APPLICATION OF PROPER DECISION SUPPORT SYSTEM TO SELECTED CASE STUDIES

DELIVERABLE 3.6

CEDR PROPER PROJECT

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Executive summary

This report is the final deliverable of WP3 (Sustainable assessment of measures and treatment systems for road runoff) of the CEDR PROPER project. It considers the application of the PROPER decision support system (DSS) (PROPER Deliverable 3.3) to five Case studies which represent highway drainage catchments in the UK and Ireland, each of which demonstrates different site characteristics. To fully understand the interpretations of the Case Studies, readers are also recommended to refer to the PROPER DSS User Guide (PROPER Deliverable 3.4) and the PROPER DSS Technical Manual (PROPER Deliverable 3.5).

Site details for each of the Case Studies are fully described including the depth to groundwater and whether this is categorised as sensitive, the nature of the surface soil, the effective contributing drainage area and the annual average daily traffic (AADT). Input of this information into the PROPER DSS provides an initial screening of the suitability of 12 different SUDS/BMPs for installation at a particular site. Incorporation of criteria/indicator weightings, relevant to each Case Study site, into the performance matrix of the PROPER DSS enables the 12 SUDS/BMPs to be prioritised according to their treatment potential. The predicted suitability and preferential order of treatment potential for different SUDS/BMPs at each Case Study site are then compared with those which have been installed.

The suitability of a treatment system for use according to the site criteria at a specific Case Study site is classified and colour coded as either recommended (green), recommended with advisement (amber) or not recommended (red). Both Case study sites on the MI motorway (Luton and Leeds) have treatment provided by balancing ponds and this is entirely consistent with the recommendation provided by the PROPER DSS (green colour coding). The filter strip and vegetated pond installed adjacent to the A34 Newbury Bypass site are also recommended although in the case of the pond only with advisement (amber colour coding). This is because of predicted concerns regarding the preservation of appropriate water levels during prolonged periods of dry weather. The practical solution to this was to identify a supplementary water source provided by a spring. Constructed wetlands are identified as the SUDS/BMP with the highest treatment potential at this site. At the A34 Oxford Bypass Case Study site, filter drains have been installed parallel to the carriageway but this SUDS/BMP only receives a predicted recommendation for use with advisement because of identified potential clogging problems. By identifying this prospective problem, the PROPER DSS facilitates the inclusion of appropriate design modifications prior to installation. Filter drains were also installed as the preferred treatment system at the M4 Maynooth Bypass site but in this case there is a conflict with the PROPER DSS prediction which does not recommend the use of filter drains (red colour coding).

Acknowledgements
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1. Introduction

The PROPER Decision Support System (DSS) allows a comparative assessment of the performance of 12 different SUDS/BMPs with regard to their ability to reduce the impacts of highway runoff. It consists of four separate components of which ‘site criteria’ and ‘performance matrix’ are important in establishing the predictions for a specific site. The ‘site criteria’ component enables a site screening operation to be conducted to establish how the prevailing site conditions influence the suitability of a particular SUDs/BMP to be able to reduce the impact of highway runoff. The site screening characteristics incorporated into the DSS include the existence of sensitive groundwater zones, soil type, groundwater depth, the effective contributing drainage area and the traffic volume. The ‘performance matrix’ component incorporates a set of performance grades allocated to a set of six controlling criteria (and sub-indicators) which allow the SUDs/BMPs to be prioritised in terms of their preferential ability to reduce the impact of highway runoff in a particular location.

The criteria incorporated into the performance matrix of the PROPER DSS include ‘Technical’, ‘Environmental’, ‘Operation and Maintenance’, ‘Socio-environmental awareness’, ‘Economic’ and ‘Legal and highway planning’ aspects with the indicators providing more detailed discriminators for each of the criteria (e.g. ‘flood control’, ‘pollution control’ and ‘adaptability to highway widening and climate change’ for the Technical criterion). The performance matrix incorporates weightings which reflect the relative importance of each criterion/indicator to the specific highway environment being considered enabling the different SUDS/BMP options to be arranged into an order of preference according to their ability to meet the required treatment performance. The site screening component of the PROPER DSS identifies the suitability of using a particular SUDS/BMP to treat the runoff from a highway catchment and groups the treatment systems as either recommended (green colour coding), recommended with advisement (amber colour coding) or not recommended (red colour coding). A recommendation under advisement indicates that a treatment system is not entirely compatible with the existing site conditions and that specific design considerations may be required to achieve a successfully operating SUDS/BMP.

By referring to five Case Study sites, examples are provided where different combinations of site criteria and performance matrix conditions (percentage weightings of criteria/indicators) exist to illustrate the impact on predicting both the suitability and order of preference for the 12 different SUDS/BMPs. Graphical representations of the predicted results are presented and comparisons with the actually installed treatment systems fully discussed and the implications interpreted. Each of the Case Study sites involve rural highway catchments which drain to established treatment systems. Four of the sites are in the UK and one in Ireland. They have been chosen to provide a range of different site conditions which influence the suitability of different SUDS/BMPs.

2. M1 Luton Case Study Site, UK

2.1. Site details

This site is situated south of the town of Luton on the M1 motorway and is located approximately 50 km north of London. The M1 motorway was Britain's first full-length motorway and is still one of the most important, representing the fastest route north from London to the industrial areas of the East Midlands and Yorkshire as well as providing access to the West Midlands, Lancashire and Scotland. The first section, which includes the Case Study site, was opened in December 1959 with the continuous route from London to Leeds finished by October 1968. The original specification was for a road to carry 13,000 to 14,000 vehicles per day compared to the current annual average daily traffic flow of between 130,000 to 140,000. Widening and junction improvements have been necessary to accommodate the increased traffic volumes with the study site now consisting of 4 lanes in each direction.

The Case Study site (located immediately north of junction 9 of the M1 motorway) constitutes a 2.6 km length of the northbound carriageway (Figure 1). The surface of the carriageway is composed of hot rolled asphalt. The traffic flow on the northern carriageway is 146,000 vehicles/day, of which approximately 11% are heavy goods vehicles. Drainage water was collected from four lanes and the hard shoulder giving a total effective contributing area of 43,375 m^2. The drainage system consists of a concrete channel and a 450 mm carrier pipe discharging to a balancing pond via an oil separator. A photograph of the site during wet weather is provided in Figure 2.

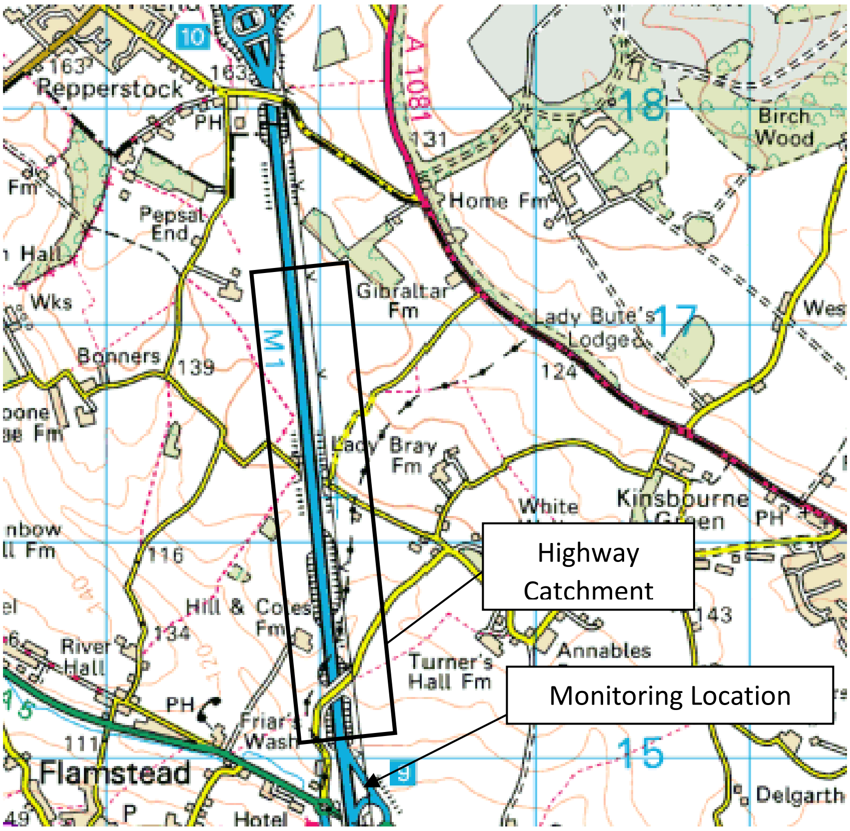

Figure 1. Highway catchment site to immediately north of junction 9 of the M1 motorway close to Luton

Figure 2. A view of the Luton M1 site during wet weather conditions.

The soil type in the immediate area of the site is classified as slightly acid loamy and clayey in nature resulting in an overall texture which presents impeded drainage. Below the site there is an unconfined aquifer in the upper Chalk at an average groundwater depth of 83.2 m. The groundwater is designated within a Special Protection Zone with a Zone II classification for the site indicating its presence in an Outer Protection Zone (i.e. typically a travel time of at least 400 days exists to allow the attenuation of slowly degrading pollutants prior to reaching the aquifer).

2.2. Application of the PROPER DSS to the Luton M1 site

2.2.1. Identification of treatment systems compatible with the site conditions

The first stage in applying the PROPER DSS is to establish how the existing site conditions influence the feasibility of using the different possible treatment systems. Table 1 summarises the responses entered into the 'Site criteria' page of the DSS based on the site details described above.

Table 1. Summary of the Luton M1 site characteristics and details entered into the 'Site criteria' page of the PROPER DSS

	Site details	Selection entered into PROPER DSS
Presence of sensitive groundwater	Yes; Zone II	Zone II
Depth to groundwater	83.2 m	>1.5 m
Surface soil type	Loamy clay; impeded drainage	Clay
Effective drainage area	43,375 m^2	>40,000 m^2
AADT	146,000	100,000-150,000

Based on the site characteristics identified in Table 1, the PROPER DSS provides the recommendations for the suitability of the different treatment systems shown in Figure 3. Retention ponds, detention basins, extended detention basins and constructed wetlands are all identified as being appropriate for treatment of the drainage deriving from the Luton M1 site. Both porous surfacing treatment options together with filter drains, soakaways, infiltration trenches and infiltration basins are not recommended with the limited infiltration possible in the clay based soils being a strong controlling factor. Swales and filter strips should only be used under advisement (amber colour coding). The site condition influencing this decision is the existence of a Zone II sensitive groundwater below the site. Therefore, if either swales or filter strips are considered for delivery of surface water drainage to another treatment system, a thorough site investigation should be conducted with a possible recommendation being that they should be lined. However, the large drainage area of the Luton M1 highway catchment site also mitigates against the use of swales (amber colour coding) because of the high runoff flows which may be generated causing excessive wear to grass lined channels. Possible design modifications to alleviate this potential problem could be to ensure shallower longitudinal gradients within the swale, the incorporation of check dams and/or the installation of an overflow pipe or weir overflow structure to convey excess flows downstream.

Runoff Treatment and Code
Swale (SW)
Porous surfacing without storage (PS)
Porous surfacing with storage (PS+)
Filter strip (FS)
Filter drain (FD)
Retention pond (RP)
Detention basin (DB)
Extended detention basin (EDB)
Constructed wetland (CW)
Soakaway (SO)
Infiltration trench (IT)
Infiltration basin (IB)

Figure 3. Suitability of treatment systems for use at Luton M1 site predicted by the PROPER DSS

2.2.2. Identification of order of priority for use of treatment systems

The performance matrix page of the PROPER DSS allows an order of preference in terms of treatment potentials to be established for the different SUDs/BMPs. This requires the allocation of percentage weightings to each of the indicators (and hence to the criteria) and the entering of grades into the performance matrix. The DSS comes with default values for both the percentages and the grades and these have been deemed to be appropriate for the Luton M1 site.

The overall scores predicted for the different potential treatment systems for the Luton M1 site are shown in Table 2 with the prioritisation increasing in descending order in the Table. These results are also plotted in Figure 4 with the coloured bars identifying the suitability of the

Table 2. Increasing order of preferential treatment for SUDS/BMPs for the Luton M1 site

Treatment system	Overall score
Porous surfacing (without storage)	231
Swale	260
Filter strip	287
Filter drain	305
Detention basin	310
Retention pond	319
Porous surfacing (with storage)	325
Soakaway	328
Infiltration trench	336
Extended detention basin	348
Infiltration basin	368
Constructed wetland	378

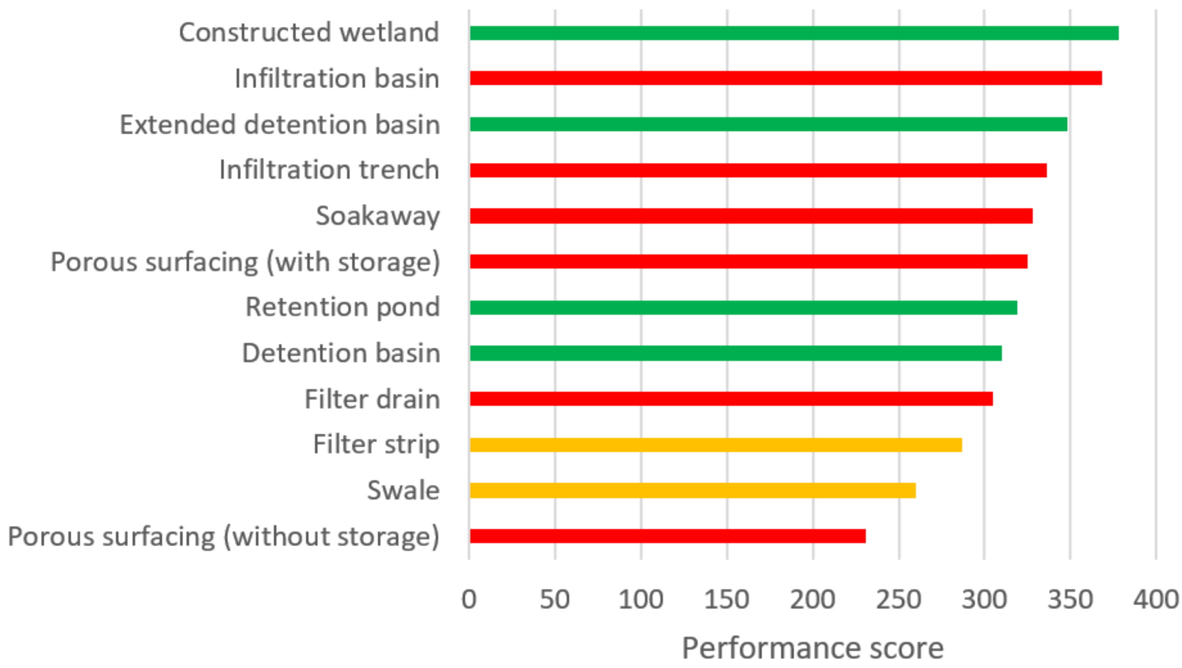

Figure 4. Performance scores and predicted suitability for treatment systems at the Luton M1 site

different systems. For the four treatment systems identified as being suitable for use at the Luton M1 site, the order of preference can be seen to be constructed wetlands > extended detention basins > retention ponds > detention basins. Although it is not clear whether the installed balancing pond is wet or dry, the use of such a treatment system is consistent with the suitability of retention ponds and detention basins predicted by the PROPER DSS tool. However, it is clear from the predictions that the use of either an extended detention basin or constructed wetland would have been preferable. The use of an extended detention basin was probably ruled out by the limited availability of space but a constructed wetland would have provided the best option with regard to efficient treatment of highway runoff at this site. Alternatively, a wetland cell could be inserted within the existing flood storage basin.

Although swales and filter strips are low in the predicted order of suitability this should not entirely rule out their application as transport systems for the highway runoff to the main treatment system, providing that the advisement conditions can be met, as previously described. Inspection of Figure 2 indicates that there could be sufficient space for the installation of such roadside controls. Currently the Case Study site employs a concrete channel and a carrier pipe to deliver runoff to the balancing pond. In the event of retrofitting works being carried out at this site, the use of appropriately designed swales should be recommended to comprise the first part of a treatment train which also constitutes a constructed wetland.

3. A34 Newbury Bypass Case Study Site, UK

3.1. Site details

The Newbury bypass is a 14 km stretch of dual carriageway road which passes to the west of the town of Newbury in Berkshire, England. It was opened in 1998 to replace a significant bottleneck which previously existed and now forms part of the A34 trunk road which runs between Winchester and Oxford. The two way traffic density is in the range of 31374 to 41727 vehicles per day.

The Case Study site is located at the southern end of the Newbury bypass (Figures 5 and 6) and drainage discharges via a culverted section of watercourse to the River Enborne, a tributary of the Kennet. Surface runoff from the carriageway passes through a bypass oil separator to a wet balancing pond planted with reeds (known as Pond D). The lower reaches of the River Enborne support a healthy wild trout population and the river provides a wide range of high quality habitats for all life stages of the brown trout. Environmental considerations are therefore of critical importance when assessing appropriate treatment systems for the highway runoff deriving from the Newbury bypass.

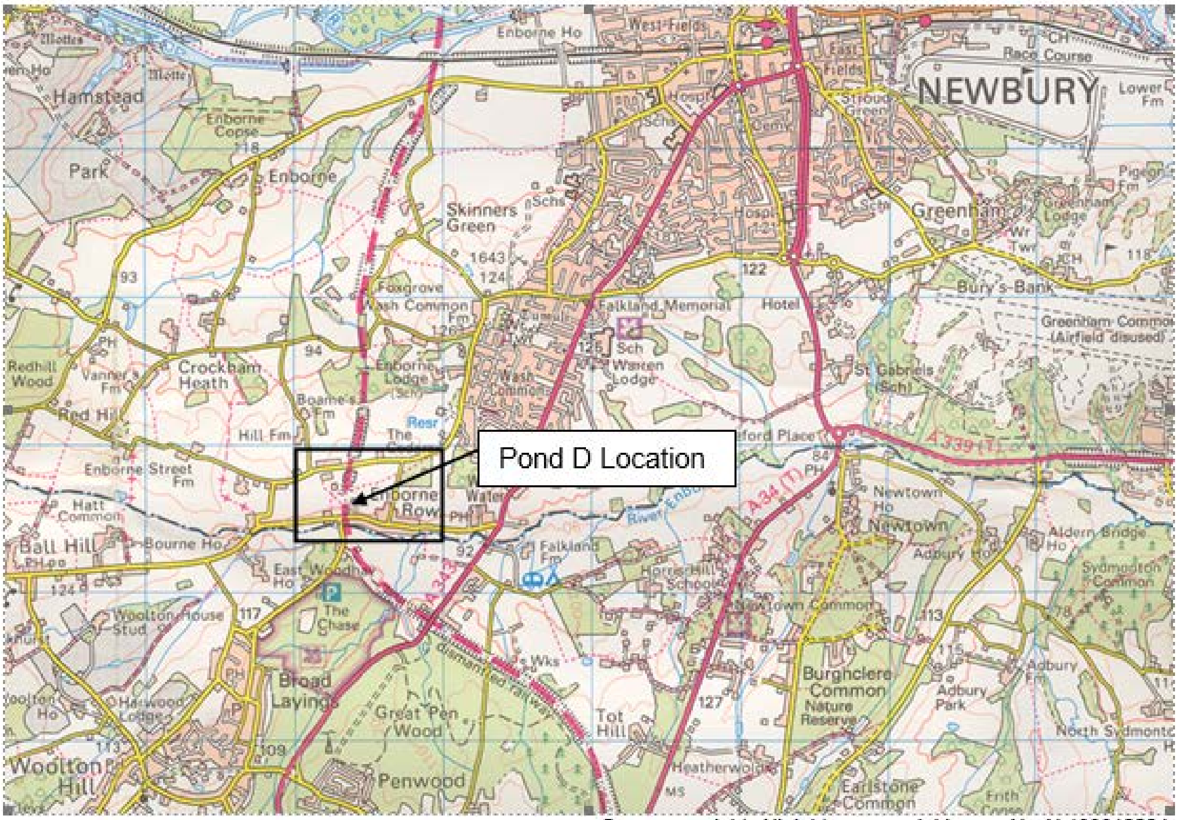

Figure 5. Location of the A34 Newbury bypass Case Study site

The catchment site constitutes 1.05 km of the dual carriageway which passes partly through a cut section and partly through an embanked section. Each carriageway is 6.8m wide and, in addition, there is a 1 m paved central reserve margin and a 1 m hard shoulder. The overall drainage area is 19,425 m^2. The highway drainage in both cutting and embankment is by 450 mm drainage channels along the downslope side of the porous asphalt surface of both carriageways. The channels discharge to online catchpits that in turn discharge to carrier drains running parallel to the carriageway. The carrier drain also collects the discharge from fin drains installed in the central reserve and at the margins of the paved surface. A section of 675mm carrier drain intercepts the carrier drains from

Figure 6. View of the dual carriageway at the A34 Newbury Bypass case study site looking south

both carriageways and discharges to Pond D via a bypass oil interceptor in a balancing pond compound adjacent to the highway. This is shown schematically in Figure 7.

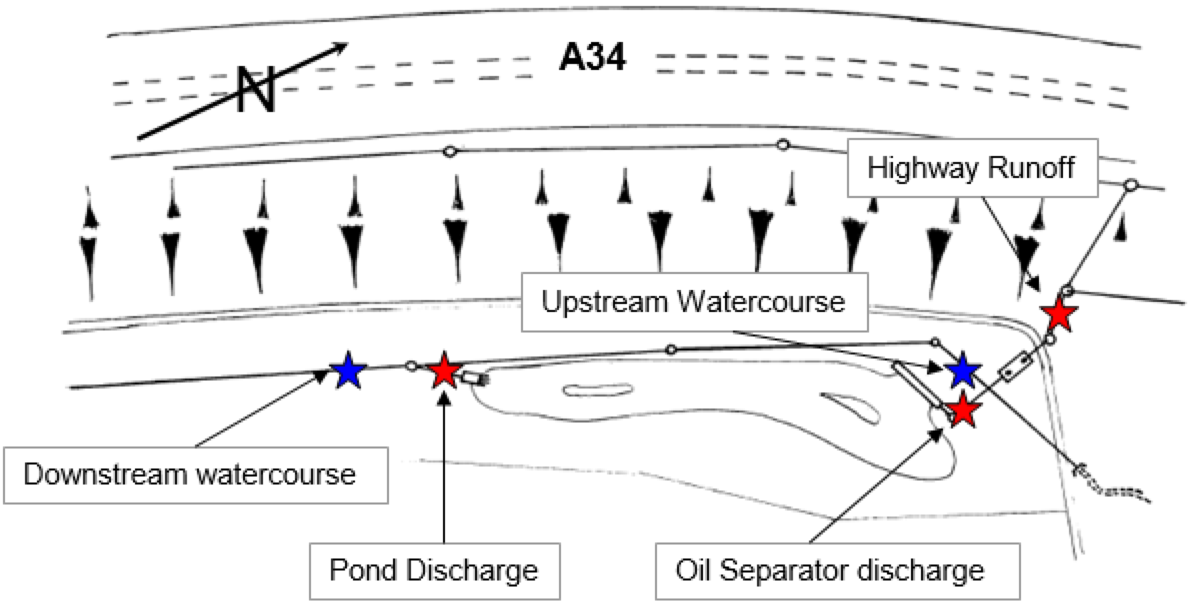

Figure 7. Schematic diagram showing locations of oil separator and balancing pond relative to runoff from highway.

The soil type in the immediate area of the site is classified as seasonally wet slightly acid loamy and clayey in nature resulting in an overall slowly permeable texture which presents impeded drainage. Below the site there is an unconfined aquifer at an average groundwater depth of 17.6 m. The groundwater is designated with Special Protection Zone III classification for the site indicating that the aquifer is confined below impermeable strata with the catchment site located at a considerable distance away from any abstraction point.

3.2. Application of the PROPER DSS to the A34 Newbury Bypass site

3.2.1. Identification of treatment systems compatible with the site conditions

Table 3 summarises the details available for the A34 Newbury bypass site and the corresponding responses entered into the 'Site criteria' page of the DSS.

Table 3. Summary of site characteristics for the A34 Newbury Bypass and details entered into the 'Site criteria' page of the PROPER DSS

	Site details	Selection entered into PROPER DSS
Presence of sensitive groundwater	Yes; Zone III	Zone III
Depth to groundwater	17.6 m	>1.5 m
Surface soil type	Loamy clay; impeded drainage	Clay
Effective drainage area	19,425 m^2	>10,000 and <30,000 m^2
AADT	31,374 – 41,727	<50,000

Based on the site characteristics identified in Table 3, the PROPER DSS provides the recommendations for the suitability of the different treatment systems shown in Figure 8. Infiltration systems represented by filter drains, soakaways, infiltration trenches, infiltration basins and both types of porous surfacing are identified as being unsuitable (red colour coding) due to the limited drainage capability offered by the surface soils at the Case Study site. The effective contributing area (19,425 m^2) is the site criterion which limits the desirability of using extended detention basins, retention ponds, detention basin, constructed wetlands and swales. The allocation of an amber colour coding to these treatment systems indicates that they should only be used under advisement.

Detention basins and constructed wetlands require a significant drainage area (normally greater than 3 ha in highway environments) to ensure effective operation and to counter drying-out and vegetation wilting effects caused by prolonged dry periods whereas for retention ponds a minimum limit of 3 ha is appropriate to maintain water level capacity. Therefore, the advisement considerations for these treatment systems should take these water supply requirements into account and in the case of vegetated systems it may be necessary to identify a supplementary water source, such as a spring, to ensure the survival of plant life. Extended detention basins are unlikely to be appropriate for the treatment of highway runoff due to space availability but they typically require an orifice size equivalent to a contributing drainage area of greater than 4 ha.

Flow velocity constraints and low storage volume/storm runoff (Vs:Rv) ratios normally limit the use of grassed infiltration systems, such as swales, to sites with effective drainage areas lower than the 19,425 m^2 at the study site. However, with appropriate design constraints they should be acceptable as part of a treatment train at this site. Filter strips are less restricted by catchment size considerations (i.e. merit a green colour coding) though, due to space limitations, they are unlikely to represent an important treatment train component at this Case Study site.

Runoff Treatment and Code
Swale (SW)
Porous surfacing without storage (PS)
Porous surfacing with storage (PS+)
Filter strip (FS)
Filter drain (FD)
Retention pond (RP)
Detention basin (DB)
Extended detention basin (EDB)
Constructed wetland (CW)
Soakaway (SO)
Infiltration trench (IT)
Infiltration basin (IB)

Figure 8. Suitability of treatment systems for use at the A34 Newbury bypass site predicted by the PROPER DSS

3.2.2. Identification of order of priority for use of treatment systems

The performance matrix page of the PROPER DSS allows an order of preference in terms of treatment potentials to be established for the different SUDs/BMPs. This requires the allocation of percentage weightings to each of the indicators (and hence to the criteria) and the entering of grades into the performance matrix. The percentage weightings which have been used for the A34 Newbury site differ from the default values and are shown in Table 4. The changes take into account the sensitive environmental requirements associated with this Case Study site due to the eventual discharge of treated runoff into the River Enborne, which is required to maintain a high quality habitat for all life stages of brown trout. Therefore the balance of weightings between the Technical and Environmental criteria has been amended to 25%:35% from the default value of 40%:20%. The weighting balance between the volume and pollution aspects for the flood control and pollution control indicators in the Technical criterion has only been modified slightly but there is now a marked difference in the Environmental criterion where the receiving water quality and receiving water ecology indicators are given equivalent and advanced status (percentage weightings of 15%) with the receiving water volume indicator being reduced to 5%. The importance of a treatment system being able to contribute to the biodiversity potential in the receiving water is recognised by increasing the weighting for the sustainable development indicator to 8% bringing the total for the Socio-environmental awareness criterion to 10%.

Table 4. Percentage weightings for indicators and criteria for the A34 Newbury bypass site.

Indicator	Percentage weighting	Criteria	Percentage weighting
Flood control	10 (20)	Technical	25 (40)
Pollution control	10 (15)		
Adaptability	5 (5)		
Impact on receiving water volume	5 (8)	Environmental	35 (20)
Impact on receiving water quality	15 (8)		
Impact on receiving water ecology	15 (4)		
Maintenance and servicing requirements	10 (10)	Operation and maintenance	10 (10)
Sustainable development (biodiversity(	8 (3)	Socio-environmental awareness	10 (5)
Aesthetics and public awareness	2 (2)		
Unit rate costing	10 (10)	Economic	10 (10)
Ability to comply with EU WFD objectives	10 (15)	Legal and highway planning	10 (15)
Total	100 (100)		100 (100)

Default weightings are given in parenthesis

The overall scores predicted for the potential treatment systems for the A34 Newbury bypass site are shown in Table 5 with the prioritisation increasing on descending the Table. These results are also plotted in Figure 9 with the coloured bars identifying the suitability of the different systems.

Table 5. Increasing order of preferential treatment for SUDS/BMPs for the A34 Newbury bypass site

Treatment system	Overall score
Porous surfacing (without storage)	234.5
Swale	275
Filter drain	287.5
Filter strip	290
Porous surfacing (with storage)	299.5
Detention basin	302
Soakaway	305
Infiltration trench	318
Retention pond	332
Extended detention basin	350
Infiltration basin	356.5
Constructed wetland	397

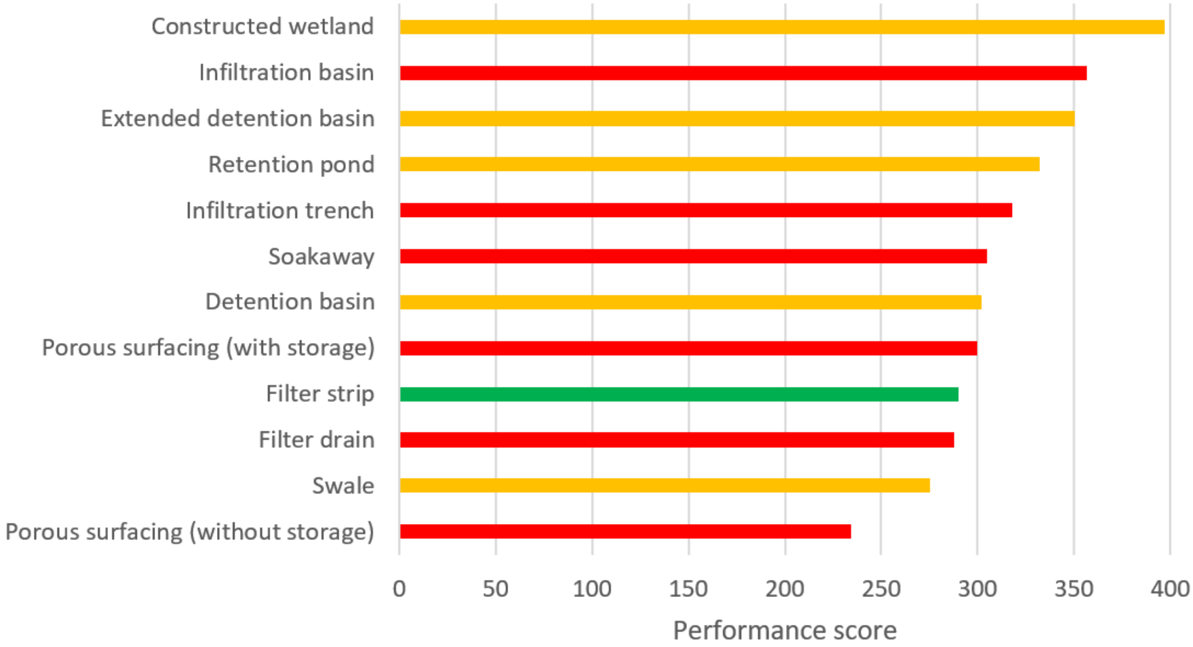

Figure 9. Performance scores and predicted suitability for treatment systems at the A34 Newbury bypass site

3.2.3. Comparison of treatment systems installed at the A34 Newbury bypass site with the PROPER DSS predictions.

The main treatment component at the A34 Newbury bypass site is a vegetated wet balancing pond (Figure 10) which has been excavated in natural ground of the Lias clay and is unlined. The pond is approximately 100 m long and tapers from an initial width of 20 m to 8 m. The pond depth is 1.5 m to the lowest bank side with banks at an average 60^{o} batter. Gabions retain the high bank along the eastern side of the pond.

Figure 10. View of the vegetated balancing pond (Pond D) adjacent to the A34 Newbury bypass

The pond was designed for a peak inflow discharge of 360 l/s for a 1 in 5 year event with a 1 in 100 year return period. A 100 mm diameter orifice plate maintains the pond water level and limits outflow discharge to a maximum of 29 l/s. A high level emergency overflow 1 m above gives a nominal storage capacity of 1020 m^2.

A silt trap is located at the head of the pond and consists of a rectangular concrete channel 11.5 m long, 1.5 m wide and 1 m deep. The trap is filled with water to produce a stilling effect to facilitate deposition of the sediment load. The water is discharged at low velocities over a side weir along the full length of the tank on to a grass filter strip allowing an even flow over the surface towards the standing water of the pond (see Figure 11).

The balancing pond has two prime functions. By providing a storage capacity it controls the rate of runoff discharged to the receiving watercourse and also facilitates physical and biological removal of pollutants through the silt trap, grass filter and reedbed planted in standing water of the pond. The presence of subsurface drainage helps to maintain a base flow during periods of drought and an area of deeper water, a micropool, provides a refuge for aquatic life. The pond margins are planted with grass and willow. The area of the pond consisting of shallow standing water is planted with *Phragmites australis* and *Carex riparia* and the areas of deep water are planted with *Scirpus lacustris* and *Alisma plantago aquatica*.

Figure 11. View of the sedimentation tank and filter strip at Pond D

The design of the balancing pond located at the A34 Newbury bypass site represents a hybrid of the essential features associated with a constructed wetland and a retention pond. Hence it is consistent with the treatment system predictions provided by the PROPER DSS which gives both constructed wetlands and retention ponds a high priority compared to other treatment systems (Figure 9). Although both these treatment systems are only recommended for use with advisement, as has been previously pointed out this restriction is related to the possible limitations in flow during periods of drought. Therefore, it is pertinent to note that a supplementary subsurface flow exists at the Case Study site and that the design incorporates a micropool to maintain a depth of water at all times. Although the filter strip only represents a small component of the overall treatment system, its use complements its fully recommended status (green colour coding) as determined by the PROPER DSS analysis.

4. A1(M) Leeds Case Study Site, UK

4.1. Site details

This Case Study site is situated close to Junction 45 of the A1(M) motorway to the east of the city of Leeds. Originally this road was designated as the A1, a major north-south trunk road connecting London to Edinburgh. Different sections were progressively upgraded to motorway status with the section adjacent to Junction 45 being completed in 2009. The Case Study site is immediately east of the village of Aberford (Figure 12) and represents a 2.5 km stretch of both carriageways (4 lanes in each direction; road surface, hot rolled asphalt) with a catchment area of 90220 m^2. The annual average daily traffic flow is 104,000 vehicles /day with a heavy goods vehicle contribution of 22%.

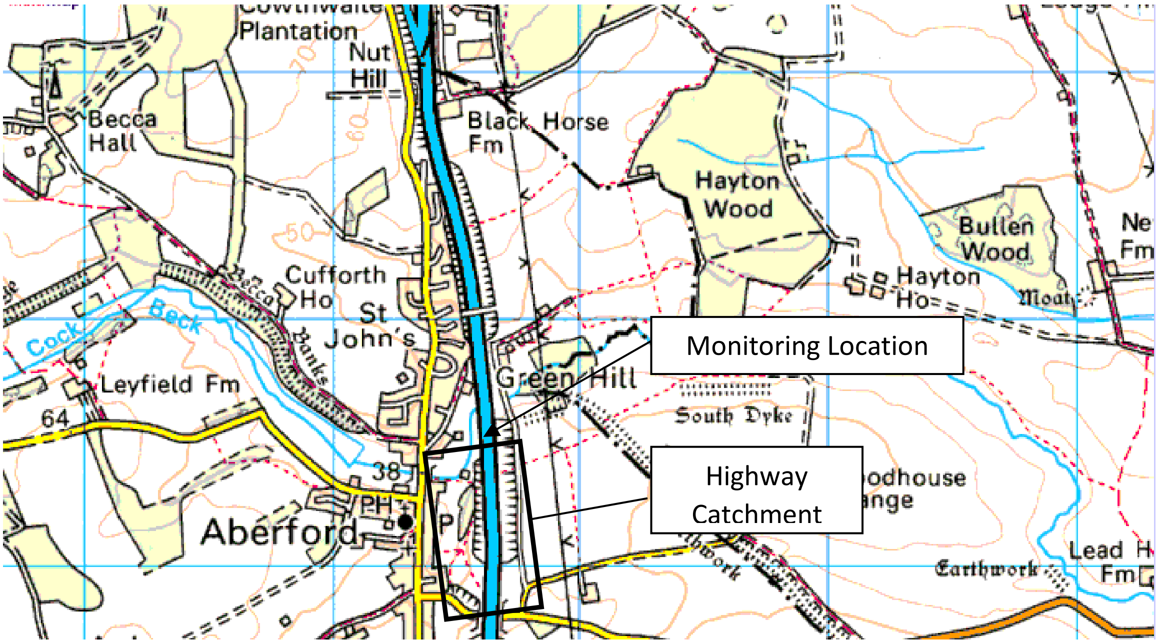

Figure 12. Highway catchment site adjacent to Junction 45 of the A1(M) close to Leeds (Aberford)

The drainage system consists of a concrete channel and a carrier pipe which discharges to a balancing pond via an oil separator. There are catchpits on the 900 mm carrier drain at each grating. The central reserve drainage is connected to the carrier drain but the central reserve has been paved and any contribution is thought to be minimal. The runoff from the A1(M) enters the Cock Brook which is a tributary of the River Wharfe. Historically the role of this river as a spawning ground for salmon and trout has been damaged by both industrial and urban pollution. However, the Environment Agency has now successfully introduced measures to support recovery of the reduced fish stock. The location of the Cock Brook in relation to the highway is shown in Figure 12 with the road surface, hard shoulder and drainage channel at this site being depicted in a view across the southbound carriageway in Figure 13.

The soil type in the immediate area of the site is classified as freely draining lime-rich loamy in nature. Below the site there is an unconfined aquifer at an average groundwater depth of 12.5 m. The groundwater is designated with Special Protection Zone III classification indicating that the aquifer is confined below impermeable strata with the catchment site a considerable distance away from any abstraction point.

Figure 13. View across the southbound carriageway of the A1(M) close to Junction 45.

4.2. Application of the PROPER DSS to the A1(M) Leeds site

4.2.1 Identification of treatment systems compatible with the site conditions

Table 6 summarises the details available for the A1(M) Leeds site and the corresponding responses entered into the ‘Site criteria’ page of the DSS. The recommendations for the suitability of the different treatment systems are identified in Figure 14

Table 6. Summary of site characteristics for the A1(M) Leeds site and details entered into the ‘Site criteria’ page of the PROPER DSS

	Site details	Selection entered into PROPER DSS
Presence of sensitive groundwater	Yes; Zone III	Zone III
Depth to groundwater	12.5 m	>1.5 m
Surface soil type	Lime-rich loamy soil; freely draining	Loam
Effective drainage area	90,220 m^2	>40,000 m^2
AADT	104,000	>100,000 and <150,000

Runoff Treatment and Code
Swale (SW)
Porous surfacing without storage (PS)
Porous surfacing with storage (PS+)
Filter strip (FS)
Filter drain (FD)
Retention pond (RP)
Detention basin (DB)
Extended detention basin (EDB)
Constructed wetland (CW)
Soakaway (SO)
Infiltration trench (IT)
Infiltration basin (IB)

Figure 14. Suitability of treatment systems for use at the A1(M) Leeds site predicted by the PROPER DSS

The absence of any red highlighting in Figure 14 indicates that none of the twelve listed treatment systems should be considered completely unsuitable for use at this site. Storage treatment systems (retention ponds, detention basins, extended detention basins and constructed wetlands) are all recommended for use which is consistent with the installation of a balancing pond at the Leeds A1(M) site. Filter strips are also recommended and therefore could be used as a delivery system to the balancing pond if space was available adjacent to the highway.

Infiltration facilities (including soakaways and infiltration trenches) and grass filter facilities (such as swales) are best suited to highway sites with effective contributing drainage areas of less than 10,000 m^2, with infiltration basins having a limit of 25,000 m^2, due to flow velocity constraints and because they have low storage volume/storm runoff ratios. Therefore, the considerably higher drainage area of the Leeds A1(M) site (90,220 m^2) merits an amber colour coding for these treatment systems indicating their use only under advisement such as where it is possible to redistribute the drainage into lower flow components prior to reaching the treatment system.

Although AADT is not always an accurate predictor of the level of pollution deriving from a highway surface, it can be used as a guide in this respect. The vehicle flow at the Leeds A1(M) site (104,000 vehicles/day) is representative of medium/high traffic usage and an equivalent pollution potential. Filter drains and porous surfacing (both with and without storage) are not strongly recommended for use under these conditions and should only be used under advisement which could stipulate the necessity of operation and maintenance schedules which incorporate regular cleaning of both porous surfaces and filter materials (in filter drains) to ensure that blocking by suspended solids does not jeopardise their efficiency. The same operation and maintenance requirement should also be attached to the installation of soakaways and infiltration trenches under elevated vehicle flow situations.

4.2.2. Identification of order of priority for use of treatment systems

The percentage weightings which have been used for the A1(M) Leeds site are similar to the default values except for a small increase in the Environmental criterion from 20% to 25% at the expense of the Legal and Highway Planning criterion (reduced from 15% to 10%). The three indicators which contribute to the Environmental criterion, together with their weightings, are presented in Table 7. The increase in the weightings for the three Environmental indicators is consistent with the previously described goal of the Environment Agency to improve the chemical and biological quality of the Cock Beck and ultimately the downstream River Wharfe.

Table 7. Percentage indicator weightings for the Environmental criterion for the A1(M) Leeds site.

Indicator	Percentage weighting
Impact on receiving water volume	10 (8)
Impact on receiving water quality	10 (8)
Impact on receiving water ecology	5 (4)

Default weightings are given in parenthesis

The overall scores predicted for the potential treatment systems for the A1(M) Leeds site are shown in Table 8 with the prioritisation increasing on descending the Table. These results are also plotted in Figure 15 with the coloured bars identifying the suitability of the different systems.

Table 8. Increasing order of preferential treatment for SUDS/BMPs for the A1(M) Leeds site

Treatment system	Overall score
Porous surfacing (without storage)	222
Swale	256.3
Filter strip	273.8
Filter drain	300
Detention basin	322
Soakaway	325
Porous surfacing (with storage)	327
Retention pond	332
Infiltration trench	333
Extended detention basin	365
Infiltration basin	384
Constructed wetland	387

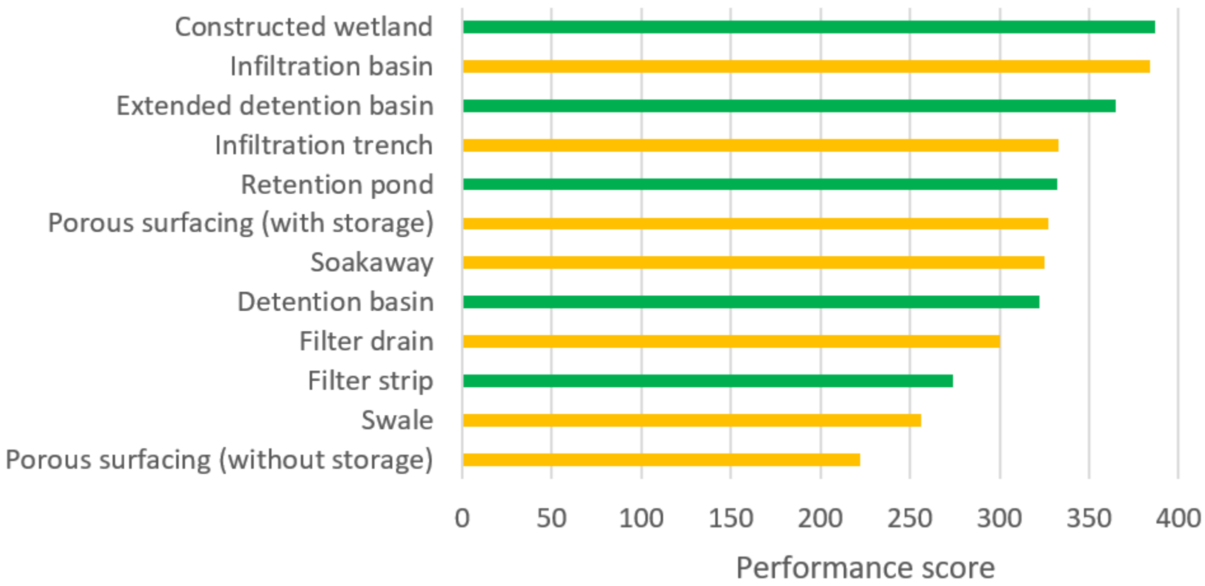

Figure 15. Performance scores and predicted suitability for treatment systems at the A1(M) Leeds site

4.2.3. Comparison of treatment systems installed at the A1(M) Leeds site with the PROPER DSS predictions.

The main treatment component for the runoff draining from the A1(M) Leeds site is a balancing pond. It is relevant to note that the balancing ponds installed on this upgraded section of the A1(M) were designed not only to attenuate and to clean the highway runoff but also to support and encourage the establishment of wildlife. This is consistent with allowing vegetation to become established within the ponds as would be the case for a constructed wetland. Therefore, the prediction from the PROPER DSS that the preferred SUDS/BMP at this site would be a constructed wetland (see Figure 15) justifies the choice of a balancing pond for installation at this site. However, a design incorporating a fully vegetated treatment system would have been preferable. Extended detention basins, retention ponds and detention basins are also favoured in the predicted order of preference indicating their feasibility as treatment systems for use at this site.

5. A34 Oxford Bypass Site Case Study, UK

5.1. Site details

The A34 is a major trunk road connecting Southampton in the south of England with Manchester and providing access to Oxford, Birmingham and The Potteries. The Case Study site is located on the Oxford ring road approximately 1 mile south of its junction with the M40 (Junction 9) and close to the Family Farm Services area. The section of highway comprising the Case Study site is identified in Figure 16 and a view of the highway looking south is shown in Figure 17. This section was constructed in 1990 and consists of two lanes per carriageway with a concrete surface. Two way traffic density is in the range of 58460 – 69461 vehicles per day with a HGV composition of 13%. Highway runoff is mainly directed to filter drains installed along the margins of both carriageways. There are no filter drain sections exceeding 800 m in length. Where the installation of filter drains is not appropriate, such as adjacent to service area slip roads and road junctions, drainage is via gully pots. Both filter drains and gully pots feed into carrier drains which transport the runoff to the local watercourse via oil trap manholes.

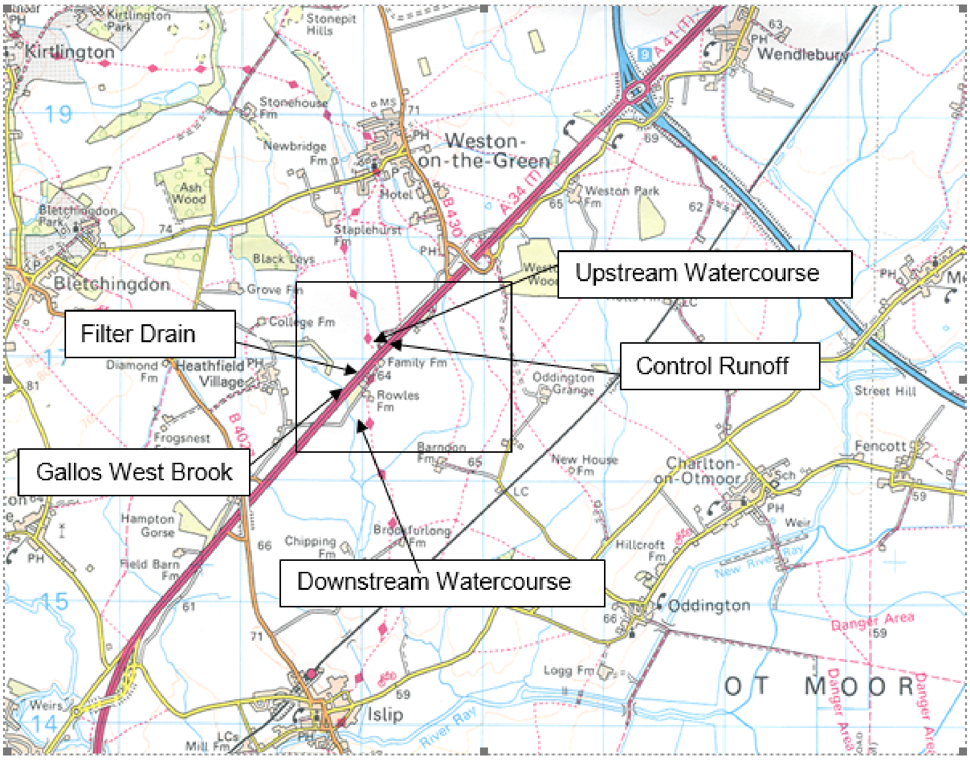

Figure 16. Highway catchment site on the A34 Oxford Bypass adjacent to Junction 9 of the M40 and close to the village of Weston on the Green.

The Case Study site is confined to the two lanes of the northbound carriageway and covers a contributing drainage area of 2420 m^2. This is composed of a paved area which is 275 m long with two 3 m wide lanes plus a 1 m wide central reserve margin and a 1.8m hard shoulder. Drainage is discharged to the Gallos Brook which rises approximately 10 km to the north at Upper Heyford before crossing a predominantly rural catchment. At a downstream distance of 290 m there is a confluence with Gallos Brook West and the combined brooks flow south to the River Ray approximately 1.5 km upstream of its confluence with the River Cherwell which subsequently discharges to the River Thames. The natural channel of the Gallos Brook varies from1.5 to 3.5 m wide and 0.8 to 1.0 m deep. During low summer flow conditions, flows typically correspond to depths of 20 mm deep increasing to depths of 560 mm during winter event responses.

Both the River Ray and the River Cherwell are regularly monitored for aquatic invertebrates and are generally of good quality with a wide range of invertebrates, including pollution sensitive mayflies, stoneflies, dragonflies and caddis-flies. However, in the streams adjacent to urban areas, such as Oxford, lower ecological quality exists with fewer species and the presence of pollution-tolerant midges, leeches and worms.

Figure 17. View of the A34 Oxford Bypass looking in a southerly direction

The soil type in the immediate area of the site is classified as being freely draining lime-rich loamy in nature. Below the site there is an unconfined aquifer at an average groundwater depth of 87.5 m. The groundwater is designated as being outside any source protection zones.

5.2. Application of the PROPER DSS to the A34 Oxford bypass site

5.2.1 Identification of treatment systems compatible with the site conditions

Table 9 summarises the details available for the A34 Oxford Bypass site and the corresponding responses entered into the 'Site criteria' page of the DSS. The recommendations for the suitability of the different treatment systems are identified in Figure 18

Table 9 Summary of site characteristics for the A1(M) Leeds site and details entered into the 'Site criteria' page of the PROPER DSS

	Site details	Selection entered into PROPER DSS

Presence of sensitive groundwater	No	No sensitive groundwater
Depth to groundwater	87.5 m	>1.5 m
Surface soil type	Lime-rich loamy soil; freely draining	Loam
Effective drainage area	2,420 m^2	<10,000 m^2
AADT	58,460 – 69,461	>50,000 and <100,000

Runoff Treatment and Code
Swale (SW)
Porous surfacing without storage (PS)
Porous surfacing with storage (PS+)
Filter strip (FS)
Filter drain (FD)
Retention pond (RP)
Detention basin (DB)
Extended detention basin (EDB)
Constructed wetland (CW)
Soakaway (SO)
Infiltration trench (IT)
Infiltration basin (IB)

Figure 18. Suitability of treatment systems for use at the A34 Oxford Bypass site predicted by the PROPER DSS.

The colour coding predictions shown in Figure 18 indicate that all investigated treatment systems can be considered suitable for use at the A34 Oxford Bypass site with swales, filter strips, soakaways, infiltration trenches and infiltration basins (all of which involve an infiltration component) being the most highly recommended. Other systems with an infiltration element, such as filter drains and both types of porous surfacing can be used but come with an advisement condition. This is interesting given that filter drains have been installed as the preferred SUDS/BMP at this site. The site criteria condition which mitigates against filter drains being allocated a green colour coding is the traffic density of 50,000-100,000 vehicles/day which is indicative of a medium pollution potential. This would not prevent the use of filter drains but should trigger the need for an operation and maintenance regime which involves regular cleaning/replacement of the filter material to preserve efficient functioning. The same argument would apply to the use of porous surfacing should a future replacement of the concrete road surfacing be required.

The predominantly storage based treatment systems (retention ponds, detention basins, extended detention basins and constructed wetlands) are all predicted to be appropriate for use under advisement. This condition arises as a consequence of the low effective contributing drainage area of 2,420 m^2 at the A34 Oxford Bypass site which may be insufficient to support their effective operation such as maintaining water level capacities and preserving the health of vegetative habitats. To counteract problems of water supply, an appropriate advisement condition could be the presence of an additional water source to prevent drying out and resulting stress for vegetation. Extended detention basins typically require contributing drainage areas in excess of 40,000 m^2 and are unlikely to be appropriate for the treatment of highway runoff due to space constraints.

5.2.2. Identification of order of priority for use of treatment systems

The performance matrix page of the PROPER DSS requires the allocation of percentage weightings to each of the indicators (and hence to the criteria) and the entering of grades into the performance matrix. The percentage weightings which have been used for the A34 Oxford bypass site differ from the default values and are shown in Table 10. The changes take into account the environmental requirements associated with this Case Study site due to the eventual discharge of treated runoff into the Rivers Ray and Cherwell. Both these rivers are generally of good ecological quality but are highly susceptible to inputs of highway and urban pollutants. This factor has influenced the adjustment of the weightings balance in favour of the Environmental criterion compared to the Technical criterion as shown in Table 10. The reduction in the Technical criterion to 30% has been achieved by lowering the flood control indicator to 10% from 20%. All the Environmental indicators have been increased but particularly the receiving water quality and receiving water ecology indicators which now both have percentage weightings of 15%. The importance of a treatment system being able to contribute to Socio-environmental awareness is acknowledged by increasing the weighting attached to this criterion to 10%. The consequences of these changes are that the Economic and Legal and Highway Planning criteria both need to be reduced to 5%.

Table 10. Percentage weightings for indicators and criteria for the A34 Oxford bypass site.

<table>
<tr><td>Indicator</td><td>Percentage weighting</td><td>Criteria</td><td>Percentage weighting</td></tr>
<tr><td>Flood control</td><td>10 (20)</td><td rowspan="3">Technical</td><td rowspan="3">30 (40)</td></tr>
<tr><td>Pollution control</td><td>15 (15)</td></tr>
<tr><td>Adaptability</td><td>5 (5)</td></tr>
<tr><td>Impact on receiving water volume</td><td>10 (8)</td><td rowspan="3">Environmental</td><td rowspan="3">40 (20)</td></tr>
<tr><td>Impact on receiving water quality</td><td>15 (8)</td></tr>
<tr><td>Impact on receiving water ecology</td><td>15 (4)</td></tr>
<tr><td>Maintenance and servicing requirements</td><td>10 (10)</td><td>Operation and maintenance</td><td>10 (10)</td></tr>
<tr><td>Sustainable development (biodiversity(</td><td>5 (3)</td><td rowspan="2">Socio-environmental awareness</td><td rowspan="2">10 (5)</td></tr>
<tr><td>Aesthetics and public awareness</td><td>5 (2)</td></tr>
<tr><td>Unit rate costing</td><td>5 (10)</td><td>Economic</td><td>5 (10)</td></tr>
<tr><td>Ability to comply with EU WFD objectives</td><td>5 (15)</td><td>Legal and highway planning</td><td>5 (15)</td></tr>
<tr><td>Total</td><td>100 (100)</td><td></td><td>100 (100)</td></tr>
</table>

Default weightings are given in parenthesis

The overall scores predicted by the PROPER DSS for the potential treatment systems for the A34 Oxford bypass site are shown in Table 11 with the prioritisation increasing on descending the Table. These results are also plotted in Figure 19 with the coloured bars identifying the suitability of the different systems.

Table 11. Increasing order of preferential treatment for SUDS/BMPs for the A34 Oxford Bypass site

Treatment system	Overall score
Porous surfacing (without storage)	217.5
Filter strip	255
Swale	260
Filter drain	292.5
Detention basin	315
Soakaway	315
Porous surfacing (with storage)	320
Infiltration trench	325
Retention pond	345
Extended detention basin	380
Infiltration basin	386.3
Constructed wetland	405

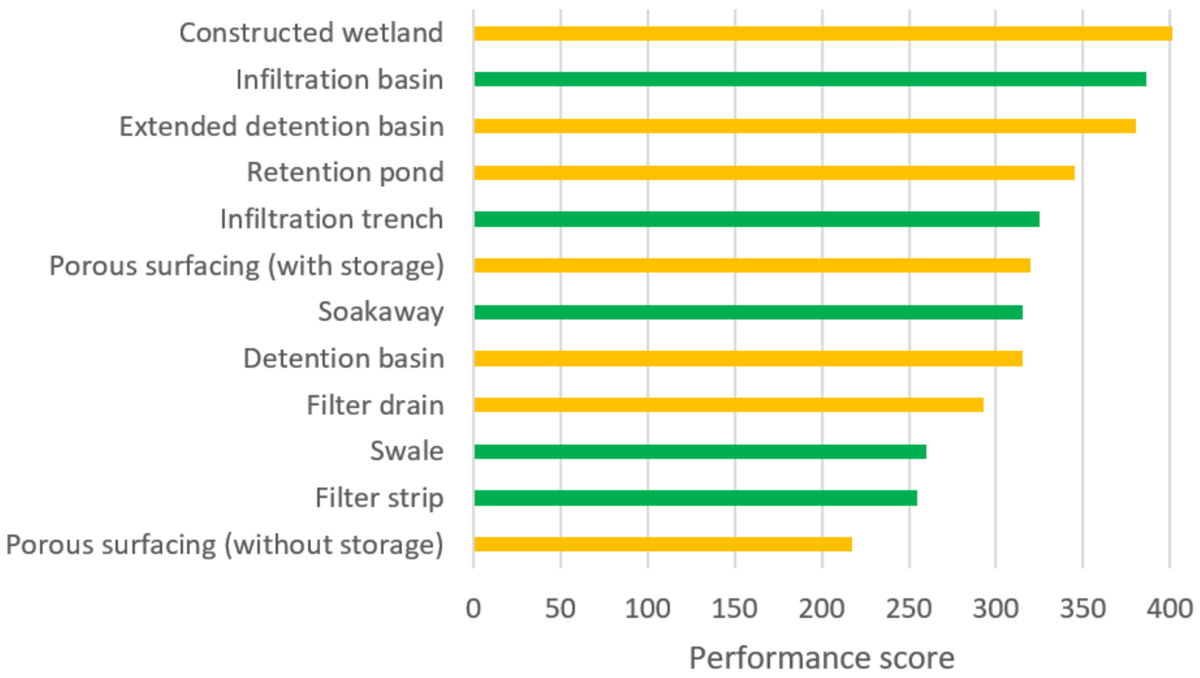

Figure 19. Performance scores and predicted suitability for treatment systems at the A34 Oxford bypass site

5.2.3. Comparison of treatment systems installed at the A34 Oxford Bypass site with the PROPER DSS predictions.

The predominant treatment system for highway runoff at the A34 Oxford Bypass site involves filter drains installed immediately adjacent to the paved surface of the carriageway hard shoulder (Figure 20). The filter medium consists of 40 mm crushed limestone to a depth of 1.8 m and laid in a 600 mm wide cut. A 300 mm concrete carrier drain is laid on the invert of the filter.

Figure 20. View of the filter drains located adjacent to the A34 Oxford Bypass Case study site

Inspection of the bar chart in Figure 19 shows that filter drains are not given a high priority for use at this site by the PROPER DSS. In addition, filter drains are only recommended for use under advisement as a consequence of the pollution levels expected to be generated by the traffic density (50,000-100,000 vehicles/day) at this site.

A common failure associated with filter drains is due to clogging by suspended solids and therefore to avoid this they should ideally be installed downstream of appropriate pre-treatment systems. This could involve the presence of filter strips and the grassed strip between the hard shoulder and the gravel surface of the filter drain (Figure 20) could act in this role as lateral flow from the road surface passes over it. However, a greater filter strip width would be preferable and although filter drains are not predicted to have a high priority for use at this site they are recommended for use without any conditions (Figure 19). Where it is not possible to have effective upstream removal of sediments and silts, a feasible advisement condition could involve a geotextile (or other effective filtration) layer placed below the filter drain surface, at a shallow depth, that can be regularly removed and cleaned or replaced.

The preferred treatment systems predicted for use at the A34 Oxford bypass Case Study site without any advisement conditions are in decreasing order of priority of infiltration basins, infiltration trenches and soakaways. If the availability of sufficient space mitigates against the use of infiltration basins, and other storage based treatment systems, infiltration trenches and soakaways would take preference although alternative storage based systems (constructed wetlands, extended detention basins and retention ponds) are rated more highly (Figure 19), albeit with advisement conditions because of the low effective contributing drainage area.

6. M4 Maynooth Bypass Site Case Study, Ireland

6.1 Site Details

This Irish site (NGR 913370) is situated south of the town of Maynooth and lies 32 km west of Dublin on the Dublin to Sligo M4 motorway (Figure 21) and was opened to traffic in December 1993. The M4 motorway consists of a two-lane highway (in both directions) each 11 m wide with two 3m wide bordering hard shoulders and a narrow grassed/hedged central reservation (Figure 22). The monitored site consists of a 800m length of the western twin lane which has a 2.3% crossfall and a 0.5% longitudinal slope. The edge of the hard shoulder is continued with a linear filter drain of 1.2 m width (Figure 23) which grades into a grassed verge,

The motorway surface consists of hot rolled asphalt which is assumed to be 100% impermeable and the monitored site has an effective drainage area of 9760 m^2. The AADT at the site was recorded in 2014 as being 39088 with a 7.5% HGV proportion. The highway surface runoff discharges to the River Lyreen via the filter (french) drain system as well as from a short 300 m stretch of over-the-shoulder drainage. Figure 24 shows the highway discharge point to the Lyreen river channel immediately downstream of the unscreened highway 300 mm outfall pipe (seen to the left of the bridge culvert on Figure 24). Figure 24 clearly shows the dominant “murky” nature of the water which occurs at this outfall point.

The soil type and associated surficial material at the site are characterised as being impacted clay with included gravels (generally described as glacial till) and includes a dispersed peaty covering. The piezometric depth (or hydraulic head) varies between 4 m to 7 m and defines a locally important (shallow) aquifer which is moderately productive but regarded as being of low vulnerability.

6.2 Application of the PROPER DSS to the Maynooth M4 Site

6.2.1. Identification of treatment systems compatible with the site conditions

The first stage in applying the PROPER DSS is to establish how the existing site conditions influence the feasibility of using the different possible treatment systems. Table 12 summarises the responses entered into the “Site Criteria” page of the DSS based on the site details described above.

Table 12. Summary of site characteristics and details entered into the “Site Criteria” page of the PROPER DSS.

	Site Details	Selection entered into PROPER DSS
Presence of sensitive groundwater	Locally important shallow aquifer. (Moderately productive) but low vulnerability. Equivalent to outer protection zone.	Designated as being equivalent to Zone III
Depth to groundwater	4 m	>1.5 m
Surface soil type	Glacial till with gravel and peat	Clay
Effective drainage area	9760 m^2	<10,000 m^2
AADT	39,088 (7.5% HGV)	<50,000

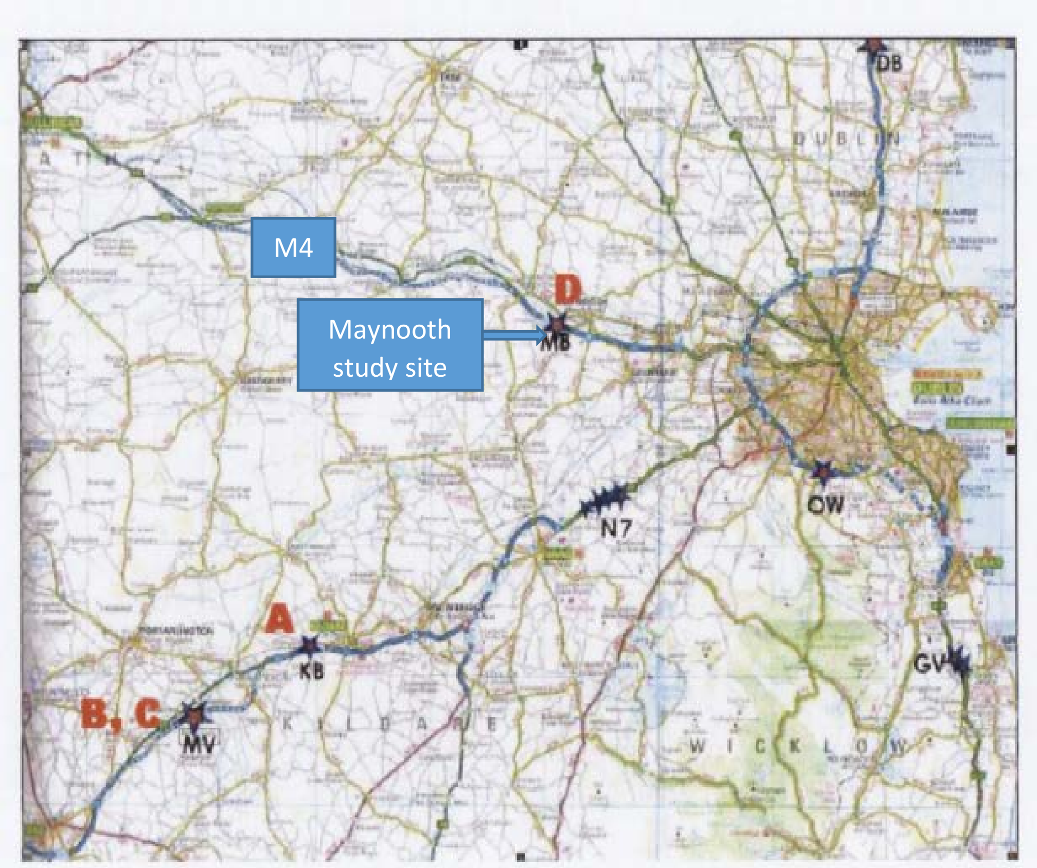

Figure 21. Location of the Maynooth Case Study Site on the M4 Motorway west of Dublin.

Figure 22. The M4 motorway at the Maynooth Case Study site.

Figure 23. The filter drain and adjacent hard shoulder at the M4 Maynooth site.

Figure 24. The discharge outfall to the River Lyreen at the Maynooth site.

Based on the site characteristics identified in Table 12, the PROPER DSS provides the output recommendations for the suitability of the different treatment systems as shown in Figure 25.

Runoff Treatment and Code
Swale (SW)
Porous surfacing without storage (PS)
Porous surfacing with storage (PS+)
Filter strip (FS)
Filter drain (FD)
Retention pond (RP)
Detention basin (DB)
Extended detention basin (EDB)
Constructed wetland (CW)
Soakaway (SO)
Infiltration trench (IT)
Infiltration basin (IB)

Figure 25. Suitability of treatment systems for use at the Maynooth M4 study site.

Swales and filter strips are the only fully recommended drainage options identified by the DSS matrix as being appropriate treatment controls for this Irish Maynooth site. Porous surfacing options, filter drains and other infiltration options such as soakaways, trenches and basins are all considered to be unacceptable. This essentially reflects the over-riding influence of the clay-based soils on the expected field infiltration rates as well as the presence of a local groundwater resource body. Retention ponds, detention basins, extended detention basins and constructed wetlands are only recommended under strong advisement as indicated by their amber colouring. Their implementation would depend on detailed site investigations particularly of minimal discharge rates during extended dry weather conditions which might predicate the efficient use of wetlands. The relatively small effective drainage area certainly might lead to severe vegetative wilting and also prove to be insufficient to support an effective retention drainage system. It is somewhat surprising however, to note that filter drains have been entirely ruled out as potential drainage options and the same might be said of soakaway systems. It might have been expected that such drainage systems would have been recommended under advisement only. Such SUDS devices are certainly appropriate in terms of the specified drainage area and rainfall intensities/duration for at least storm events equivalent to a 1:30/1:50 design level.

6.2.2 Identification of order of priority for use of treatment systems

The performance matrix page of the PROPER DSS allows an order of preference in terms of treatment potentials to be established for the different SUDS/BMPs. This requires the allocation of percentage weightings to each of the indicators (and hence to the criteria) and the entering of grades into the performance matrix. The DSS comes with default values for both the percentages and the grades and these have been deemed to be appropriate for the Irish M4 Maynooth site.

The overall scores predicted for the different potential treatment systems for the Maynooth M4 site are shown in Table 13 with the prioritisation increasing in descending order in the table. These results are also plotted in Figure 26 with the coloured bars identifying the suitability of the different systems. There is relatively little difference in the performance scores of the two recommended systems (swales and filter strips) although the latter is preferred in terms of the relative scoring structure.

Table 13. Increasing order of preferential treatment for SUDS/BMPs for the Maynooth site.

Porous surfacing (without storage)	231
Swale	260
Filter strip	287
Filter drain	305
Detention basin	310
Retention pond	319
Porous surfacing (with storage)	325
Soakaway	328
Infiltration trench	336
Extended detention basin	348
Infiltration basin	368
Constructed wetland	378

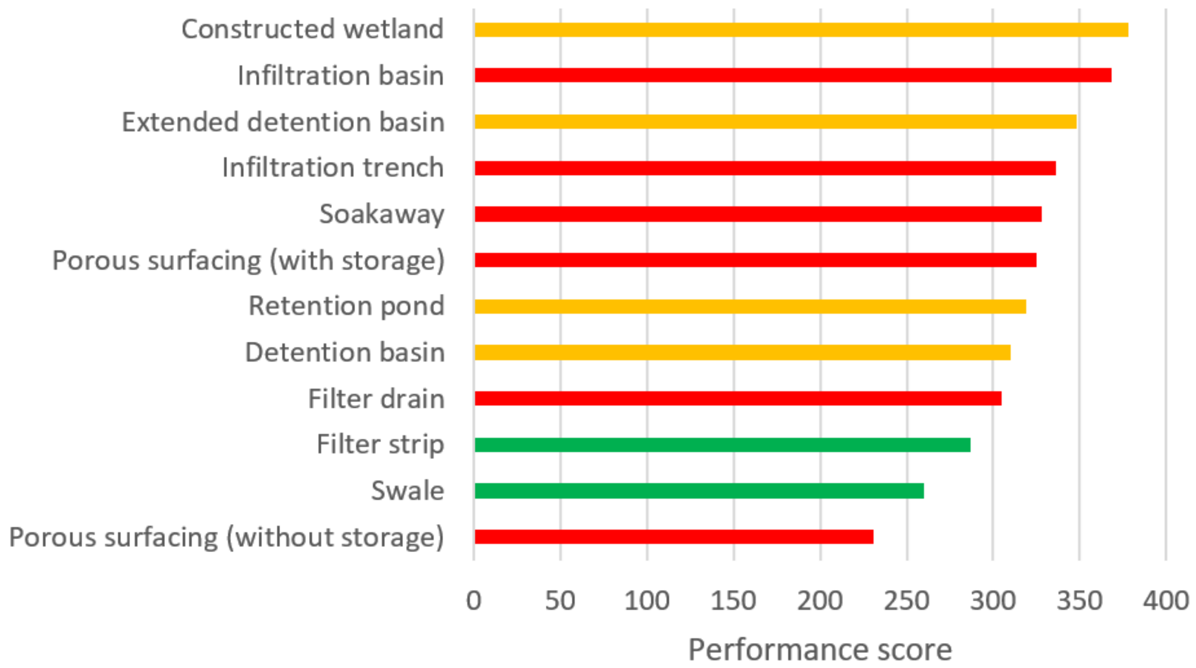

Figure 26. Performance scores and predicted suitability for treatment systems at the Maynooth M4 site.

The limited over-the-shoulder drainage which occurs on the site concurs with the recommendation for filter strips and might be able to be extended at little cost and effort although there may be issues regarding the existence of a grass "kerb" face as seen in Figure 23. The preference order would suggest that detention and retention basins, both of which scored only a little higher than filter strips, might offer the best alternative drainage options if detailed field investigations proved them to be feasible in terms of lifetime performance and maintenance. A dry detention facility located after a swale system might provide an effective design to protect and improve the receiving watercourse particularly if the existing filter drain is retained. However, it would be essential to ensure that this front-line filter system is operating at near design capacity, especially as the expected life of such SUDS/BMP systems are only 10 – 15 years. The existing filter system is now over 25 years old and there is no record of any maintenance or renewal having been undertaken over this period of time. It must be assumed that the system has little if any treatment potential for influent runoff, which if correct, would imply that at this site virtually untreated highway discharges are regularly occurring to the receiving Lyreen watercourse.

6.2.3 The Maynooth M4 highway filter drain

The use of highway filter drain systems have been discouraged in the UK due to the high cost of filling material (and replacement), potential pollution risks to groundwater, stone scatter and maintenance problems. The latter concerns are primarily related to vehicular over-run of the roadside filter drain causing over-compaction. The relatively narrow hard shoulder does not provide sufficient clearance especially for HGVs (or at least drivers do not perceive it to provide enough clearance especially given safety concerns about passing fast traffic). Following over-run and compaction, the hydraulic efficiency of the drainage system rapidly decreases allowing little surface runoff to permeate down to the drainpipe. The result is surface water ponding as illustrated in Figure 27 at the Maynooth M4 site. As can be seen from the figure the adjacent

Figure 27. Filter drain ponding on the Maynooth M4 site.

grassed verge forms a virtual “kerb” face which further diverts runoff to the ponding low point and clearly the ponded water would indicate an overloading of the filter media. The SUDS/BMP device shown in Figures 23 and 27 represents a “combined filter drain” consisting of an open-jointed, non-porous underdrain pipe set at the base of an unlined gravel trench and thus fulfils the dual function of surface and sub-surface drainage in addition to a secondary treatment function. It is however mainly used where there is a likelihood of groundwater volumetric problems, although over two thirds of all Irish motorways have such linear roadside SUDS/BMP drainage systems. It is argued that the filter drain drawdown of groundwater levels below the carriageway is much more effective than narrow fin drains or swale channels.

Water quality monitoring at the Maynooth M4 site showed that there were reduced TSS and heavy metal concentrations in the outfall discharges from the filter drain compared to sampled direct runoff from the motorway surface. In addition, there were more limited reductions noted in PAH concentrations. In this respect, the filter drain would appear to be functioning irrespective of any deficiencies in hydraulic capacity even if at much reduced performance levels. However, field observations during wet weather noted substantial overland flow bypassing directly across the surrounding grass verges and not draining into the filter trench. The overflows might also suggest that the filter drain intersects the groundwater table leading to leakage into the filter drain during dry weather.

Excavation of a section of the Maynooth M4 filter drain indicated that there was substantial intrusion of fines into the gravel infill with over 65% of the material infill showing major blockage (Figure 28). The contaminated infill material was found to exceed Irish EPA EQS levels for all

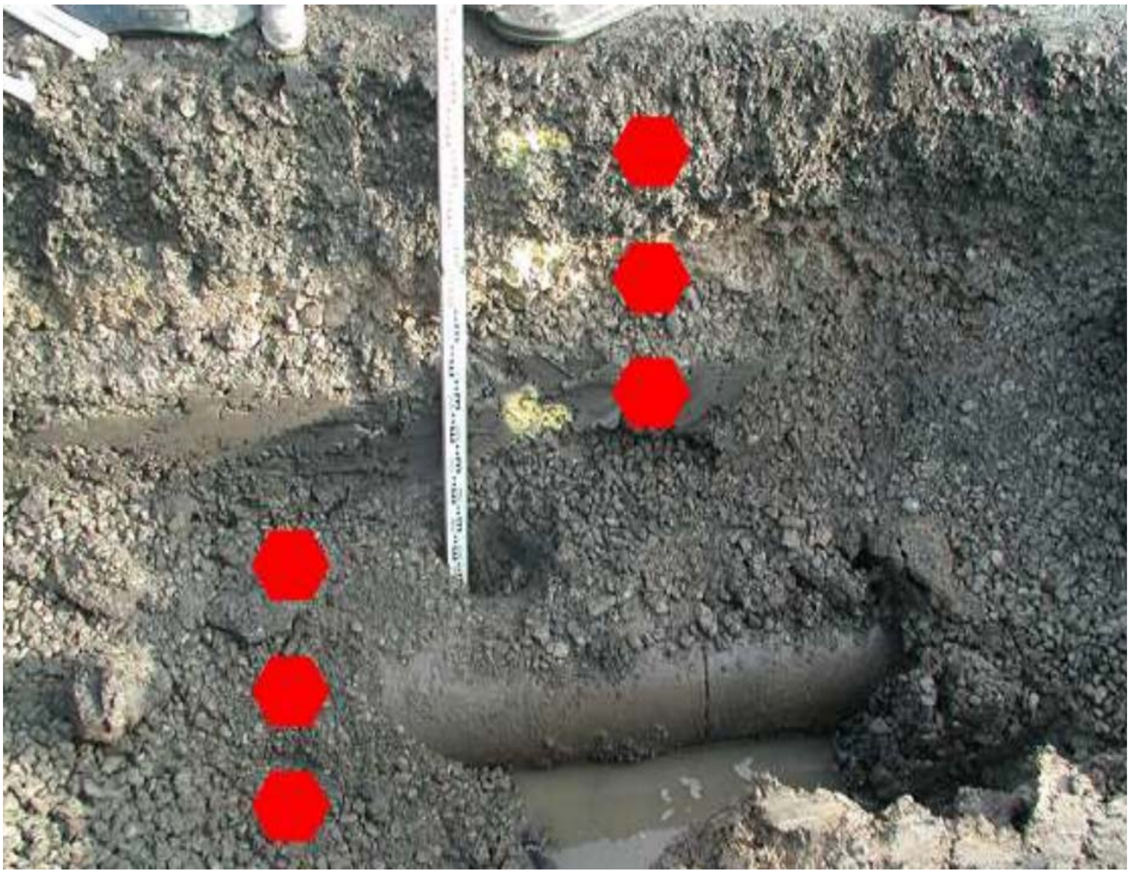

Figure 28. Section through the Maynooth M4 filter drain

metal species and PAH which emphasises the need for more regular maintenance. There are therefore various issues regarding the long term performance and effectiveness of filter drains and in this respect the negative recommendation resulting from the application of the PROPER DSS represents an appropriate outcome as derived from the prevailing Maynooth site conditions, irrespective of any national strategic policy regarding their adoption.

7. Conclusions

The PROPER DSS contains data for 12 different SUDS/BMPs and allows the user to utilise an extensive database in a consistent way to distinguish between acceptable and unacceptable treatment possibilities, to prepare a shortlist or ranking of the different treatment options, and to identify the single most preferred treatment option. This has been demonstrated by applying the PROPER DSS to five different case study sites located in the UK and Ireland, selected as representative of a range of site conditions.

In addition to providing predictions the DSS, together with the User Guide, can be used interactively to determine the site considerations which determine why specific treatment systems are considered either unsuitable or suitable only with advisement. In the case of the M1 Luton Case Study (see Section 2) the presence of clay soils mitigate against the use of predominantly infiltration based treatment systems whereas swales and filter strips can be used under advisement. Inspection of the site criteria listed in the User Guide identifies the critical factors associated with the advisement condition as being the presence of a Zone II sensitive groundwater and the large area occupied by the highway catchment at this site. Based on this information the user is able to incorporate relevant design aspects when proceeding to install a treatment system recommended under advisement. For example, if swales were required as part of a treatment train, liners could be used to protect the groundwater and the expected high flows could be compensated for by using shallower swales combined with the installation of check dams. There is also evidence that the DSS can identify situations where installed treatment systems do not always perform satisfactorily. Thus, for the M4 Maynooth Case Study site in Ireland the predicted unsuitability of filter drains, due to poor drainage associated with the underlying clay based soil, is reinforced by the presented evidence of frequent ponding on the surface of the installed filter drains.

The site criteria constraints incorporated into the PROPER DSS are based on the recommendations currently relevant to the UK and certain other European countries, particularly with respect to sensitive groundwater conditions and the overlying soil type and depth. These requirements adopt a conservative approach to establishing appropriate benchmarks but nevertheless have been shown to fully explain the choice of treatment systems in the described Case Studies. However, it is acknowledged that alternative national approaches, in terms of the detailed methodological assessments, may also exist. Where such differences occur with respect to groundwater sensitivity, it is recommended that the user selects the status identified in the DSS which is most relevant to their situation. In situations where piezometric depth measurement are used as the benchmark unit in place of the groundwater table level, it will be necessary for users to derive a corresponding groundwater depth to allow incorporation into the site screening characteristics of the DSS. Therefore, in all situations where there is a mismatch between site criteria requirements identified in the DSS and the national emphasis with regard to the relevant site conditions, it is considered that it should be possible to cross-link national approaches to criteria allow incorporation into the DSS and hence prediction of the feasibility of using a specific treatment system.