5.3.7 Drainage, diffuse pollution and water quality

5.3.7.1 Current quality

Water Chemistry

The Silk Stream generally shows poor chemical water quality as it is highly impacted by urban diffuse and point source pollution. According to water quality records, there was a slight improvement in the chemical quality of the Silk Stream between 2000 and 2004, but it declined to grade E in 2006 (over a scale ranging from A to F). The main problems come from impervious paved areas (and London Clay) that exacerbate discharge of pollutants from urban runoff (BOD, sediments, pathogens, heavy metals, hydrocarbons), as well as possible misconnections that lead to the discharge of untreated water to the watercourse.

Ecology

The Silk Stream has also shown poor biological river quality (grade E), the biology of the river being restricted to species that tolerate pollution, and sensitive species being rare or absent from the watercourse.

As an urban river system, its banks are largely restrained by wood and concrete, but throughout its length there are at least a few narrow strips of scrub and grassland on either side, forming a valuable green corridor through the built-up area. The rivers support little aquatic vegetation, though curled pondweed (*Potamogeton crispus*), Nuttall's waterweed (*Elodea nutallii*) and floating sweet-grass (*Glyceria fluitans*) occur in places. Mallards and grey wagtails can often be seen, and three-spined sticklebacks are present.

It is important to note that the Silk Stream is part of the Blue Ribbon Network (London Plan) and is a Site of Borough Importance. These are strong drivers to support biodiversity improvements in the river corridor. Development proposals should thus be seen as an opportunity to protect and enhance public amenities and leisure assets (walking and cycling paths, recreational areas, ecological amenity etc.), as well as to reduce flood risk (flood storage areas, rehabilitation of the river corridor, etc.). These opportunities should also be considered, on a catchment basis, with due regard to the current status and ecological objectives set out for the Silk Stream in the Environment Agency's Draft Thames River Basin River Management Plan.

5.3.7.2 The Silk Stream and the Water Framework Directive (WFD)

The Silk Stream, together with the Edgware Brook, is classified in the Draft Thames River Basin River Management Plan[18] as *candidates for Heavily Modified Water Bodies* (HMWB), under the Water Body ID 22970.

The WFD indeed recognises that some water bodies have been historically physically modified to support various uses which provide valuable social and economic benefits. In some cases these modifications cannot be removed without having a major negative effect on the social and economic benefits that these uses bring. In other words, a water body that can be classified as Heavily Modified when achieving "Good Status" would require hydrogeomorphological changes that would have significant adverse effects on the social or economic activity. In the case of the Silk Stream, the specific reasons for the classification as HMWB are:

- Water storage (the Brent Reservoir)
- Urbanisation
- Flood protection (the recently completed Silk Stream flood alleviation scheme comprising six flood storage areas)

[18] Environment Agency *Draft River Basin Management Plan* - Annex - B Thames River Basin District, December 2008.

Whilst "good ecological status" is defined as a slight variation from undisturbed natural conditions in natural water bodies, HMWBs are considered as unable to achieve this natural condition. Instead, they have an alternative target to achieve at least Good Ecological Potential (GEP), which is similar to good status but takes into account the constraints imposed by social and/or economic uses. Ecological potential is also measured on the scale high, good, moderate, poor and bad. The chemical status of these water bodies is measured in the same way as for natural water bodies.

Target chemical status

The current chemical status and the proposed status objectives have not yet been assessed for the Silk Stream.

Target ecological status

The Silk Stream has a current Ecological and Overall status listed as *Moderate*. It has been assigned a *Good* Ecological and Overall Potential by 2027. The reported justification for postponing the Good Status Objective from 2015 to 2027 is that the improvement is currently not worthwhile because the costs of the measure are out of proportion to the benefits.

Table 12 below provides a list of the biological and physico-chemical elements of status classification currently available for the Silk Stream.

Table 12 - Biological and physico-chemical elements assessed for the Silk Stream and achieved status

Elements	Current Status	How confident we are that the status is less than good	Predicted status	Justification for not achieving good status by 2015
pH	High	N/A	N/A	N/A
Ammonia	Good	Low	N/A	N/A
Fish	Moderate	Medium	Moderate by 2015	Disproportionately expensive - Measure not worthwhile
Dissolved Oxygen	Moderate	Low	Moderate by 2015	Still to be determined - assessment insufficiently advanced
Phosphate	Poor	High	Poor by 2015	Disproportionately expensive - Measure not worthwhile

A list of applicable mitigation measures that would be required to achieve the Good Ecological Potential has been identified for the Silk Stream in the Thames River Basin District within the Draft River Basin Management Plan (December 2008). It should be noted that this is a comprehensive list of actions that could be adopted, rather than the final proposed actions. Further appraisal of the technical feasibility and cost effectiveness needs to be carried out before confirmation of these mitigation measures.

Table 13 below provides an initial assessment of the specific relevance / suitability of each mitigation measure in the Colindale AAP. Measures assessed as relevant should be considered for a coupled implementation as development proposals come forward (partnership approach).

Table 13 - Potential hydromorphological mitigation measures for the Silk Stream

Actions that could be adopted	Relevant to the Colindale AAP?	Reasons
Remove obsolete and redundant structures	**Yes**	Several structures represent a severe constriction of the cross section (see Section 3.1.3)
Removal of hard bank reinforcement / revetment, or replacement with soft engineering solution	**Yes**	Potential for removal / replacement, but consideration needs to be given to flood risk protection to adjacent properties
Preserve and, where possible, restore historic aquatic habitats	**Yes**	Current ecological quality in the Silk Stream creates potential for aquatic habitats enhancement.
Increase in-channel morphological diversity	**Yes**	Potential for biological enhancement and channel alterations possible through redevelopment.
Re-opening existing culverts	**Yes**	Should be further explored as part of regeneration of sites adjacent to river corridor.
Alteration of channel bed (within culvert)	**Yes**	Should be further explored as part of regeneration of sites adjacent to river corridor.
Flood bunds (earth banks, in place of floodwalls)	**Yes**	Potential for removal / replacement, but consideration needs to be given to flood risk protection to adjacent properties
Set-back embankments	**Yes**	Adjacent existing infrastructures
Improve floodplain connectivity	**Yes**	Yes, but options currently limited (see Section 5.5, Measure 8 - Re-establish river corridor)
Structures or other mechanisms in place and managed to enable fish to access waters upstream and downstream of the impounding works	**Yes**	No such structure identified within the study area and relatively limited population of fish, therefore potential exist.
Preserve and where possible enhance ecological value of marginal aquatic habitat, banks and riparian zone	**Yes**	Current ecological quality in the Silk Stream creates potential for ecological enhancement.
Operational and structural changes to locks, sluices, weirs, beach control, etc.	**No**	Not applicable in Colindale. Opportunity to create fish passage through weir notch at Colindeep Lane.
Retain marginal aquatic and riparian habitats (channel alteration)	**Yes**	Potential for biological enhancement and channel alterations possible through redevelopment.

5.3.7.3 Summary

In summary, the water chemistry of the Silk Stream is currently identified as "poor" (Grade E). The Silk Stream also suffers from a poor ecological status (Grade E).

There are several opportunities to improve the biological river quality and the water chemistry of the Silk Stream through the implementation of measures described in detail in Section 5.5 below.

5.4 The Surface Water Management Train

5.4.1 Concepts

The Surface Water Management Train[19] is a useful concept in the development of a drainage system. Just as in a natural catchment, a combination of drainage techniques can be used in series to change the flow and the water quality of the runoff in stages, and be designed to fit into all developments, from hard surfaced areas to soft landscaped features. There are many design options available.

When considering a drainage strategy (for a whole site or just a proportion of runoff), it is beneficial to work through the Surface Water Management Train, whereby SUDS components fall into three broad categories that first consider source control, and then deal with site / regional control:

1. Source control and prevention techniques: these techniques aim to counter increased discharge from development sites as close to the source as possible, therefore minimising the volume of water discharged directly to a watercourse. These systems work best when dealing with small quantities of water, and are most effective when distributed throughout a catchment at the point where runoff arises. Provided there is no danger of increasing downstream flood risk, such installations need not be designed large storm flows. A system designed to accept a "twice per year" storm before an overflow or bypass takes effect can still have significant environmental benefits by reducing the frequency of discharge, providing protection from the highly polluting "first flush" and allowing time for the peak flows in the receiving watercourse to pass. Like in most urban developments, downstream flooding in Colindale is a concern, and additional storage will need to be provided (see Section 5.3.2 and Appendix C).
2. Conveyance systems: designed to slow the velocity of runoff to allow for storage, settlement, filtering and some loss of runoff water through infiltration and evaporation before it reaches the discharge point.
3. Passive treatment systems: use natural processes to remove and break down pollutants from the collected surface water runoff, before discharge into groundwater or to a watercourse. Large "end of pipe" systems usually involve storage in constructed ponds where natural purification processes can be encouraged. Wetlands or ponds also provide the opportunity to improve wildlife habitat in urban areas, and ponds can be made into amenity features for the local community.

5.4.2 Application to the Colindale AAP Outline Drainage Strategy

5.4.2.1 Source control and prevention techniques

When undertaking a detailed drainage strategy for each development site, or the Colindale AAP as a whole, the scope for minimising the quantity of water will have to be considered first since this determines the sizing of downstream systems and provides the greatest savings. Due to the impermeable geology, important restrictions will apply to the implementation of source control techniques over the entire Colindale AAP. However, the following prevention techniques may still be suitable:

- Permeable pavements: an alternative to conventional paving in which water permeates through the paved structure rather than draining off it. In the present situation, water may not be able to infiltrate directly into the subsoil, but could still be held in a tank or similar structure under the paving for subsequent reuse or delayed discharge.

[19] CIRIA Website, http://ciria.org/suds/suds_management_train.htm, July 2005.

- Green roofs: this system offers significant benefits in terms of reduction of the amount of water running off a roof, as well as the rate and quality of runoff. Many conventional flat roofs systems used in industrial buildings could be converted to green roofs without exceeding design loadings and with the additional benefit of improving insulation and extending roof life.
- Water butts: please refer to Section 5.5.

The extent to which infiltration-based source control techniques could be implemented should be confirmed at development stage through infiltration tests, as there may still be infiltration potential in areas underlain by made ground and/or alluvium (see Figure 11). It is generally considered[20] that infiltration techniques may not be effective if the infiltration rate is below 10 mm/hr for the upper soil layers.

5.4.2.2 Conveyance systems

The overland flow paths delineated through pluvial modelling and presented on Figures 12 and 13 provide an overall framework based on natural drainage patterns that could form the starting point of a "swales network" within the entire Colindale AAP. These networks typically use the green space on roadside margins to drain surface water to a storage or discharge system.

At implementation stage, contractors should bear in mind that swales work best with small topographic gradients both for their side slopes and longitudinally. Performance can also be increased by placing check dams across the swale to reduce flow velocities, therefore reducing the risk of erosion.

When compared to traditional piped systems, swales present the following benefits:

- swales achieve a considerable reduction in the pollution load before discharge to a watercourse: sediment is deposited and oily residues and organic matter retained and broken down in the top layer of soil and vegetation;
- the surface water flow is retarded and a proportion of the runoff can be lost by evaporation and transpiration (little infiltration is expected in the present case);
- wrong connections become obvious and can be fixed without the need for expensive surveys associated with underground pipes;
- swales avoid the need for expensive roadside kerbs and gullies and for their ongoing maintenance (however, some regular maintenance is required to keep a grassed swale operating correctly);
- swales reduce the risk to amphibians (toads and newts) which are often trapped in gully pots;
- due to the underlying geology and the absence of shallow aquifers in the Colindale area, swales may not need to be lined below the soil.

5.4.2.3 Passive treatment systems

The potential ponding areas indicated by the models (see Figures 12 and 13) provide an initial indication, based on natural drainage patterns, of suitable locations for storage systems that can be fed by a swales network or a conventional surface water system.

Indicative storage calculations carried out in Section 5.3.2 provide a preliminary assessment of the storage volumes required for runoff rate and volume attenuation / treatment. The total storage volume for each Corridor of Change can be broken down into several units, as long as the unit storage volumes are representative of the runoff to be accomodated within their respective sub-catchment.

[20] Environment Agency, Sustainable Drainage Systems (SUDS) - A guide for developers, p.8, March 2003.

SUDS such as ponds and wetlands provide additional green areas that are useful for urban recreation and pollution tolerant wildlife. By providing a network of varied habitats threading throughout the urban environment of Colindale, they can provide valuable corridors for the movement of wildlife.

The following three techniques may be suitable to the Colindale AAP:

- Detention basins: these are designed to hold back storm runoff for a few hours to allow peak flows to subside and the settlement of solids, before draining via a low level outlet orifice or similar hydraulic structure into a watercourse or surface water drainage system. Therefore basins are completely drained, leaving detention basins dry outside of storm periods. This particular feature may not fit with the current indicative masterplan for the Colindale AAP, owing to the unsightly exposure of sediment banks.
- Retention ponds: retention ponds retain a certain volume of water at all times. However, their design has to allow for a considerable variation in water level during storms. Although the permanent water feature may be more attractive, elevated nutrient concentrations can result in algal blooms. Inlet and outlet sumps will, as for detention basins, enhance performance by trapping sediment and preventing clogging of the outlet. Should retention ponds be selected as the preferred storage option for the Colindale AAP, they should have a catchment of at least 5 hectares each[21] and/or a reliable source of baseflow to be successful as an amenity. All Corridors of Change have a larger catchment, but should total volumes for each Corridor of Change (see Table 11) be broken down into several units, this 5 hectares threshold must be considered.
- Wetlands: these are a further enhancement of retention ponds, and incorporate shallow areas planted with marsh or wetland vegetation, thus providing a much greater degree of filtering and removal of nutrients. Once again, inlet and outlet sumps will enhance performance, but should be considered almost obligatory in this case, since excessive sediment can overwhelm the shallow area.

5.5 Identification & short-listing of measures

An initial identification of the potential runoff mitigation measures for the four Corridors of Change has been undertaken. This shortlist of measures aims at avoiding inefficient and piecemeal investments in surface water management.

This short list of measures follows on from the results of the urban pluvial modelling and the gross storage volume calculations, as follows:

[21] Environment Agency, Sustainable Drainage Systems (SUDS) - An introduction, p.17, May 2003.

Table 14 - Summary of measures

Measure	Integrated urban drainage measure	Lead organisation	Priority
1	Increase frequency of gully pot maintenance within critical drainage areas	LB of Barnet	H
2	Adopt risk-based approach to gully maintenance cleaning	LB of Barnet	H
3	Develop GIS database of Council-owned drainage assets – Asset Register (spatial location of gully pots)	LB of Barnet	H
4	Increase levels of Ordinary Watercourse maintenance	LB of Barnet	L
5	On-site storage / attenuation solutions	Developer / LB of Barnet	H
6	Regional storage / attenuation solutions	Developer / LB of Barnet	H
7	Rainwater harvesting via installation of water butts	Developer / LB of Barnet	H
8	Re-establish the river corridor of the Silk Stream (combining surface water storage and public amenity)	Developer / LB of Barnet	H
9	Remove redundant/abandoned structures along river channel	Environment Agency	M
10	Increase level of river maintenance – Main River (Silk Stream & Tramway Ditch)	Environment Agency	M

Discussion of Preferred Measures

Measures 1, 2 & 3: Risk-based approach to drainage maintenance & development of centralised database (High Priority)

Urban flooding is very complex process that may involve a combination of flooding from a variety of sources. Asset management is a useful concept / tool to help organisations get the best value from their existing asset base as well as to help clarify roles and responsibilities of the organisations responsible for flood risk management. The management and maintenance of urban flood risk assets in Colindale covers three key organisations:

- Environment Agency - flood risk management assets (culverts, raised defences, trash screens, Main River channel);
- Thames Water (main sewer, lateral sewer);
- London Borough of Barnet (gully pots, non-main river channel maintenance and surface water).

Based upon our consultation with Barnet Council Highways Department, we understand that there are approximately 26,000 road drainage gully pots within the Council boundaries. Gully pots are fundamental to integrated urban drainage in that during intense precipitation events, surface water runoff is routed off roadways and other hard-standing and into gully pots and then into the public sewer system. In essence, gully pots are a critical link in the performance of the overall drainage network.

Asset management is a cross-cutting theme in integrated urban drainage. An activity by one organisation (e.g., Thames Water undertaking pipe upsizing) may lead to increased conveyance and discharge to the river system thus affecting the performance of another organisations asset (e.g., flood storage reservoir).

Table 15 - Summary of identified drainage maintenance issues (Measures 1 – 3)

Levels of Service	The current Barnet Council Highways Department maintenance cycle is on a 1-year maintenance regime for cleaning gully pots.
Development Pressures and Urban Creep	During site visits, the conversion of front gardens to paved areas for car parking (see Figure B5 in Appendix B) was observed. This gradual increase in hard-standing (impervious area) results in cumulative impacts and additional pressure on the drainage system to cope with increased runoff. In addition, it appeared (anecdotally) that there were many houses with extensions and conservatories that would also contribute additional runoff to the road drainage system.
Weaknesses in data systems	Improvement in the management of the Council's Highway Department drainage system is needed. While it appears that the London Borough of Barnet Highways Department has made some minor improvements to the management of its drainage assets, further improvement is recommended.

It is recommended that the Council:

- Focus attention on the maintenance of gully pots in the identified Critical Drainage Areas (CDAs) which are considered to be high risk;
- Develop a GIS database of all Council-owned drainage assets

Given the issues highlighted above, it is felt that the creation of a Centralised Database on drainage and ordinary watercourse assets including data on flooding events (GIS format) should be considered for implementation in the London Borough of Barnet. This is broadly in line with the draft Floods & Water Bill (April 2009). In the particular context of the study area, this database would have a dual objective:

- A basis for addressing and resolving responsibility following flood event or asset failure;
- To share asset information (asset condition, asset location, asset age, asset owner, etc.). This is seen as essential to provide real weight to the database and ensure collaboration from all stakeholders in its development and regular updating.

In order to simplify procedures and improve inter-agency communication, each identified stakeholder could designate a contact person responsible for the provision of data with a formerly agreed content, frequency and format. It is believed that this process could largely be systematized, thus reducing costs, through the production of automated monthly exports from each stakeholder's database. As these databases often cover other aspects relevant to each organisation's duties, the process of automated reports production aims at extracting the relevant information in a format common to each stakeholder.

Measures 5 & 6: Flood storage attenuation (High Priority)

In Section 4.2, a high-level analysis of three potential flood detention storage sites within the Colindale AAP was provided. Based upon the urban modelling and field investigations, these measures should be assessed in additional detail and reviewed as part of a potential Section 106 developer contribution. These flood storage sites could provide significant attenuation, water quality and ecological benefits to the AAP study area.

Measure 7: Rainwater harvesting (High Priority)

One of the preferred measures to reduce peak discharges and downstream flood risk, is the robust implementation of water butts on all new development in Colindale. Given the constraints associated with infiltration (due to the presence of London Clay), the wholesale implementation of water butts can significantly reduce peak discharges. Should the Council be interested in quantifying the benefits of various

source-control measures (in terms of flow attenuation, water re-use and water quality), this can be included as part of a future scope of work.

Thus, it is proposed that wherever suitable, domestic properties within the regeneration areas will have rainwater from the front and rear roofs collected via water butts for later use in gardens.

Whether to construct formal spill pipes to soakaways, or to allow simple overspill to the adjacent ground are detailed decisions that will be made based on factors beyond the scope of this outline Surface Water Management Strategy. Such a decision will have only minor significant on the proposals with respect to the surface water drainage. However, the principle of not connecting the building roofs to the surface water sewers will have a significant beneficial effect on the discharge of surface water from the development sites in the long term.

Rainwater Harvesting – Water Butts		
Description	**Benefits**	**Impacts**
Installation of water butts for all new development within the Corridors of Change	Ties in with SUDS hierarchy and reduces peak discharges to surface water	Positive impacts to sustainability and water re-use.
Retrofit water butts on all existing development (as shown on Figure 17)	Supplementary benefits beyond regeneration and redevelopment sites (volumetric reduction with opportunity for complimentary water quality improvements).	Currently no available incentives to encourage homeowners to install water butts.

Figure 17 - Example of a 100L water butt in Colindale, in front of the Underground Station

Measure 8: Re-establish river corridor and enhancements to Silk Stream (High Priority)

The Silk Stream is part of the Blue Ribbon Network and a Site of Borough Importance (London Plan 4C.1). These are strong drivers to support biodiversity in the river corridor. Development proposals should be seen as an opportunity to protect and enhance public amenities and leisure assets (walking and cycling paths, recreational areas, etc.), as well as to reduce flood risk (flood storage areas, rehabilitation of the river corridor, etc.).

Site surveys along the Silk Stream have highlighted the poor level of access to the river corridor within the Colindale AAP. Except for reaches located adjacent to Montrose Playing Fields and Rushgrove Park

(outside the study area), most of the river corridor is occupied by back gardens, un-maintained green areas, allotments etc., hence restricting access to the river due to legal (private riparian ownership) or physical constraints (absence of footpaths, fences protecting empty areas). It is clear that over time, the ecological character of the river has been altered by extensive urbanisation, whereby inadequate consideration has sometimes been given to the location of new developments, so that opportunities to make space for water, improve recreational access to and along the watercourses, provide attractive riverside greenspace, and enhance biodiversity, have been lost.

A more coordinated long term approach to river corridor enhancements is therefore needed, especially in the broader context of the need to adapt to future climate change impacts, managing associated flood risks and the need to maximise social, economic and environmental benefits from major regeneration initiatives in the Colindale area.

The key objectives of re-establishing a green corridor along the Silk Stream are:

- To setback new development, thereby making space for water, allowing for more storage and a better opportunity for river maintenance (buffer zone);
- To re-naturalise the channel to provide biodiversity and landscape enhancement;
- To provide a green pedestrian route through the Colindale AAP, improving recreational access to the river and the public realm;
- To stimulate regeneration, promote social inclusion and community identity.

Based on simple satellite observation, it is obvious that a green corridor along the Silk Stream cannot be created throughout the entire Colindale AAP without extensive repossession of private land, which may be a costly and long-term project. However, as a short-term measure, two particular areas could qualify for immediate rehabilitation and improvement of the river corridor:

- The green space located between Sheaveshill Avenue, Colindeep Lane and the railway (upstream of the bridge): approximately 1.52 ha of currently un-maintained green space covered by trees and scrub land (see Figure 18) could be cleared to provide a pedestrian and cycle path along the left bank. This could then be connected, at its north-western corner, to the recreational garden adjacent to the British Library. However, mitigation measures would be required to protect the flow gauging station managed by the Environment Agency from vandalism.
- The green space located between Colin Crescent and Rushgrove Park (downstream of the bridge): approximately 0.35 ha of a similar land use could also be cleared to provide access to the left bank of the Silk Stream, thus improving the current quality of Rushgrove Park. Health and Safety measures would be required around the culvert and the trash screen at the outlet of the Aerodrome Ditch.

Figure 18 - The Silk Stream upstream of the bridge on Colindeep Lane; scrub land and Environment Agency's flow gauging station

Both areas are encompassed by Flood Zone 3b (functional floodpain). Therefore, only water-compatible uses such as amenity open space, outdoor sports and recreational areas should be permitted. Essential infrastructure could be permitted (provided the PPS25 Exception Test is passed), but the potential for such infrastructures (transport infrastructure, primary substations, etc.) is considered very low.

These measures go hand-in-hand with Measure 4 regarding watercourses maintenance, as described below.

Measure 9: Remove redundant/abandoned structures along river channel (Medium Priority)

Section 3.1.3 provided an initial identification of hydraulic structures (mainly bridges) that represent a constriction of the cross section, restricting the channel's capacity during major storm events. Amongst the three identified structures, only the bridge at Montrose Playing Fields, immediately upstream of the confluence with the Tramway Ditch, seems to have a redundant function with regards to the other upstream bridge on The Greenway, and could be considered for removal. The other two bridges (at Sheaveshill Avenue and Colindeep Lane) obviously fulfil a transportation function and could only be considered for cross section upgrading (e.g. raise soffit levels).

Measures 4 & 10: Main River and ordinary watercourse maintenance (Low to Medium Priority)

There is only one listed Environment Agency flood defence structure within the Colindale AAP (see Table 16 and Figure 19 below).

Table 16 - Characteristics of flood defence structure within Colindale

Asset reference	0623838SI0103R02
Asset type	Insitu concrete lined channel
Maintainer	Private
Asset location	Upstream of Colindale Avenue
Last routine inspection	24/05/2007
Asset condition	Concrete in good condition - some vegetation growth in bagwork - natural banks stable. Channel bed originally lined with concrete - starting to erode out in places.
Design standard	1 in 5 year storm event.

Figure 19 - Pictures of a concrete lined reach of the Silk Stream within the study area, showing erosion (taken 17/03/2009)

The Standard of Protection (SoP) for the Silk Stream Channel within the study area is currently listed by the Environment Agency as 1 in 5 years. However, as highlighted in both the Colindale and the North London SFRAs, the National Flood and Coastal Defence Database (NFCDD) may be incorrect and would require updating.

There are a number of relatively minor maintenance issues that have been identified during site visits along the Silk Stream channel. One maintenance issue is associated with the illegal dumping of rubbish into the channel and this could become problematic during heavy rainfall events (see Figure 20 below). It is recommended that the Environment Agency and the Council work together to raise awareness amongst local residents regarding the flood risk related to blockages resulting from fly-tipping.

Figure 20 - Maintenance and fly-tipping issues observed along the Silk Stream

6 Developer Guidance

Gross storage volumes have been determined in Section 5.3.2 (see also Appendix C) for all four Corridors of Change and can be used to provide indicative sizes for attenuation ponds which receive on-site runoff.

The goal is to allow developers flexibility in selecting whether to implement a regional SUDS solution (e.g., Corridor of Change scale) or focus on an individual development site scale. Given the probable generally impermeable nature of the underlying soil, there is little difference between attenuation storage at a regional-scale or localised scale, other than land-take issues with respect to masterplan layout.

Critical success factors & goals

- Reduce and potentially remove uncertainties for developers
- Provide high-level storage criteria for future development
- Identify the development constraints.

Future management of SUDS systems

One of the key elements of the design of sustainable drainage systems is to ensure their long-term management and maintenance.

Problems may arise if SUDS are not well maintained and maintenance requirements for SUDS differ from those for conventional systems. Hence it is crucial that responsibilities for the maintenance of SUDS are allocated early in discussions before planning approval for each development is granted.

No legally binding obligation relating to the provision and maintenance of SUDS currently exists, as opposed to conventional foul and surface water drainage systems. The most appropriate way of achieving adoption, operation and long-term maintenance of SUDS is presently an agreement under Section 106 of the Town and Country Planning Act, 1990 that provides greater security for the implementation of SUDS and for which templates have been developed. This does not preclude the need for additional negotiations and legal preparatory works on a case-by-case basis, in order to assess the preparedness and willingness to adopt SUDS systems by each stakeholder.

As part of a future detailed SWMP or Flood Risk Assessment, we recommend the preparation of tailored Outline Model Agreements providing guidance for Operation & Maintenance, in order to improve uptake by providing a mechanism for maintenance. The choice of a Model Agreement and the mechanism for implementation is usually under the responsibility of the Local Planning Authority, the London Borough of Barnet.

To assist the London Borough of Barnet and the local developers in Colindale, we recommend the identification, at an early stage of planning, of the most appropriate legal framework for the various components of the integrated drainage strategy to be managed, most likely in the following situations:

- Implementation and maintenance of SUDS through the planning process, either as a Planning Obligation under Section 106 of the Town and Country Planning Act 1990 or as a condition attached to planning permission
- Implementation and maintenance of SUDS between two or more parties (outside of the requirements for planning permission), i.e. Private SUDS Model Agreements. These are primarily setup to help facilitate ongoing maintenance of SUDS that are in private ownership (large landowner, housing association, corporate body or single household).

The following table, based on DEFRA's Interim Code of Practice for Sustainable Drainage Systems (2004) provides guidance on the most suitable mechanisms for maintenance. As the overall drainage strategy for the Colindale AAP reaches the final stage, each component or group of components of the drainage

system should be attributed one of the following three Model Agreements. The choice of Model Agreement and the mechanism for implementation will usually be determined by Barnet Council.

Table 17 - SUDS adoption & maintenance guidance

Type of Model Agreement	Planning obligation under Section 106 of the Town and Country Planning Act		Condition attached to planning permission which requires SUDS	Private Model Agreement
	Incorporating Maintenance Framework Agreement	With stand alone Maintenance Agreement		
Description	Legal agreement to enforce a properly implemented and maintained SUDS scheme. The Maintenance Framework Agreement sets out responsibilities for implementation and maintenance.		Requires the developer to use SUDS within the development. An agreement should be produced to facilitate ongoing maintenance.	Contract between the property owner/tenant (landowner, housing association, corporate body or single household) and the maintenance provider, setting out the responsibilities of the parties, the number of maintenance visits and the charges for the services.
SUDS implementation and maintenance required as part of the planning process?	YES		YES	NO
Type of SUDS scheme	Large / Complex		Small / Simple	Small / Simple
Level of control required by local Authority	High	Low	Low	None
Advantages	- Offers more security as it may only be varied by agreement. - Allows for financial contributions in the form of a bond or a periodic payment.		More flexible approach	- Facilitates ongoing maintenance of SUDS that are in private (freehold) ownership. - Suitable for either existing or new developments.
Drawbacks	The Section 106 route requires negotiations and legal preparatory work in advance of the development taking place.		- Planning conditions can be appealed against. - Enforcement can be difficult.	Shared responsibilities between the customer and the maintainer may become a problem in case of a failure of SUDS that affects downstream areas.

Also, it is recommended that the Council consider establishing criteria for the performance of SUDS systems. Even though no conditions have been placed on the maintainer for the performance of the SUDS, it is crucial to secure funding in order to demonstrate the long term impact of SUDS on both the quantity and quality of water leaving the site as well as environmental and social implications.

7 Conclusions & Recommendations

7.1 Conclusions

The outline SWMP process has produced the following key conclusions for consideration in the development of the Colindale AAP:

- Gully pot maintenance is an issue and appears to have exacerbated previous surface water flooding and ponding incidents. A risk-based approach to gully pot maintenance is recommended which is based upon technical data, local surface water flooding history and the outputs from our urban pluvial modelling. In addition, it is recommended that the Council consider the development of a centralised database focused on asset management and maintenance.
- This risk-based approach to maintenance could be enshrined within a Drainage Operations & Maintenance Plan (O&M Plan). Such a plan could be used to minimise the failure of drainage assets, such as gullies, drains and flood attenuation storage areas.
- Three Critical Drainage Areas have been identified within the Colindale AAP.
- The presence of London Clay in the underlying soil, in combination with a high urban surface proportion, is an important feature contributing to the surface water flooding mechanism. Due to the low permeability of the soil, runoff rates and volumes are high and will increase over time with Climate Change. The Greenfield runoff rate for clayey soil is high which means the required volume for attenuation is relatively low.
- Surface water storage will be required to manage drainage within the AAP area. The total required storage volume calculations provided in Section 5 are indicative and do not take into account the effect of the current sewer system. As part of the future detailed development proposals, storage volumes can be split between several storage ponds, allowing more developer flexibility (bearing in mind the drainage hierarchy as set out in The London Plan Section 4A.14 (pg 213) on Sustainable Drainage).
- There are several opportunities for regional strategic flood storage (SUDS solutions) within the Colindale AAP study area. It is recommended that these flood storage areas are explored in more detail as the proposed development sites come forward, but the present information can be used directly to inform the development of the Colindale AAP masterplan, in particular its layout with respect to CDAs.
- The current lack of Thames Water sewer network data presents a challenge in developing a shared understanding of all sources of flood risk. An analysis of the Thames Water network model is recommended to determine whether the network surcharges under a range of rainfall scenarios and to assess the interaction between the piped network, sewer exceedance and surface water flood risk. This activity would be central to a future detailed SWMP.
- Access to the Silk Stream and the floodplain is limited throughout Colindale, the river and floodplain can be better utilised with improved public access and signage to provide a greater resource to the community.
- The water chemistry and biological water quality of the Silk Stream is currently identified as ‘poor’ or Grade E (Thames RBMP). However, through robust implementation of the measures identified in Section 5.4 above there are several complimentary opportunities to reduce the volume of runoff from the proposed new development sites thereby reducing flood risk as well as opportunities to improve the quality of runoff thus helping to achieve targets identified in the Water Framework Directive and Thames River Basin Management Plan.

- The Silk Stream crosses the administrative boundaries of four Local Planning Authorities and that each of these Councils contribute to the hydrologic inflows of the Silk Stream. The development of a future catchment-based SWMP, with support from the Environment Agency and Defra, is recommended.
- One of the identified recurring maintenance issues noted through site visits and consultation is associated with the illegal dumping of rubbish into the Silk Stream. This issue is compounded and has become problematic during heavy rainfall events. It is recommended that the Environment Agency and the Council work together to raise awareness amongst local residents regarding the flood risk related to blockages resulting from fly-tipping.

7.2 Recommendations

Public awareness and outreach: we recommend the Council take steps to encourage public awareness of SUDS and increase community participation, in order to ensure positive reactions for the implementation of flood storage areas as well as household water butts.

We also recommend a public awareness campaign to encourage retrofitting of existing development with water butts. If the uptake of water butts on existing development in Colindale is successful, this will have a positive impact beyond the installation of water butts on the growth areas only.

We recommend that developers and the Council undertake public presentations or erect site display boards to let the public know what is being done to address stormwater runoff and reduce the risk of flooding in Colindale.

The surface water flood risk maps can be used by the Emergency Planning Team at Barnet and the London Local Resilience Forum (LRF) to inform multi-agency flood plans and emergency procedures as required by the Cabinet Office (COBR) and under the Civil Contingencies Act (2004).

We recommend that the Council work closely with the Homes & Communities Agency (HCA) to ensure that the quality standards for the proposed new development (including SUDS and soakaways) are incorporated into the development proposals. Where possible, Code Level 6 (Code for Sustainable Homes, CLG) should be the target for the developers to achieve

An evaluation of the Thames Water sewer network capacity was not included in the scope of services for this project. Therefore, as part of a future Borough-wide Surface Water Management Plan, we recommend a full hydraulic assessment the Thames Water sub-surface piped drainage network. This assessment will enable a fuller understanding of the interactions between the sewer network, the Local Authority drainage network and the river system.

7.3 Supplementary policy recommendations

Draft proposals for new planning policies - as this surface water management strategy is carried out at an early stage of planning, it represents the ideal opportunity to make recommendations that may result in innovative binding obligations. These could include for instance, but not limited to:

Proposed Flood Risk & Water Quality Mitigation Fee - based on the amount of new impervious land coverage being created by a development project and consisting in money set aside for future Infrastructure and Environmental Improvement Projects (EIP) within Colindale.

Proposed Security Deposit – to ensure conformity with the approved SUDS designs, we recommend that the Council consider establishing a small performance security deposit (bond) which is required by the developer to guarantee the SUDS are installed as per the approved plans.

This policy proposal is based upon evidence from other Local Planning Authorities who have reported discrepancies observed between technically sound SUDS designs and the actual implementation of SUDS that do not meet the agreed standards in terms of flood storage sizing, drainage and flood mitigation.

Critical success factors

- Coordination between the London Borough of Barnet, the Environment Agency and Thames Water and the commitment of key people within these organisations has been shown to be important in delivering sustainable development that provides integrated solutions to drainage.
- To this end, we recommend that each of these organisations sign up to this Outline Surface Water Management Plan, thereby agreeing the principles and outputs herein. A coordinated investment plan for the full implementation of the SWMP may be necessary to secure future government funding. This should be considered as part of a borough-wide SWMP.

7.4 Broader Policy Recommendations – Catchment & National scale (Beyond study area)

7.4.1 Recommendations for the Environment Agency

To achieve the aims of 'Making Space for Water' and Surface Water Management Plans as set out in the Technical Guidance, Living Draft Version 1, (Feb 09), we recommend the following:

- The Environment Agency develop a Surface Water Management Plan communication strategy specifically targeted to Local Planning Authorities & Water Companies (including information on best practice, completed project examples, single point of contact, groundwater flooding data, web site and fact sheets).
- We recommend that the Environment Agency establish a Regional single point of contact to help with the coordination of Surface Water Management Plans (similar to the EA Regional Reservoir Coordinator and SFRA Coordinator roles).
- We recommend that the Environment Agency develop streamlining protocols to facilitate data requests (e.g., gauge data for model calibration, asset condition data, channel survey and conveyance data, etc.) for the production of Surface Water Management Plans.
- We recommend that the Environment Agency utilise the information contained in our final report to update their 'Areas Susceptible to Surface Water Flooding Maps' similar to the process for updating the 'Flood Map'.

7.4.2 Recommendations for the Greater London Authority

- We recommend that the Greater London Authority update the Drain London draft Scoping Study report with information from our Final Technical Report.

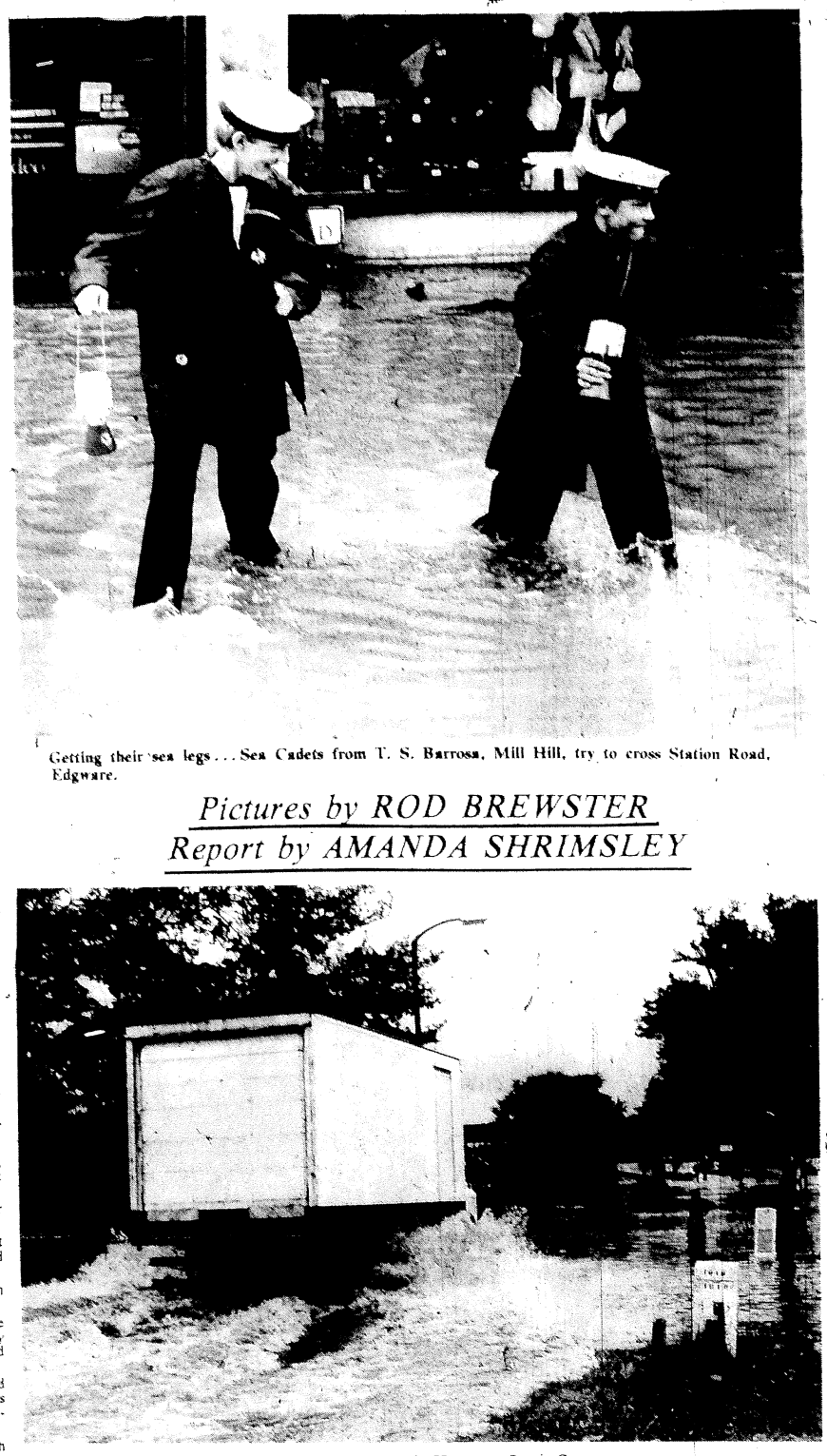
Appendices

Appendix A: Excerpt from The Hendon Times, July 1982

THE GREAT FLOOD

The heartache, the horror and the humour of one of the worst local floods in living memory

Mr Terry Jarvis bails out his home in Burrell Close, Edgware, where carpets and fittings were ruined.



Getting their sea legs... Sea Cadets from T. S. Barrosa, Mill Hill, try to cross Station Road, Edgware.

Pictures by ROD BREWSTER
Report by AMANDA SHRIMSLEY

SATURDAY'S torrential storms caused flood chaos, a lot of distress — and thousands of pounds worth of damage in Barnet and North-West London.

The sudden downpour meant:

- Traffic on most of the area's main roads ground to a halt for periods — then had to crawl along through surface water.
- Houses on the Springwood Estate, Edgware, were flooded.
- Many shops in Hale Lane, Edgware, had to shut for the afternoon — so staff could clear out floodwater.
- Stanmore Broadway was soaked in up to 18 inches of water.
- The basement of W. H. Smith, Station Road, Edgware, was flooded in 6ft. of water, which took firemen hours to pump away.
- Firemen at Stanmore, and Mill Hill Stations together received over 120 flood-distress calls.
- Wildlife by the Welsh Harp was destroyed when at least six nests of Great Crested Grebe eggs were washed into the reservoir.
- And the AA at Stanmore was besieged by calls from distressed motorists whose cars had broken down.

Probably the worst flooding occurred at Burrell Close and nearby roads on the Springwood Estate, where angry residents battled for hours to get the brownish flood water out of their living rooms and kitchens.

Long-suffering tenants — who say the water caused thousands of pounds worth of damage to their carpets and property — plan to ask Barnet Council for compensation.

Mr Terry Jarvis, whose ground floor was awash with water, said: "We can't stand it here any longer. We just want to get out like the residents of the Springwood flats that are being blown up."

As neighbours helped her sweep the water out of her home, Mrs Margaret Phillips said: "It's disgusting. Some of this is sewage. I saw sewage go past my door.

"I'm terrified about the health hazard because I have two tiny babies here at the moment. This happened before on the estate two years ago."

"It's a disgrace," said Springwood Residents' Association chairman John Sullivan. "The drains are inadequate."

The 40-odd calls about the estate flooding were dealt with by firemen from Mill Hill, Paddington, Willesden and Acton.

Water had to be pumped out of homes back into the street where drains were already overloaded.

A Barnet Council spokesman said emergency teams were at the estate on Saturday helping clear the flood water. One tenant was temporarily re-housed. Estates officers spent Monday calling at all the affected homes offering advice and help. And drainage problems were being examined.

"North-West London got it the worst," said a spokesman from the AA, Stanmore, as he listed how, after initial stoppages:

- The A1 was reduced from three lanes to one between Apex Corner and Potters Bar.
- Bad flooding hit Fiveways Corner, Mill Hill.
- And traffic was held up on the A41 Hendon and Watford Way because of surface water.

Sainsbury's supermarket, Hale Lane, Edgware, was among the shops that had to shut at lunchtime. Deputy manager Mr Eric Bull estimated that even though no stock had been damaged by invading floodwater, "quite a lot of money" had been lost because of losing a third of the day's trade.

Hundreds of pounds worth of the store's perishable stock had to be destroyed.

Four days before Saturday's floods, Barnet's Public Works Committee agreed to ask Thames Water Authority for an increased allowance for maintaining the borough's sewer system.

After receiving a report on damage — including 11 foul sewer eruptions after the flooding in early June — chairman Councillor Bill Hart described the £1m. yearly allocation as "totally inadequate."

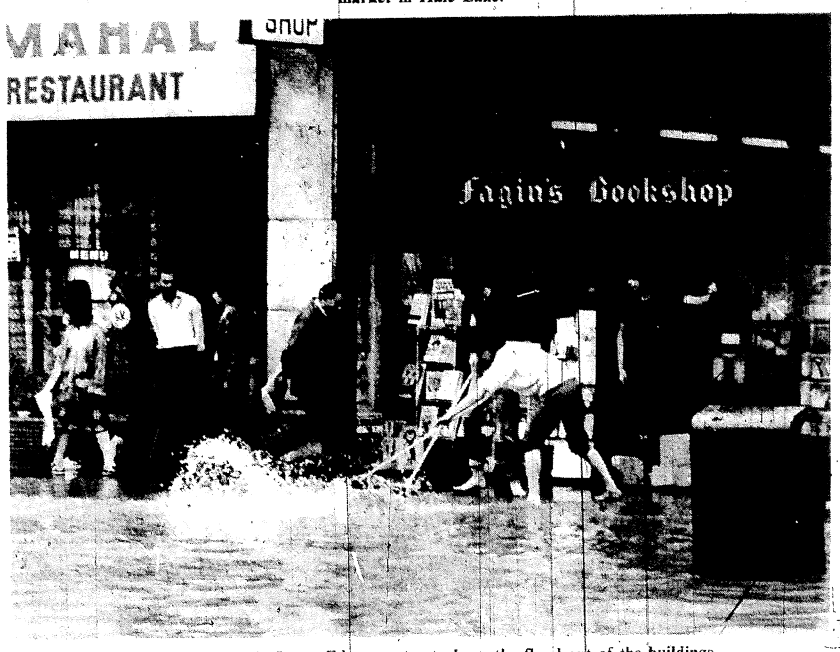
A lorry braves the floods in Honeypot Lane, Stanmore.

Youngsters paddle in the Le Bretton family's flooded garden, behind their house in Warrens Shawe Lane, Edgware.

Mothers and children form a human chain to clear water from houses in Burrell Close, Edgware.

A motorist tried to get through flooded Hale Lane, Edgware. The engine stalled and it had to b pushed on to dry land.

Mopping up in Edgware. Sainsbury's assistants cheerfully try to get the floodwater out of the supermarket in Hale Lane.



Shopworkers in Hale Lane, Edgware, try to keep the flood out of the buildings.

Alison Gower, 12, Janet Mitcham, 11, and Tony Mejuot, 14, fight a losing battle as flood water pours through the Gower family's living room in Burrell Close, Edgware.

Appendix B: On-site data collection results of identified drainage issues

Several localised drainage issues were identified during the site surveys. They usually consist in low-lying areas were gullies more quickly fill with sediments and detritus. These and the already identified critical gullies throughout the London Borough of Barnet, should form the basis of a risk-based maintenance programme for the Highways Authority, where critical gullies are cleared on a more regular basis (typically twice a year and after major storm events).

Figure B1 - Example of localised drainage issues: underground footpaths at Grahame Park and corresponding blocked gully

Figure B2 - Example of localised drainage issues: low point at Further Acre and corresponding blocked gully

Figure B3 - Example of localised drainage issues: low point at Lanacre Avenue and corresponding blocked gully

Figure B4 - Example of localised drainage issues: blocked gully at Colindeep Lane and low point at Rushgrove Avenue

Re-development should also be seen as an opportunity to improve surface water management through very simple measures, regarding land cover (avoiding extensive paved front gardens, etc.) or drainage layout (avoiding direct surface discharge from extensive roofs, strategically placed and properly sized drainage gullies, etc.). The site surveys provided an opportunity to identify several key issues below that could easily be avoided at implementation stage, as highlighted in Figure B5.

Figure B5 - Examples of drainage arrangements and building standards to avoid during re-development

Appendix C: Site-specific storage volumes calculations

Attenuation storage aims to limit the peak rate of runoff from the development to the receiving watercourse to the corresponding Greenfield runoff rate for a range of annual flow rate probabilities. The outlet structure dictates the rate at which the attenuation volume will drain.

Long-term storage is used to achieve a reduction in the additional volume of runoff caused by the development, by allowing the volume equal to the Greenfield runoff to discharge at Greenfield rates, while retaining the rest of the runoff to discharge as infiltration or at very low rates. For Colindale it is expected that long term discharge cannot be achieved through infiltration, hence the need for the installation of a hydro-brake to limit long term discharge to a maximum of 2 l/s/ha. As a rule of thumb for preliminary assessment, the 1 in 100 year, 6 hour rainfall event is used to size the long term storage volume, as this is linked to extreme flooding rather than frequent, high intensity short duration rainfall events.

Treatment storage is designed to retain and treat the most polluted water from all events, and to retain the full volume from most events. The treatment volume can be managed by splitting it between several components in series.

No.	Site Name	Area (Ha)	Public open space not modified (Ha)	Greenfield Runoff Rates (l/s/ha)			Development Option A					Development Option B					Development Option C				
				Q_{1yr}	Q_{30yr}	Q_{100yr}	$V_{ATT,1yr}$ (m^3)	$V_{ATT,30yr}$ (m^3)	$V_{ATT,100yr}$ (m^3)	$V_{LT-100yr\ 6hr}$ (m^3)	$V_{treat.-5yr\ 60min}$ (m^3)	$V_{ATT,1yr}$ (m^3)	$V_{ATT,30yr}$ (m^3)	$V_{ATT,100yr}$ (m^3)	$V_{LT-100yr\ 6hr}$ (m^3)	$V_{treat.-5yr\ 60min}$ (m^3)	$V_{ATT,1yr}$ (m^3)	$V_{ATT,30yr}$ (m^3)	$V_{ATT,100yr}$ (m^3)	$V_{LT-100yr\ 6hr}$ (m^3)	$V_{treat.-5yr\ 60min}$ (m^3)
1	Grahame Park (Lanacre Avenue)	35	4.19	4.10	11.18	15.38	4,622	13,092	19,968	10,676	5,546	2,712	8,204	12,693	4,367	4,167	1,346	4,273	6,725	485	3,000
2	Beaufort Park (Aerodrome Avenue)	10		4.10	11.18	15.38	1,500	4,249	6,481	3,465	1,800	880	2,663	4,120	1,418	1,352	437	1,387	2,183	158	974
3	Zenith House (Edgware Road)	1		4.10	11.18	15.38	150	425	648	347	180	88	266	412	142	135	44	139	218	16	97
4	Former National Grid/Kidstop Premises (Edgware Road)	0.6		4.10	11.18	15.38	90	255	389	208	108	53	160	247	85	81	26	83	131	9	58
5	Barnet College (Grahame Park Way)	5.1		4.10	11.18	15.38	765	2,167	3,305	1,767	918	449	1,358	2,101	723	690	223	707	1,113	80	497
6	Peel Centre East (Colindale Ave/Aerodrome Road)	3.8		4.10	11.18	15.38	570	1,615	2,463	1,317	684	334	1,012	1,565	539	514	166	527	829	60	370
7	Peel Centre West (Aerodrome Road)	14.7	2.93	4.10	11.18	15.38	1,765	5,000	7,625	4,077	2,118	1,036	3,133	4,847	1,668	1,591	514	1,632	2,568	185	1,146
8	Farrow House (Colindeep Lane)	0.9		4.10	11.18	15.38	135	382	583	312	162	79	240	371	128	122	39	125	196	14	88
9	British Library (Colindale Avenue)	2.3		4.10	11.18	15.38	345	977	1,491	797	414	202	612	948	326	311	100	319	502	36	224
10	Colindale Hospital (including frontage & Phase 2)	6.6		4.10	11.18	15.38	990	2,804	4,277	2,287	1,188	581	1,757	2,719	936	893	288	915	1,441	104	643
11	Middlesex University Halls (Grahame Park Way)	2.2		4.10	11.18	15.38	330	935	1,426	762	396	194	586	906	312	298	96	305	480	35	214
12	National Blood Service expansion site	0.6		4.10	11.18	15.38	90	255	389	208	108	53	160	247	85	81	26	83	131	9	58
13	Brent Works (Colindale Avenue)	0.7		4.10	11.18	15.38	105	297	454	243	126	62	186	288	99	95	31	97	153	11	68
14	Land between railway line (Aerodrome Road)	0.7		4.10	11.18	15.38	105	297	454	243	126	62	186	288	99	95	31	97	153	11	68
15	Site along Watford Way	1		4.10	11.18	15.38	150	425	648	347	180	88	266	412	142	135	44	139	218	16	97
16	McDonalds Site (Edgware Road)	0.5		4.10	11.18	15.38	75	212	324	173	90	44	133	206	71	68	22	69	109	8	49
17	Burger King & Eyeland Site (Edgware Road)	0.4		4.10	11.18	15.38	60	170	259	139	72	35	107	165	57	54	17	55	87	6	39
18	Merit House (Edgware Road)	1		4.10	11.18	15.38	150	425	648	347	180	88	266	412	142	135	44	139	218	16	97
19	Green Point (Edgware Road/The Greenway)	0.5		4.10	11.18	15.38	75	212	324	173	90	44	133	206	71	68	22	69	109	8	49
Optional	Former electricity board land site	0.3		4.10	11.18	15.38	45	127	194	104	54	26	80	124	43	41	13	42	65	5	29
Optional	Land inbetween Library and Brent Works	0.25		4.10	11.18	15.38	38	106	162	87	45	22	67	103	35	34	11	35	55	4	24
Sites in Brent																					
20	Oriental City (Edgware Road)	3		4.10	11.18	15.38	450	1,275	1,944	1,040	540	264	799	1,236	425	406	131	416	655	47	292
21	Capitol Way (Edgware Road)	3.15		4.10	11.18	15.38	473	1,338	2,041	1,091	567	277	839	1,298	447	426	138	437	688	50	307
22	Asda Site (Edgware Road)	2.5		4.10	11.18	15.38	375	1,062	1,620	866	450	220	666	1,030	354	338	109	347	546	39	243
23	Sarema House (Edgware Road)	1.7		4.10	11.18	15.38	255	722	1,102	589	306	150	453	700	241	230	74	236	371	27	166
24	Retail Park (Edgware Road)	4		4.10	11.18	15.38	600	1,700	2,592	1,386	720	352	1,065	1,648	567	541	175	555	873	63	390

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