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Research Paper

Residents' perceptions of sustainable drainage systems as highly functional blue green infrastructure

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ABSTRACT

Blue-green infrastructure for storm water management in the UK is considered to be part of Sustainable Drainage Systems (SuDS). Design guidance recommends that source control and treatment trains are embedded within developments. This means that residents live next to SuDS performing functions such as infiltration, conveyance and storage. In addition to hydraulic attenuation, SuDS can provide benefits such as water quality improvement, wildlife habitat and amenity. However, economic pressure to maximise development opportunity means that designs do not always maximise these benefits. Therefore, residents' perceptions of the benefits and problems of living with SuDS are important as these may affect residential property values and willingness to pay management fees, which could justify high quality designs that deliver multiple benefits. This study aimed to investigate these issues through a survey of residents living with SuDS across six housing developments in England, 406/2916 responses were collected. The developments had good quality SuDS, with an established residential population and active housing market. The residents had varied levels of awareness of the presence and function of SuDS. Generally, residents liked the wildlife and green space but this was tempered with concerns over pests (rats and mosquitoes) and litter. Maintenance of SuDS was also an issue and at three sites residents were charged management fees which were not well understood and caused concern. The majority of residents were unwilling to contribute more to maintenance. Most residents and local estate agents did not perceive that SuDS increased property values. Raising awareness of the benefits of SuDS may lead to greater acceptance by residents and encourage developers to include them in developments, which could contribute to overcoming one of the barriers to wider implementation.

1. Introduction

Green Infrastructure (GI) can comprise of various features at different scales, so has many definitions: The EU Green Infrastructure Strategy defines GI as 'a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services' in both rural and urban settings (EC, 2013). This encapsulates natural areas through to engineered infrastructure where ecosystem services can arise from good design. Within the application of Blue-Green Infrastructure (B-GI) to storm water management there are graduations of intensity and integration of natural, semi-natural and engineered features, these have various terms such as Low Impact Development (North America and New Zealand), Water Sensitive Urban Design (Australia), Sponge Cities (China), Alternative Techniques (France), Best Management Practices (North America) and Sustainable Drainage Systems (SuDS – UK). In the UK these systems mainly focus on flood management but, in countries with greater water stress, storm water recovery and reuse can be the main driver. The evolution of these terms, and a model for classifying them according to "Primary Focus" and "Specificity", was investigated by Fletcher et al. (2014). SuDS are about half way along the model's continuum, with an aim to maintain pre-development hydrology but incorporating the aspiration that other benefits ***can*** be achieved. These include water quality improvement, habitat protection and increased urban amenity (Wentworth & Clark, 2016; Woods-Ballard et al., 2015). As the function of engineered B-GI components generally dictate the form, the perceptions and interaction of residents living with semi-natural B-GI streetscapes is likely to differ from residents close to natural B-GI.

Various barriers to implementing B-GI have been identified. For example a study in the USA considered that policy (national and municipal), governance, resources and various cognitive factors, such as familiarity with traditional infrastructure, low public awareness, perception of higher costs, risk and lack of maintenance knowledge contributed to low uptake (Dhakal & Chevalier, 2017). Similar barriers to SuDS uptake have been suggested in England, including weak planning enforcement, lack of national design standards, confused maintenance responsibilities and low public awareness (Ellis & Lundy, 2016; Melville-Shreeve et al., 2018). In England, SuDS are promoted by Lead Local Flood Authorities and by the Government (UK Government, 2018a, p54). The 2018 National Planning Policy Framework (NPPF) requires major developments to incorporate SuDS, unless this would be

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inappropriate (UK Government, 2018b), and proposes that planning authorities should require SuDS to provide multifunctional benefits and that at planning approval maintenance arrangements should in place. However, a survey of SuDS professionals questioned if these authorities have sufficient resources to enforce delivery (Grant, Chisholm, & Benwell, 2017). Hence, a survey of UK practitioners and regulators found that pipes and tanks are routinely favoured over softer SuDS (Melville-Shreeve et al., 2018).

The main UK design guidance is "The SuDS Manual" from the Construction Industry Research and Information Association (CIRIA) (Woods-Ballard et al., 2015), which recommends source-control and a sequential treatment train of different SuDS components. Designs that maximise multiple benefits often reduce the immediate opportunity to developers, as semi-natural SuDS require > 7% of development area (Stewart pers comm.). Financial viability of developments can therefore influence the scope for multiple benefit which are often undervalued in decision-making (Ossa-Moreno, Smith, & Mijic, 2017). It is therefore important that developers can assess the value of SuDS during master planning if the uptake of SuDS promoted by professional bodies and Government is to be achieved (Melville-Shreeve et al., 2018; UK Government, 2018b; Woods-Ballard et al., 2015).

Adoption and long-term maintenance of SuDS are major uncertainties for developers and constitute a barrier to SuDS implementation in England (Grant et al., 2017; Melville-Shreeve et al., 2018). The situation is complicated: Some SuDS are adopted by local authorities or water companies, with variable policies between areas, and maintenance funded through commuted sums or utility bills: Otherwise residents pay a service charge to an adopting body. The Flood and Water Management Act 2010 proposed national design standards, statutory approval bodies and that SuDS in housing development be adopted by local authorities. In England these aspects of the bill have not been enacted (Ellis & Lundy, 2016) but the Welsh Government is currently implementing this legislation. In Scotland, Scottish Water or local authorities are the preferred adopting bodies. Uncertainty over adoption has led to concern among professional bodies of "orphan" SuDS and poor planning for refurbishment (Grant et al., 2017; Wildlife Trusts, 2017). The fragmentation of adoption reduces the opportunity for holistic management of treatment trains and exposes adopters to risks from unforeseen events, such as pollution incidents or engineering failure. There are some progressive moves, for example Water UK (2019) has proposed a common position for adoption by water companies, but a comprehensive solution for England is not apparent.

Many studies have developed methodologies to assess the value of ecosystem services supplied by BG-I, such as the BeST Tool developed by CIRIA specifically for SuDS (CIRIA, 2019). However, these valuations include offsite benefits and externalities not of immediate benefit to residents. The value of SuDS to residents is important as this affects decisions to move to a development, house prices and willingness to pay for maintenance (Bastien, Arthur, & McLoughlin, 2012; Jarvie, Arthur, & Beevers, 2017; Wild, Henneberry, & Gill, 2017). This value depends residents being aware of the presence and/or function of SuDS and their perceptions of the subsequent benefits, or problems. This study therefore focused on these factors in the context of residents living with SuDS, based on the definitions summarised in Fig. 1.

Previous studies of residents' perceptions of installed SuDS have predominantly been in Scotland, either on a relatively small scale (Everett, Lamond, Morzillo, Chan, & Matsler, 2016) or focussing on ponds (Bastien et al., 2012; Jarvie et al., 2017), with early studies

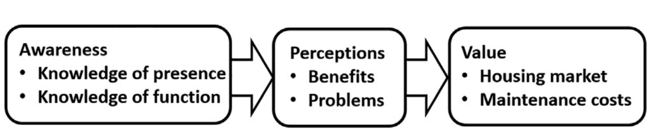

Fig. 1. Aspects of residents' awareness, perceptions and value of SuDS.

examining end of pipe systems (Apostolaki, 2003). In other countries studies have examined public perceptions of theoretical concepts or demonstration sites (Baptiste, Foley, & Smardon, 2015; Chui & Ngai, 2016; Izawati, 2008; Wang, Sun, & Song, 2017). Therefore, there is a need to assess the perceptions of residents living with embedded SuDS complying with best design guidance (Woods-Ballard et al., 2015). Greater understanding of the perceptions and value residents place on embedded SuDS could inform guidance for developers to capture this at master-planning, so promoting uptake of SuDS providing multiple benefits.

2. Methods

A comparison of six housing developments was undertaken using a survey of resident households, interviews were also sought with local Estate Agents to assess their perceptions of SuDS in housing markets. The study was part of a Natural Environment Research Council Green Infrastructure Innovation project entitled Providing Real World Opportunities for Sustainable Drainage (PROSuDS) which was informed by a steering group of representatives from professional bodies, developers, local authorities and SuDS practitioners (University of Portsmouth, 2016). The overall aim was to provide developers with tools to better assess the costs and value of SuDS to promote uptake.

2.1. Site selection

Sites were selected with good quality SuDS integrated into developments that had been inhabited for more than five years. Scoping visits to approximately 20 sites were undertaken to generate a shortlist of six. The criteria for selection were the quality of SuDS (e.g. many rejected sites had ponds at the end of piped drainage), the visibility of SuDS and development maturity (some rejected sites were affected by ongoing construction). The six sites identified were in the South East and the East Midlands of England and Fig. 2 shows their locations. The site characteristics are summarised in Table 1 with further details in Appendix A, this also contains "pen portraits" which, although subjective, aim to describe the appearance of SuDS to residents. All the sites were connected to existing towns and close to regional population concentrations. Table 1 compares demographic and housing market details for the towns. The UK Census is every 10 years, the last in 2011, therefore demographic data at postcode level was not available as the developments have changed over this period. Barking Riverside in East London was the most urban of the sites and, apart from the Hamptons, the remainder were greenfield developments. At the Hamptons previous excavation for brick production created several large ponds and subsequently this site had most green space.

2.2. Survey structure and delivery

The survey (Appendix B) aimed to assess the awareness of residents of the presence and function of SuDS, their perceptions of potential benefits and problems and to assess the value placed on SuDS through perceptions of their influence on the housing market and willingness to pay maintenance costs. A list of potential benefits and problems was compiled from previous studies (Apostolaki, 2003; Bastien et al., 2012; Jarvie et al., 2017) and SuDS information body websites (e.g. SusDrain), then refined to a short list in collaboration with the project Steering Group. The final list covered many of the benefits identified in the introduction and also emerging concerns such as building temperature control. We followed the lead of Bastein et al. (2012) and used "wildlife" as a surrogate for biodiversity and habitat protection. The survey was undertaken in January–March 2018. To maximise responses paper surveys were delivered by hand with the option of collection the next day, return by pre-paid post or completion online. Some of developments had phases under construction and the population of the completed phases (Appendix A) was estimated to be 12,000, meaning a

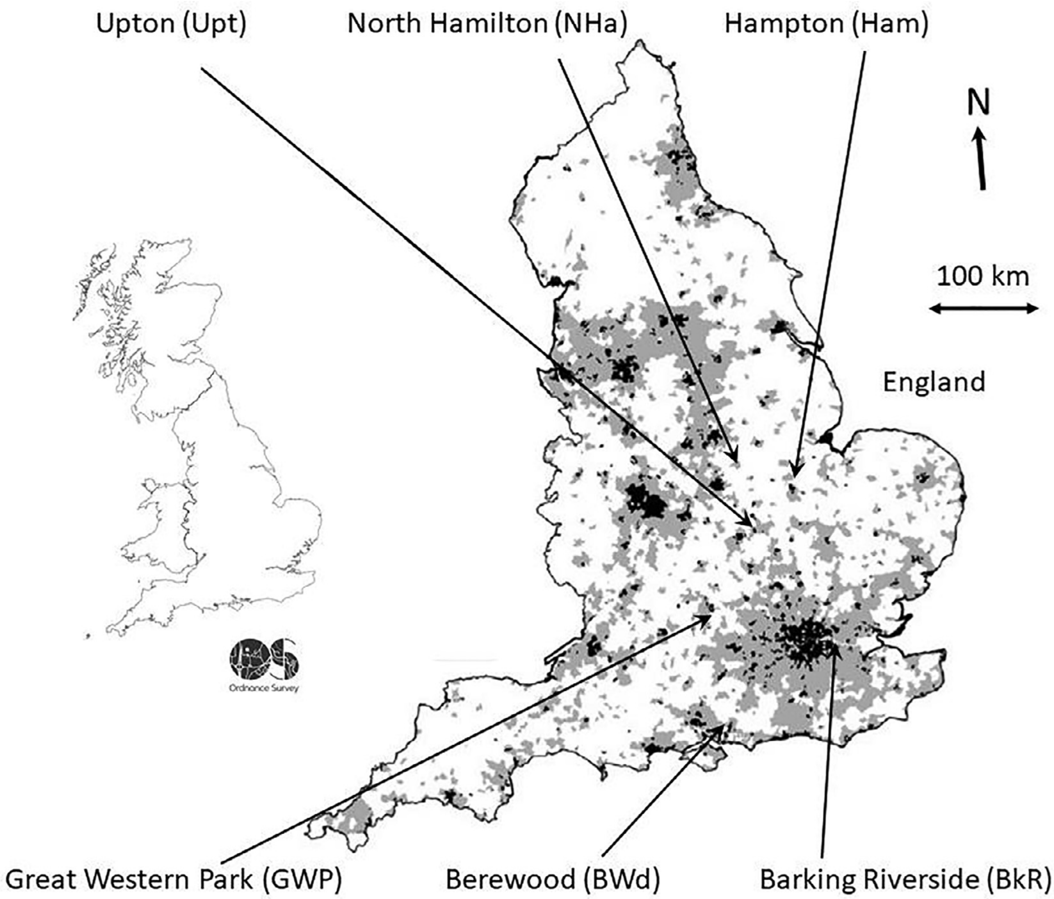

Fig. 2. Locations of the six case study sites on a map of England showing urban and semi-urban areas. The map is compiled from outline material reproduced from Ordnance Survey map data by permission of the Ordnance Survey © Crown copyright 2001 and urbanisation rendering is from Ander, Johnson, Cave, Palumbo-Roe, Nathanail, and Lark (2013) reproduced under a creative commons licence CC BY-NC-ND 4.0.

Table 1
Case study site characteristics.

Site	Location	Development Size	House Price*	Home Ownership*	Average Salary*	SuDS Features
Barking Riverside (BkR)	Barking, East London	Area: 180 Ha Units: 10,800 Brownfield	£314,978[3]	48%[1]	£572 (£671 London)[3]	Rain gardens, green roofs, tree pits, permeable paving, swales, detention basins and detention ponds.
Berewood (BWd)	Waterlooville Hampshire	Area: 298 Ha Units: 2550 Greenfield	£306,573[3]	69%[1]	£553[3]	Permeable pavement, swales, basins, underground storage and ponds.
Great Western Park (GWP)	Didcot, Oxfordshire	Area: 185 Ha Units: 3300 Greenfield	£ 315,658[3]	69%[1]	£698[3]	Permeable paving (storage) soakaways swales attenuation basin, detention basin and pond
Hamptons (Ham)	Peterborough, Cambridgeshire	Area: 1000 Ha Units: 13,000 Brownfield	£198,038[3]	65%[1]	£484[3]	Large detention ponds, swales, filter strips, detention basins, green roofs, permeable paving.
North Hamilton (NHa)	Leicester, Leicestershire	Area: 54 Ha Units: 1684 Greenfield	£215,602[3]	50%[1]	£526[3]	Swales with check dams, detention basins, bioretention areas, detention ponds and wetlands.
Upton (Upt)	Northampton, Northamptonshire	Area: 54 Ha Units: 1220 Greenfield	£237,532[3]	63%[1]	£536[3]	Permeable paving, extensive swale system detention basins and ponds
UK			£226,798[3]	63%[1]	£571[3]	

[2]https://www.nomisweb.co.uk extracted from ONS data.
* Average for Town.
[1] Office for National Statistics (ONS).
[3] https://www.rightmove.co.uk/ all accessed 11/6/19.

Table 2
Survey response rates and mode of response by site.

Site	Code	Collection	Postal	Online	Total Valid	Response (%)
Barking Riverside	BkR	15 (+5)	16	3	34	6.8
Berewood	BWd	61 (+7)	36	5	102	24.5
Great Western Park	GWP	39 (+7)	37	6	82	16.4
Hamptons	Ham	35 (+6)	36 (+1)	4	75	15.0
North Hamilton	NHa	22 (+1)	22	1	45	9.0
Upton	Upt	45 (+10)	19 (+1)	4	68	13.6
Overall		217	166	23	406	14.0

(+*x*) = number of invalid responses collected.

sample of 399 was required (margin of error of < 5%) (Scheaffer, Mendenhall, Ott, & Gerow, 2012).

The experimental design was to deliver 3000 questionnaires, 500 at each site. Random sampling was not possible given the logistics of delivery and collection. Purposive sampling aimed to provide a cross-section of experiences of SuDS in the developments. This was done by identifying roads close to different SuDS and also sampling matched roads away from the features, based on map studies and observations made during scoping visits. During survey delivery it was noted that the well-embedded SuDS gave varied exposures within all of the roads sampled and as the sample approximated to a cross section of the development they were considered geographically as a single group and differences investigated based on household and resident characteristics. Field modifications were required when ongoing construction to adjacent phases became intrusive, for example at Berewood the sample was limited to 416 as some mapped roads were not completed or inaccessible. Hence, 2916 surveys were delivered. Overall, 442 surveys were returned (Table 2) with a valid response rate of 14%. Overall a satisfactory sample was collected, but the response rate varied by site (6.8 to > 24%) with a similar range to other SuDS surveys (Bastien et al., 2012; Jarvie et al., 2017; Jose, Wade, & Smart, 2015).

Of the 406 valid responses, 54% were collected, 41% returned by post and 6% submitted online. The preference for postal over web returns has been observed in other household surveys (Shih & Fan, 2009) and the mixed mode helps avoid demographical sampling errors seen in web surveys (Campbell, Tyron, Venn, & Anderson, 2018). The data were coded into Minitab 17 statistical software and the responses investigated using descriptive statistics and differences between groups assessed using the Kruskal-Wallis test, the results are adjusted for ties ($H_{(DF,\ N=)} =, p =$). The coded survey responses are available as a linked data set and the free text comments are included as Appendix C. Interviews with estate agents were also conducted to assess their perceptions of the influence of SuDS on house prices. The target was to interview one agent at each site, but interviews could only be arranged at Berewood, Great Western Park, North Hamilton and Upton. The Berewood interview was face-to-face and the Great Western Park agent opted for e-mail. The other interviews were by telephone. The comments are presented in Appendix C7.

3. Results

3.1. Characteristics of respondents

The median age group at Barking Riverside, Berewood and Great Western Park was 30–44 years (Table 3) this was significantly different to the 45–60 year category at the other sites ($H_{(5,\ N=393)} = 22.03$, $p = 0.001$). There was wide variance in the % of respondents owning their houses ranging from 55% at Barking Riverside to 88% at the Hamptons.

Table 3
Age range, residential category and reasons for moving to the development as % and number of the respondents by site.

Variable	Class		BkR	BWd	GWP	Ham	NHa	Upt
Age Range	18–29	%	12%	15%	8%	0%	2%	8%
		N	(4)	(15)	(6)	(0)	(1)	(5)
	30–44	%	48%	43%	57%	27%	42%	39%
		N	(16)	(43)	(45)	(20)	(18)	(25)
	45–60	%	36%	18%	22%	51%	40%	30%
		N	(12)	(18)	(17)	(37)	(17)	(19)
	> 61	%	3%	25%	14%	22%	16%	23%
		N	(1)	(25)	(11)	(16)	(7)	(15)
Residential Category	Owner	%	55%	83%	76%	88%	61%	77%
		N	(18)	(84)	(62)	(64)	(25)	(49)
	Shared	%	18%	2%	1%	3%	10%	8%
	Ownership	n	(6)	(2)	(1)	(2)	(4)	(5)
	Rent	%	3%	8%	11%	1%	12%	6%
		n	(1)	(8)	(9)	(1)	(5)	(4)
	Social Rent	%	24%	7%	12%	8%	17%	9%
		n	(8)	(7)	(10)	(6)	(7)	(6)
Reasons for Moving to Site	Green Space	%	35%	38%	28%	59%	64%	49%
		n	(12)	(39)	(23)	(44)	(29)	(33)
	Commute	%	21%	45%	60%	36%	31%	24%
		n	(7)	(46)	(49)	(27)	(14)	(16)
	Schools	%	9%	16%	4%	33%	9%	21%
		n	(3)	(16)	(3)	(25)	(4)	(14)
	House Price	%	52%	39%	52%	24%	20%	38%
		n	(18)	(40)	(43)	(18)	(9)	(26)

3.2. Role of green space in development

The presence of green space was identified as a factor in the decision to move to all the developments (Table 3), with North Hamilton and the Hamptons having the highest number of responses and Great Western Park the lowest (respondents could select more than one factor). The reported use of green space (Appendix B: Q3) was similar at five sites with a median between four and five visits per month (see SI), but at the Hamptons, this was significantly higher at 12 visits per month ($H_{(5,\ N=405)} = 22.88$, $p = < 0.001$). There was also a significant difference in visits to green space by age, but not by gender, with residents in the two older categories reporting more visits (Mdn = 12) than the younger two categories (Mdn = 4) ($H_{(5,\ N=392)} = 15.56$, $p = 0.001$). Private tenants tended to visit green space more frequently than homeowners and those in social housing (median = 12 per month compared to 4 or 5). The main use of green space at all sites was walking (87–68% of respondents by site), dog walking was more popular at Berewood (35%) than Barking Riverside (3%), Great Western Park residents reported most running (38%) and the Hamptons the most cycling (29%). The contribution of SuDS to open space and the aesthetics of the SuDS was highly regarded at all developments (Q5; Mdn ≥ 4) with the Hamptons being significantly higher for both aspects (Mdn = 5) ($H_{(5,\ N=372)} = 19.53$, $p = 0.002$ and $H_{(5,\ N=375)} = 19.86$, $p = 0.001$ respectively).

3.3. Awareness of SuDS

Residents reported very different awareness of SuDS before moving to the developments with 69% at Upton, 60% at Berewood, the other sites were between 36 and 38% and the lowest at North Hamilton (27%) (Appendix B: Q16 + SI dataset). There was a neutral view about the influence of SuDS on the decision to move (Q17: *Mdn* = 3.00) with no significant difference between the case studies ($H_{(5,\ N=247)} = 5.06$, $p = 0.409$). At most sites developers were the main information source on SuDS before moving (Table 4), however at the Hamptons information boards were the main source. Estate agents contributed little to awareness, with only Upton identifying them by > 10% respondents. The "Other" sources of information before moving were predominantly

Table 4
Resident information sources concerning SuDS before and after moving as % and number of the respondents by site.

Information Source		Site											
		BkR		BWd		GWP		Ham		NHa		Upt	
		Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Developer	%n	24% (8)	–	44% (45)	–	24% (20)	–	9% (7)	–	16% (7)	–	31% (21)	–
Estate Agent	%n	9% (3)	–	4% (4)	–	0% (0)	–	7% (5)	–	7% (3)	–	21% (8)	–
Information Boards	%n	6% (2)	9% (3)	14% (14)	3% (3)	1% (1)	0% (0)	19% (14)	12% (9)	4% (2)	11% (5)	9% (16)	0% (0)
Residents Groups	%n	–	21% (7)	–	3% (3)	–	4% (3)	–	8% (6)	–	9% (4)	–	6% (4)
Maintenance Company	%n	–	0% (0)	–	4% (4)	–	4% (3)	–	3% (2)	–	11% (5)	–	6% (4)
Other	%n	15% (5)	32% (11)	22% (22)	24% (24)	18% (15)	38% (31_	12% (9)	25% (19)	4% (2)	24% (11)	19% (13)	12% (8)

prior knowledge and individual research. “Other” sources were also important after moving for all sites, free comments suggested that this was predominantly through individual research. However, 68 respondents (overall 17%) indicated this survey was the first information they had received about SuDS. Residents’ groups were identified as useful sources of information at Barking Riverside but information boards and maintenance companies made little contribution to awareness after moving.

Residents reported a high degree of awareness of SuDS contributing to flood management (80–97% of respondents by site, Appendix B:Q6 + dataset), with highest levels at Upton and Berewood. Residents were more aware of how SuDS promoted wildlife (46–65%) than pollution control (7–33%) with the lowest awareness of this function at Upton and Great Western Park (7 and 13% respectively).

3.4. Perception of SuDS: Benefits

“Flooding”, “Pollution Control” and “Air Quality” were consistently rated as the main benefits of SuDS (Fig. 3), there were however significant differences in the rating of the other benefits by site, these are explored in Table 5. The Hamptons and Barking Riverside residents gave higher ratings for “Urban Design”, “Property Values” and “Education”, while the Hamptons and North Hamilton residents gave higher ratings for “Wildlife”.

Table 5
Kruskal-Wallis analysis (tie adjusted) of the responses to the perceived benefits of SuDS by site. Sites with medians that are significantly different from the overall median ($P < 0.05$) are identified in the comments column.

Aspect	N	H	DF	P	Comments
Flooding	379	10.69	5	0.058	
Wildlife	373	15.58	5	0.008	Ham + NHa high (Mdn = 5)
Urban Design	365	12.42	5	0.029	Ham + BkR high (Mdn = 5)
Health	358	12.52	5	0.028	Upt low (Mdn = 3)
Recreation	353	31.12	5	< 0.001	Upt + BWd low (Mdn = 3)
Air Quality	339	9.94	5	0.077	
Pollution	305	7.07	5	0.215	
Prop. Value	339	23.89	5	< 0.001	Ham + BkR high (Mdn = 4)
Education	334	17.37	5	0.004	Ham + BkR high (Mdn = 4)
Build. Temp.	291	17.10	5	0.004	BwD low (Mdn = 2)

3.5. Perception of SuDS: Problems

Fig. 4 shows “Litter”, “Pests” and “Cost” were of most concern to residents. “Litter”, “Pests” and “Untidiness” were perceived to be more problematic at Barking Riverside than the other sites, while “Cost” was

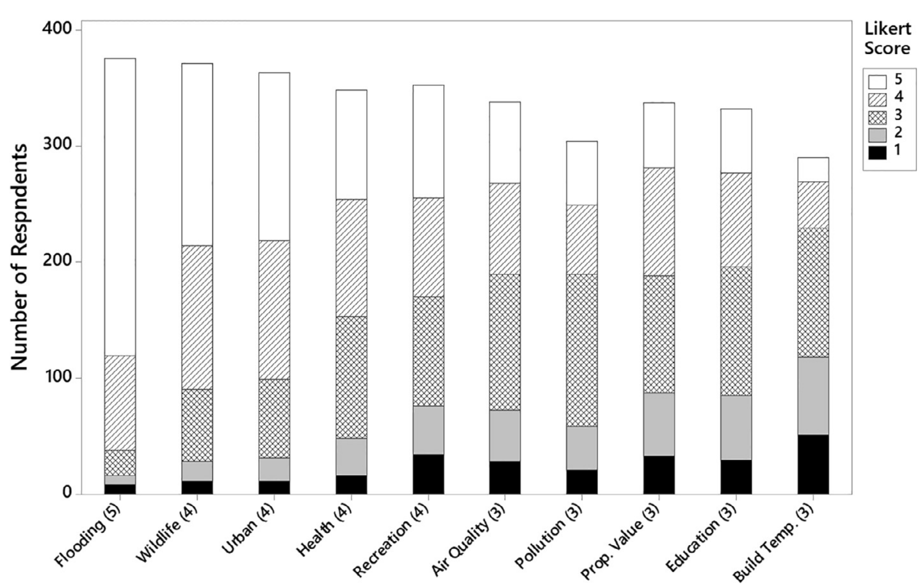

Fig. 3. Perceived benefits of SuDS by residents. The bars show the number of respondents for each Likert score category and are in the order of mean score. The median Likert score for each benefit is shown in brackets after the x-axis label.

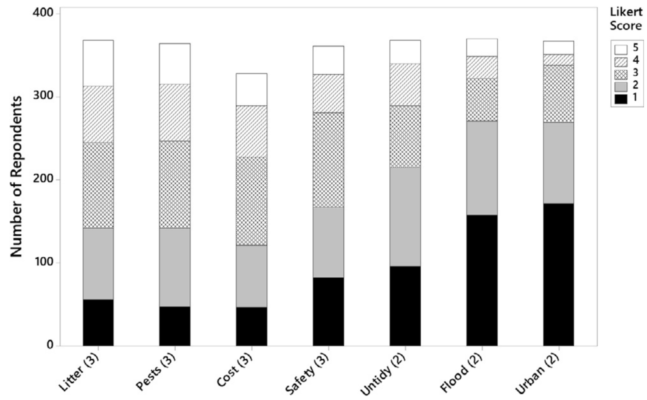

Fig. 4. Perceived problems with SuDS by residents. The bars show the number of respondents for each Likert score category and are in the order of mean score. The median Likert score for each benefit is shown in brackets after the x-axis label.

Table 6
Kruskal-Wallis analysis (tie adjusted) of the responses to the perceived problems with SuDS by site. Sites with medians that are significantly different from the overall median ($P < 0.05$) are identified in the comments column.

Aspect	N	H	DF	P	Comments
Litter	370	13.52	5	0.019	BkR high (Mdn = 3.5)
Pests	365	40.56	5	< 0.001	BkR high (Mdn = 5), GWP low (Mdn = 2)
Costs	350	31.45	5	< 0.001	Upt high (Mdn = 4)
Safety	361	5.63	5	0.344	
Untidy	370	14.67	5	0.012	BkR high (Mdn = 3)
Flood	372	6.20	5	0.287	
Urban	369	14.82	5	0.011	Ham + Upt low (Mdn = 1)

more of an issue at Upton (Table 6).

3.6. Paying for SuDs

Residents were asked about the understanding of their financial contribution to SuDS upkeep and if they would be willing to pay more, tallied responses are presented in Table 7.

3.7. Estate agents' views

During the interviews, it was discovered that Estate Agents have little knowledge of SuDS and they generally thought that SuDS had no influence on buying decisions and no impact on house prices (Appendix C). They stated that potential buyers rarely reference SuDS and that purchasing decisions focus on the conventional concerns of location and property characteristics. When SuDS are mentioned it is their aesthetics rather than functional utility that is considered. Moreover, marketing literature rarely mentions SuDS and some stated that was not their responsibility to raise awareness, but that of the developers.

4. Discussion

This study aimed to investigate the experiences of residents' living with SuDS embedded in housing developments through a survey at six sites in England to assess the level of awareness, perceptions and value placed on the systems. The selection criteria generated a narrower geographical range than envisaged, but covered a range of locations from predominantly urban settings to suburban housing estates. The survey generated a satisfactory number of respondents, but this varied with the lowest response at the most urban site. This range of responses has the potential to introduce bias into the results as site-specific demographic data was not available to test how representative the samples were. The study focussed on housing type and more demographic data may also have allowed further interpretation of the responses. Some of the benefits and problems included in the survey may also have been unclear for lay people, this may explain the relatively low number of respondents rating "Pollution Control" and "Building Temperature" benefits (Fig. 3).

4.1. Awareness of SuDS

SuDS were very visible at all the sites (Appendix A) and created streetscapes atypical of new build housing in the UK. However, only at Upton and Berewood were a majority of residents' aware of the SuDS before moving. Upton had high profile sustainability credentials and the developer and Estate Agents may have exploited this in marketing. At Berewood the developer was also pro-active in informing residents about SuDS. Residents' groups and interpretation boards also contributed to raising awareness, a North Hamilton resident suggested greater use of boards stating "brilliant system, should put up notices about wildlife that lives in and around the SuDs". However, a previous study at the Hamptons found that interpretation boards had no effect on resident ratings of the ancillary benefits of SuDS compared to an offsite control group, and concluded that a dynamic and direct information campaign was required (López, 2014). Inquisitiveness concerning SuDS was apparent, with many residents reporting undertaking independent research after recognising differences to traditional drainage and many respondents introduced to SuDS concepts by this survey requested more details. Bastien et al. (2012) found a high level of awareness of the water quantity and quality functions of SuDS ponds (69%) that increased when there were local environmental benefits. A survey of

Table 7
Residents' understanding of current charges for SuDS and their willingness to pay extra as the % and number of the respondents by site.

Charge Range(£/a)		Site											
		BkR		BWd		GWP		Ham		NHa		Upt	
		Current	Extra	Current	Extra	Current	Extra	Current	Extra	Current	Extra	Current	Extra
0	%n	82% (28)	59% (20)	92% (102)	62% (63)	95% (78)	51% (42)	89% (67)	45% (34)	49% (22)	62% (28)	34% (23)	72% (49)
1–50	%n	3% (1)	12% (4)	1% (1)	21% (21)	0% (0)	32% (26)	0% (0)	25% (19)	2% (1)	16% (7)	0% (0)	9% (6)
51–100	%n	0% (0)	12% (4)	1% (1)	7% (7)	2% (2)	7% (6)	0% (0)	5% (4)	18% (8)	4% (2)	1% (1)	4% (3)
101–150	%n	0% (0)	6% (2)	4% (4)	2% (2)	1% (1)	1% (1)	1% (1)	9% (7)	16% (7)	4% (2)	6% (4)	1% (1)
151–200	%n	3% (1)	3% (1)	0% (0)	1% (1)	1% (1)	1% (1)	0% (0)	0% (0)	4% (2)	2% (1)	35% (24)	3% (2)
> 200	%n	3% (1)	3% (1)	0% (0)	0% (0)	0% (0)	1% (1)	3% (2)	0% (0)	2% (1)	0% (0)	26% (18)	4% (3)

residents in New York also showed high awareness of the potential role of B-GI SuDS to manage local combined sewer overflows (Baptiste et al., 2015). Highlighting local environmental benefits could therefore be a key communication strategy in making residents aware of the presence and function of SuDS.

4.2. Perceptions of the benefits and problems of SuDS

At all sites, SuDS were perceived as contributing to green space and many respondents cited this as a factor in their decision to move (Table 3). The form and accessibility of this space varied from green fingers next to houses (NHa, GWP), informal squares enclosed by housing (BKr), swales\ponds sometimes inaccessible (BWd, Upt) and large open ponds (Ham) (Appendix A). During the site visits the green fingers in particular were being used by children at play and North Hamilton had the highest % of residents saying the green space influenced their decision to move. This suggests that proximity and accessibility of green space to houses, with facilities for play, can be as influential in decisions to move as total amount of green space. At Great Western Park commuting was the most important factor in the decision to move, a reflection of the congested towns in the Thames valley. House price was identified as important by a majority at Great Western Park and Barking Riverside, which corresponds to their locations in areas with the highest house prices (Table 1). The highest ranking for schools was at the Hamptons (25%), where a high-quality school was delivered as part of planning conditions (CBRE, 2016). Previous studies have identified environment, particularly ponds and green space, as being important in moving decisions, but less so than property characteristics and price (Bastien et al., 2012; Bowman, Thompson, & Tyndall, 2012; Jarvie et al., 2017). The findings of this study are in general agreement, but highlight that local conditions can influence moving decision factors and that accessibility of green space is important.

Residents ranked “Flooding”, “Wildlife” and quality of “Urban Space” as the top three benefits of SuDS (Fig. 3). High ratings for wildlife and quality of urban space have been seen in other perception studies. Flood management has previously had lower ratings (Apostolaki, 2003; Bastien et al., 2012; Jarvie et al., 2017), but media coverage of flooding in England has regularly identified the potential of SuDS for flood control which may have raised awareness. Concern over the contribution of SuDS to local flooding was highlighted in comments (Appendix C) suggesting that the function of systems was not universally understood. Posts on a residents’ Facebook group at Upton during a major storm in Spring 2018 demonstrate these concerns. Initial worries that the detention features were filling up and possibly going to flood, eventually gave way to collective relief when it was realised that the systems were functioning as intended and protecting vulnerable areas of the site.

The role of B-GI in attracting wildlife into urban areas is consistently ranked highly by residents and was frequently referred to in the free text comments, with the following quotes: *“we see lots of dragon flies and neighbour had a grass snake in garden which SuDS may have encouraged”* (UpT); *“this is great for wildlife and I see lots of common newts around”*(BWd); *“our house overlooks one of the ponds which we very much enjoy. Observed frogs”* (Ham); *“also welcome the wildlife which is quite harmonious to see in urban dwelling”* (BkR); and *“it is a great benefit to wildlife by encouraging invertebrates to developments which help the local wildlife population”* (GWP). Some of the wildlife encountered during the survey is illustrated in Fig. 5. The high ranking for wildlife is consistent with other studies (Apostolaki, 2003; Bastien et al., 2012; Jarvie et al., 2017; Persaud et al., 2016).

In addition to “good” wildlife there was concern that the SuDS also attracted unwelcome wildlife, with “Pests” one of the highest ranked problems (Fig. 4). In particular there were concerns about mosquitoes and rats at Barking Riverside and rats at Berewood, with the following comments: *“the mosquitoes in this area are a joke and nothing is ever done about them. Ponds areas and walkways are overgrow so this causes a problem with rats”* (BkR); *“area is infested by mosquitoes in summertime and rats”* (BkR); *“we get lots of mosquitoes here due to the water ponds we have”* (BkR); *“garden was infested with rats last winter”* (BWd); *“unfortunately, we have seen a few rats around the swales and lots of litter”* (BWd); *“just today while walking my dog I saw 2 dead rats”* (BWd). Similar concerns over insects and vermin have been expressed in other resident perception studies (Apostolaki, 2003; Bastien et al., 2012; Jarvie et al., 2017). There is no evidence that rats are more prevalent in SuDS or even more visible. However, the mosquito problems in the Thames estuary (BkR) are well-documented (Malcolm, 2009) and complaints from residents have featured in the local press (Dubuis, 2013). The contribution of SuDS is unknown, as there are other open water bodies in the area, but there is clearly a link in residents’ perceptions and mosquito breeding in storm water systems is documented in warmer climates (Metzger et al., 2018). This balance between “good” and “bad” wildlife habitat is a design challenge not yet addressed. The approach in California highway runoff Best Management Practice has been to remove standing water (Metzger et al., 2018) which would be contrary to achieving many multiple benefits of SuDS.

“Safety” was less of a concern than previous studies, but these have focused on ponds with concerns over drowning (Apostolaki, 2003). “Litter” was a major concern for residents (Fig. 4) and “The SuDS Manual“ suggests a link between litter and rats (Woods-Ballard et al., 2015). The concern over litter and the preference for tidy systems with evidence of “cues to care” has been reported in other SuDS surveys (Bastien et al., 2012; Everett et al., 2016). Residents comments on this issue were strong: *“the SuDS only make the area look scruffy and unkempt”* (Upt); *“when it is windy and people put out their recycling it blows into the drainage system and looks horrible”(Upt); “I think the upkeep of the suds would benefit from an increase in manpower to clean and tidy them – they look particularly untidy in the Winter with litter and rubbish”* (NHa); *“we have experienced issues of littering which gets trapped in the lakes and is an eyesore.”* (BkR); and at *“but on a downside, the drainage areas regularly get filled with LITTER!”* (BWd). Therefore, maintenance plans including regular litter removal would overcome one of the major concerns.

4.3. Perceptions of different SuDS types

At all the sites the SuDS components were in close proximity, so separating perceptions by SuDS type was difficult. Generally, residents preferred tidy SuDS providing wildlife habitat which is consistent with general preferences for GI (Derkzen, van Teeffelen, & Verburg, 2015; Hayden, Mary, Cadenasso, Haver, & Oki, 2015). However regularly cut vegetation may be less suitable for wildlife and pollution control. Other studies indicate that scale and appearance is important to residents with larger scale, well-established, natural looking SuDS with “cues to care” being preferred (Apostolaki, 2003; Bastien et al., 2012; Hayden et al., 2015; Jarvie et al., 2017). However, the source control and treatment train philosophy mean that smaller, less natural, systems may predominate close to homes and larger regional control ponds may be some distance away. On permeable sites, source control will be predominantly infiltration which in study was mainly permeable paving. Visually, permeable block paving is similar to standard block paving, but residents at Great Western Park expressed concern about workmanship, maintenance and safety with the following comments; “*block paving is uneven and unkempt which makes the area look untidy*”; “*permeable paving looked good when laid at first, but now that weeds come through*”; and “*the permeable paving outside my house is lethal when icy, much more slippery than normal paving*”. A study in the Netherlands suggested that residents in GI-poor areas may be more willing to accept more functional GI that can be used for sport and play, compared with those living in GI rich areas (Derkzen et al., 2015). The well-used multipurpose green fingers at North Hamilton may support this observation. Further research is required to assess the interaction of form, function and amenity on residents’ perception of B-GI close to homes.

Fig. 5. Wildlife in case study SuDS: (a) Residents encouraging birds to a swale (b) Brent geese in detention basin, (c) amphibian spawn in a linear detention basin and (d) heron hunting in a pond.

4.4. SuDS maintenance costs and adoption

The main concerns residents had with SuDS were "Costs" and "Litter" (Fig. 4) which both relate to adoption and maintenance. At master planning it was assumed that most of the case study SuDS would be adopted by local authorities. However, a range of adoption routes have been followed (Appendix A). At Great Western Park and Berewood SuDS are managed by the developers and no charges have been made, although adoption arrangements are being explored. At the Hamptons phase studied the developer will adopt the SuDS in perpetuity with no charge, but charges will be levied on latter phases. At these sites the majority of residents correctly recognised that they did not contribute to SuDS maintenance. At the other three sites residents pay a service charge for maintenance of the SuDS (Appendix A). Although a majority of respondents at North Hamilton (51%) and Upton (66%) were aware that they paid, a sizable minority were not aware they contributed (Table 7). At Barking Riverside, the majority of residents were not aware that SuDS upkeep was included in estates charges. These charges are therefore not well understood. At Upton residents had complained about charges to the local press and many comments reflected this concern, e.g. *"it was not made clear at anytime that I would incur any costs for the maintenance of SuDS areas at the point of sale. This only arose last year − 8 years after purchase"; "common area\SuDS managed by a so is called "charity" over which the residents have no control. These areas should be serviced by accountable local authorities, not government quangos and organisations like the xxxx xxxxx which charge exorbitant management fees and provide mediocre service"; "another burden on households. Should be paid for by developer and adopted by the local authority. Not willing to pay more, xxxx xxxxx already get sufficient income from this development"; "complex management arrangements for the maintenance of the area. why should we pay more for maintenance? No one else in the borough has to pay more for drainage"*; and *"waste of residents money, no benefits to residents who have to pay for them"*. North Hamilton also had a service charge and two residents complained that "*we are given no choice as to the provider and cost of maintenance*" and *"cost of maintenance too high"*. There was also concern by an Upton resident that uniform charges meant they contributing to others views of green open space "*I have to pay an enormous amount of money so some people can have green open space when all I see is bricks. I don't understand why the payment is not charged according to the green spaces*"**.** This raises an issue of equity of estates charges if visual benefits are not shared equally.

The majority of respondents were not willing to contribute more to SuDS maintenance (Table 7) which made investigating this question difficult. Overall 33% of respondents (135/406) were willing to contribute, ranging from 22% at Upton to ≥40% at the Hamptons and North Hamilton. Those who visited green space less than once per month (n = 33) were less willing to pay extra (mean < £5/year taking mid-points of bands) than those with higher visit frequencies (£27-26/year, but no increase with more frequent visits). Older residents also appeared willing to pay more than younger residents, rising from £18/year in the youngest age to £33/year in the oldest group, but both had high standard deviations (£31 and £58 respectively). Although some researchers have suggested that residents are willing to pay for SuDS amenity this is mostly theoretical (Bastien et al., 2012; Chui & Ngai, 2016; Jarvie et al., 2017), and others have concluded that charges can be unpopular with SuDS professionals consistently overestimating residents' willingness to pay (Bowman et al., 2012). Research in the Netherlands and China indicated that higher income residents may be willing to pay more for GI (van Derkzen, Teeffelen, & Verburg, 2016; Wang et al., 2017). However, a study in Chile showed that lower income neighbourhoods used green space more and had a greater sense of responsibility for maintenance (de la Barrera, Reyes-Paecke, Harris, Bascuñán, & Farías, 2016). Therefore, providing green spaces that people can use and encourage wildlife could increase willingness to contribute or to undertake maintenance.

4.5. Housing market and SuDS

Uplift in house prices was not considered a significant benefit by residents (*Mdn* = 3, Fig. 3) which is consistent with another UK studies (Jarvie et al., 2017). Estate Agents also had a common perception that SuDS did not influence buyers' decisions and had no impact on house prices. Previous valuation studies have focused on ponds where there is some evidence of increased prices and reduced sale times, but this is inconsistent even for direct views (Bastien et al., 2012; Lee & Li, 2009). House value uplift, was more highly rated at Barking Riverside and the Hamptons, two very different developments. In a Royal Institution of Chartered Surveyors (RICS) study of "placemaking" developments (CBRE, 2016), the Hamptons achieved premiums over the local market, especially for terraced houses, of up to 118%. Upton also featured in this study and less consistent premiums of 10–27% were estimated, with the highest being for semi-detached houses. During scoping visits it was observed that large detached properties tended have best views of SuDS which, considering the RICS study, may not be the optimal strategy to maximise returns on investment for developers installing high quality B-GI.

5. Conclusions

This study contributes to the understanding residents' perceptions of living with embedded B-GI treatment trains, as opposed to theoretical designs or just considering ponds, which as natural looking features are likely to be considered favourably. It was not possible to differentiate perceptions of specific components from this survey. There were concerns about litter, pests and maintenance charges at some sites highlighting the downside to living with B-GI. There is therefore a need to study of perceptions of specific SuDS components and how designs can address residents' concerns.

Residents prefer natural looking systems providing green space and wildlife habitat. Therefore, if developers promote these benefits there may be more acceptance of the functional aspects of SuDS. Raising awareness amongst developers and practitioners that the benefits residents rate most are delivered by softer vegetated SuDS could promote selection of these B-GI features during master-planning.

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Appendices. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.landurbplan.2019.103610.

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