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ROAD POLLUTION SOLUTIONS TOOL

Project Summary

Funded by The Mayor of London, Zoological Society of London & the Environment Agency.

Undertaken in partnership with Middlesex University, South East Rivers Trust, Thames Water and the British Geological Survey.

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1. Background

The nation's rivers are polluted. Along with sewer overflows, missconnections and agriculture a key source of river pollution is 'road run off'. Road run off pollution occurs when pollutants that settle on the road, such as residue from oils spills and tyre and brake wear from vehicles build up during dry weather events and are then washed into nearby rivers and streams when it rains. Road runoff pollution has long been one of the most challenging diffuse pollution issues to identify, quantify and resolve.

Road runoff pollution is notoriously difficult to track and quantify because of its intermittent nature (driven by weather events) and because it occurs simultaneously from multiple outfalls across a catchment. To date, this has proved challenging to monitor by taking water samples by hand and – unlike for air quality - there is currently no national real-time monitoring network that measures the impact of this type of pollution. This is because of:

- the wide range of pollutants (more than 300 are present in road runoff including toxic metals, hydrocarbons, other organic pollutants and sediments, known to cause both long- and short-term harm to aquatic life)
- the temporal nature of the pollution (which is most polluted after long dry spells when rainfall occurs and a 'first flush' (Figure 1) washes pollutants built up since the last rain event off the roads into rivers)
- and because the most polluting roads may be some way from the outfall where they enter the river.

This all makes it difficult to prioritise where to focus treatment interventions such as sustainable drainage systems (SuDS).

Figure 1: Black water resulting from road runoff pollution in the Hogsmill Stream, South East London. (Photo taken by Toby Hull, South East Rivers Trust 2014)

To address this, the Mayor of London, TfL (Transport for London) and Thames Water commissioned Thames 21 to conduct a study in 2019 quantifying the amount of pollution from roads entering our rivers (https://www.thames21.org.uk/improving-rivers/road-run-off/). This ‘first phase’ study categorised roads in terms of potential to contribute towards pollution of London’s rivers and helped to identify the best locations for interventions to address this issue. This information was then used to identify the best locations for interventions to address this issue.

Four years later, this second phase of the project has created an online, interactive and evidence-based decision tool (Titled: Road Pollution Solutions) that predicts the level of pollution risk posed by London’s strategic road network, identifies pollution pathways into the river and guides and prioritises where and how nature-based solutions (for example, rain gardens and swales) can be used to tackle road runoff pollution. It should be noted that priority pollutants should be captured at source by sedimentation devices including grit separators and oil/water separators which can capture up to 80% of the suspended solids in the runoff. The modelling focuses on London’s larger rivers and is limited to outer London, which has a separate surface water drainage network. It also does not include all of London’s road network, due to data availability. Consequently, it includes TfL’s roads, National Highways roads, and larger local authority highway roads.

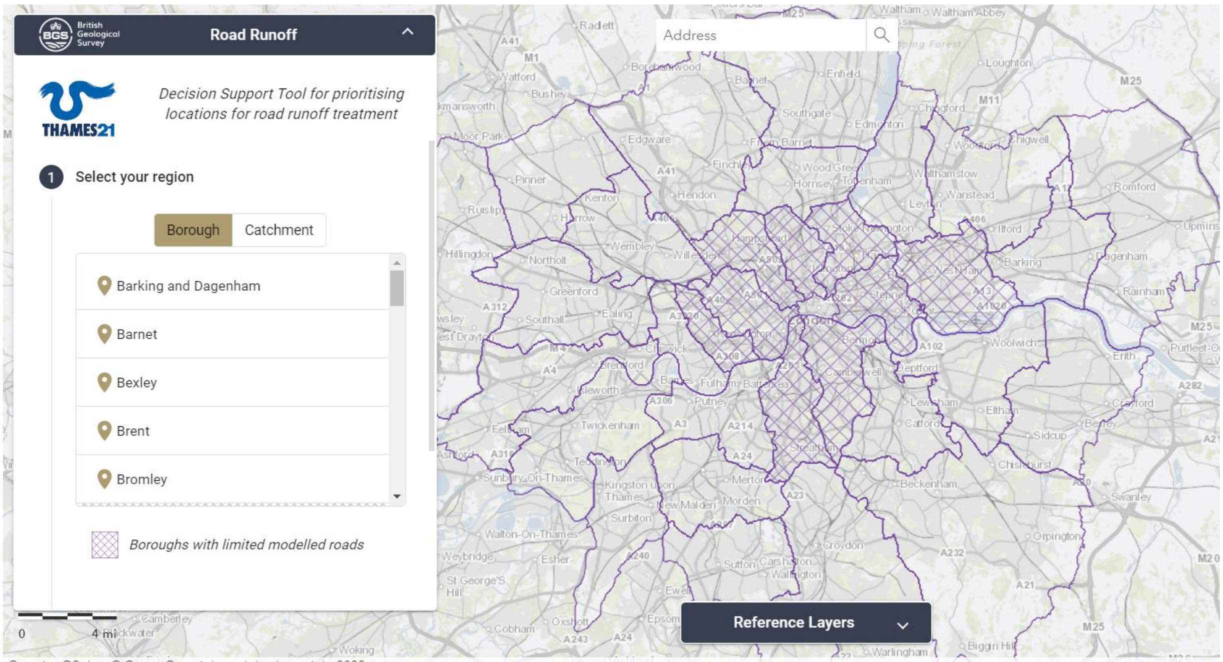

Figure 2: The boroughs of London not included in the Road Pollution Solutions Tool, depicted as hatched areas with limited modelled road network contained within them.

To our knowledge, this work, is the first attempt at this scale to develop an evidence-based strategy for the characterisation and resolution of road runoff at this scale.

Source control (prevention of, or dealing with, the problem where the pollution is created) should always be the priority to reduce the quantity of pollutants entering our waterways. This includes measures TfL is taking to reduce traffic volumes, congestion and the numbers of the most heavily polluting vehicles.

Nature-based solutions can complement this activity: this tool identifies the nature-based solutions that can be used in different locations to tackle road runoff pollution.

The Road Pollution Solutions Tool is available here: https://mapapps.bgs.ac.uk/road-pollution-solutions/

This study focuses on nature-based solutions due to the additional benefits they can provide to local communities, for example, flood risk mitigation, enhanced biodiversity and improvement of greenspaces for public enjoyment.

2. The Project Team

The Environment Agency, Zoological Society of London (ZSL) and the Mayor of London funded Thames21 and Middlesex University to develop the Road Pollution Solutions Tool: a new road runoff risk characterisation and SuDS decision- support model. The project was supported by the South East Rivers Trust.

The British Geological Survey, supported by the as part of the UKRI NERC-funded Community Water Management for a Liveable London (CAMELLIA) programme, have played a vital part in bringing the underpinning model to life and developing the online visualisation for a user friendly, decision support tool.

The first phase of the project, the Road Runoff Pollution Risk Modelling, was funded by Transport for London, along with the Environment agency and the Mayor of London in 2019.

3. How can the Road Pollution Solutions Tool be used?

This project has identified a significant level of road runoff pollution is contributing to the poor health of our rivers. The outputs of this work can be used by decision makers (including National Highways, the Environment Agency, Transport for London (TfL), Catchment Partnerships, and London boroughs) to tackle pollution levels at source by prioritising road locations for action. Additionally, the outputs will help deliver water quality improvement interventions; such as those delivered by the use of sustainable drainage systems (SuDS). At a more local scale, community groups will be able to use this tool alongside local authorities to use local knowledge to support the planning and delivery of projects within specific London boroughs or catchments.

Key water quality improvement interventions that have been incorporated into this model are SuDS including constructed wetlands. The use of these nature based solutions will allow road runoff pollutants to be captured, therefore reducing the concentrations entering our rivers. The Road Pollution Solutions tool supports decision makers and end users to determine suitable SuDS options for roadside treatment.

Whilst the tool has limitations (see Section 6), it can be used to further systematically explore areas of interest even if a specific location is not highlighted by the Road Pollution Solutions tool as a potential opportunity.

Sites identified as having potential for a SuDs for treating road run off pollution must be further evaluated by local site and catchment managers in relation to 'real world' site conditions. The nature-based solutions should be designed to ensure access for periodic maintenance activities to ensure operational performance is maintained. For further guidance on how to construct e.g. Wetlands the Mayor, ZSL and Enfield have developed the Urban Wetland Design Guide - CaBA (catchmentbasedapproach.org).

The issues and opportunities highlighted by the tool can be incorporated into local decision making, aligning local priorities and catchment partnership plans and local authority plans to manage flood risk, climate action plans, revitalisation of urban greenspaces and biodiversity enhancements. As noted above, all results generated from use of this screening tool should be verified locally through full feasibility assessments.

This project not only supports identification of the relatively most polluted roads (in terms of road runoff pollution), but also provides suggestions for site-appropriate treatment systems. Allowing end users and decision makers to identify the problem and how to manage it directly supports actions to improve the health of our rivers.

4. How does the Road Pollution Solutions Tool work?

The tool was created to help to identify the sections of London's roads that are likely to contribute the most pollution to our rivers. The tool is only applied to outer London because of the presence of a separate surface water runoff piped system. Surface water is rainwater that passes over roads, pavements, roofs, driveways etc. In outer London surface water runoff (and the pollution load it mobilises) drains directly to rivers through a separate surface water drain system, whereas central London has a combined drainage system, where surface water drains empty alongside domestic foul water pipes to sewage treatment works.

The methodology underpinning the tool was developed by Middlesex University and has been adopted here to determine the relative risk posed by road runoff to receiving waters across Greater London and to identify which types of sustainable drainage systems (SuDS) treatment options may be suitable for addressing those risks.

Pollutant Emissions

Using data from the literature, the mass of each pollutant deposited on a road surface per vehicle type was identified for each of the following emission categories: tyre wear, engine emissions, brake wear, road surface wear and oil leakage (Revitt, et al., 2022):

- Exhaust Emissions: Particulates being deposited from exhaust fumes are mainly deposited down onto the roads directly, with a small proportion staying airborne.

- Break Wear Emissions: Metallic compounds such as copper, zinc and cadmium are regularly found in break dust. Polycyclic aromatic hydrocarbons (PAH) such as pyrene and benzo-a-pyrene are also found in break dust due to build up when the breaking motion takes place.
- Tyre Wear Emissions: Zinc oxide is used in a range of processes to harden rubber used for tyres, this leads to significant quantities zinc in tyre tread and tyre wear debris. PAHs are also used in the tyre manufacturing phase to make the product easier to work with, and to improve the tyre's grip onto wet roads.
- Road Surface Wear Emissions: The road surfaces breakdown causing emissions of varying levels, contributing to levels of suspended solids and particulates.
- Oil Leakage Emissions: Oil leaking from the engine is dumped directly onto the roads with some oil lost due to high operating temperatures ending up vaporised or retained within the vehicle (10%).

Road Data

The pollution risk for London's Strategic Road network was calculated from traffic counts (generated by TfL and includes some sections of National Highways and Local Authority Highways roads) and published values of pollution deposition on roads for six pollutants which – between them - are representative of a range of road runoff pollution sources. These are the metals zinc, cadmium and copper, total suspended solids and the organic compounds pyrene and benzo(a)pyrene (Revit et al., 2022). The risk posed by individual road sections was assessed based on the comparison of predicted concentrations to relevant receiving water standards (including Water Quality Standards (WQS); adopted under a legal framework to address the impact of pollution on receiving waters as set out by Water Framework Directive). Although pyrene does not currently have a WQS – and therefore its environmental impact could not be estimated - it was still included in the model as an important indicator of traffic pollution.

Water Catchment Data

Thames Water's surface water sewer network information was used to trace the pathway of the pollution once it washes off the roads and outfalls into our rivers.

River Data

Data from the OS has been used to highlight the rivers that the surface water sewers drain into.

Rainfall Data

The data used consisted of the Hadley UK gridded climate observations for the UK with daily 1km rainfall grids derived from the Met Office Station Data were used. The data was averaged over for a five- year period (1/1/2017 to 31/12/2021) and then converted to vector cells which intersected with the retrospective road segments. This information is then used in two ways to identify which nature-based solutions can be used to treat the pollution and therefore protect and restore London's rivers. The use of nature-based solutions allows interception and treatment of road runoff pollutants therefore reducing the concentration entering our rivers.

1. **Greenspace treatment opportunities.** The first approach identifies potential locations for constructed wetlands in parks and greenspaces throughout London for treatment of road runoff pollution. To aid prioritisation and decision making, these greenspace opportunities are ranked according to the cumulative amount of pollution received from the roads in the sewer catchment upstream.
2. **Roadside treatment opportunities**. The second approach evaluates the potential feasibility of 12 nature-based treatment options (to see the full list, please refer to the Technical Summary) commonly used in urban areas (CIRIA, 2015) against a range of site specific criteria including depth to ground water, ground water sensitivity, soil type, and pollution load. The user is able to click on any modelled road to see the shortlist of potentially suitable SuDS.

Further detail about the methods used can be found in the "Technical Summary".

5. Key Findings

To support use of results, predicted road runoff pollutant concentrations were allocated to one of four categories as follows:

Table 1: Priority classification and the number of road sections, and total length of roads within each category.

Priority Classification	Definitions	Colour in online 'Road Pollution Solutions Tool'	Number of Road Sections	Total Length of Road Sections
High Priority	roads with concentrations that fell into the top 5% of predicted concentrations	Red	2,415	451.3km
Moderate Priority	roads with concentrations that fell into the 6 - 15% of predicted concentrations	Pink	4,830	445.47km
Lower Priority	roads with concentrations that fell into the next 16 - 40% of concentrations were	Orange	12,074	947.87km
Lowest Priority		Teal	28,979	2017.53km

Modelling has shown that road runoff from 2,415 road sections (covering a total of 451.43km out of 3,862.3km (10%) of London's major roads that were modelled) are deemed high priority and pose a higher risk to receiving waters and are therefore a priority for treatment. Roads where heavy goods vehicles regularly apply their brakes are often the worst affected.

The London boroughs that contain roads with the highest concentration of 'predicted' pollutants are listed below. This data correlates to road sections that are receiving high volumes of traffic.

- Barking and Dagenham
- Barnet
- Havering
- Haringey
- Waltham Forest

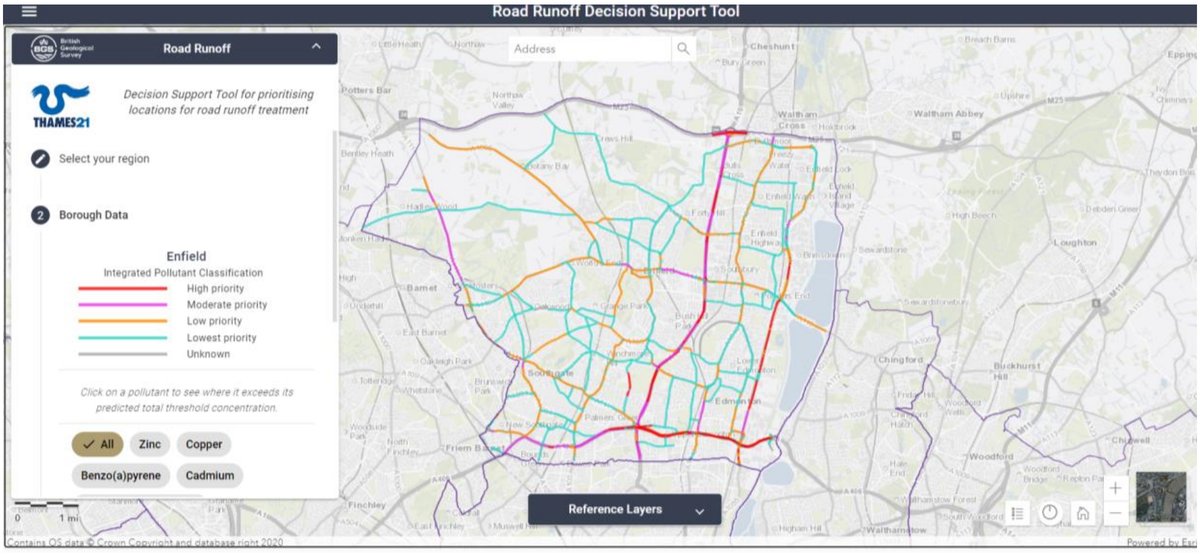

Figure 3: , Example output of the Road Runoff Pollution Solutions tool showing the modelled roads in the London Borough of Enfield ranked and prioritised in various colours according to their predicted road runoff pollution risk.

Table 2: The quantity of 'high pollution' roads within boroughs that have separate surface water sewers and how many kilometres of road sections this covers across the borough.

Borough	**The number of modelled roads of high priority**	**Proportion of Roads of High Priority %**	**The total modelled road length of high priority**
Barking and Dagenham	11 out of 80	6.11	18.2km out of 118.1km
Barnet	23 out of 235	9.79	26.8km out of 292.5km
Bexley	19 out of 149	12.75	19.1km out of 175km
Brent	20 out of 162	12.35	20.4km out of 153.4km
Bromley	16 out of 223	7.17	8.8km out of 269.3km
Croydon	13 out of 238	5.46	4km out of 206.6km
Ealing	16 out of 203	0.79	36.4km out of 192.1km
Enfield	22 out of 166	13.25	43.1km out of 226.9km
Greenwich	29 out of 176	16.48	30.7km out of170.6km
Hammersmith and Fulham	7 out of 35	20.00	4.8km out of 20.4km
Haringey	16 out of 126	12.70	1.9km out of 100.3km
Harrow	10 out of 149	6.71	3.5km out of 132.9km
Havering	23 out of 132	17.42	45.5km out of 245.7km
Hillingdon	16 out of 138	11.59	29.3km out of 236.5km
Hounslow	19 out of 141	13.48	27.6km out of 192.2km
Redbridge	18 out of 134	13.43	27.3km out of 176.7km
Richmond	14 out of 124	11.29	4.3km out of 122.2km
Sutton	4 out of 101	3.96	0.3km out of 86.4km
Waltham Forest	10 out of 104	9.62	18.9km out of 119.2km
Wandsworth	28 out of 165	16.97	8.4km out of 130.1km

In terms of specific pollutants, modelled cadmium concentrations never exceeded the associated water quality standards for any of the road sections. In contrast predicted concentrations of benzo(a)pyrene exceeded the associated water quality standards for all road sections.

Table 3: Water quality standards used in this study, taken from (Revitt, et al., 2022).

Pollutant	Equivalent Total Water Quality Standard
Total Suspended Solids	25 mg/l
Zinc	96 ug/l
Copper	28 ug/l
Cadmium	0.25 ug/l
Benzo-a-pyrene	0.0001 ug/l

6. Summary of Limitations

To our knowledge, this report and associated work, is the first attempt at this scale to identify and prioritise the roads and drainage networks polluting our rivers and to develop evidence-based strategies for their resolution using nature-based solutions. There is considerable opportunity to expand and refine this work and confirm the theoretical findings.

The following limitations should be noted when using the Road Pollution Solutions Tool as guidance for installing treatment solutions:

- Smaller tributaries and ephemeral streams are not included.
- Some sections of National Highways and key Local Authority Roads which interacts with TfL roads was assessed as the TfL traffic model was, at the time, the only traffic model available to us that consistently encompassed most of the London area.
- Issues with the reliability of the surface water drainage network mapping (discussed further in the Technical Summary).
- TfL's AADT model was constructed to understand the contribution of vehicle traffic to London's atmospheric pollution concentrations, which is a different (coarse spatial scale) purpose to its use here for prediction pollution deposition on individual sections of road surfaces.
- The surface water drainage network map needs improvement. Thames Water's surface water network data is poor.
- Pollution risk is not based on predicted impacts on receiving waters and requires ground-truthing. Predicted pollutant concentration values are not validated and caution should be taken when interpreting these results.
- Road width data was manually estimated.
- Mean monthly runoff was used to estimate pollution risk posed by roads, whereas the most damaging first flush events occur after prolonged accumulation of pollutants on the roads during extended dry periods. This means some pollution events may be significantly more damaging to the river than are currently estimated by this model.
- The tool currently does not offer a holistic view to compare roads between boroughs/catchments by displaying all boroughs/catchments in one go. Instead the user must manual change between the different areas of interest; hence direct visual comparisons between boroughs are difficult to make by the user.

For a more detailed reasoning behind the limitations please see the document ‘Technical Summary’.

References

CIRIA, 2015. *The SuDS Manual,* London: s.n.

Revitt, D. M. et al., 2022. Development and application of an innovative approach to predicting pollutant concentrations in highway runoff. *Science of the Total Environment.*