to convert the rainfall to the rate of flow into the ponds
- The method adopted by Haycock to determine the Probable Maximum Flood.

Assessment of pond storage capacity with respect to the PMF
To put the size of the flood into context, the Table below shows the proportion of the Probable Maximum Flood volume that can be accommodated above the existing overflow pipe.

Chain	Pond	Total PMF volume in (m^3) including spills from the upstream pond	Min. Crest Level (m AOD)	Top Water Level TWL (m AOD)	Pond Surface Area m^2	Available storage (m^3) above TWL	% of inflow PMF can be stored
Highgate	Stock	114,438	81.65	81.06	4,401	2,597	2
	Ladies Bathing	153,055	76.87	76.00	6,926	6,026	4
	Bird Sanctuary	171,407	72.57	71.95	7,694	4,770	3
	Model Boating	116,765	71.62*	71.35	16,280	4,379	4
	Men's Bathing	217,067	68.16	67.59	18,250	10,403	5
	Highgate No 1	275,972	63.50	62.45	13,660	14,343	5
Hampstead	Vale of Health	25,539	105.44	105.04	8,646	3,458	14
	Viaduct	13,444	89.97	89.50	3,329	1,565	12
	Mixed Bathing	67,020	75.46	74.95	7,148	3,645	5
	Hampstead No 2	89,542	74.91	74.39	10,910	5,673	6
	Hampstead No 1	117,819	70.91	69.39	15,190	23,089	20

*This is the minimum level of the auxiliary spillway.

The Table above shows that Highgate No.1 can absorb only 5% of the volume of the Probable Maximum Flood from its natural catchment including overflow from upstream reservoirs with the rest passing over and around the dam. Hampstead No 1 is shown to be able to store 20% of the PMF from its catchment and the overflow from the upstream ponds. The percent of the inflow PMF that can be stored is the volume available between the reservoir Top Water Level (TWL) and the dam crest level. The outflow pipes will be discharging flow downstream, but may not be able to do so to match the rate of the inflow. Hence this storage provides a buffer, or a delay (attenuation) in the outflow until the water level reaches the dam crest and the reservoir begins to discharge over the top of the dam.

Flood Routing

Floods with various return periods were routed through the reservoir systems and the results of this work are shown in the Table below:

Summary of Current Standard of Protection

Pond	5 year	20 year	50 year	100 year	1000 year	10,000 year	PMF
Highgate Chain							
Stock							
Ladies Bathing							
Bird Sanctuary							
Model Boating							
Men's Bathing							
Highgate No 1							
Hampstead Chain							
Vale of Health							
Viaduct							
Mixed Bathing							
Hampstead No 2							
Hampstead No 1							

	Overtopped
	Not overtopped
	Auxiliary Spillway Overtopping

The above Table shows the following Standards of Protection:

- 1 No. Up to 5 year Standard
- 3 No. 5 year to 20 year Standard
- 1 No. 20 years to 50 year Standard
- 3 No. 50 years to 100 year Standard
- 2 No. 100 years to 1,000 year Standard
- 1 No. 1,000 years to 10,000 year Standard

The Probable Maximum Flood was routed through the ponds using a hydraulic model. The results of this exercise are shown below with the equivalent results from the Haycock study.

PMF Summary Results of Flood Routing

Pond	Peak Water Level (m AOD)	Flood Rise (m)	Maximum Dam Overtopping Depth (m) - Atkins	Maximum overtopping depth (m) – Haycock 2010
Highgate Chain				
Stock	82.10	1.04	0.45	0.66
Ladies Bathing	77.11	1.11	0.24	1.31
Bird Sanctuary	73.02	1.07	0.45	0.71
Model Boating	72.24	0.89	0.37	0.49
Men's Bathing	68.54	0.95	0.38	0.6
Highgate No 1	64.12	1.67	0.62	0.7
Hampstead Chain				
Vale of Health	105.59	0.55	0.15	0.48
Viaduct	90.09	0.59	0.12	0.5
Mixed Bathing	75.77	0.82	0.31	1.08
Hampstead No 2	75.18	0.79	0.27	0.59
Hampstead No 1	71.10	1.71	0.19	0.59

The Table above shows that the depths of flow over the embankments (overtopping depth) are generally less than those suggested by the Haycock Report.

The velocity of the flow on the downstream slope of the embankments has been estimated. As the crests of the embankments are not level, there will be tendency for flow to concentrate at the low spots. The estimated velocities of the flow on the slopes are shown in the Table below.

Summary of Peak Velocity on Downstream Slope

Chain	Pond	Peak overtopping discharge (m3/s)	Crest length (m)	Slope	Maximum depth of overtopping (m)	Peak velocity, over existing embankment (m/s)	Overtopping duration (hrs)
Highgate	Stock Pond	10.95	43	0.30	0.45	5.07	9.25
	Ladies Bathing Left Bank	2.99	46	0.18	0.24	2.66	2.08
	Bird Sanctuary	17.01	100	0.17	0.45	3.73	6.75
	Model Boating	16.09	78	0.32	0.37	4.72	6.17
	Men's Bathing	30.74	147	0.25	0.38	4.12	7.42
	Highgate No 1	32.18	100	0.24	0.62	5.42	8.75
Hampstead	Vale of Health	2.13	130	0.24	0.15	2.34	4.00
	Viaduct	1.40	55.5	0.44	0.12	2.75	3.75
	Mixed Bathing	7.28	44	0.22	0.31	3.38	4.92
	Hampstead No 2	9.13	100	0.22	0.27	3.15	3.83
	Hampstead No 1	7.60	112	0.31	0.19	3.07	3.33

The Table above shows that velocities close to 5.5m/s could occur on the downstream slope during overtopping. At the speeds estimated in the above Table, standard guidance suggests that the dam slopes would need reinforcement to prevent erosion which could lead to a breach of the dam. The velocities shown are based on a uniform surface; in reality the outer slopes are uneven with trees and other coarse vegetation which will contribute to locally greater speeds. In addition coarse vegetation is readily pulled out by flowing water. These factors will exacerbate erosion damage to the slope which emphasizes the need to either to prevent flow over the crest by channelling flow around the dams or where this is not possible, to reinforce the slope using "soft" engineering techniques such as reinforced grass.

The duration of the overtopping event are estimated to be up to 9.5 hours and this could be long enough to cause significant saturation of the downstream shoulder of the dam. The influence of saturation on the stability of the embankment slopes will be taken into account in the detailed design and also emphasizes the need to avoid flow over the crests and over the outer slopes.

Outline Approach to Dealing with the Probable Maximum Flood

The approach to the work into the future will look at the system as a whole and identify the sites at which the most benefit, in terms of flood attenuation, can be achieved.

Atkins believes that there is the potential to limit the overall impact of the works on the Heath by limiting the number of dams on which work will be undertaken and to make use of 'soft' engineering solutions – based on reinforced grass. The flow of water around the dams, using spillways in areas out of the general view of the public will be the favoured approach.

1. Introduction

This document reports on the findings of the fundamental review and problem definition for Hampstead Heath Pond Project. It is the first technical element of the project, as it is essential to defining the problem. The key output of this assessment is an estimation of the Probable Maximum Flood (PMF) and other design floods, and an assessment of the overtopping risk under these floods at each dam. The main aim of the assessment is to estimate the overtopping depth at each dam under the extreme floods (PMF, 10,000 year, 1,000 year), and to estimate the current standard of protection of each dam. A key feature of our assessment is the use of industry standard methods and software, ensuring that the work is in line with current industry best practice.

The study involved the following elements:

1) Review of the previous studies. Of particular interest was the review of the methods and hydrological parameters used to derive the PMF and other design floods. Previous work by Haycock used percentage runoff values of 90% while industry-standard flood studies suggested values much less than this. The aim of our review was to examine the source of Haycock's percentage runoff and determine the most appropriate value to take forward in our estimation of the PMF and design flows for this study.
2) Development of hydrological and hydraulic models of the Heath catchments and ponds using industry standard methods and software
3) Assessment of the current standard of protection (SoP) of each dam, or the event that would not result in overtopping of the dams

This report sets out in detail the methodology adopted for the re-calculation of rainfall and runoff events on the Heath for a number of flood events, the routing of these rainfall profiles and runoff hydrographs through hydraulic reservoir routing modelling to determine the performance of the existing structures during 'normal' and extreme flood events.

1.1. Structure of the report

The report is organised into the following sections:

1) Study area background
2) Review of previous studies
3) Hydrological Modelling
4) Hydraulic Modelling
5) Overtopping Assessment
6) Current Standard of protection
7) Conclusions and Recommendations

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2. Study Area Background

This Chapter provides background information on the location and land use for the Heath, a description of the ponds and a discussion of the local geology and soils.

2.1. Location and Land Use

Hampstead Heath is the largest area of open space in north-west London and comprises 275 hectares located to the north-east of Hampstead and to the south-west of Highgate. The City of London Corporation is responsible for the management and protection of the Heath, and for making it available as open space in accordance with The Hampstead Heath Act 1871. There are two statutory committees; The Management Committee which is responsible for the implementation of policies and programmes and The Consultative Committee which makes representations to the Management Committee about Heath matters. The adjacent 45 hectare Kenwood Estate, including Kenwood House, is owned and managed by English Heritage.

The Heath attracts in excess of 7 million visitors per annum including walkers, cyclists and swimmers. The area is characterised by a wide range of habitats and landscape features (including woodland, scrub, grassland, Heathland and standing water) which support an abundance of wildlife, including rare and protected species.

2.2. Ponds

There are four chains of ponds on Hampstead Heath. To the north there is the Golders Hill Park chain in the designed landscape of the former Golders Hill Mansion, and the Heath Extension chain (also known as the Seven Sisters chain). These two chains were not included in the scope of the current study and are therefore not discussed further. To the south are the Hampstead and Highgate pond chains, the former of which was constructed by the Hampstead Heath Water Company in the late 18th century for the supply of water to north London. The Hampstead chain consists of five ponds: Vale of Health Pond, Viaduct Pond, Mixed Bathing Pond, Hampstead No. 2 Pond and Hampstead No. 1 Pond. The Highgate chain consists of eight ponds: Wood Pond, Thousand Pounds Pond (both located in Kenwood Park and owned by English Heritage), Stock Pond, Kenwood Ladies Bathing Pond, Bird Sanctuary Pond, Model Boating Pond, Highgate Men's Bathing Pond and Highgate No. 1 Pond. All of the Hampstead and Highgate chain ponds (with the exception of the two owned by English Heritage) are the subject of the current study.

2.3. Geology and Soils

The Heath Geology is composed mainly of Bagshot Beds, underlain by Claygate Members, in turn underlain by London Clay.

Bagshot Beds are present on the ridge to the north between north east and south west flowing streams of the Heath. London Clay is exposed at the lower elevations within the Heath and is the dominant geology over which most of the ponds are built. Hampstead Heath and Highgate chain tributaries start on Claygate Beds before flowing into London Clay. Highgate Pond, Wood Pond and Concert Pond are on Claygate Beds.

Bagshot Clay is across-laminated yellow, orange-brown and brown fine grained sand which has a basal bed of coarse grit and sub-rounded flint pebbles. The Claygate Member consists of alternating beds of clayey silt, very silty clay, sandy silt and silty fine sand. Claygate and Bagshot formations were both deposited in marine conditions shallow enough to be influenced by tidal sequences although supply of sediments during deposition of Bagshot formations is thought to have been higher than the Claygate Member. Claygate Member is mainly comprised of quartz (up to 50%) then clays (mainly montmorillonite, kaolinite and chlorite), which have a tendency to swell and shrink from wet to dry conditions. Bagshot is mainly comprised of quartz with montmorillonite and kaolinite clays. Clays are more common than silts in the Bagshot formation and Bagshot sands are fine grained.

The shear strength of the Bagshot formation can vary quite appreciably reflecting the variability of the constituents of the formation. The strength of the material is affected by the amount of cementation and compaction of the interlocking grains. The sand in the Bagshot formation and Claygate Member make them relatively permeable compared to London Clay, allowing water to flow through them readily. The water within these strata is recharged at the surface from precipitation which, owing to the relatively high porosity of the deposits, is stored within the matrix of the strata and forms a local aquifer. At the junctions of the Bagshot formation with the Claygate Member, and the Claygate Member with the London Clay, spring lines form at the ground surface. Areas overlaying Terrace Deposits and the Claygate Member/Bagshot formation are designated as 'Secondary A' aquifers by the Environment Agency, meaning permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of baseflow to rivers.

The vegetation of the Heath can give an indication of the dominant soils on the Heath and in conjunction with the soils, plays an important role in the permeability of the Heath. The presence of gorse or broom is a strong indication that locally, soils are light, well-drained and probably quite loose in texture. There is little broom on the Heath which suggest that this is unlikely to be a reliable indicator of soil types or that soils are not loose in texture. At the junction between sands and clays the main springs come to the surface. The presence of the Old sand quarry near Kenwood House is also an indication of the presence of sand. The Old Quarry in North Wood has been designated a Regionally Important Geological Site (RIGS) by Natural England. The sands within the quarry are fine grained and free-running rather than gritty and extend several metres deep.

3. Review of Previous Studies

The Chapter outlines the findings of the review of the previous studies and includes:

- Lists of the key documents reviewed;
- Explains earlier method of derivation of the peak flows;
- Describes the distributed rainfall-runoff hydrology model; and
- Describes the reservoir routing model used.

The key previous studies reviewed as part of this project were as follows:

1) Haycock, 2010 - Hydrology Improvements Detailed Evaluation Process (HiDEP): Hydrology and Structure Hydraulic and Recommendations,
2) Haycock 2006 – Hydrological and Water Quality Investigation and Modelling of the Hampstead Heath Lake Chains and associated Catchments

In 2010 Haycock undertook a review of the hydrology and hydraulics of Hampstead Heath with the stated aim of determining the current operation of the dams and their compliance with the Reservoirs Act (1975) and the upcoming Flood and Water Management Act (2010). Their 2010 review built on their 2006 study which examined the existing hydrological competency of the flow structures and provided recommendations for their management with respect to floods and water quality, as well as the reservoir Panel Engineer inspection reports of 1987, 1997 and 2007. In 2007, Haycock also undertook a dam breach study of the Heath, to examine the flood risk due to the failure of the two bottom ponds in the Hampstead and Highgate chains; this risk was revisited in their 2010 study. In addition, CARES Limited undertook a dam breach and consequence assessment of the Heath in 2009 to assess the risk to properties downstream. A full review of the dam breach and consequence assessment work will be provided when we undertake our dam breach and consequence assessment as part of this project. However both studies showed that in the event of a breach, there will be significant flooding to downstream property, and potential loss of life.

The Haycock 2006 approach to modelling the hydrology of the Heath catchments can be summarised as follows:

Derive peak flows using 'standard' flood studies methods
Haycock used the following equations to estimate flow peaks:

Q_{mean} = 0.373*(catchment area)$^{0.7}$ * ((stream junctions/km sq)$^{0.52}$)* ((1+%Urban area)$^{0.25}$) [1]

Q_{100} = Q_{mean}*3.2 (where 3.2 is taken from the FSR regional rating curves. [2]

Q_{PMF} = (catchment area$^{0.397}$)*(S1085$^{0.328}$)*(SAAR$^{0.319}$) [3]

All other T-year floods are based on the Q_{mean} multiplied by the appropriate regional growth curve factor.

The equation for a rough estimate of the PMF that is provided in Floods and Reservoir Safety is:

Q_{PMF} = 0.454A$^{0.937}$*S1085$^{0.328}$*SAAR$^{0.319}$ [4]

Using equation 4 assumes that the catchment soils are impermeable and that there is no urban area in the catchment (it is assumed that Haycock's power factor for the area term in equation 3 is a typo in their report and should be 0.937 rather than 0.397 in equation [3] above (which is quoted as stated in Haycock's report))). It is not clear why the 0.454 multiplier on the AREA term has been dropped by Haycock. Equation 4 is taken from Institute of Hydrology 114 – Reservoir Flood Estimation: Another Look (1992) report (IH114) and in its full form is:

$$Q_{PMF} = 0.454A^{0.937} * S1085^{0.328} * SOIL^{0.475} * (1+URBAN)^{2.04} * SAAR^{0.319}$$
[5]

Which, when the SOIL term is assumed to be 1 and URBAN assumed to be zero, results in equation 4. The IH114 report states that although the rapid method (i.e. Equation 5) provides a good initial estimate of the PMF peak inflow, the full method needs to be used to obtain the complete inflow hydrograph for subsequent routing through the reservoir.

Distributed rainfall-runoff hydrology model

Haycock used a bespoke distributed rainfall-runoff model to derive the reservoir inflow hydrographs (referred to as the Haycock Model from now on), developed by Haycock ,instead of using the FSR rainfall-runoff method.

Haycock describe the model as a distributed model which seeks to route rainfall through or over the soil, apportion flow into groundwater, account for groundwater discharges and then route surface flows through the drainage network. The model undertakes these calculations at a 10m x 10m grid for the whole landscape enabling changes to land cover and associated infiltration values and the roughness of the surface routes.

The model takes as input data (gleaned from a description in the report, but uncertain of the specific parameters within the model representing these datasets).

1) Observed rainfall depth. Using hourly rainfall data from (Hampstead Heath Scientific Society (HHSS) from which Haycock developed rainfall intensity plots of observed events.
2) Elevation of the Aquitard (impermeable layer below which no water enters) – defined with reference to the BGS Geology data, geology memorandum notes and additional catchment on spring locations and associated elevation
3) Starting elevation of the water table (ensuring permanent springs give effective indication of the low water table levels. It was assumed that the water table ranged from 0 to 0.1m below the surface for most of the catchment except for the London Clays where the water table was assumed to be 0.4m below ground level to the springs. For the 2002 event the distribution of water table levels was initially unsaturated for most of the soils but saturated locally at springs and the main channel. In addition to this configuration, they also considered a situation of completely saturated soils at the start of the events modelled
4) Channel geometry and roughness. Basic parameters required for application of Manning's flow routing.
5) Land cover classification and land cover merged with geology.
6) Footpath network – derived from aerial photos and DEM. Infiltration rates on the footpaths and 1m, 5m and 10m offsets from the footpath centreline. Infiltration rates for the footpaths were adjusted to examine different scenarios of footpath permeability.

Haycock state that the model simulates 'real events' and 'enables scenarios to be built around real rainfall events'

Haycock stated that they used the bespoke distributed hydrological model as they wanted to examine four major configurations of land cover for the Heath, and that the flood studies methods do not have the versatility to do this. The FEH and FSR methods do make allowance for changes to the terms that represent soil permeability which can be used to assess changes in landuse and this can be used to examine different landuse scenarios, for example different permeability of the footpaths. As will be seen in our assessment, the standard percentage runoff factor has been adjusted in this manner in the current study.

The data requirements and derivation of the parameters required for the Haycock model seem extensive for a study which, ultimately is aiming to estimate the most extreme floods which themselves are associated with a degree of uncertainty. Perhaps the most important element of the hydrograph estimation lies in the representation of percentage runoff and the resultant peak flow, regardless of the rainfall-runoff model used. We discuss the issues of percentage runoff in more detail in Section 4.4. Haycock used a percentage runoff of 80-90% based on a small number of infiltration tests undertaken on the Heath. We have used the FEH and FSR facilities to adjust standard percentage runoff to account for low infiltration rates on the footpaths, which have resulted in percentage runoff values lower that those used by Haycock.

Reservoir Routing Model

Haycock used the output of the Haycock model as input to a reservoir routing model to route flow through the structures. The reservoir routing model used is Stella, which we believe allows for a 'level pool' representation of the reservoirs with flow routed from one to the next via the overflow pipes and over the dams. While the Stella model would represent the flood rise, it may miss important processes such as overflow of the sides of the reservoirs (in addition to the dam itself) and routing of that flow to the downstream reservoir via overland flow paths. Hence, for the reservoir, water level may increase faster and higher than would occur in reality and reservoirs will effectively 'glasswall' predicting higher than expected water levels. To get around this, a linked 1Dimensional and 2Dimensional (1D-2D)[1] representation of the reservoirs and the overland floodplain between the reservoirs, would provide a better representation. This is what has been done in our assessment.

In 2010 Haycock, after collating all available data and modelling attempts to derive the hydrology of the Heath, re-confirmed their view that the 'standard methodology' for calculating the PMF was 'severely underestimating' the flow that the structures of the Heath should be able to cope with. They stated that '*based on the ambiguity of the standard Q_{pmf} methodology, it was agreed that Haycock would design spillways on each pond to the 10,000 year rainfall event*'. They further stated that the dam structures would be designed and armoured to safely pass the PMF which they estimate as double the 10,000 year flow. We compare and contrast the values used by Haycock in more detail in the hydrology section, but would point out the Haycock estimate of the PMF as double the 10,000 year event is based on a rapid assessment method which should be replaced with the full PMF method for more accurate flood estimation required for structure design.

[1] 1D-2D refers to the different dimensions within which flow can be modelled. 1D models simulate flow in one direction from upstream to downstream, for example into and out of the Hampstead Heath ponds. In this instance, the 1D aspect of the model has been used to calculate water levels in the ponds and the flow passing over the pond embankments and through the connecting pipes. In contrast, 2D models simulate flow in multiple directions according to the ground topography. They are commonly used to model flows over a floodplain. In this instance, the 2D aspect of the model has been used to define the overland flow between the ponds, and in the downstream valley.

4. Hydrology

This Chapter describes the following aspects of the hydrology study carried out by Atkins:

- Methodology;
- Sources of Data;
- The catchment boundaries and pond areas;
- The catchment descriptors for the hydrology model, including the percentage run-off;
- Rainfall Analysis including a discussion on the 1975 rainfall event;
- Generation of the flood hydrographs; and
- Presents the results of the hydrological modelling;

4.1. Methodology

Hydrological modelling was undertaken to provide input to the hydraulic model and was generated using current industry-standard best practice. The design flood events modelled are the 'standard' extreme events for reservoir safety studies (1 in 1,000 year, 1 in 10,000 year and the Probable Maximum Flood (PMF)) as defined by the Guidance on Floods and Reservoir Safety, and a range of lower return period events (1 in 5 year, 1 in 20 year, 1 in 50 year and 1 in 100 year) which were examined for the purpose of determining the current Standard of Protection (SoP) of each dam.

The assessment is based on a combination of the Flood Estimation Handbook (FEH)[2] and Flood Studies Report (FSR)[3] rainfall-runoff methods and is in line with all the appropriate current industry guidelines on normal and extreme flood estimate including:

1) Floods and Reservoir Safety, 3rd Edition, ICE, 1996
2) Floods and Reservoir Safety: Revised Guidance for Panel Engineers, Defra, 2004
3) $URBEXT_{2000}$ - A new FEH catchment descriptor. Calculation, dissemination and application. R&D Technical Report FD1919/TR
4) Flood Estimation Handbook (FEH) Manuals Vols., 1-5, IOH, 1999

4.2. Sources of Data

The following sources of data were used for the Hampstead Heath hydrology and hydraulic modelling:

- Digital Elevation Model (DEM) obtained from the City of London Corporation, Infoterra, 2006;
- Hampstead Scientific Society Daily Rainfall records 1910 – 2009;
- Hydrological and Water Quality Investigation and Modelling of the Hampstead Heath Lake Chains and Associated Catchments, Haycock Associates Limited, 2006;
- Hydrology Improvements Detailed Evaluation Process (HiDEP): Hydrology and Structure Hydraulics, Haycock Associates Limited, 2010;
- Flood Estimation Handbook (FEH), Centre for Ecology & Hydrology, 1999;
- FEH CD-ROM Version 3;
- Flood Studies Report (FSR) maps, 1975.
- Hampstead Heath Dam 3D Topographic Survey, Plowman Craven, 2010;
- Haycock Hampstead Heath Stella model, 2010; and
- Hampstead Heath Reservoirs On-Site Emergency Response Plan for Reservoir Dam Incidents. City of London, November 2012.

[2] The Flood Estimation Handbook (FEH) is the current standard UK method for estimating rainfall, and flood frequency and flows, developed by the Centre for Ecology and Hydrology in 1999.

[3] The Flood Studies Report (FSR) was the first UK-wide flood estimation method developed in 1975 by IoH. FEH largely supersedes the FSR.

4.3. Catchment Boundaries

Catchment boundaries for each individual pond in the Hampstead and Highgate chains were initially obtained using the FEH CD-ROM. The FEH boundaries however rely on coarse topographic data (based on a 50m resolution DEM) that is less suited to accurately determining boundaries for such small catchments. Figure 4-1 illustrates the FEH catchment boundaries for the Hampstead and Highgate chains.

Figure 4-1 Hampstead and Highgate FEH Catchment Boundary Map

Haycock (2006) derived catchment boundaries using the Digital Land Elevation Model of Hampstead Heath. As part of the Atkins study, these boundaries were verified using the topographic data and where appropriate, minor modifications made. These modifications made no significant difference to the overall catchment areas. These catchment boundaries and areas were consistent with the FEH-derived catchments and were used in place of those derived from the FEH CD-ROM and are illustrated in Figure 4-2 and Figure 4-3.

Several of the catchments, particularly those for the Highgate chain include the urban areas adjacent to the Heath. Surface water runoff from these urban areas is likely to drain into the surface water sewer system. Sewers are however designed to convey only low return period events (typically up to the 1 in 30 year event) and would therefore take an insignificant proportion of the runoff during an extreme event (for example the 1 in 1,000 year and the PMF) before becoming overwhelmed. The remaining runoff will be routed over the natural topography and would therefore contribute to flows in the whole topographic catchment. Given the relatively low proportion of the total flow that can be carried in storm sewers,the industry-standard assumption is that any surface water sewers are already overwhelmed by the time a storm of this magnitude arrives. Furthermore, while roof tops, guttering and roads will drain to surface water sewers, there are some parts of urban areas (for example property gardens) which will allow for some infiltration. This part of urban rainfall that does not runoff into the sewer system will become overland / subsurface flow and will be routed according to the natural topographic catchment throughout the event. For these reasons, the full topographic catchment areas were used for subsequent flow estimation, with no exclusion of the urban areas.

Table 4-1 documents the total upstream topographic catchment area for each Hampstead Heath pond included in this study, the total pond surface area in these catchments and the catchment area excluding all pond surfaces. The latter was taken forward for use in flow derivation. The impact of rain falling directly on the pond surfaces has been included as direct rainfall boundaries in the hydraulic model (with no loss component to the rainfall). This will ensure that the effect of reservoir routing and storage will be included only in the hydraulic model and will not be double counted in both the hydrology and hydraulics. It will also account for the fact that no rainfall is lost to interception, infiltration or evaporation when it falls directly over the pond surface.

Table 4-1 Catchment Areas and Pond Area

Catchment	Topographic Catchment Area (km^2)	Cumulative Pond Area (km^2)	Hydrological Catchment Area (km^2)
Highgate Chain			
Stock	0.63	0.02	0.61
Ladies Bathing	0.78	0.02	0.76
Bird Sanctuary	1.18	0.03	1.15
Model Boating	1.27	0.05	1.22
Men’s Bathing	1.43	0.07	1.36
Highgate No 1	1.56	0.08	1.48
Hampstead Chain			
Vale of Health	0.08	0.01	0.07
Viaduct	0.13	< 0.01	0.13
Mixed Bathing	0.58	0.02	0.56
Hampstead No 2 Pond	0.67	0.03	0.64
Hampstead No 1 Pond	0.72	0.05	0.67

Note: The two most upstream ponds on the Highgate chain (Wood Pond and Thousand Pound Pond) are not included in this table but the contribution of the catchment areas has been taken into account as described below.

Kenwood Pond has not been modelled explicitly in this study as it was judged that any the additional storage available was negligible. However, its catchment contributes to flow into Stock Pond and so has been accounted for as part the Stock Pond catchment area.

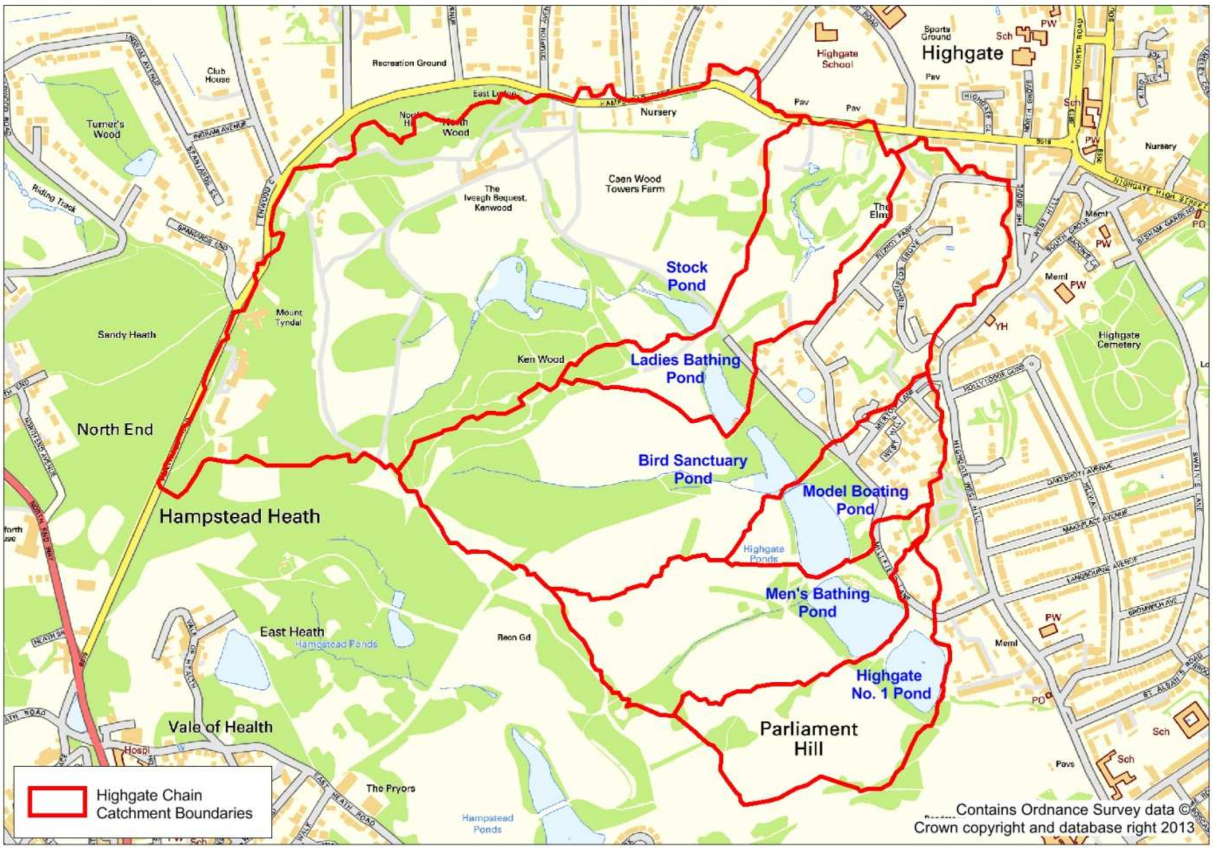

Figure 4-2 Highgate Chain Catchment Boundary Map

Figure 4-3 Hampstead Chain Boundary Map

4.4. Catchment Descriptors

Catchment descriptors were obtained from the FEH CD-ROM for the FEH catchment and from the FSR maps. Catchment area was established using the method described above. The catchment descriptors used in the subsequent hydrological assessment are provided in Table 4-2 and Table 4-3. Further details of the derivation of urban extent values and the Standard Percentage Runoff (SPR) are given below. The FEH Manual (Centre for Ecology and Hydrology, 1999) provides descriptions of all the catchment parameters.

Table 4-2 Catchment Descriptors

Catchment	Area (km^2)	URBEXT	Urban Fraction	SAAR (mm)	DPLBAR (km)	DPSBAR (m/km)
Highgate Chain						
Stock	0.61	0.079	0.162	682	0.64	67.7
Ladies Bathing	0.76	0.113	0.231	682	0.77	66.3
Bird Sanctuary	1.15	0.133	0.273	681	0.83	68.7
Model Boating	1.22	0.151	0.308	680	1.00	69.4
Men's Bathing	1.36	0.144	0.296	680	1.04	68.7
Highgate No 1	1.48	0.149	0.306	679	1.15	69.0
Hampstead Chain						
Mixed Bathing	0.56	0.075	0.153	669	0.73	83.4
Hampstead No 2	0.64	0.084	0.172	668	0.80	82.2
Hampstead No 1	0.67	0.126	0.259	668	0.89	82.9

Table 4-3 Hampstead Heath Descriptors for all Catchments

Descriptor	All Catchments
PROPWET (dimensionless factor)	0.29
SPR (%)	53
Em-2h (mm)	185
Em-24h (mm)	270
Em-25d (mm)	370
M5-2d (mm)	50.5
M5-25d (mm)	20.5
Jenkinson's r (ratio)	0.43

Urban Extent

The FEH CD-ROM provides values for the $URBEXT_{1990}$ and $URBEXT_{2000}$ to describe the level of urbanisation of a catchment. These two descriptors were derived using different methods and are therefore not directly comparable (Defra, 2006). Methods for hydrological estimation developed using $URBEXT_{1990}$ should therefore not be applied with $URBEXT_{2000}$ (Defra & Environment Agency, 2006). The FEH method was developed for the $URBEXT_{1990}$ parameter and can therefore only be used with the $URBEXT_{1990}$ parameters, with an adjustment made for changes to urbanisation since 1990. Hence, for this study, the $URBEXT_{1990}$ values from the FEH CD-ROM were extracted for all catchments and updated using the FEH (volume 5) equation 6.8 (p53) to take into account estimated development over the last two decades. The resulting descriptors were used directly in the FEH Rainfall Runoff (RR) analysis of flood events.

Flood estimation using the FSR rainfall-runoff methodology requires input of an urban fraction, which has been calculated from the updated $URBEXT_{1990}$ using the FEH (volume 5) equation 6.4 (p48).

Percentage Run-off

The percentage run-off of a catchment is the percentage of the total rainfall that becomes direct runoff. Estimation of percentage runoff is the most important part of flood estimation using the FSR/FEH rainfall-runoff methods as it has a direct scaling influence on the magnitude of the resulting rapid response runoff. It is also the most uncertain part of the runoff estimation, as it is reliant on a number of datasets that are difficult to collect including catchment type, catchment state and storm variability.

Previous hydrological studies for Hampstead Heath have used a variety of methods for determining the percentage runoff and these have resulted in widely ranging flow estimates for the catchments. The 1987 flood studies report (Binnie and Partners) utilised a runoff percentage of 27%. In contrast, and following a small number of infiltration tests, Haycock (2006) suggested that a runoff percentage of 80 – 90% should be expected during an extreme event given the highly compacted nature of the soils on the Heath, particularly adjacent to the footpaths. Included in the scope of this study was therefore a detailed consideration of the most suitable runoff percentage to apply to the catchments.The FSR/FEH rainfall-runoff methods apply the unit hydrograph and losses model, which assumes that the percentage runoff is constant throughout an event and is applied to each block of total rainfall hyetographs i.e. a constant proportional loss model. However, in reality, percentage runoff will not be constant, but will increase as deficits are made up and soils become saturated.

The Percentage Runoff is made up of the SPR (Standard Percentage Runoff) which represents the normal capacity of the catchment to generate runoff, and dynamic terms representing the variation in runoff depending on catchment antecedent conditions (i.e. the state of the catchment prior to the event, due to previous rainfall events. Hence the calculation takes account of the average rainfall that could have fallen for the 5 days prior to the event) and the storm magnitude itself.

$$PR = PR_{RURAL}(1-0.615URBEXT) + 70(0.615URBEXT) \quad [4.1]$$

$$\text{Where } PR_{RURAL} = SPR + DPR_{CWI} + DPR_{RAIN} \quad [4.2]$$

$$DPR_{CWI} = 0.25(CWI-125) \quad [4.3]$$

$$DPR_{RAIN} = \begin{cases} 0 & for\ P \leq 40mm \\ 0.45(P-40)^{0.7} & for\ P > 40mm \end{cases} \quad [4.4]$$

The urban adjustment of the PR assumes that 61.5% of the urbanised area is impervious and gives 70% runoff, whilst the other 38.5% of the urbanised area acts as a natural (open area of the Heath and gardens i.e. rural) catchment. It should be noted that impervious surfaces are likely to incorporate localised depressions which will store some of the rainfall. This stored water will be lost by evaporation rather than run-off and therefore the value of 70% takes account of depression storage in urban areas. The adjustment reflects the mixed natural and impervious areas that occur within urbanised areas, and makes the effect of the urbanisation dependent on the underlying soils. On Hampstead Heath the urban percentage is small and the calculation for urban adjustment will have little impact on the percentage runoff.

SPR is fixed for all storms for the catchment, while the DPR allows the percentage runoff to vary between different storm events and different catchment antecedent conditions.

SPR can be derived by a number of methods:

1) From concurrently observed rainfall and discharge records. The SPR is derived for several events (of different sizes) and an average value obtained;
2) Derived from the baseflow index using the equation SPR=72.0-66.5BFI. BFI can be derived from flow records, using baseflow separation, and is a measure of a watercourse's long-term discharge from stored sources.
3) In the absence of observed records, SPR can be estimated from catchment descriptors using the following equation:

$$\sum_{1}^{29} SPR_i HOST_i$$

Where $HOST_i$ is the percentage of the catchment covered by HOST types 1 to 29 and SPR is the percentage runoff assigned to each class, taken from Table 2.2 in FEH Volume 4 (Plate C.1 of FEH Volume 4 is the HOST map for the UK). The Hydrology of Soil Type classification allows SPR to vary from 2% to 60% and reflects runoff from different soil types.

Deriving an adjusted SPR for Hampstead Heath

Haycock, in 2006, undertook infiltration tests on the Heath and found that the footpaths had lower infiltration rates than the underlying soil type, due to compaction from being heavily trafficked. They also concluded that a 10m buffer either side of the footpaths would be similarly compacted. Based on a limited number of infiltration tests, Haycock concluded that a runoff rate of 90% should be applied to the entire Heath.

We have examined the effect of the footpaths, by utilising FEH methods for deriving a revised SPR value.

The FEH CD-ROM provides a SPR value calculated from the HOST (Hydrology of Soil Types) classification of around 30% for the Hampstead Heath catchments. This reflects the balance between the less permeable soils (HOST 25) overlying the London Clay geology and the more permeable soils (HOST 2) overlying the Claygate Beds and the Bagshot Beds. The low SPR will result in correspondingly low runoff estimates, with the risk that these will significantly underestimate flows in the catchments, especially during extreme events.

Haycock (2006) calculated the total length of paths on the whole of Hampstead Heath to be 105km. Based on an even distribution of the path network, including desire lines, it has been assumed that the Highgate catchments have 40km of paths and the Hampstead catchment has 18.4km of paths. Adopting Haycock's assumption of a 10m path width representative of the heavy use of the Heath and for the path lengths set out above, a calculated 26% of the Hampstead and Highgate catchments consist of compacted path areas. The SPRHOST for these areas was increased to the maximum SPR value of 60% which, when combined with the remaining areas results in a revised SPR of 46%. Judgement was then used to further increase the value to 53% to account for drying / cracking of the soil during the summer. When compared with the theoretical output from the industry methods, this is consistent with the minimum value recommended in the recognised PMF methodology. In our opinion therefore the value of SPR=53% can be justified on the basis of science and site specific conditions.

The chosen SPR value of 53% was applied to all catchments and for all flood events. The actual Percentage Runoff (PR) is calculated separately and will vary with flood event (as described by equations 4.1 and 4.2 above). When used to calculate the PMF for example, an SPR of 53% will result in a PR of around 76% and a PR of 54% for a 100 year event.

4.5. Rainfall Analysis

Methodology

The methodology for the generation of design rainfall events was consistent with Defra's (2004) recommendations to Panel Engineers namely:

- The use of the Flood Studies Report (FSR)[4] for estimating the Probable Maximum Precipitation (PMP);
- The use of the FSR design rainfall method for the 1 in 10,000 year event;
- The use of both the FEH and FSR design rainfall methods for the 1 in 1,000 year event and the most extreme of the rainfall depths used in the subsequent flood assessment. For Hampstead Heath, the FEH method was found to provide significantly higher design rainfall depths for this flood event compared with the FSR method; and
- The use of the FEH design rainfall method for all other smaller return period events.
- The use of the Revitalised FEH (ReFH) methodology was considered for lower return period events but the FEH methodology was favoured by the Panel Engineer as ReFH only provides reliable estimates up to the 1 in 193 year rainfall event. Given the focus of this study on the extreme flood events, and for consistency, the FEH method was adopted for all design rainfall events with the exception of the PMP and 1 in 10,000 year events. This is widely accepted as the current best practice methodology for reservoir flood hydrology.

Design Rainfall Depth

The FEH CD-ROM provides Depth-Duration-Frequency (DDF) curves for a 1km^2 grid covering the whole of the UK. Design rainfall depths were extracted for the four grid squares covering Hampstead Heath for a range of storm durations and rainfall events up to the 1 in 1,000 year. An average of these depths was taken and where necessary interpolated using logarithmic regression relationships to provide values for intermediate storm durations.

Current Defra Guidance (Defra, 2004) states that use of the FEH DDF curves is not an appropriate way to calculate design rainfall depths for the 1 in 10,000 year event or the PMP used to estimate the PMF. Rainfall depths for the 1 in 10,000 year event were therefore derived using the FSR methodology for all storm durations in line with the guidance. The PMP was similarly derived from the FSR.

A summary of the total rainfall depth is provided in Table 4-4 for selected storm durations. The appropriate rainfall depth was applied to each individual catchment to reflect the likelihood that over this small area, a single storm event could occur over the whole Heath.

Table 4-4 Hampstead Heath Design Rainfall Depths

Flood Event	Rainfall Depth (mm) for varying storm durations			
	1.5 hours	2.5 hours	4.5 hours	9.5 hours
1 in 5	20.4	25.9	30.7	38.0
1 in 20	36.0	40.8	47.3	56.9
1 in 100	60.8	67.5	76.3	89.0
1 in 1,000	127.7	137.8	150.3	167.8
1 in 10,000	135.0	150.0	164.0	183.1
PMP	Not calculated	187.9	208.5	235.0

Observed Rainfall Depths

The Hampstead Heath Scientific Society owns and maintains a weather station close to the south-west corner of Hampstead Heath, about 1km from Hampstead No. 1 pond. The Society has been collecting daily rainfall data for the last 100 years and the digitised gauged record was provided for use in this study (Atkins is grateful to the Hampstead Heath Scientific Society for allowing access to this data). An Annual Maximum (AMAX) series was derived, consisting of the maximum 24-hour duration rainfall depth observed in each water year. A total of 99 AMAX records were derived ranging from a minimum of 17.8mm in September 1998 to a maximum of 170.8mm in August 1975. The latter resulted in a well documented flood event on Hampstead Heath.

A statistical analysis was then undertaken on this dataset to derive a site-specific depth-frequency curve for the 24-hour storm duration. A range of statistical distributions was investigated, two of which are presented in Table 4-5 below (see Figure 4-4 for a graph of other distributions). Figure 4-4 shows that different distributions give widely different curves for return periods greater than about 50 years. However, the Generalised Logistic distribution appears to give the best fit to the observed data at higher return periods.

Table 4-5 Hampstead Scientific Society Rainfall Gauge Depth Frequency Curves

Return Period (1 in T years)	24-hour Rainfall Depth (mm)	
	Log Normal Distribution	Generalised Logistic Distribution
1 in 5	48.96	43.46
1 in 20	73.32	66.28
1 in 50	90.05	88.15
1 in 100	103.27	110.14
1 in 1,000	151.60	239.92
1 in 10,000	207.95	543.70

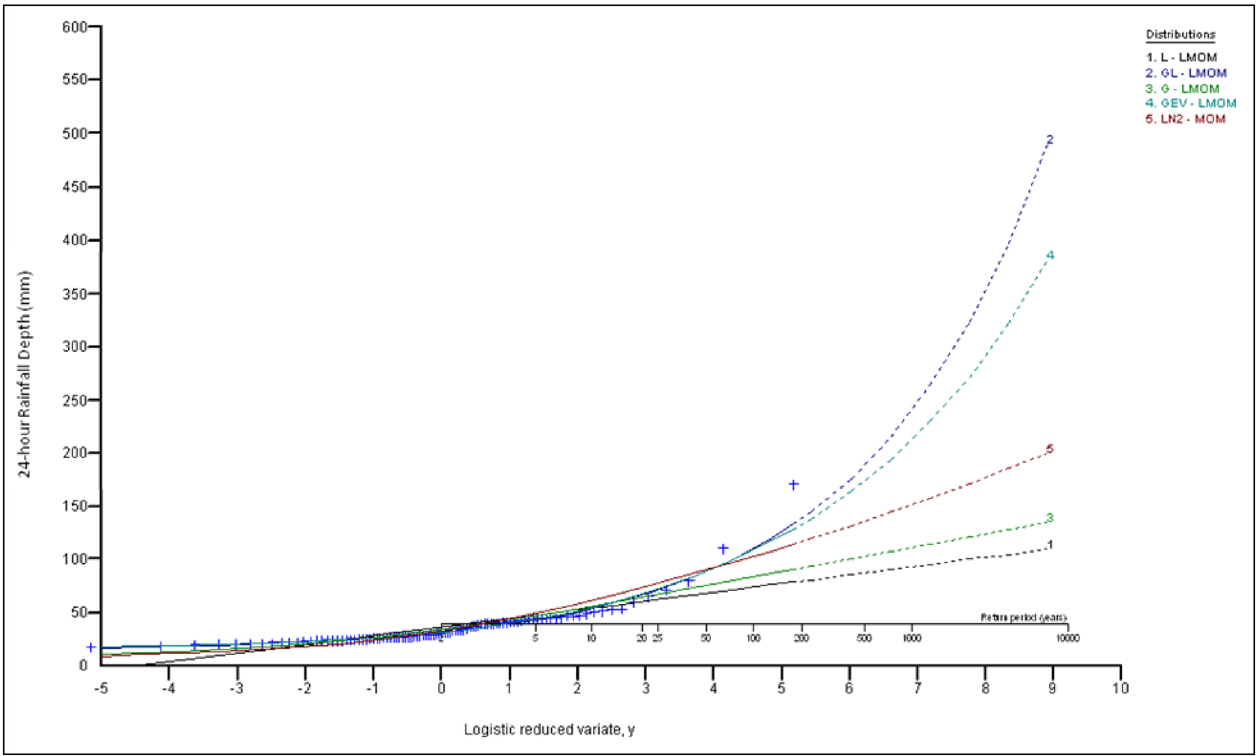

Figure 4-4 Hampstead Heath Scientific Society Rainfall Gauge Depth Frequency Curves

The analysis of the HHSS gauge provides site-specific information that can be compared with the FEH and FSR DDF curves. Consistent with industry best practice recommendations (Defra, 2004) however, the data from the HHSS gauge was not used in this design storm statistical assessment. Instead the DDF rainfall, which is based on a larger number of rain gauges, was used. The graph below provides a comparison between the 24-hour DDF curve from FEH (for each of the 4, 1km^2

squares covering the Heath), and that generated by the GL distribution for the HHSS single point gauge data (up to the 1,000 year event). It shows that the HHSS curve is much steeper than the FEH DDF curve for large return period events.

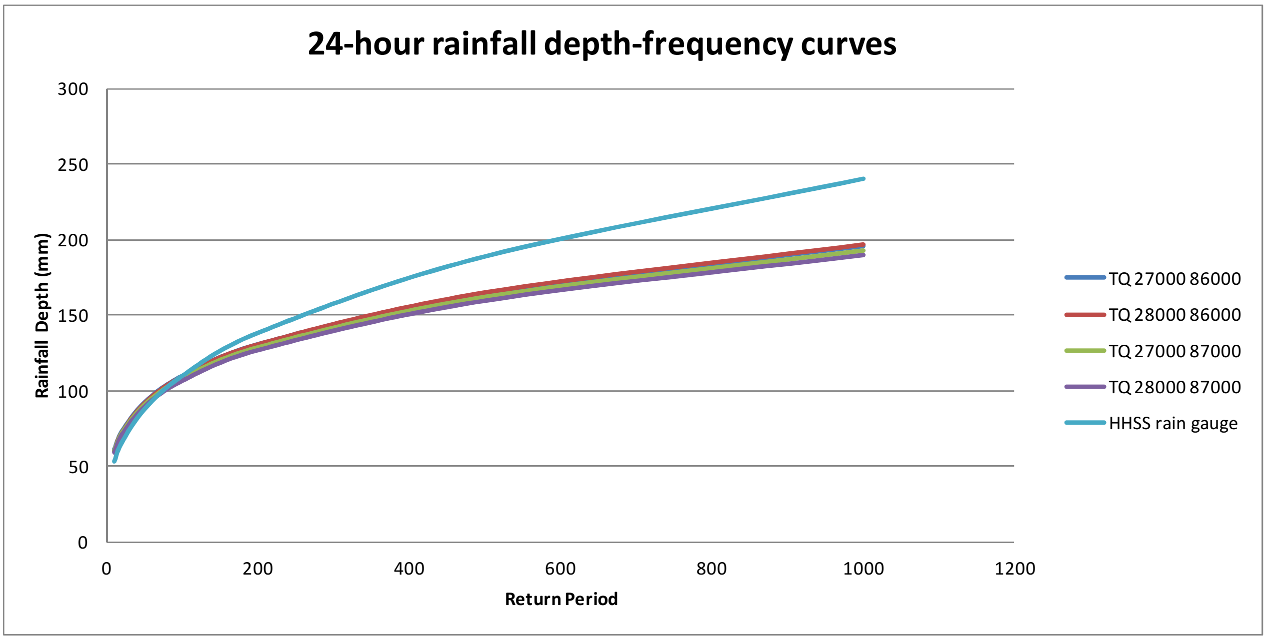

Figure 4-5 24-hour Rainfall Depth Frequency Curves

While the HHSS rainfall gauge data provides a useful local record of rainfall for an extended period of 100years, from a statistical perspective, it cannot be used to provide design rainfall depths for the very large return period events being considered in this study. To do so would involve excessive extrapolation of the data beyond its useful and reliable limit. As can be seen, the 24-hour DDF curve derived from the HHSS gauge has given rise to much higher rainfall depths for events above the 100 year event and the curve is much steeper that the FEH DDF. Hence, if the HHSS curve is extrapolated further, it will give increasingly divergent and higher rainfall depths, resulting in very large predicted flood peaks. It should be noted that, while the HHSS data cannot be used within the statistical analysis, it will be used to provide the depths for observed events such as the 1975 and 2002 events which will be modelled later on to examine how the system performed under these storms.

Design Rainfall Profiles

Design rainfall profiles have been examined for both the summer and winter events. The summer rainfall profiles resulted in higher peak flows for all events. Hence the summer storm profile was carried forward for the rest of the analysis

4.6. Hydrograph Generation

The methodology for the generation of flood hydrographs was consistent with Defra's (2004) recommendations to Panel Engineers namely:

- The use of the PMF option in the ISIS software FEH RR unit. This derives Time to Peak (Tp), Percentage Runoff (PR) and Baseflow (BF) using FEH catchment descriptors, but retains the FSR-calculated PMP;
- The use of the ISIS software FSSR16 unit to derive hydrographs for the 1 in 10,000 year event, using the FSR rainfall depths described above; and
- The use of the ISIS software FEH RR unit to derive hydrographs for all other return periods (up to and including the 1 in 1,000 year event), using the FEH rainfall depths described above.

For each event a variety of storm durations was tested and hydrographs calculated to determine the critical hydrological storm duration. These were run in the hydraulic model to confirm the critical duration for the two Hampstead Heath pond chains.

Hydrographs were calculated for each total catchment down to the respective pond outflow. For all events and durations, the upstream catchment hydrograph was then subtracted from the total catchment hydrograph to derive hydrographs for the intervening catchment areas. These formed the inflows to each pond in the hydraulic model. This approach was used as the FEH / FSR methods are less reliable for flow calculation for the very small intermediate catchments less than $0.5km^2$ in area.

Vale of Health pond and Viaduct pond have very small contributing catchment areas ($0.08km^2$ and $0.13km^2$ respectively). Hydrographs were therefore derived for the larger upstream Hampstead catchment (to the Catch Pit which has an area of $0.45km^2$) and were scaled by catchment area to provide three separate inflows to the respective ponds within the hydraulic model.

These flow hydrographs exclude the contribution of rain falling on the ponds. The rainfall profiles derived for each event / storm duration have been converted to flow-time hydrographs and inserted as inflows to the pond areas in the hydraulic model.

4.7. Hydrological Modelling Results

Table 4-6 provides the peak inflows derived for the two downstream catchments (total catchment to Highgate No. 1 Pond and Hampstead No. 1 Pond) for the (varying) hydrological critical storm durations[5] for the range of flood events.

Table 4-6 Highgate No. 1 and Hampstead No. 1 Ponds - Critical Storm Duration and Peak Flow

Flood Event (1 in T year)	Highgate No. 1 Pond		Hampstead No. 1 Pond	
	Critical Duration (hours)	Peak Flow (m^3/s)	Critical Duration (hours)	Peak Flow (m^3/s)
1 in 5	2.3	2.49	2.3	1.18
1 in 20	2.7	3.96	2.7	1.87
1 in 100	2.3	7.02	2.1	3.34
1 in 1,000	1.9	16.08	1.5	7.72
1 in 10,000	1.9	18.44	1.9	8.49
PMF	9.5	39.10	9.5	18.82

Table 4-7 provides a comparison between the peak flows for the total catchments to each of the Hampstead Heath ponds, as calculated by Haycock (2010) and Atkins (2013). This illustrates that the flows calculated by Atkins for the 1 in 10,000 year and the PMF events are significantly lower than those previously calculated by Haycock, largely as a result of the lower SPR / PR values used for the Atkins analysis. In contrast however, the 1 in 100 year event calculated by Atkins has mostly higher peak flows compared with the Haycock analysis. As noted above, it is believed that Haycock derived the T-year flood peaks by deriving the Q_{mean} from the FSR equation using catchment descriptors, and then applied the FSR regional growth curve to derive the other T-year peaks. This will give results that are different to using FEH for deriving the T-year hydrographs, as we have done. When comparing the 10,000 year and the PMF flows, the following should also be noted:

[5] Critical Storm Duration is the rainfall storm duration which results in the peak flow or level at a given point of interest. All durations longer or shorter than the critical duration, will result in lower peak flow and level at the point of interest

- Haycocks used a storm duration of 4.4 hours for all events. The Atkins flows listed in the table below are for the calculated hydrological critical storm duration for each catchment. This was found to vary between 1.9 and 2.7 hours for the 5, 20, 100, 1,000 and 10,000year return period events, and to be 9.5 hours for the PMF;
- The Atkins peak flow values in Table 4-7 were calculated by summing the total runoff from non-pond areas of the catchment and the flow resulting from rain falling directly on the pond surfaces; The Haycock (2010) PMF was calculated as an approximation by doubling the calculated 1 in 10,000 year event peak flow wthe Atkins PMF was calculated using the appropriate deterministic approach underlying the PMP rainfall applied to the FSR/FEH rainfall-runoff model. Table 4-7 illustrates that the Atkins ratio of the 1 in 10,000 year and PMF peak flow is 2.1 for Highgate 1 and 2.2 for Hampstead 1.
- Haycock used a percentage runoff of 80-90% while Atkins percentage varied from 53% for the 1 in 100 year event to 60% for the 10,000 year event and 76% for the PMF.

Table 4-7 Comparison of Hampstead Heath Peak Flows Haycock (2010) and Atkins (2013)

Pond Catchment	Peak Flow (m^3/s)					
	1 in 100 year		1 in 10,000 year		PMF	
	Haycock	Atkins	Haycock	Atkins	Haycock	Atkins
Highgate Chain						
Stock	2.34	2.74	14.49	6.86	28.98	15.54
Ladies Bathing	2.85	3.63	18.15	9.10	36.30	20.35
Bird Sanctuary	3.76	5.82	24.14	14.53	48.28	31.88
Model Boating	4.15	6.15	31.23	15.65	62.46	33.71
Men's Bathing	4.48	6.57	34.13	17.02	68.26	36.48
Highgate No 1	4.79	7.02	36.84	18.44	73.68	39.10
Hampstead Chain						
Vale of Health	1.64	0.57	4.67	1.45	9.34	3.32
Viaduct	0.85	0.31	6.04	0.78	12.08	1.78
Mixed Bathing	2.49	2.46	22.80	6.31	45.60	14.15
Hampstead No 2	2.58	2.81	25.62	7.27	51.24	16.14
Hampstead No 1	2.78	3.34	26.30	8.49	52.60	18.82

5. Hydraulic Modelling

This Chapter describes the following aspects of the hydraulic modelling:

- The output provided by the hydraulic modelling;
- Modelling methodology and assumptions;
- The hydraulic modelling results including confirmation of the critical storm durations; and
- The depths of flow over the crests of the dams and as assessment of the implications of these flows on the performance of the ponds during extreme floods.

5.1. Study Output

The following was required as output from the hydraulic model:

- Flow-time hydrographs over each dam crest;
- Flow-time hydrographs through each pond outfall pipe; and
- Stage-time relationships for each pond.

These times series were then used to determine the following:

- Maximum flood rise for each pond (peak water level minus starting water level); and
- Maximum dam crest overtopping depth (peak water level minus minimum crest level).

The design flood events used in the modelling were the standard extreme events for reservoir safety studies (1 in 1,000 year, 1 in 10,000 year and the Probable Maximum Flood (PMF)) and a range of lower return period events (1 in 5 year, 1 in 20 year and 1 in 100 year) for the purpose of determining the current SoP of each dam.

5.2. Modelling Methodology and Assumptions

A linked 1D-2D hydraulic model of Hampstead Heath was constructed using InfoWorks RS modelling software, version 12.0.3. As discussed in Section 3, the representation of reservoir as 1-dimentsional units linked to the overland flow routes all the way around the perimeter of the reservoir will best represent the overflow from the reservoirs during extreme flood events. This is the approach that was taken here to good effect, and the following sections summarise the modelling methodology, key assumptions and results of the modelling.

5.2.1. Model Inflows

Flow-time boundary nodes were used to provide each modelled pond with two hydrological inflows:

- A flow hydrograph representing the event runoff from the catchment to each pond (i.e. runoff from land draining into the pond); and
- A flow hydrograph representing the volume of rainfall that would enter the pond directly from rainfall falling onto the pond surface.

5.2.2. Ponds

Storage Area

The five ponds on the Hampstead chain (Vale of Health, Viaduct, Mixed Bathing, Hampstead 2 and Hampstead 1) and the six ponds on the Highgate chain (Stock, Ladies Bathing, Bird, Model, Men's Bathing and Highgate 1) were modelled in the one dimension (1D) as storage areas. This means that they have been presented as frictionless buckets that fill up and then discharge when the water level reaches the overflow pipe and dam crest levels. The starting water level in each pond was set to the invert level of the respective overflow pipe (pond Top Water Level – TWL). These values were obtained from the Haycock Stella Model (2010) and confirmed using data from the Emergency Response Plan (City of London, 2012) and are listed in Table 5-1.

Table 5-1 Pond Top Water Level and Surface area

Pond	Top Water Level (TWL) (m AOD)	Surface area @ TWL(km^2)
Highgate Chain		
Stock	81.06	0.00440
Ladies Bathing	76.00	0.00693
Bird Sanctuary	71.95	0.00769
Model Boating	71.35	0.01628
Men's Bathing	67.59	0.01825
Highgate No 1	62.45	0.01366
Hampstead Chain		
Vale of Health	105.04	0.00865
Viaduct	89.50	0.00333
Mixed Bathing	74.95	0.00715
Hampstead No 2	74.39	0.01091
Hampstead No 1	69.39	0.01519

The surface area of each pond at top water level was determined from mapping. The level-area relationship above this level was abstracted from the DEM.

Dam Crest

The dam crests were modelled using spill units, with elevations taken from the topographic survey (Plowman Craven, 2010). A weir coefficient value of 1.5 was used to represent the grassed nature of the embankments and steep downstream slopes. Infoworks RS recommends a value of 1.0 to 1.7 for spills representing broad crested weir flow as would occur for the embankments. A value of 1.5 was chosen on the basis of guidance given in CIRIA Report No. 116 for flow over embankments such as the Hampstead Heath dams. The spill units were connected to the upstream pond and either directly to the downstream pond or to the 2D floodplain area. Table 5-2 provides the modelled minimum dam crest level, the modelled dam length and the downstream connection unit.

Table 5-2 Dam Minimum Crest Level, Length and Connections

Pond	Minimum Crest Level (m AOD)	Crest Length (m)	Downstream Connection
Highgate Chain			
Stock	81.65	60	2D Floodplain
Ladies Bathing	76.87	54	2D Floodplain
Bird Sanctuary	72.57	61	Model Boating Pond
Model Boating	71.87	75	Men's Bathing Pond
Men's Bathing	68.16	124	Highgate No 1 Pond
Highgate No 1	63.50	130	2D Floodplain
Hampstead Chain			
Vale of Health	105.44	130	2D Floodplain
Viaduct	89.97	65	2D Floodplain
Mixed Bathing	75.46	70	Hampstead No 2 Pond
Hampstead No 2	74.91	105	Hampstead No 1 Pond
Hampstead No 1	70.91	121	2D Floodplain

Pond Banks

The right and left banks of the ponds upstream of the dams were also defined using spill units, but the elevations were taken from the DEM. A weir coefficient value of 1.0 was used to represent the grassed nature of the pond edges. Infoworks RS recommends a value of between 0.7 and 1.0 for overbank spills representing side or lateral spills of this nature. The spill units were connected to the pond and the neighbouring 2D floodplain area. This enabled flows to pass to and from the 1D and 2D parts of the model.

Overflow Pipes

Most of the pond outfall pipes were included in the model as Flow-Head Control Weirs. These had a defined crest level and a flow-head relationship derived based on the number, length and diameter of the pipes. The pipe details were obtained from the Haycock Stella Model (2010) and confirmed using data from the Emergency Response Plan (City of London, 2012).

The weirs connected the upstream pond with either the downstream pond or the 2D floodplain area, consistent with the connection information provided for the dam spills in Table 5-2. Where the pipe length was less than 10m, the outfall pipes were instead modelled using ‘short conduit’ orifices. This applied to the outfall pipes from Bird Pond and Mixed Bathing Pond. The orifice units had defined invert, soffit & sill levels, and bore areas. This information was also obtained from the Haycock Stella Model (2010) and confirmed using the Emergency Response Plan (City of London, 2012).

5.2.3. Floodplain

Flows across the floodplain were modelled in 2D using a 2D simulation polygon with a maximum triangle size of 150m^2. All ground elevations were taken from the DEM, with no changes made. Some areas surrounding the ponds have dense vegetation / tree cover. Examination of the DEM data provided suggested that the method that was used for determining ground levels in these locations, which would have involved interpolation across areas where tree elevations would have been removed, may have been less effective resulting in potentially poorer quality elevation data in these areas. This reduced quality data may affect floodplain flow routes in these locations. A universal Manning’s n roughness value of 0.02 was used for the entire modelled floodplain area. This is a widely recognised value for short-grassed areas with relatively deep flowing water as would be the case in the extreme floods. All channels and the catch pit on the Hampstead Chain were modelled in the 2D domain. Figure 5-1 is the Hampstead Heath Infoworks Model schematic.

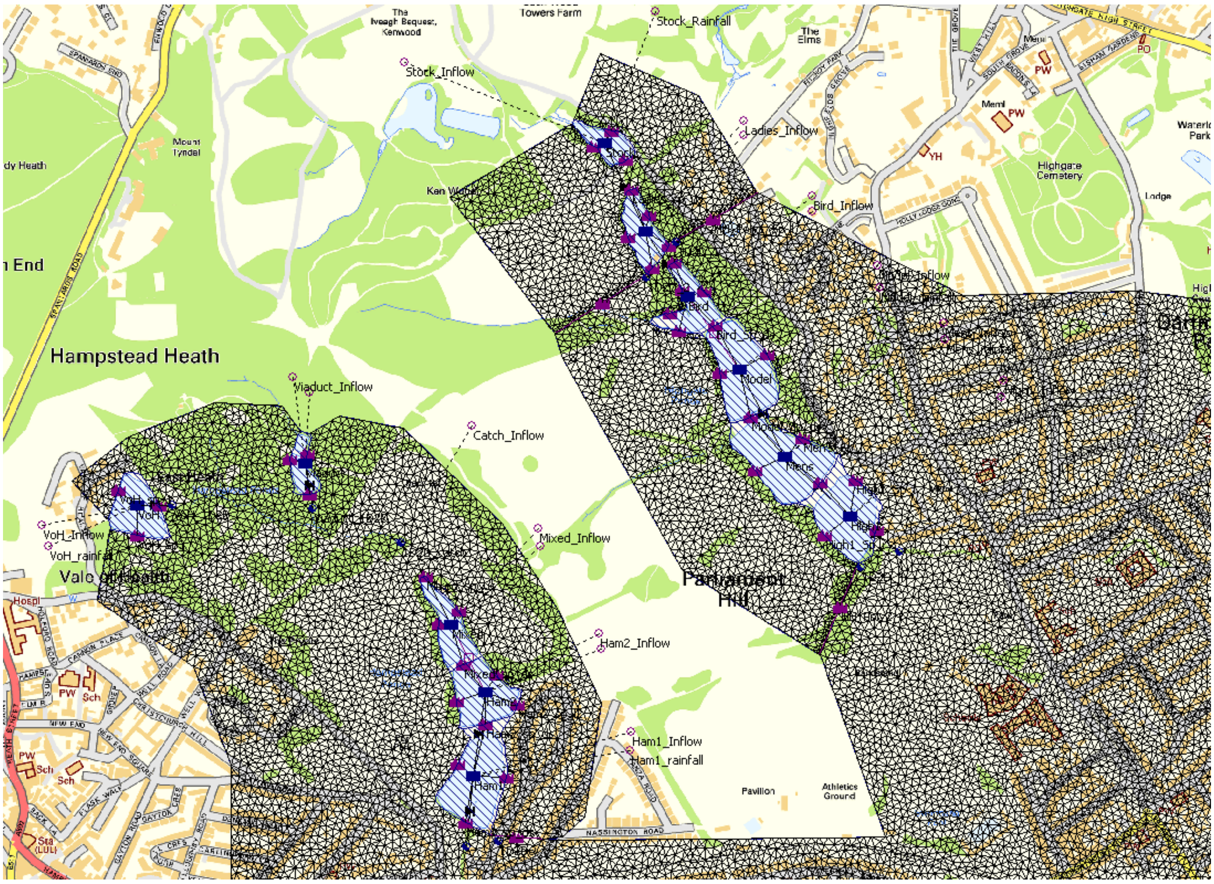

Figure 5-1 Model screen shot showing ponds (blue striped polygons), 2D floodplain (black netted polygon) and inflows (small purple circles)

5.3. Hydraulic Modelling Results

5.3.1. Confirmation of Critical Storm Duration

Each flood event was run in the hydraulic model with four different storm durations centred around the storm that was found to give the largest peak flow in the hydrological model (i.e. the hydrological critical duration). The results were then extracted from the storage areas to determine the peak water level in each pond. The hydraulic critical storm duration was assessed at each pond and the overall system critical duration was determined to be the duration which resulted in the highest water levels at the greatest number of ponds or the critical duration of the lowest pond in the chain if different from that of the other ponds. The results demonstrated that hydrological critical storm duration was confirmed as the critical duration after running through the hydraulic model. This is largely because the ponds provide little storage, particularly for the larger storm, which is the main factor that could attenuate the inflow and result in a longer hydraulic critical duration. The final durations selected for use in the modelling are listed in Table 5-3.

Table 5-3 Confirmation of Critical Storm Duration

Flood Event	Critical Storm Duration (hours)
1 in 5 year	3.9
1 in 20 year	2.9
1 in 50 year	2.9
1 in 100 year	3.9
1 in 1,000 year	1.9
1 in 10,000 year	2.3
PMF	9.5

5.4. Summary of Model Results

5.4.1. Overtopping Assessment

Table 5-4 to Table 5-6 provide a summary of the depth of overtopping assessment model results. This information will be used to determine the performance and safety of the existing structures. Table 5-4 provides a comparison to the Haycock 2010 overtopping depths for the PMF which shows that, in general, overtopping depths produced by the current study are lower than those produced by the 2010 study, with as much as a 1m reduction in depth over the Ladies Bathing Pond dam and 770mm reduction in depth over Mixed Bathing Pond. The ponds that show very little difference in overtopping depth are likely to have very limited storage capacity above TWL relative to the volume of the inflow. Hence a flood of any magnitude will result in overtopping of these ponds, resulting in similar overtopping depths. This appears to be the case with Stock Pond, Model Boating and Highgate 1. Table 5-7 is an assessment of the storage capacity of each pond relative to the inflow PMF from its natural catchment (i.e. not including any outflow from the upstream reservoirs either over the dam or through the outflow pipes). It shows that Stock Pond can store 2% of the PMF, Model Boating 27% and Highgate 1, 56%. However Highgate 1, at the bottom of the chain will have a much smaller storage capacity than this, after all overflowing spills into it from upstream are account for. The table shows that Hampstead 1 can store 138% of its natural catchment PMF, but similar to Highgate 1, will also need to accommodate overflow from all upstream reservoirs. The volume of storage at the Kenwood ponds was investigated and judged to be insignificant.

Figure 5-2 shows the flood map for the PMF event. It shows that for many of the ponds, there is overbank flow out of the sides of the reservoirs in addition to flow over the dam crest. An examination of the 2D flow velocities and flows over the spills revealed a very dynamic interaction between the reservoirs and the floodplain. The flood maps also show that there could be significant flooding to properties downstream during the PMF due to overtopping alone.

Table 5-4 PMF Summary Results

Pond	Peak Water Level (m AOD)	Flood Rise (m)	Maximum Dam Overtopping Depth (m) - Atkins	Maximum overtopping depth – Haycock 2010
Highgate Chain				
Stock	82.10	1.04	0.45	0.66
Ladies Bathing	77.11	1.11	0.24	1.31
Bird Sanctuary	73.02	1.07	0.45	0.71
Model Boating	72.24	0.89	0.37	0.49
Men's Bathing	68.54	0.95	0.38	0.6
Highgate No 1	64.12	1.67	0.62	0.7
Hampstead Chain				
Vale of Health	105.59	0.55	0.15	0.48
Viaduct	90.09	0.59	0.12	0.5
Mixed Bathing	75.77	0.82	0.31	1.08
Hampstead No 2	75.18	0.79	0.27	0.59
Hampstead No 1	71.10	1.71	0.19	0.59

Table 5-5 1 in 10,000 year Summary Results

Pond	Peak Water Level (m AOD)	Flood Rise (m)	Maximum Dam Overtopping Depth (m)
Highgate Chain			
Stock	81.97	0.91	0.32
Ladies Bathing	77.06	1.06	0.19
Bird Sanctuary	72.86	0.91	0.29
Model Boating	72.11	0.76	0.24
Men’s Bathing	68.42	0.83	0.26
Highgate No 1	63.96	1.51	0.46
Hampstead Chain			
Vale of Health	105.53	0.49	0.09
Viaduct	90.04	0.54	0.07
Mixed Bathing	75.65	0.70	0.19
Hampstead No 2	75.08	0.69	0.17
Hampstead No 1	70.97	1.58	0.06

Table 5-6 1 in 1,000 year Summary Results

Pond	Peak Water Level (m AOD)	Flood Rise (m)	Maximum Dam Overtopping Depth (m)
Highgate Chain			
Stock	81.96	0.90	0.31
Ladies Bathing	77.05	1.05	0.18
Bird Sanctuary	72.84	0.89	0.27
Model Boating	72.10	0.75	0.23
Men’s Bathing	68.40	0.81	0.24
Highgate No 1	63.93	1.48	0.43
Hampstead Chain			
Vale of Health	105.52	0.48	0.08
Viaduct	90.04	0.54	0.07
Mixed Bathing	75.64	0.69	0.18
Hampstead No 2	75.06	0.67	0.15
Hampstead No 1	70.84	1.45	- 0.07

Table 5-7 Assessment of pond storage capacity with respect to the PMF

Chain	Pond	Total PMF volume in (m^3) including spills from the upstream pond	Min. Crest Level (m AOD)	Top Water Level TWL (m AOD)	Pond Surface Area m^2	Available storage (m^3) above TWL	% of inflow PMF can be stored
Highgate	Stock Pond	114,438	81.65	81.06	4,401	2,597	2
	Ladies Bathing	153,055	76.87	76.00	6,926	6,026	4
	Bird Sanctuary	171,407	72.57	71.95	7,694	4,770	3
	Model Boating	116,765	71.62*	71.35	16,280	4,379	4
	Men's Bathing	217,067	68.16	67.59	18,250	10,403	5
	Highgate No 1	275,972	63.50	62.45	13,660	14,343	5
Hampstead	Vale of Health	25,539	105.44	105.04	8,646	3,458	14
	Viaduct	13,444	89.97	89.50	3,329	1,565	12
	Mixed Bathing	67,020	75.46	74.95	7,148	3,645	5
	Hampstead No 2	89,542	74.91	74.39	10,910	5,673	6
	Hampstead No 1	117,819	70.91	69.39	15,190	23,089	20

*This is the minimum level of the auxiliary spillway.

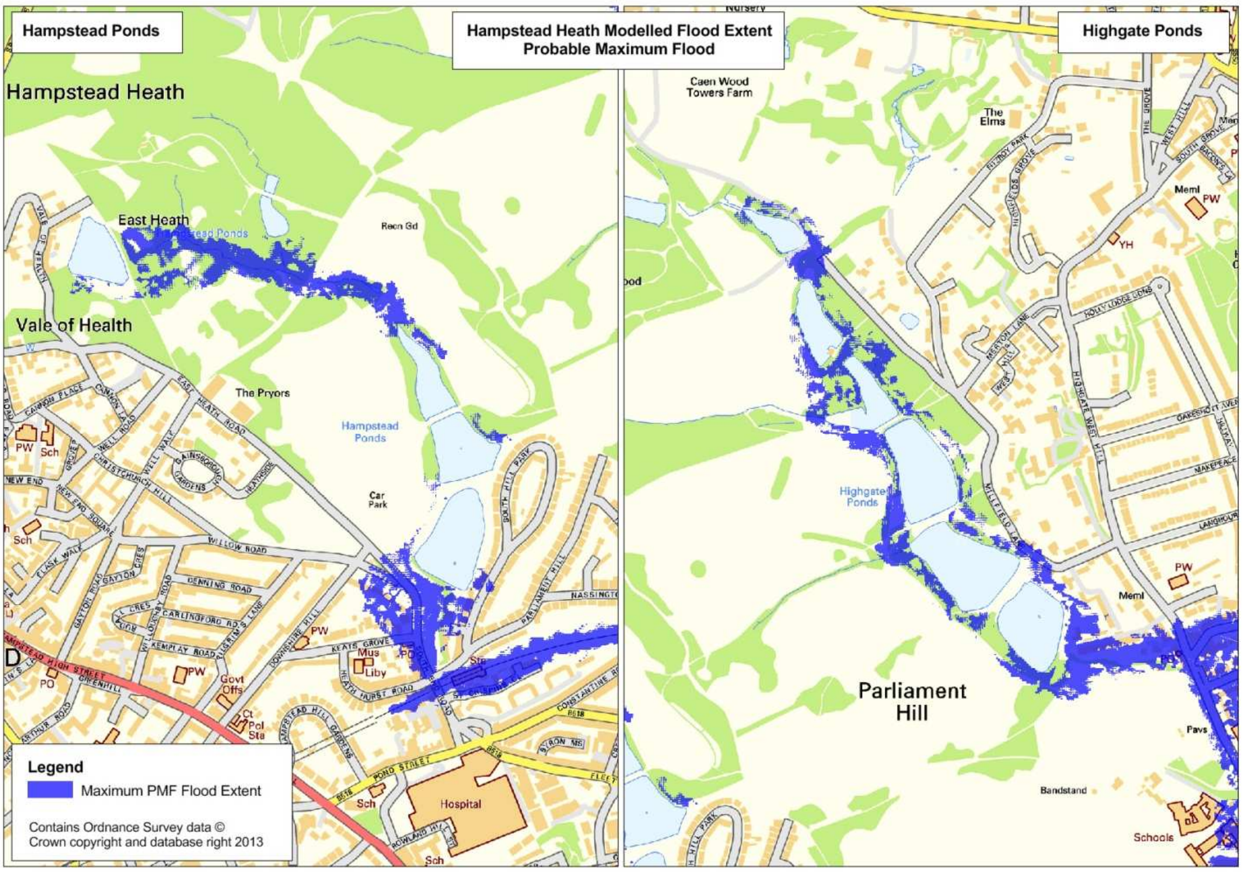

Figure 5-2 Flood map around the ponds for the PMF event

5.4.2. Standard of Protection Assessment

The four lower return period events were run through the hydraulic model to estimate the current standard of protection of each dam in the chain. Table 5-8 to
Table 5-11 provide the depths of overtopping for the 5, 20, 50 and 100 year events. These results were used to estimate the approximate SoP for each pond as presented in Table 5-12.

Table 5-8 1 in 5 year Summary Results

Pond	Peak Water Level (m AOD)	Maximum flood rise (m)	Maximum Dam Overtopping Depth (m)
Highgate Chain			
Ladies Bathing	81.80	0.74	0.15
Bird Sanctuary	76.79	0.79	-0.08
Model Boating	72.44	0.49	-0.13
Men's Bathing	71.35	0.00	0.52
Highgate No 1	67.59	0.00	-0.57
Ladies Bathing	62.45	0.00	-1.05
Hampstead Chain			
Vale of Health	105.11	0.07	-0.33
Viaduct	89.50	0.00	-0.47
Mixed Bathing	74.95	0.00	-0.51
Hampstead No 2	74.39	0.00	-0.52
Hampstead No 1	69.39	0.00	-1.52

Table 5-9 1 in 20 year Summary Results

Pond	Peak Water Level (m AOD)	Maximum flood rise (m)	Maximum Dam Overtopping Depth (m)
Highgate Chain			
Ladies Bathing	81.83	0.77	0.18
Bird Sanctuary	76.89	0.89	0.02
Model Boating	72.62	0.67	0.05
Men's Bathing	71.84	0.49	- 0.03
Highgate No 1	67.86	0.27	- 0.30
Ladies Bathing	62.45	0.00	- 1.05
Hampstead Chain			
Vale of Health	105.24	0.20	-0.20
Viaduct	89.67	0.17	-0.30
Mixed Bathing	75.08	0.13	-0.38
Hampstead No 2	74.39	0.00	-0.52
Hampstead No 1	69.49	0.01	-1.42

Table 5-10 1 in 50 year Summary Results

Pond	Peak Water Level (m AOD)	Maximum flood rise (m)	Maximum Dam Overtopping Depth (m)
Highgate Chain			
Stock Pond	81.85	0.79	0.20
Ladies Bathing	76.93	0.93	0.06
Bird Sanctuary	72.68	0.73	0.11
Model Boating	71.94	0.59	0.07
Men's Bathing	68.25	0.66	0.09
Highgate No 1	63.42	0.97	- 0.08
Hampstead Chain			
Vale of Health	105.34	0.30	- 0.10
Viaduct	89.76	0.26	- 0.21
Mixed Bathing	75.27	0.32	- 0.19
Hampstead No 2	74.41	0.02	- 0.50
Hampstead No 1	69.58	0.19	- 1.33

Table 5-11 1 in 100 year Summary Results

Pond	Peak Water Level (m AOD)	Maximum flood rise (m)	Maximum Dam Overtopping Depth (m)
Highgate Chain			
Stock	81.87	0.81	0.22
Ladies Bathing	76.95	0.95	0.08
Bird Sanctuary	72.72	0.77	0.15
Model Boating	71.98	0.63	0.11
Men's Bathing	68.30	0.71	0.14
Highgate No 1	63.70	1.25	0.20
Hampstead Chain			
Vale of Health	105.42	0.38	- 0.02
Viaduct	89.90	0.40	-0.07
Mixed Bathing	75.54	0.59	0.08
Hampstead No 2	74.97	0.58	0.06
Hampstead No 1	69.99	0.60	-0.92

Table 5-12 below indicates whether overtopping occurs at each reservoir for each return period storm. It shows that the standard of protection (SoP) is generally higher on the Hampstead chain than in the Highgate chain. Stock pond has a SoP of less than 1 in 5 year, while Highgate 1 has a SoP of between 1 in 50 and 1 in 100 year. Model Boating overtops via its auxiliary spillway for the 1 in 20 year, but the main embankment has a SoP of between a 1 in 20 and a 1 in 50 year event. On the Hampstead chain Mixed Bathing and Hampstead 2 have a SoP of between the 1 in 100 and 1 in 1,000 year event, while Vale of Health and Viaduct have a SoP of between 1 in 50 and 1 in 100 year event. Hampstead 1 has a SoP of between the 1 in 1,000 and 1 in 10,000 year event.

Table 5-12 Summary of current Standard of Protection

Pond	5 year	20 year	50 year	100 year	1000 year	10,000 year	PMF
Highgate Chain							
Stock	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped
Ladies Bathing		Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped
Bird Sanctuary		Overtopped	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped
Model Boating		Auxiliary Spillway Overtopping	Overtopped	Overtopped	Overtopped	Overtopped	Overtopped
Men's Bathing			Overtopped	Overtopped	Overtopped	Overtopped	Overtopped
Highgate No 1				Overtopped	Overtopped	Overtopped	Overtopped
Hampstead Chain							
Vale of Health					Overtopped	Overtopped	Overtopped
Viaduct Pond					Overtopped	Overtopped	Overtopped
Mixed Bathing				Overtopped	Overtopped	Overtopped	Overtopped
Hampstead No 2				Overtopped	Overtopped	Overtopped	Overtopped
Hampstead No 1						Overtopped	Overtopped

(blue)	Overtopped
(white)	Not overtopped
(grey)	Auxiliary Spillway Overtopping

The Table above shows that eight of the eleven ponds are likely overtop before or during a 100 year flood. This frequency of overtopping with the attendant risks described below is unacceptable for ponds which pose a significant risk to the urban area below the Heath.

5.4.3. Implications of overtopping for Dam Stability

The velocity of the flow on the downstream slope of the embankments has been estimated. As the crests of the embankments are not level, there will be tendency for flow to concentrate at the low spots. The estimated velocities of the flow on the slopes are shown in the Table below.

Table 5-13 Summary of PMF Peak Velocity on Outside Slope

Chain	Pond	Peak overtopping discharge (m3/s)	Crest length (m)	Slope	Maximum depth of overtopping (m)	Peak velocity, over existing embankment (m/s)	Overtopping duration (hrs)
Highgate	Stock	10.95	43	0.30	0.45	5.07	9.25
	Ladies Bathing Left Bank	2.99	46	0.18	0.24	2.66	2.08
	Bird Sanctuary	17.01	100	0.17	0.45	3.73	6.75
	Model Boating	16.09	78	0.32	0.37	4.72	6.17
	Men's Bathing	30.74	147	0.25	0.38	4.12	7.42
	Highgate No 1	32.18	100	0.24	0.62	5.42	8.75
Hampstead	Vale of Health	2.13	130	0.24	0.15	2.34	4.00
	Viaduct	1.40	55.5	0.44	0.12	2.75	3.75
	Mixed Bathing	7.28	44	0.22	0.31	3.38	4.92
	Hampstead No 2	9.13	100	0.22	0.27	3.15	3.83
	Hampstead No 1	7.60	112	0.31	0.19	3.07	3.33

The Table above shows that velocities close to 5.5m/s could occur on the downstream slope during overtopping. At the speeds estimated in the above Table, standard guidance suggests that the dam slopes would need reinforcement to prevent erosion which could lead to a breach of the dam. The velocities shown are based on a uniform surface; in reality the outer slopes are uneven with trees and other coarse vegetation which will contribute to locally greater speeds. In addition coarse vegetation is readily pulled out by flowing water. These factors will exacerbate erosion damage to the slope which emphasizes the need to either to prevent flow over the crest by channelling flow around the dams or where this is not possible, to reinforce the slope using “soft” engineering techniques such as reinforced grass.

The duration of the overtopping event are estimated to be up to 9.25 hours and this could be long enough to cause significant saturation of the downstream shoulder of the dam. The influence of saturation on the stability of the embankment slopes will be taken into account in the detailed design and also emphasizes the need to avoid flow over the crests and over the outer slopes where practicable.

6. Conclusions and Recommendations

- The report presents a review of current overtopping risk associated with the Hampstead Heath ponds.
- It examines the previous work done and concludes that the previous work was based on non industry-standard methods, and a percentage runoff, based on limited field measures, which was greater than values calculated using current industry standard methods. The use of very high percentage runoff values for the Heath is the main reason for PMF peak flows that are on average twice that obtained using industry standard methods.
- Using industry standard methods, a reasonable revision of the SPR was obtained based on FEH methods, which resulted in Percentage Runoff values that were less that those used in the Haycock model and more reasonable for the catchment.
- Reservoir routing resulted in generally lower overtopping depths than those predicted by Haycock.
- Complex overland flow paths around the dams have been modelled and these will need to be considered in an assessment of dam stability and risk of erosion of the dams
- It can be concluded that the current study has been robust and utilised best available data and industry best practice and software, and has resulted in flows and overtopping depths with a reasonable degree of confidence. It is of the appropriate level of detail for the detailed design of options for upgrading the dams to pass the PMF.
- The problem definition assessment has revealed that all dams are overtopped during the PMF and that the current standard of protection of the dams ranges from less than 5 years to between 1 in 1,000 and 1 in 10,000 years. The Highgate chain has a generally lower standard of protection (less than 1 in 5 to below the 1 in 100 years) while the Hampstead chain has a SoP in excess of 1 in 50 years (and as high as between the 1 in 1,000 years and 1 in 10,000 year).

Floods estimated by Atkins were generally 30% to 50% lower than those estimated by Haycock Associates. Even with reduced flood volumes water will still flow over the dam crests during the design flood (PMF). The speeds of the flow on the outer face are estimated to be in the range 2.3m/s to 5.5m/s with durations from 2 hours to 9.5 hours. Flows at these speeds and duration on the outer slope, in conjunction with the uneven nature of the slopes with coarse vegetation, are such that the embankments are likely to suffer erosion damage which in some cases could lead to a breach.

This means that to reduce the risk of breaching, improvements will need to be made to some of the dams to enable them to cope with the design flood (PMF), although the extent of the work needed should be less than that proposed by Haycock.

Glossary

Terminology	Definition
Annual Maximum (AMAX) series	The maximum observed rainfall or flow for a given gauging station within each water year. In this report the term is used in reference to the 24-hour duration rainfall depth observed in each water year of the Hampstead Heath Scientific Society rainfall record.
Antecedent conditions	The 'wetness' of the catchment prior to the event, due to previous rainfall events.
BFI (Base flow Index)	Base flow is the proportion of a river's flow which is not related to rainfall runoff contributions i.e. the proportion of flow which would flow in the rivers when no rainfall has occurred.
Catchment	The area which drains to a specified point/outflow.
Critical Storm Duration	The rainfall storm duration which results in the peak flow or level at a given point of interest. All durations longer or shorter than the critical duration, will result in lower peak flow and level at the point of interest
Depth-Duration-Frequency (DDF) Curves	A curve which defines the rainfall depth as a function of duration for given return periods.
Digital Elevation Model (DEM)	A digital model of the terrain or surface elevation of the land.
DPLBAR (m/km)	Mean drainage path length. The mean distance of all drainage paths in the catchment.
DPRCWI	Dynamic Percentage Runoff which is dependent on the catchment wetness index (CWI) and allows the percentage runoff to vary based on the state of the catchment prior to the storm
DPRRAIN	Dynamic Percentage Runoff which is dependent on storm depth, and allows the percentage runoff to vary between different storm based on storm magnitude
DPSBAR	Mean drainage path slope. The mean slope between pairs of nodes in the catchment, based on the steepest route of decent between nodes.
Em-2h	FSR parameter. Maximum 2 hour precipitation.
Em-24h	FSR parameter. Maximum 24 hour precipitation.
Em-25d	FSR parameter. Maximum 25 day precipitation.
Flood Estimation Handbook (FEH)	FEH is the standard UK method for estimating rainfall, and flood frequency and flows.
Flood Studies Report (FSR)	The FSR was the first UK-wide flood estimation method developed in 1975. FEH largely supersedes the FSR.
Flood Studies Supplementary Report 16 (FSSR16)	A supplementary report to the FSR published in 1985.
Flow	The discharge of a river, measured in metres cubed per second (m3/s or cumecs).
HHSS	Hampstead Heath Scientific Society
HOST	Hydrology of Soil Type classification. UK soils have been delineated according to their hydrological properties and then grouped into the HOST classification. There are 29 classifications.
Hydrograph	A graph showing the flow of a river over a period of time, often in response to a rainfall event, this may be called a Storm or flow Hydrograph.
ISIS software	Modelling software used to assist in the estimation of rainfall and flood hydrographs as per the FEH, FSR and ReFH methods.
Jenkinson's r	The ratio of M5-60min to M5-2D where M5-60min is the maximum rainfall depth for a 5-year event of 60min duration and the M5-2D is the maximum rainfall depth for a 5-year event of 2days duration.
M5-2d	FSR parameter. 1 in 5 year rainfall event 2 day maximum precipitation.
M5-25d	FSR parameter. 1 in 5 year rainfall event 25 day maximum precipitation.
Percentage Runoff	The percentage of the total rainfall that becomes direct runoff after account for losses (such as infiltration, interception, evaporation).
Probable Maximum Flood (PMF)	The largest flood that may reasonably be expected to occur from the most severe combination of critical meteorologic and hydrologic conditions that are possible in a catchment.
Probable Maximum Precipitation (PMP)	The largest rainfall event that may reasonably be expected to occur from the most severe meteorologic conditions over a catchment.

PROPWET	Index of the proportion of time that soils are wet.
Rainfall Hyetograph	A graph showing the distribution of a storm with depth over time i.e. mm per hour.
Revitalised Flood Hydrograph (ReFH) model	A lumped conceptual rainfall-runoff model, which has been developed for modelling flood events and is considered to be an improvement over the models used within FSR/FEH.
Return Period	The return period of an event is a statistical measure of the rarity of the event. The return period can be expressed as an annual chance or annual exceedence probability. For example a 1 in 100 year flood can also be described as a flood with a 1 in 100 annual chance or with an annual exceedence probability of 1% i.e. in any given year there is a 1% chance of the event occurring.
Rainfall Runoff (RR)	The conversion of rainfall over a catchment into the water which flows within river channels. Takes into account the losses which occur i.e. through infiltration into the ground.
SAAR	Standard Average Annual Rainfall. The average of all annual rainfall depths over a specified period (the FEH includes SAAR for the period 1941-1970 and for 1961-1990 for Great Britain and Northern Ireland.
S1085 (m/km)	The slope of the stream between points 10% and 85% of the length from the lowest point on the mainstream.
Spill and orifice unit (in hydraulic model)	A structure within a hydraulic model which allow water to be transferred (or spill) along a length of bank (e.g. a reservoir embankment or the side banks of the reservoir).
SPR	Standard Percentage Runoff. The normal capacity of the catchment to generate runoff.
SPRHOST	Standard Percentage Runoff from the Hydrology of Soil Types Classification.
Standard of Protection (SoP)	The flood event to which a structure is designed to withstand flooding (normal expressed as a return period. Hence a reservoir has a standard of protection of 20 years if its dam is not overtopped during floods of the 1 in 20 year magnitude or less.
Summer vs. Winter rainfall profiles	In modelling seasonal rainfall profiles depth and duration remain the same, summer profiles have a higher peak depth, whereas winter profiles the depth is more evenly spread across the duration.
Time to Peak (Tp)	The time between the start of an event and the time when the flow or rainfall reaches its peak.
TWL	Top Water Level. The invert level of the outflow pipes. Hence the level above which outflow from the reservoir will start
Unit hydrograph	A tool for converting a given depth of rainfall over a catchment, during a specified duration, into a Storm Hydrograph.
Urban fraction	FSR index of fractional urban extent.
URBEXT	FEH descriptor to describe the level of urbanisation of a catchment.
Water Year	In the UK the water year runs from the 1st October to 31st September of the following year. This coincides with the start of the 'wetter' season and the recharge of groundwater supplies. It ensures the flood peaks of each year are independent statistically.
Weir Coefficient value (in hydraulic model)	Enables the model to represent the surface and therefore the resistance water will encounter and impact on flow when flowing across or through the surface/object.

Appendices

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Appendix A. References

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Mike Woolgar
Atkins
Woodcote Grove, Ashley Road, Epsom, Surrey KT18 5BW

mike.woolgar@atkinsglobal.com

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Ponds Project Stakeholder Group

Monday 18 March 2013, 6.00pm
Parliament Hill meeting room

Present:

Ian Harrison	IH	Vale of Health Society (Chairman)
Jeremy Simons	JLS	City of London (Deputy Chairman)
Karen Beare	KB	Fitzroy Park RA
Tom Brent	TB	South End Green
Mary Cane	MC	Kenwood Ladies Pond Association
Rachel Douglas	RD	Mixed Pond Association
Michael Hammerson	MH	Highgate Society
Harriet King	HK	Brookfield Mansions RA
Simon Lee	SL	Superintendent, Hampstead Heath
Charles Leonard	CL	Oak Village RA
Mary Port	MP	Dartmouth Park CAAC
Ellin Stein	ES	Mansfield CAAC
Robert Sutherland-Smith	RSS	Highgate Men's Pond Association
Peter Wilder	PW	Strategic Landscape Architect, Wilder Associates
Jeremy Wright	JW	Heath & Hampstead Society
Jennifer Wood	JMW	Communication Officer, City of London (notes)

Alternate members observing

Harley Atkinson	HA	Fitzroy Park RA
Mary Cane	MC	Kenwood Ladies Pond Association
Tony Gilchick	TG	Heath & Hampstead Society
Ed Reynolds	ER	Oak Village RA
Susan Rose	SR	Highgate Society

Atkins

Andy Hughes	AH	Panel Engineer
Tony Bruggemann	TB	Principle Engineer on Ponds Project, Atkins

City of London (CoL) officers observing:

Richard Chamberlain	RC	Senior Project Liaison Officer, City Surveyors
Declan Gallagher	DG	Operations Service Manager, Hampstead Heath
Paul Monaghan	PM	Assistant Director Engineering
Peter Snowdon	PS	Projects Director, City Surveyor's Department
Peter Young	PY	Corporate Property Director

1. **Apologies**

Marc Hutchinson	Highgate Men's Pond Association
Nick Bradfield	Dartmouth Park CAAC

2. **Approval of previous note and matters arising**

- Note accepted as an accurate record.

3. Presentation on results of Fundamental Review or Design Flood Assessment by Dr Andy Hughes

- AH gave presentation on the findings of the Design Flood Assessment (slides to be circulated)
- He said Atkins reviewed Haycock's data, which had used bespoke methodology and was predicting high-run-off figures. Atkins have looked at different storm durations and have used industry standards for assessing hydrology and methods for analysing hydraulic methods. Their studies show lower run-off percentages and design rainfall depths resulting in lower flood peaks and potentially less intrusive work on Heath.
- But work is still required as all of the ponds can overtop even in smaller rainfall events. With earth dams (such as those on the Heath) overtopping can cause erosion and potentially lead to dam failure.
- AH said one table in the report – table 5.7 will be replaced as it is misleading as does not show effects of the chain of ponds. Updated report will be circulated.
- IH asked if the Kenwood ponds had been taken into account. AH said yes, they were included in the catchment area for Stock Pond. Table 4.1. The catchment areas are cumulative going down the pond chains.
- JW asked if upstream spills had been included. AH said yes.
- MH asked why does velocity vary so much? AH said reflection of volume of water and width of the dam and downstream slope.
- HK asked what about if the ground is dry rather than saturated? AH said they calculate with both dry and wet ground conditions (which give fairly similar results) and take worst case. The design flood is for summer event for the Heath.
- AH said the type or rainfall events we need to design against are happening with more frequency and even though peak flood is less than previously considered – risks to CoL are still unacceptable.
- AH said Model Boating Pond is a potential site for storing more water and reducing work further down the chain, as is creating a storage area at Catch-pit.
- RSS asked how much storage can be created at Model Boating Pond? AH said this is still to be calculated and there were various ways he can create more storage. He can raise dam and dig out area on west-side of the pond to get the fill to build this bigger dam. He could create a larger area for potential storage of water and allow water to spread further in a safe way during extreme rainfall events.
- HK asked what happens when the bottom pond in the chain overtops? AH said the bottom ponds will still overtop and water will pass downstream in the larger flood events, but after the work takes place the dams will not fail, which is the responsibility CoL have in meeting its legal obligations and duty of care.
- ES asked about the maps and whether they could see a map with the residential areas marked so they can see which areas the Atkins review shows too be at risk of flooding. AH said the Environment Agency have published maps but said that they were to be used with caution as they are not precise enough to show a specific address. AH said CoL had not asked for maps but they could be provided. CL and MP said they would also like to see maps; IH hoped the CoL would be able to see that such maps are provided. PM said the Haycock maps are on the website as well as the Environment Agency maps.
- It was noted that all of the stakeholders would like to see maps showing the extent of flooding. AH advised caution with mapping as it could not predict with absolute accuracy the extent of flooding.
- MH asked if the works would require cutting into the ground. AH said much of the work could take place on the surface and invasive works would be avoided where possible.
- TB said the report is clear and reassuring and asked if Atkins were looking at two 'sacrificial areas,' also were Atkins coordinating with Camden Council? AH said Atkins would get most 'bang for their buck' or best solution possible within budget.

- CL asked AH to confirm that the works on the Heath will not leave downstream communities worse off in terms of risk of being flooded downstream than current situation for all levels of storm but especially the smaller storm events, not just the ones that would threaten dam failure. AH said that works on the Heath would not make the situation worse downstream in any level of storm including the smaller flood events.
- KB asked why Haycocks infiltration figures were so much higher, and why national rainfall data had been used over local. AH said Haycock did some tests for infiltration on the Heath and assumed the whole Heath was very compacted due to high number of visitors. AH said they looked at soil results which have been gathered in 1km squares across the country. He then calculated how much of the Heath was paths to come up with their figure which is less than Haycock. As regards rainfall, it was more statistically sound to use national data sets which have more figures and from a longer duration from a larger number of rainfall gauges.
- JLS said the run-off rate depends on the rainfall event.
- IH asked if AH is confident the data takes into account the micro-climate effects. AH said the Insititute of Hydrology realized there are unusual events, such as the 1975 event and the data takes this into account.
- JW said Haycock had calculated the PMF event and asked what are the comparable figures for Atkins. AH said the calculations had been made using varying durations and different rainfall events which is the correct way to make this calculation.
- JW asked how to calculate the PMF. AH said you can do this on table 4.7.
- Tony Bruggemann said Probable Maximum Precipitation was calculated using a deterministic approach by looking at meteorology and physics, not statistical.
- HK asked if possible to look at smaller events and how the sewers and drainage would cope. AH said it was complex to look at drainage and out-side the scope of this project but data from their study can be shared with Camden Council and Thames Water.
- CL asked if it was too late to for Camden Council to potentially get involved with the project to help solve their surface water problem at the same time. AH said not too late but Camden would need to move quickly.
- IH asked if maps and data could be shared with Camden. SL said this was possible.
- JS said the people who live in Camden should lobby them.
- CL said he thought more works on Heath could solve the surface water flooding.
- JS said any works on the Heath are going to raise huge objections and great care was needed in terms of what is proposed.
- JW said surrounding areas will flood in even small events.
- IH said we need to know what possible solutions look like before they can be accepted or rejected.
- CL said it would be good if CoL gave Camden all the data and the residents could encourage them to act now.
- KB said if we do the works we will be helping the situation for the residents. AH said yes but said Atkins are not there to build a surface water flood alleviation scheme for Camden and that for some the 1871 Act is likely to be a major concern.
- SL said he was aware that there were potential issues arising from the revised methods used by Atkins to determine the quantum and referred to H&HS concerns and their role in protecting the Heath.
- PW asked if the scheme was now going to cost less does that mean more for environmental improvements. SL said he needs to have that discussion with CoL.
- AH said if there is delay by a legal battle he might have to go through the legislative route and call a Section 10 as he cannot continue to continue with the liability.
- JW asked if there will be a Quantified Risk Assessment. AH said yes on situation now and on the different solutions.
- JW asked if he could submit formal queries? SL said yes and he would attach queries to paper going to HHCC and his deadline is **March 27**.

4. **Consultation and Communication**

- SL said he had held meeting with more groups and was attending a meeting of the Highgate Area Action Group to talk about the project.
- JMW said the website was being updated and the project name had been changed.

5. **Update on programme**

- Contractor will now hopefully be appointed in time for the shortlisted solutions so will be able to give a more accurate costing for the project.

6. **AOB**

IH noted that the HHCC meeting at 7.00pm on April 8 at the Education Centre (at the Lido) is open to the public if other SG members want to attend.

Dates for future meetings:
- Monday, 15 April
- Monday, 13 May
- Monday, 17 June
- Monday, 22 July

JMW/IH 22/03/13

Originating Group and date	Query	Atkins Response 12/04/13	City of London Corporation Response 18/04/13
Fitzroy Park RA 20/03/13	Can we have more specific detail of exactly how much local data was integrated into the Atkins macro model for calculating the quantum? What local weighting did they integrate into to this new calculation?	"Local" data was integrated as follows: For the estimation of the percentage run-off the soils map for Hampstead Heath was used to adjust the Standards Percentage Run-off which was provided by the automated routine with the FEH CD ROM. The HHSS rainfall record was analyzed and it was demonstrated that it was statistically inconsistent with the information from FEH. This is to be expected as it is statistically unreliable to apply data from a single rainfall gauge and with a short record length in comparison with the events being predicted (see Figures 4-4 and 4-5 in the main report).	
Fitzroy Park RA 20/03/13	Prof Hughes said pathways plus a bit extra either side was assumed as hard landscaping. This is very vague. We need more detail.	See page 27 of the main report – a width of 10m was adopted.	
Fitzroy Park RA 20/03/13	With regard to rainfall, Prof Hughes talked about using weather stats from around the country yet his colleague (sitting to the side) talked about a Met	When estimating events with return periods i.e. 5, 20, 50, 100, 1, and 10,000 years, the national rainfall records are used on a statistical basis. For the estimation of the PMF, the	

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	Office determination methodology. Which one is it?	Probably Maximum Precipitation (PMP) is required. The PMP is derivied in a deterministic manner and the FSR report includes maps of PMP which were prepared by the Met Office.	
Fitzroy Park RA 20/03/13	Atkins implied their computer software was far superior/sophisticated to Haycock's version? I cannot find in the report a definitive explanation of the key differences between them. Can this be provided.	Atkins used computer software which is widely used within industry to the extent that it can be considered to be industry "standard" software. The Atkins' hydraulic modeling incorporated 2 dimensional modeling of the land around the ponds linked to a 1 dimensional representation of the ponds and overflow arrangments. In the 1 dimensional model, the ponds are represented by mathematical expressions of the relationship between water levels and pond surface area, and the overflows by a mathematical expression for the relationship between the water and the level and discharge (flow) out of the pond. The 2 dimensional model allows better representation of the topography around the ponds by breaking the area up into a series of interlinked discrete elements. The software solves the equations for fluid flow within the elements as well as across the boundaries between elements thereby showing the spatial	

		variation of the flow around the ponds. Haycock by contrast used only 1 dimensional modeling techniques. The software they used is not widely used in industry in the UK and we have not carried out a detailed appraisal of the software. The Atkins modeling was more sophisticated in that it also modeled the areas around the ponds.	
Fitzroy Park RA 20/03/13	Who wrote 'Floods and Reservoir Safety – 3rd Edition'?	Floods and Reservoir Safety – 3rd Edition, was published by the institution of Civil Engineers in 1996.	
Heath & Hampstead Society 25/03/13	Percentage Run-off: Atkins has made two apparently reasonable simplifications. They have assumed that there is an even distribution of the path network across the Heath. However there appears to be less paths (and hence less compaction) on the higher Heath. Also, they have applied an average SPR value of 53% to all catchments, rather than use a specific lower SPR on the upper more permeable soils. Might these simplifications result in the calculated run-off into the	The FEH guidance on run-off estimation for the PMF states that when the SPR estimate is less than 53%, the SPR should be set at 53%. On basis of this advice, the SPR was not varied between the higher and lower Heath.	

	upper more sensitive ponds being too high, leading to too much work on these ponds? Should the total run-off be adjusted to discharge less into the upper ponds and more into the lower ponds?		
Heath & Hampstead Society 25/03/13	Upstream Spills: The original Table 1-4, Pond Storage Capacity, [Table 5-7 is identical], states in column 3 *excludes spills from the upstream pond*. A revised Table was issued on 21.3.2013 with altered % storage figures in the last column. Column 3 heading now reads *including spills from the upstream pond*. Should the data in the 3rd column [Total PMF volume...] be altered to show increased inflow?	The Table has been revised and the report reissued.	
Heath & Hampstead Society 25/03/13	Section 4.6 indicates that inflow hydrographs were calculated for each pond's individual catchment. It is not clear if the following sections and tables include or	The hydrographs presented are for the whole upstream catchment generated by the hydrological model. These hydrographs have been routed through the hydraulic model and it is this that	

	exclude upstream spills. Please therefore confirm from Section 4.6 onwards, whether or not upstream spills have been included, and if not, please provide amended Tables including upstream spills where appropriate.	provides the spills from upstream reservoirs. These spills are therefore not included in the tables showing hydrographs. The tables have not been updated to include the spill inflows as they are complex and difficult to incorporate. It has been done for the PMF and updated PMF peak inflows.	
Heath & Hampstead Society 25/03/13	Flood Estimates Table 1-1, [Table 4-7 is identical]: This table compares Atkins maximum flows for different storms at every pond with Haycock's flows, which have been extracted from his Table 7, p.43. Are these two tables directly comparable? For example, Haycock states that *these flows will be attenuated by the lake chain and these values thus represent the boundary conditions of the lake model.* Please therefore clarify this aspect, particularly for upstream inflows and whether current attenuation has been allowed in this and other relevant tables. Quantified Risk Assessment: Atkins has confirmed in Appendix A of their Design Review Method Statement and separately that	The Tables are directly comparable. As per the response above, both tables contain the peak of the hydrographs calculated from the respective hydrological models and they are therefore directly comparable. The Quantitative Risk Assessment will be carried out but we expect that lives will still be at risk in the urban area downstream of the Heath.	

	they will carry out a QRA of the current dam situation. When will this be carried out? We urge that it be as soon as the design flood has been agreed.		
Heath & Hampstead Society 25/03/13	Precipitation / Design Rainfall Depths: Please explain how PMP and 1:10,000 rainfall depths and durations were calculated. Was 1:10,000 rainfall derived from PMP [or vice versa]?	The 10,000 year rainfall depth was determined from the FEH statistical rainfall data. The PMP was determined from the PMP maps provided in the FSR and is deterministic, not statistical.	
Heath & Hampstead Society 25/03/13	Are the PMP and 1:10,000 rainfall depths and durations proposed for design 235mm over 9.5 hours and c.141mm over 1.9 hours respectively? (If so, the PMP/1:10,000 ratio is presumably c. 1.67?). If not, please state.	There is no predetermined ratio between the PMP and 10,000 rainfall depths. As noted above, the PMP was derived using deterministic methods whereas the 10,000 year value is derived statistically.	
Heath & Hampstead Society 25/03/13	Haycock used 270mm and 135mm respectively, both over 4.4 hours. This presumably gives a much slacker PMP than Haycock, but a much more intense 1:10,000 storm, which may be the main influence on dam design. Please explain why then so much difference from Haycock in depths	Atkins expected rainfall depths from the FSR for the PMP and the 10,000 year events (all other events used the FEH rainfall). We do not know where Haycock's rainfall depths come from, but based on their assumed 4.4 hour storm, if they had used FSR rainfall (as per the guidance) the rainfall depth should have been around 164mm (see	

	and durations, and why the Atkins durations of 9.5 hours and 1.9 hours are so different	our table 4.4). Furthermore, it would appear that Haycock based their PMP value on double the 10,000 year value (wherever that came from) which is wrong. Atkins' storm durations were optimised to determine the critical storm duration for each event, whereas Haycock chose a fixed 4.4 hour duration, which is not a correct approach.	
Heath & Hampstead Society 25/0313	Maximum Flood Estimates: Haycock used the approximate rapid assessment PMP/1:10,000 rainfall ratio of 2.0. From this he derived flood estimates at both Highgate No 1 and Hampstead No 1 which both had a PMF/1:10,000 ratio also of 2.0. These are shown in Tables 1-1 / 4-7, i.e. both his input rainfall and his outflow flood ratios on the bottom ponds are the same. In contrast, Atkins' more detailed calculations of rainfall inputs result in flows at both bottom dams with a PMF/1:10,000 ratio of 2.12 and 2.22 respectively, which are greater than Haycock's 2.0. Why are Atkins outflow ratios not both of the order of 1.67?	The ratio of 2 from the rapid assessment was intended to be applied to the Peak Flows derived from the rapid method, not rainfall depths. The ratio is used only with the rapid assessment and the rapid assessment is not appropriate for design. The ratio of 10,000 year rainfall and PMP depths should not be expected to be the same and ratio of the peak flows. This is because the relationship between rainfall depth and flow is not linear and we should not expect the ratios between 10,000 and PMP rainfall to be the same as the ratio between the 10,000 flow and the PMF.	

Heath & Hampstead Society 25/03/13	Overtopping, and Dam Stability and Spillway Protection: Table 5-13 gives shows maximum depth of overtopping. Atkins Conclusions and Recommendations, p.45, state that *Reservoir routing resulted in generally lower overtopping depths than those predicted by Haycock.* Haycock's PMF overtopping depths are shown in his Tables 16 and 33. These show that Atkins statement is correct for all the Hampstead chain and for the Ladies Bathing dam. However, for the other 5 dams on the Highgate chain, Atkins overtopping PMF depths are all higher than Haycock's. How, therefore, is it that Atkins has these higher overtopping depths, bearing in mind that Atkins PMP (if this is 235mm) is only 87% of Haycock's, and is spread over a duration of over twice as long?	Tables 16 and 33 from the Haycock Report refer to the 10,000 year flood. Tables 17 and 34 from the Haycock report are for the PMF and these show that the Atkins statement is correct.	
Strategic Landscape Architect	The calculations for Stock Pond seemed to attribute the entire catchment north of Stock Pond to	The temporary storage capacity of the Kenwood Ponds was judged to be negligible.	

22/03/13	that pond alone and do not take into account any attenuation or holding back that the two Kenwood Ponds offer. Therefore, although we do not expect to carry out works on these ponds we still need Atkins to provide the attenuation capacity and take into account the effect of these ponds when assessing Stock Pond, otherwise the measures required at Stock Pond look disproportionate to the scale of the problem. This is fundamental to Atkins Problem Definition document.		
Brookfield Mansions 27/03/13	Although the primary objective of the work to be undertaken by City of London is to prevent dam failure whilst preserving the character and quality of Hampstead Heath, the secondary objective must be to lessen the quantity of surface water arising from overtopping, spillways and drains onto the Heath and subsequently into surrounding residential areas. While we welcome your assurance that the situation will not be made	City of London to respond.	Camden Council are the Lead Local Flood Authority and have statutory responsibilities in terms of surface water flooding. The City of London Corporation has a duty to ensure the safety of the dams, and works are necessary to ensure that the Probable Maximum Flood is safely passed through the catchment. Dr Hughes (the Panel Engineer) has

	worse we would wish assurances that all flood waters are managed and controlled into the drainage and storm water systems in such a manner that it minimized any risk to life and property. The results from the investigation as shown in your report should be considered in conjunction with the capacity of the drains and sewers to cope with any water arising. All parties should be able to easily understand and to compare what the effect of future proposals may be with the existing situation, particularly where the residential areas affected by surface water from the Heath are likely to be affected.		advised that the proposed works on the Heath will not increase surface water flooding.
	We understand that Dr. Hughes and CoL will liaise with Camden (as lead authority), TWA, EA and DEFRA and provide them with up to date information. We should like to know how and with whom this information will be shared.	City of London to respond	The City of London Corporation has shared the current Design Flood Assessment with Camden Council and Thames Water Authority and put this report on the City's website.
	Clear information should be made available that will enable residents to assess their exposure to flood	City of London to respond	Flood maps are available on the City of London Corporation and Environment Agency websites. We

	risk and insurers to determine the cost of the risk.		are unable to comment on insurers' requirements.
	Camden have said that they may have access to government funding if flooding is likely to occur in an event of 1:75 or less. TWA have a statutory obligation (I believe) to drain surface water arising from a 1:30 event. We should like confirmation in the light of the new calculations that anticipated volumes, speed and location of surface water arising from all events, including 1:30 and 1:75 events, be made available to statutory authorities.	City of London to respond.	The City of London Corporation will continue to liaise with the responsible statutory authorities.
	We should like consistent and reliable information made available on the size, location and connections of drains and sewers, both for surface, foul (combined sewers) and storm water.	City of London to respond.	Thames Water Authority holds information on the surface water sewer system. The City of London Corporation has provided all of the information that has been made available to it.
	The figures given for the Hampstead chain indicate that the capacity of the Hampstead chain to cope with major events is better than that of the Highgate chain. A dry reservoir which will further	City of London to respond.	The issue of attenuating water is a key component in both chains of ponds. All options will be considered.

	mitigate downstream flooding is being considered to improve the capacity of the Hampstead chain. We wish to be assured that similar measures be considered for the HIghgate chain.		
Brookfield Mansions 27/03/13	Table Page 8: Why are the 1:100 peak flows for the Highgate chain the only ones that Atkins have estimated to be greater than Haycock?	We have used the FEH rainfall-runoff model to calculate all hydrographs below the 10,000 year hydrograph. Haycock calculated the 100 year peak flow using an empirical formula to calculate Q_{MEAN} (mean annual flood), and combined this with the old FSR regional flood frequency curve. This approach used by Haycock was superseded in 1999 by the FEH and will give very different results to the FEH rainfall-runoff approach.	
EGOVRA 28/03/13	We now hope to persuade the authorities (including Camden, Thames Water, the Environment Agency, DEFRA, etc) to go the vital step further and investigate and include in their designs works that will improve our situation at least in line with the predicted increase in frequency and intensity of rainfall storm events. We understand from Dr Hughes and	City of London to respond.	Camden Council are the Lead Local Flood Authority and have statutory responsibilities in terms of surface water flooding. Camden Council are undertaking studies to model surface water flooding in parts of Camden where flooding has previously occurred. The City of London Corporation has not been provided with the outcome

	Simon Lee that should funds become available, such mitigation factors can be investigated and implemented as part of the main Works by CoL - there is still time but it is tight apparently. To do such works on the Heath would be hugely more cost-effective than trying to achieve the same result by works off the Heath. Has the CoL asked Atkins to investigate and cost 'on the Heath' mitigation measures?		of any of these studies.
EGOVRA 28/03/13	At what storm event do the two chains start overtopping currently? In particular, with reference to Table 5-12, are you able to give us more precise estimates of when Highgate No 1 pond starts overtopping? Will the Works change this?	See Tables 5 – 12 in the main report. All Atkins can say at this stage is that the works will not make the situation worse than they are now.	
EGOVRA 28/03/13	At what storm event level will surplus water passing through Hampstead No 1 pond cause flooding to our community? We appreciate that this may be beyond the scope of this report but any figures, estimations, indications or even explanations of 'how to asses this' would be most helpful.	No comment.	

EGOVRA 28/03/13	Will Atkins make all relevant information freely available to other authorities (such as Camden Council and Thames Water) so that they can include such information in their flood alleviation designs?	Work produced by Atkins is the property of the City of London. City of London to respond.	The City of London Corporation has shared the current Design Flood Assessment with Camden Council and Thames Water Authority and put this report on the City's website.
EGOVRA 28/03/13	We are still unsure about the run-off calculations. The gully down the side of our path (to the East of the Lido) is constantly full to overflowing with water. Often, even in light rainfall, the path itself has water flowing down it especially at the top (near the Depot) and stepping off the path means stepping into sodden, soggy mud. Instinct says that therefore any storm event rainfall would simply have to run off the surface of the Heath since the ground is already 'full'. We find it hard to understand how it is that in a 1 in 100 year storm event that 47% of the rainfall would soak into the ground...	While some parts of the Heath will have high runoff rates, many of the vegetated areas and areas away from compacted footpaths will, allow rainfall to infiltrate. It is also a function of the ability of the underlying soil to accept and transmit rainfall, and according to the soil maps from the Heath, the composition of soil does allow for infiltration on some parts of the Heath.	
EGOVRA 28/03/13	May we have the equivalent figures for storm events smaller than 1:100, say 1:10, 1:20, 1:30, 1:50 and 1:75 ? Mark Dickinson of	Atkins output is the property of the City of London.	The City of London Corporation has shared the current Design Flood Assessment with Camden Council and Thames Water Authority and put

	Thames Water told us that Ofwat will only allow them to upgrade areas who are at risk from a 1:10 storm event and can only upgrade them to a 1:30 level. Thus, as per our point 7 above, such information would be very useful.		this report on the City's website. The City of London Corporation can be required to carry out works to ensure that the risk of failure of the dams on its statutory reservoirs due to overtopping is "virtually eliminated". The Design Standards therefore require modelling of extreme rainfall events rather than more frequent rainfall events.
EGOVRA 28/03/13	Are there any discussions being had with Camden Council and/or Thames Water about where the rainfall water that 'passes through' Highgate No 1 pond and Hampstead No 1 pond will enter their drainage systems?	City of London to respond.	The City of London Corporation has a duty to ensure the safety of the dams, and works are necessary to ensure that the Probable Maximum Flood is safely passed through the catchments.
EGOVRA 28/03/13	What is the capacity of the Emergency Valve system on Highgate No 1? Is this system being retained for operational use? Do any of the figures in the report reflect how much this reduces eg overspill for different rainfall storm events?	City of London to respond.	This has not been evaluated; the valve is a draw down mechanism enabling maintenance works and currently emergency drawdown of water. It is too early to say whether this will be retained.
EGOVRA 28/03/13	May we have any information Atkins has about the pipeworks underneath and around the Heath (in our area), including	City of London to respond.	The attached plan shows the location of outflow and drawdown valves associated with Heath ponds and the Thames Water Authority

	information about the Flood Alleviation Tunnels? We (and others) have asked CoL and Thames Water for such information without success. We have various 'maps' that conflicting and very limited information.		'Flood Alleviation Tunnels'.
Hampstead Garden Suburb Residents Association 04/04/2013	My understanding is that the risk to be addressed is that of a dam failing and causing damage to property (other than the City's), injury or loss of life. Although Rylands v Fletcher liability is strict, the risk cannot realistically be reduced to zero. What has to be decided is what works are necessary to reduce the risk of a dam failing in the event of a specified level of rainfall to an acceptably low level. Is this correct? Although there is a lot in the paper about overtopping and volumes and speeds of flood water, not much detail is provided on the risk of dam failure. On page 53 (page 43 of the paper) it's stated that "standard guidance	The current guidance for reservoir safety standards in Floods and Reservoir Safety, 3rd Edition, published by the Institution of Civil Engineers in 1996. Table 1 in this document provided the dam categories and the design flood inflow. The approach is consequence based and so the catergorisation is based on the potential effect of a dam breach i.e. it considers the consequences of a dam breach, and does not assess the probability of failure of the dam. Where a breach could endanger lives in a community, the dam Category A and the design flood is the Probable Maximum Flood.	

	suggests that the dam slopes would need reinforcement to prevent erosion which could lead to a breach of the dam". My understanding is that the City is not liable if water passes over the dams without a breach, even if flooding occurs lower down (indeed this is what the works are designed to achieve) but most of the risks addressed are about overtopping. I think we need more information about the "standard guidance" referred to and evidence about the likelihood of breach.		
Hampstead Garden Suburb Residents Association 04/04/2013	The conclusion says that "to reduce the risk of breaching, improvements will need to be made to some of the dams". This doesn't say anything about what an acceptable reduced level of risk would be. It appears that the risk to be guarded against is the risk of breach in the event of a "probable maximum flood" (occurring less than once in 10,000 years). I think we need more information about what the current risk of breach is (as	Risk is the product of the probability of failure and the consequence of failure. We will be carrying out a Quantitative Risk Assessment (QRA) as part of this project and this should provide an understanding of the overall risk of failure of the embankments. It should also be noted that the velocities given in the report are based on a smooth uniform slope and do not take into account the localized effects of trees, fence post, small changes in slopes all of which contribute	

	opposed to overtopping) and what the aim is in terms of the reduced level of risk, including the reason for selecting "probable maximum flood" as the event to be guarded against.	significant concentrations of high velocity flow. These concentrations will exacerbate erosion damage which could lead to a breach.	
		Atkins Response 12/04/12	
Protect Our Ponds 8/4/2013	But work is still required as all of the ponds can overtop even in smaller rainfall events. With earth dams (such as those on the Heath) overtopping can cause erosion and potentially lead to dam failure. "Can" is the operative word. We are back with the original disaster movie scenario.	Overtopping can cause failure and has caused failure on the Heath and in other places. The predicted return period for overtopping, the depth and velocities are such that most ponds will suffer significant damage and could fail in their current state.	
Protect Our Ponds 8/4/2013	Even more sinister is the statement (from the recent memo by Atkins to the City of London referring to the spread sheet matrix of opinions on the plans): It should be noted that where a particular option has been flagged as red, i.e. the option has been	It would not be precluded from our scheme provided that appropriate environmental mitigation and/or enhancement measures can be implemented on the advice of the	

	identified as likely to result in significant negative effects on any particular discipline, or will not be supported by a particular stakeholder group, this does not necessarily preclude that particular engineering option for inclusion in the scheme. It seems pointless having this elaborate consultation if the designer reserves the right to ignore significant comments made by stakeholders and others. If this actually happens, the whole process will have been a sham. Remember that the (now much criticised) designs in the Haycock Report were made by Atkins (not Haycock), a fact that has somehow escaped comment recently.	relevant technical specialist. Stakeholder comments will be taken into account. The designs in the Haycock Report were by Haycock and NOT Atkins.	
Highgate Society 09/04/13	Have the same calculations re. flow rates, velocity etc. been done for the Kenwood ponds as for the Heath ponds? What are the figures? How does this information impact on the measures needed to protect the Heath dams?	Explicit calculations for the Kenwood ponds have not been carried out as these ponds are not the responsibility of the city of London. Their catchments have been taken into account in estimating the flows into the other ponds on the Highgate Chain.	

Highgate Society 09/04/13	In the events of a Kenwood pond dam overtopping or collapsing would EH be liable under Rylands and Fletcher?		It is not appropriate for the City of London Corporation to comment on the potential liability of other organisations. Any concerns regarding the Kenwood ponds should be addressed to English Heritage.
Heath & Hampstead Society 10/04/13	<u>Rainfall Run-off from the Urban Fraction of the Highgate Catchment</u>: Section 4.3 states that the urban areas adjacent to the pond chain will be included for flow estimation. Section 4.4 states that 61.5% of 'urban' areas is assumed to be impervious. This may be appropriate for high density housing in much of London, but we suggest that it is not appropriate for the catchments of the Highgate slopes. Figure 4-2 shows that Highgate Ponds 1 to 5 all have catchments that lie outside the Heath. The Bird Sanctuary Pond has a very large area and the	We cannot change the percentage that FEH assumes in its equation for urban area adjustment.	

	Ladies Bathing Pond and Model Boating Pond also have sizeable areas, external to the Heath. These areas, such as Fitzroy Park and Highfields Grove are not typically urban and heavily built up, but generally are isolated dwellings in very large gardens. We suggest that a much lower percentage be assumed as impervious.		
Heath & Hampstead Society 10/04/13	Overall Rainfall Run-off Percentages: Haycock used 80% to 90%. Atkins has reduced this to 76% for PMF. Both Binnie in 1987 and Black & Veatch in 2007, both highly respected dam engineers, used 27%. There is judgement in selecting an appropriate run-off. Should not Atkins percentage be significantly lower than 76%? Please clarify in detail.	There appears to be a difference in the terminology used by previous consultants who have undertaken flood estimation for the Heath. We have reviewed the Binnie and Partner's 1987 hand calculations and computer printouts of their FSR model. Their 1987 model print outs show that they used an SPR value of 47% which resulted in PR values of 53.5% and 69.64% for the 10,000 year and PMF respectively. The reference to the 27% is from a table in the Haycock report, which is given for Highgate No. 1 pond for the 10,000 year event. The 27% seems to be referring to the percentage of the	

		10,000 year volume that outflows from the pond (after it has been routed through the pond, presumably through a hydraulic model) compared to the rainfall volume in (this appears to be the gross rainfall depth and not the net rainfall after the percentage runoff (PR as we understand it for the FEH/FSRR-R model is pplied). So we are not comparing like for like with respect to the 27%. We believe that the 80-90% that Haycock have been talking about is comparable (interms of what is mean by it) with our 76% and BBV's 69.64% and is the percentage of rainfall that is converted to runoff into the reservoir (i.e. only in the hydrological model). However the 27% value attributed to BBV is the percentage of outflow from Highgate No. 1 compared to the total gross rainfall volume for the pond and is not comparable to the SPR and the PR we have been discussing. The Binnie SPR value of 47% is very similar to the adjusted value of 46% we got for our SPR before increasing it to 53% to account for summer drying and sompaction, and these values resulted	

		in PR of 76% for Atkins and 69.64% for Binnie for the PMF respectively.	
Heath & Hampstead Society 10/04/13	Release of Water from the Ponds: We understand from the City's Position Statement on Discharge of Water, November 2012, that the City is not liable for downstream consequences for additional flood water that safely overtops a dam. However, if there is an escape or a deliberate release of stored water, then liability under Rylands and Fletcher may apply. It may be necessary to open the valve on the outlet pipe of a pond for two reasons: in an emergency to lower rapidly the water level to prevent a dam breach; and also more routinely to release attenuated (stored) water after it has been held back behind higher dams during an extreme storm, to provide storage capacity for a future storm. What is the maximum rate of release from both Highgate and Hampstead No 1 ponds that will not incur liability under Rylands and Fletcher? If stored water is	Not in Atkins scope of work. City of London to respond.	This would need to be determined on a case by case basis.

	deliberately released from raised dams at upper ponds which then overtops the bottom ponds, what liability, if any, then applies? Has the City sought or received technical or legal advice on how it should exercise a choice between releasing water to prevent dam breach and not doing so?		
Heath & Hampstead Society 10/04/13	Natural Spillways: Dr Hughes has stated that it is essential for the dams to be designed with spillways to take flood flow safely without significant erosion to the dam slopes, and that these may have to be in reinforced construction to minimise damage. He has indicated that 3 phase spillways may be considered (hard, soft with reinforced grass, and some crest overtopping), all sited on the dam and discharging down the downstream slope. We have suggested that an alternative concept of 'natural spillways' could be far preferable. These could be designed for extreme floods to discharge as overbank flows out of the sides of some reservoirs, and	While the natural spillway concept might appear feasible, flow through scrub, trees and fencing causes increased erosion on the downstream side of these features. These would tend cause further flow concentrations with enhanced erosion which could channel water back towards the dam mitres and cause damage in this location. Moreover, there could be backward erosion until the contents of the pond and cause increased damage downstream. It is more reliable to provide a soft engineered spillway to control the flow in a more reliable manner.	

	then flow through scrub, trees and fences, all left untouched, on a natural route to the lower pond which leaves the dam slopes, toe and mitres untouched. This would be similar to the way the spillway on the Model Boating pond discharges at present. Because natural ground slopes are shallow and the route avoids the dam structure, no surface reinforcement would be necessary, the existing landscape could remain untouched, and reinforced spillways may not be needed on the dam itself. Figure 5-2 clearly shows this side overbank possibility on the Highgate chain. Highgate Nos 2, 3 and 5 ponds appear easily suitable, and the other ponds may be able to use this principle with some ground re-shaping. Will Atkins investigate this in preference to reinforced spillways sited on the dams?		
Heath & Hampstead Society 10/04/13	<u>Overtopping Data:</u> detailed queries:- - 1:5 year overtopping depth for Model Boating Pond seems odd.	Table 5-8 shows a negative overtopping depth which means that the pond does not overtop.	

	Please confirm. - why is the overtopping depth increase between 1:1,000 to 1:10,000 years so small generally in comparison with the increases between all other events? - will Atkins provide graphs of overtopping velocity x time for all overtopping heights shown?	Because between the 1,000 and 10,000 year floods we change the FEH to FSR rainfall and there is little difference between the 1,000 year and the 10,000 year rainfall depths, hence similar for the overtopping depths. We have not produced such charts as they would be misleading because they would be based on a uniform smooth surface and the localized influences of fences, tress and slop irregularities and concentrated flows at low points on the crest would not be accounted for.	
Heath & Hampstead Society 10/04/13	<u>Dam Breach Scenario and Quantified Risk Assessment:</u> Dr Hughes, Atkins Design Review Method Statement, and the City of London's report to the Consultative Committee on 8 April all state that the next steps should be to define the potential design options. We disagree and urge that a Tier 3 QRA be immediately carried out. Dr Hughes has previously advocated the use of QRA to inform the design process, and we understand that a dam breach analysis is required under	The breach modelling is in progress and the inundation areas are required to assess the population at risk and therefore to attempt a Tier 3 Quantitative Risk Assessment is premature. Moreover, from our experience QRA is unlikely to make a difference as to whether or not works are required because the probability of failure and the likely population at risk are too high in this case.	

	the Reservoir Act 1975. We urge that this should include the probability of dam failure. We therefore request that a QRA be carried out before potential design options are developed. (This qualifies our query of 25 March). When will this be available?		
Heath & Hampstead Society 10/04/13	Legal Issues: Atkins Design Review Method Statement November 2012 states that *Dr Hughes has written to the Government asking for a hierarchy of Acts, i.e. Acts promoting Reservoir Safety (i.e. human life) vs 1871 Hampstead Heath Acts ensuring future of the Heath.* At the Consultative Committee meeting on 8 April 2013, Dr Hughes stated that he had not received a reply, even after a further request to the Minister, but he would show the response to us if received. We have previously stated that we consider it essential that the designers, and the community have a clear brief on all legal issues before design proceeds, and this issue remains outstanding. May we be given	The issue that is trying to be resolved is reservoir safety legislation works being delayed by other legislation. Resolution of this issue will not make any difference to need for works required on the Heath. Dr Hughes's communications with the Minister are personal and will not be made available.	

	copies of all correspondence by Dr Hughes with the Government and its agencies on this issue?		
Vale of Health Society 18/04/13	The catchment area figures in Table 4.1 (and the consequent flood estimates) are presumably based on the Boundary Maps in Figures 4.2-4.3, but I am concerned that part of the boundary VoH Pond and the Catch Pit catchment may not be drawn in quite the right place: • Fig 4.3 shows the boundary between in the NE corner of the VoH catchment area (i.e. where it runs through the Vale) as running down the S side of the (E-W) Vale road which runs down to Spencer House and between the N & S Fairgrounds to the causeway which leads to the VoH Pond dam. • However, it is clear (from a visual check this morning) that the camber on this road runs N to S, so I don't see that the boundary can be on the S side of the	See Note of Meeting held on the 19th April 2013 (Appendix 6)	

	road. • Perhaps more importantly, the N fairground slopes down N to S, and at least some of its run-off would therefore go across this road onto the S fairground and thence into the VoH Pond. • If this is correct, then a significant part of the run-off from the N (curved) part of the main Vale road and from the path in front of The Gables (and, a fortiori, from at least some of the NW corner of the Catch Pit catchment area: the bit shaded white on Fig 4.3) would also go into the VoH Pond. If my analysis is valid, all this could shift quite a bit of flood water from Catch Pit to VoH Pond. It may be that any such move would nevertheless be insufficient to have a material effect on design recommendations but I would be grateful if the point could be checked.		

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HAMPSTEAD HEATH CONSULTATIVE COMMITTEE
Monday, 8 April 2013

Minutes of the meeting of the Hampstead Heath Consultative Committee held at Education Centre, Parliament Hill Fields, Hampstead Heath, NW5 1QR on Monday, 8 April 2013 at 7.00 pm

Present

Members:
Jeremy Simons (Chairman)
Deputy Michael Welbank (Deputy Chairman)
Xohan Duran (Representative of People with Disabilities)
Colin Gregory (Hampstead Garden Suburb Residents' Association)
Michael Hammerson (Highgate Society)
Ian Harrison (Vale of Health Society)
John Hunt (South End Green Association)
Nigel Ley (Open Spaces Society)
Alix Mullineaux (Marylebone Bird Watching Society)
Susan Nettleton (Heath Hands)
Mary Port (Dartmouth Park Conservation Area Advisory Committee)
John Rogers (Ramblers' Association)
Susan Rose (Highgate Conservation Area Advisory Committee)
Richard Sumray (London Council for Sport and Recreation)
Jeremy Wright (Heath & Hampstead Society)

Officers:

Lorraine Brook	-	Town Clerk's Department
Sue Ireland	-	Director, Open Spaces
Simon Lee	-	Superintendent of Hampstead Heath, Queen's Park & Highgate Wood
Richard Gentry	-	Constabulary and Queen's Park Manager
Paul Monaghan	-	City Surveyor's Department
Richard Litherland	-	City Surveyor's Department

1. **APOLOGIES**
   There were no apologies for absence.

2. **MEMBERS DECLARATIONS UNDER THE CODE OF CONDUCT IN RESPECT OF ITEMS ON THE AGENDA**
   There were none.

3. **MINUTES**
   The minutes of the last meeting held on 11th March 2013 were tabled.

   RESOLVED:- That consideration of the minutes of the last meeting on 11th March 2013 be deferred to the next meeting.

4. **REPORTS OF THE SUPERINTENDENT OF HAMPSTEAD HEATH:-**

5. **HAMPSTEAD HEATH PONDS PROJECT - ASSESSMENT OF THE DESIGN FLOOD**

The Superintendent of Hampstead Heath introduced the report before the Committee relative to the results on the first major task undertaken by the Design Team in relation to the Hampstead Heath Ponds Project and the Fundamental Review of the basis for the whole project. The report before Members set out the details of the Design Flood assessment and Members views were sought thereon.

Following an earlier presentation to the Heath Ponds Project Stakeholder Group by Dr Andy Hughes (Panel Engineer on the Fundamental Review) on 18th March 2013, written queries in respect of technical aspects of the project were submitted to Atkins. An updated list of questions was tabled to Committee Members and further questions were invited by no later than the evening of Wednesday, 10th April 2013. The Committee noted that following submission to Atkins, responses would be provided in advance of the special meeting of the Hampstead Heath Management Committee on 29th April 2013.

Ian Harrison (Vale of Health Society and Chairman of the Stakeholder Group) updated the Committee about the Stakeholder Group's progress to date. He felt that the group was now working well and, even before seeing Atkins' new, lower, flood projections, had a good prospect of reaching consensus on at least the majority of key issues. The new flood assessment was very encouraging but Stakeholder Group Members felt that a face-to-face meeting with Atkins was vital if full confidence was to be established that the revised assessment was soundly based. Such a meeting was offered for April but might now be deferred to May but this was not deemed to be acceptable. More generally, if the Stakeholder Group was to be able to inform to a great degree the deliberations and discussions of the Consultative Committee, it was essential (not least in order to reduce any risk of subsequent judicial review challenge), that they have adequate time and information to be able to reach properly considered conclusions at each stage of the process, even if this ultimately meant stretching the existing City of London decision-making timetable. Given how well the Stakeholder Group was working, it would be a tragedy if avoidable time constraints were to prevent proper decision-making and input.

In noting Mr Harrison's comments, the Chairman confirmed that a discussion about the Design Flood assessment would not take place at the Hampstead Heath Management Committee on 15th April 2013 but would instead take place at a special meeting on 29th April 2013. At this stage, the views of the Consultative Committee and the Stakeholder Group would be taken into account. The Committee was therefore invited to submit any additional queries by no later than Wednesday evening to ensure that all responses were submitted to Atkins.

Dr Andy Hughes then delivered a short presentation to the Committee in respect of the Fundamental Review of the basis of the project undertaken by

Atkins and explained how they had determined that whilst works were still essential to reduce the City of London's liability and meet its duty of care to communities south of the Heath, the size of potential floods in "extreme rainfall events" was less than those derived by previous hydrology consultants. He also outlined the consultation activities that had been undertaken to date, and those planned in the future, involving the Stakeholder Group.

Dr Andy Hughes provided an overview of the Design Flood assessment and the Fundamental Review, highlighting the sympathetic approach to the works that would be taken and the balance that would have to be sought in respect of minimising the risk of dam failure and damage resolution; and environmental soutions. Commenting on the Panel Engineer requirements, it was noted that best practice led solutions had to be delivered and future modelling would be intended to address both short and long term considerations. The Committee was advised that more accurate calculations to those previously used by Haycock Associates had been reviewed and an industry standard hydraulic modelling package used which would be beneficial both now and in the longer term. Such calculations enabled the team to predict how the water would affect the dams both flowing over and around them.

In respect of the flood assessment, it was noted that the recent calculations differed to Haycock Associates and a reduced flow of water was now anticipated which, in turn, meant that less engineering works were anticipated. Following a brief explanation about over-topping and peak velocities of water through the dam, Dr Hughes explained that whilst works were required, they may not be required on all dams. Consequently, the current position was that the least amount of works as possible would be undertaken.

Dr Hughes outlined the current options available in respect of the Ponds Project and explained that, in light of the need to meet best practice and satisfy existing standards, there were two approaches:- (1) the legislative approach and (2) the non-legislative approach- with the second option favoured as it enabled a holistic approach to providing the best solution for the Heath. Thereafter, the focus of the project would be on identifying suitable options such as minimising engineering solutions, raising dams and consideration of the ponds as a whole rather than in isolation. In terms of next steps, Dr Hughes stressed the need to identify those schemes that would reduce the flow of water and focus on the appropriate engineering solutions.

A number of questions were raised following the presentation:-

Referring to future liability considerations and case law precedent, Dr Hughes outlined the implications of Ryland's and Fletcher, common law and the Reservoirs Act in respect of managing the situation at Hampstead Heath and went on to explain that a risk based approach would ensure that the best solutions were identified across the dams and with minimal impact.

In noting that some damage of a dam was acceptable but failure was not, a Member of the Committee asked as to what extent of damage would be acceptable. Dr Hughes explained that the matter was very complex and that the current situation in respect of over-topping was very uncertain. He further explained that some over-topping could be acceptable subject to velocity and duration levels. Consequently options to minimise over-topping and reduce velocities and duration, whilst minimising hard engineering, would be based on judgement taking into account the comprehensive hydrology results. Responding to a question about the implications of vegetation on the dams, Dr Hughes explained that natural growth on dams did not necessarily mean that they would fail. Consequently whilst it was hoped that as much vegetation could be retained on dams across the Heath, the conditions needed to be as favourable as possible and therefore the situation would be carefully managed.

Following a query about the Kenwood Ponds and how these had been factored into the peak velocity figures, Dr Hughes explained that the Kenwood system had been modelled even though this did not fall within the Corporation’s remit. Dr Hughes further explained that the ponds were already over-topping and whilst discussions with English Heritage had taken place, the focus remained on the Heath ponds. Simon Lee (Superintendent) explained that meetings had been conducted with English Heritage and that works to the two ponds in Kenwood had been undertaken in 2006/07. It was noted that English Heritage was aware of its current responsibilities.

Following a question in respect of future flood risk to surrounding neighbourhoods as a result of any future works up-stream, Dr Hughes explained that the future works would not compromise the surrounding neighbourhoods in any way. Simon Lee advised the Committee that this was a critical issue and that discussions had taken place with Thames Water and the London Borough of Camden at a past Stakeholder Group meeting regarding the surface water drainage issues. Paul Monaghan (City Surveyor's Department) advised the Committee that whilst the Corporation would continue to work closely with Camden and provide assistance where necessary, it would not compromise its own objectives and/or risk increased liability.

Referencing earlier discussions in respect of the existing legislation, the apparent hierarchy between different Acts and the implications for liability as a result of competing legislation, a Member of the Committee asked whether a response had been received from DEFRA. Dr Hughes explained that he had written to Ministers and DEFRA but that no responses had yet been received. He advised that in respect of the Corporation’s legal obligations, Counsel’s opinion had previously been sought.

Following a query about why Atkins’ run-off percentage calculations differed to those previously provided by Haycocks and Binney's, a brief explanation was provided about Atkins’s calculation methodology. It was suggested that default values may have been quoted in the past, thus leading to a figure of 90% and 27% respectively, as opposed to Atkins’s figure of 76%.

In respect of calculating loss of life, Dr Hughes explained that this was very complicated, taking into account a wide range of issues and variables such as velocity and duration levels, the type of property and whether people were located at home during the daytime. Loss of life is then evaluated across the variables to determine both low and high extremes, taking into account legislative requirements.

A query was raised about the decision-making process and how the future options for each dam would be considered in the context of all of the ponds rather than in isolation. Dr Hughes advised that the views of the Stakeholder Group and the Consultative Committee would be fed back to the Management Committee so that all views expressed thus far were taken into account. In respect of the next steps the committee noted that all of the possible options would need to be quickly but carefully considered, taking into account best use of the sites and a desire to minimise impact. It was noted that the Committee felt that sufficient time should be built into the process to ensure that people were fully briefed about, and able to comment on, the options as they emerged. Dr Hughes and the Chairman acknowledged the complexity of the issues and the need to provide people with as much information as possible. The Chairman stated that following consideration of the long list of options by the Stakeholder Group, the constrained list needed to be reviewed and refined so that appropriate options could be agreed in the future.

Following an earlier request at a meeting of the Stakeholder Group, a Committee Member requested an expanded map of flooding areas.

RESOLVED:- That –

(i) the Consultative Committee's comments in respect of the Hampstead Heath Ponds Project –Design Flood Assessment be noted and;
(ii) any additional questions be submitted in writing to the Superintendent, Hampstead Heath by no later than 10th April 2013 so that written responses could be provided ahead of the special meeting of the Hampstead Heath Management Committee on 29th April 2013.

6. **PROVISIONAL ANNUAL WORKS PROGRAMME 2014/15**

Simon Lee (Superintendent, Hampstead Heath) introduced a report before Members relative to a provisional list of cyclical projects being considered for Hampstead Heath in 2014/15 under the umbrella of the "additional works programme." The Committee was advised that the draft cyclical project list for 2014/15 totalled approximately £0.67m for Hampstead Heath, as opposed to the figure of £0.78m specified in the report and which included Highgate Wood and Queen's Park.

Richard Litherland (City Surveyor's Department) invited the Committee to comment on the proposed list ahead of submission through the usual decision-making channels. He advised that the list reflected cyclical maintenance rather than improvement works and had been informed by a sound dialogue with the Superintendent of Hampstead Heath in order to maintain a collaborative approach to undertaking works on the Heath. In respect of some of the proposed works, it was noted that further work had been proposed at the Lido and the Athletics Pavilion, as well as a more strategic approach to footpath works.

In response to a question concerning funding of the proposed cyclical and major works at the Lido, Richard Litherland explained that the works were funded through different streams and that as the funding programme was reducing in scale, future funding constraints were likely to have a longer term impact on the volume of works that could be undertaken.

Following a query about how works were prioritised, the Committee was advised that a range of criteria were used to determine priority such as whether or not a building was Listed, when work had last been undertaken and how urgent works were. In respect of other issues such as the Pergola, whilst the Masterplan set out a phased approach to the works, the bid in the additional works programme would release money so that additional works could be undertaken.

In respect of the differentiation between cyclical and core works, the Committee was advised that as the core funding stream was limited, the additional works programme provided much need additional funding. Following a question about remedial action in respect of the erosion of some pathways, the Superintendent advised that large areas of the Heath had been eroded as a result of the exceptional weather. Whilst acknowledging that this would be a significant piece of work, it was proposed that temporary fencing be erected to prohibit public access and thus enable the open spaces to recover.

RESOLVED:- That the Consultative Committee's views on the provisional list of works be submitted to the Superintendent or the City Surveyor's Department by no later than 29th April 2013.

7. **QUESTIONS**
There were none.

8. **ANY OTHER BUSINESS THAT THE CHAIRMAN CONSIDERS URGENT**
The Lord Mayor's Tree Party
The Chairman referred to the Lord Mayor's forthcoming tree party at The Mansion House on 25th June 2013, in aid of the Lord Mayor's Appeal. An event flyer was tabled by way of further information about the fundraising event.

Deputy Chairman's last meeting, Deputy Michael Welbank
The Committee noted that this would be Deputy Welbank's last meeting in his capacity as Deputy Chairman of the Consultative Committee. The Chairman commented on Deputy Welbank's life-long interest and love of Hampstead Heath and thanked him, on behalf of the Committee, for his valuable contributions throughout his 6 years' service as Chairman and Deputy Chairman. In closing, the Chairman wished Deputy Welbank well for the future and in his new role as Chairman of the Planning & Transportation Committee.

9. **DATE OF NEXT MEETING**
The next meeting of the Hampstead Heath Consultative Committee will take place on 8th July 2013.

The meeting ended at 9.00 pm

Chairman

Contact Officer:

Lorraine Brook,
Committee & Member Services, Town Clerk's Department
Lorraine.brook@cityoflondon.gov.uk
Tel: 020 7332 1409

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Hampstead Heath Ponds Project
Meeting to discuss outstanding queries on Design Flood Assessment

19 April 2013, 2pm
Epsom Gateway

Present:

Atkins		
Andy Hughes	AH	Panel Engineer
Tony Bruggemann	TB	Head of Design Team
Margaretta Ayoung	MA	Lead Hydrologist
Mike Woolgar	MW	MD Environment and Water Mgmt
Capita Symonds		
Ivan O'Toole	IT	Cost Consultant/Project Manager
Stakeholders		
Karen Beare	KB	Fitzroy Park RA
Charles Leonard	CL	Elaine Grove and Oak Village RA
Jeremy Wright	JW	Heath & Hampstead Society
City of London		
Richard Chamberlain	RC	Project Liaison, City Surveyors
Peter Snowdon	PS	
Jennifer Wood (notes)	JMW	Communications Officer

Introductions

Meeting started with introductions and it was decided IT should chair. JW's questions would be taken first, followed by those from CL. Harriet King from the Stakeholder Group also had other questions given in writing which would be worked in.

Following the meeting, it was agreed that a non technical preamble to the answers to the questions would assist in conveying the message to the Stakeholders. The preamble is included below.

Hampstead Heath Ponds– Hydrological Problem Statement
The Hampstead Heath ponds, a central part of the special landscape of the heath, were not built to standards to allow large flood volumes to pass without causing collapse. If the water in the ponds overtops the embankments for more than a couple of hours there is a strong likelihood that the earth embankments will erode leading to damage and possible collapse. When the ponds were built the downstream impact of a wave of water might not have been significant but nowadays the area of Camden immediately downstream is densely populated and such a wave presents a risk to life and property. The City of London, as owners of the ponds, must ensure proper maintenance and repair of the embankments to ensure their continued existence and avoid the effects of a collapse of some or all of the dams.

We have established that all of the dams will overtop for rare events above 1:1000 years but some will overtop for events even as likely as the 1:5 year event. This is an unacceptable level of risk for City of London and they must act to ensure that the dams will not collapse.

How are floods assessed?

Floods are essentially excess water, when the rainfall on an area exceeds the rate at which the land can absorb the rain or carry it away in a river or drain. The main factors which govern the amount of excess water are the amount of rain and the ability of the land to absorb water before runoff starts.

Standard UK information – which relates the location, area and slope of all catchments in UK down to $1km^2$ to rainfall events from 1 in 5 year all the way up to the "probable maximum precipitation" - has been used to obtain the necessary hyetographs (rainfall intensities in mm/hr over the period of the storm) for the Hampstead Heath catchments. The probable maximum precipitation is a physical constraint to the water carrying capacity of the atmosphere and, as a credible extreme value, is not sensitive to possible effects of climate change.

The runoff factor for all catchments is also taken from UK information, which accounts for differences in soil type. Although runoff factors are sensitive to the amount of urbanisation, they are most sensitive to the rainfall depth which increases as the rarity of the event increases. Runoff factors for the Heath have been adjusted to take account of local soils and compaction information in accordance with standard UK practice. Factors used are between 53% and 77% for various events which is a credible range; 90-100% runoff is normally associated with completely impermeable surfaces such as concrete and sheet metal, and therefore 90%, as suggested by Haycock, is excessive for a natural landscape like the Heath.

How is the likelihood of overtopping assessed?

The hydrological information, namely hydrographs and runoff factors, are used in computer models representing the physical characteristics of the ponds (area, depth, crest levels, overflow facilities, ground levels) to establish how the chains of ponds respond to the excess water that flows from the surface into the ponds, and then down the chains of ponds. The output of the models shows that the volume of water is significantly larger than the ponds can store for many of the rainfall events and water will overtop the earth embankments.

Sensitivity testing

We have tested the sensitivity of the outputs from our hydrological model by looking at reduced runoff rates in the upper catchment where there is potentially less soil compaction. The output is not sensitive to these marginal effects, or to the capacity of the existing overflow pipes which carry flows of between $1/500^{th}$ and $1/3000^{th}$ of the floods examined.

We have also examined how the Kenwood ponds affect the results and can confirm that the overall impact of the Kenwood ponds on the system capacity is very low with modelled water levels varying by between 0 and 20mm. Given the level of assumptions which are made in the assessment of rainfall and runoff this sort of difference can be said to be insignificant.

Overall therefore we are clear that the flood events that we have assessed and the effects of these flood flows on the ponds have been carefully and correctly derived, in accordance with UK best practice and taking appropriate account of locally available information. We have undertaken sufficient sensitivity testing to be sure that the embankments are at risk of overtopping for a wide range of events and that some of these events, although of low probability of happening, will overtop with sufficient depth and for sufficient time to erode the embankments and cause failure.

Questions from Jeremy Wright, Heath and Hampstead Society

Q1. Is calculated percentage run-off into the upper and more sensitive ponds too high?

Answer: MA described percentage run-off and how it had been calculated. AH said Atkins must follow best practice methodology and think of the next Inspecting Engineer – they must be happy with his estimates and must be able to reproduce them in the future. They would follow best practice and take into account local conditions.
KB asked how they had taken into account local conditions?
MA showed on the slides the different catchment areas and how they are cumulative as you go down the chain. She said the Flood Estimation Handbook (FEH) has a high level of detail. The FEH provides depth/frequency curve and it includes rain gauges over a wide area. The point of using a large data set, as included in the FEH information, is it is much more statistically reliable.
JW asked how detailed is the FEH.
MA said data is provided for half km squares.
CL asked if slopes were taken into account.
MA said yes.
MA went on to explain the difference between the Standard Percentage Runoff (SPR) and the Percentage Runoff (PR). The SPR is the runoff associated with the 29 soil types included in the FEH data base. The PR is the estimate of the runoff that would be expected to occur in the field and is calculated by adjusting the SPR by two dynamic factors (copies of pages 26-27 of the Assessment of Design Flood Report were handed out). MA explained that the FEH provides for 29 different soil types (using the UK Hydrology of Soil Type (HOST) values) representing all of the different soil types found in the UK.
MA said 30.97% is the default SPR for Hampstead which is based on the two main soil types that occur in the Heath. The FEH default SPR was adjusted to the local conditions on the Heath by taking account of the area (plus 10m buffer) of footpaths that Haycock assessed as being heavily compacted. This adjusted SPR was carried through to the PR calculation.
KB asked if it included the overlay of geology.
MA - The FEH soil type data base takes into account the geology of the area.
MA said a width of 10 m was added on either side of the footpaths to allow for additional soil compaction on either side of the footpaths. – this was then used to adjust the 30.97% to get 46%. This derived value, 46%, was then increased to a value of 53% as is recommended by the FEH for catchments prone to drying and compaction.

MA responded to JW's query regarding whether the adjustment for compaction should have been used for the upper catchments which potentially have fewer footpaths. MA showed the results of sensitivity analyses, which showed that any resulting difference in overtopping depth is not significant.

Q2: When will a Quantitative Risk Assessment (QRA) be available?

Answer: AH noted that the need for a QRA depends on what was necessary to be looked at.
AH said QRA will show the risk of loss of life is more than one person and thus the risk to COL of failure is far too high. The preferred time to do the QRA would be when there are one or two preferred solution and a QRA would be done on the current situation and the new proposal to show the reduction in risk achieved by implementing the project.
JW asked why not do the current situation now?
AH said it could be done now but he was concerned that it would be over-interpreted and is best used for comparison of before and after.
KB said the H&HS is coming from the direction less is more, so they want a baseline.
JW said not only H&HS also Hampstead Garden Suburb are interested in the results of a QRA.
MW said the QRA was useful as long as it is understood it is more for a comparator.
AH said he can start work on QRA as soon as the flood has been agreed.
TB said it would take between 6 to 8 weeks to do this piece of work once the design flood had been agreed.
ACTION: Atkins agreed to do the QRA in six to eight weeks after agreeing the flood

Q3. Can stakeholders have a detailed explanation of the method of calculating 1:10,000 and PMP flows and the peak storm durations?

Answer: MA said the Probable Maximum Precipitation (PMP) was estimated by the Meteorological Office and is based on the physics of the atmosphere – it is an estimate of the maximum amount of water the atmosphere can hold. This exercise was carried out by the Met Office over the whole country and a series of maps for the whole country is included in the Flood Studies Report. The 10,000 year rainfall is based on a statistical examination of rain gauge data for the whole country. For any catchment that you choose you can obtain the 10,000 year rainfall information from the Flood Studies Report. KB asked what weighting was given to local data and if climate change was taken into account.
MA said climate change was not taken into account as these are already extreme events.
CL asked about the EU directive.
MA said EU flood directive is for floods of a smaller return period and the PMF is a flood so extreme that it does not have an adjustment for climate change as is required by the EU directive for smaller floods.
MA said that there was only 100 years of local rainfall data which is too short a record length to use in deriving the extreme floods required for this project. She stated that a common rule of thumb is that the return period which can be reliably derived from a dataset of N years in length, is N/2. Hence for Hampstead Heath the HHSS rainfall data could also be used to reliably derive rainfall depths of up to the 1

in 50 year rainfall. When asked why the HHSS data was not used to provide the rainfall depth up to the 1 in 50 year rainfall, she said the local HHSS 1 in 50 year rainfall depth agrees with the FEH 1 in 50 year rainfall depth for the 24 hours duration storm, so the local data would not make a meaningful difference for these short return period floods.

POST MEETING NOTE: In addition, the HHSS rainfall data is daily total rainfall and the flood estimation for Hampstead Heath requires sub-daily data (because the critical storm durations are of a few hours rather than days), so the HHSS data set could not be used in any case on its own.

Q4. JW was surprised that the PMF/1:10,000 ratio at the bottom dams results in ratios of 2.12 and 2.22, bearing in mind that ratios on some dams in other parts of the country can be much lower, e.g. Tilgate Dam PMF is only 1.14x10,000 year flood. Why does the Heath have what appears to be an unusually high ratio?

Answer:
MA and AH explained that there is no fixed ratio between the 10,000 year PMF peak flow. The ratio is a function of the physical characteristics of a given catchment. Floods and Reservoir Safety provides approximate guidance and suggests a ratio of 2 which is close to ratio Atkins obtained on the Heath.
AH added that the floods at Tilgate would be influenced by the presence of the M23 and the reservoir chain is much smaller than on the Heath. AH confirmed that he is happy with the ratio for Hampstead Heath.

Q5. What detailed work has been carried out by Atkins to demonstrate that flows into the Stock Pond are not over-estimated? Please give details of the modelling done on the Kenwood Ponds

Answer: AH said the Kenwood ponds had been modelled to assess how much water they would store during the PMF event and it was found they would provide negligible storage so the effect of them would be insignificant.
AH said output from the modelling of these ponds could be shown to the stakeholder group.

MA showed a table of results which showed that when the storage of the Kenwood Ponds is taken into account, the depth of overtopping at Stock Pond changed by 10mm to 20mm, thus showing that the influence of the Kenwood Ponds is negligible.

Q6.H&HS believe the run-off taken for the Highgate slopes is far too high and account needs to be taken of the fact that much of the area described as urban is in fact of rural character (large gardens) that would absorb much of the water. Also asked why the urban catchment percentage for the Ladies Pond is higher than Stock pond.

Answer: MA responded that the catchment areas used to derive the floods are cumulative so that urban extent values were for the cumulative catchments and not the intermediate catchments which JW was describing. This is why the urban extent value generally increases as you go down chain. Gardens have been taken into account as FEH urban extent value is comprised of values for urban as well as suburban grid cells based on a half a kilometre square resolution. FEH therefore preserves the green areas within each 0.5 kilometre square cell if the cell is not 100% covered by urban landuse and treats urban and suburban differently. In addition, the urban extent has been updated using OS mapping and there is a facility to update urban extent to take account for urbanisation since urban extent was derived.

Q7. Stakeholders would like further details on the rate of release from the scour pipe of Highgate No. 1 Pond.

Answer: AH said the estimated rate of release from this pipe is 10 litres per second and it would take 15 hours to get the water level down 0.4m. The PMF flood peaks at 32000 litres per second.
CL asked if the scour pipe would be removed as Simon Lee had indicated it might not form part of the final design.
AH said he had no intention of getting rid of the scour valves, as there was no reason to do so and they are useful for normal circumstances
CL asked how often the valves had been used to release water downstream.
AH said he was not sure – anecdotally he had heard they had been used a couple of times in the past.
PS said the City would probably not have that information but he had also heard anecdotally they had been used a few times.
AH said he opens the valves every six months when he inspects the dams.

Q8. H&HS said Atkins have rejected spillways which would follow small natural "valleys" on the sides of some of the ponds, and asks why?

Answer: AH said nothing had been rejected as the project was not in the design stage. The decision on what sort of spillways has still to be made.
JW said he would like clarification on some of the terminology used, particularly around spillway. Natural spillway / grass spillway.
Atkins said they would be consistent in future about their description of spillways.
It was agreed that an illustrated guidance note would assist the stakeholders in understanding the terminology.

Questions from Charles Leonard, EGOVRA

Q1. Do Thames Water/ Camden Council / Atkins /City of London all mean the same when they talk about different event sizes e.g. 1 in 20, 1 in 50 etc.

Answer: Yes they should all mean the same thing. Haycock had made an "off-the-cuff" remark about all of the ponds overtopping in a 1 in 25 year flood. The basis of this remark is not known.

Q2. Can the runoff data for other rainfall event sizes be given to stakeholders?

Answer: ACTION: Atkins will provide the runoff data (in a hydrograph) for a 1 in 5, 1 in 20, 1 in 50 and 1 in 100 year events for each pond.
Harriet King had asked about the overflow pipe and whether it was significant.

AH said Highgate No. 1 has an overflow and a drain pipe at a lower level (which release water at 10 litres per second. AH said the overflow is at high level and is running all the time. He drew a simple plan of the dam to illustrate the point.

Q3. KB said there was some confusion about other large rainfall events that had happened on Hampstead, i.e. 1975 event, 2002 event, 2010 event. Could Atkins work out how much rain had fallen during these large events so it can be communicated to stakeholders and the wider public what has been happening on the Heath.
Answer: MA said that an estimate of the return period for these storms could be made .
ACTION: Atkins to estimate the return period of these storms and share data.

Q4. What is the capacity of the emergency valve system on Highgate No. 1 pond?

Answer: AH said city should have some details of this, which can be passed to stakeholders. The map of the sewers/pipes was discussed and Atkins showed which was the overflow and which was the scour pipe (see Question 7 above). CL advised that he has seen a plan which shows a third pipe.

ACTION: CL to provide a copy of the plan with the third pipe for Atkins.

Q.5 Stakeholders would like verification that situation downstream will not be made worse following the work.

Answer: AH described that any work they do will help the situation downstream as they will be creating more storage area for water further up the chain so it will be released downstream in a controlled manner less than the natural peak rate. This is true for all sizes of storms, including the smaller storm events and not just the ones that threaten dam failure and that this could be verified through the hydraulic model.

JW asked when the written notes from the meeting would be made available.
It was decided that JMW's notes of the meeting would be sent to Atkins for them to add the technical details and this would be done within 10 days.
(Note added by JMW – this needs to be done sooner than 10 days as the note must be included in the papers going to the Management Committee which is taking place on May 2.).

ACTION: Note of meeting with answers written in layman's terms to be shared before Management Committee

JW mentioned the area above Stock Pond where the terrain appeared to be favourable to the temporary storage of runoff and he queried if this had been taken into account.
MA replied that localised micro-topography does not have a significant influence on flood estimates, particularly for the longer return periods and PMF.

Q6. Ian Harrison has questioned whether the catchment boundaries shown in Figures 4-2 and 4-3 have been drawn correctly as visual observations on the ground

suggested more water would flow to Vale of Health Pond and less to Catch Pit than suggested by the boundary shown on Figure 4-3.
MA replied that because the flood estimates have been based on cumulative catchment area above each pond, these variations in the catchment boundaries would have an insignificant effect on the flood estimates. Moreover, that in the context of the size of the catchment area as a whole, the suggested boundary variations would have negligible effect on the estimated flood flow.

Following the technical discussions, communications were discussed and it was agreed that that the team needs to improve the accessibility of their communications.

Meeting ended: 4.30pm

Agenda Item 12

By virtue of paragraph(s) 3 of Part 1 of Schedule 12A
of the Local Government Act 1972.

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Agenda Item 13

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Agenda Item 14

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Agenda Item 15

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Agenda Item 16

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