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The Design, Construction and Maintenance of a SuDS management Train to Address Surface water Flows by Engaging the Community: Gawilan Refugee Camp, Ninewah Governate, Kurdistan Region of Iraq

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Refugee camps are set up under crisis conditions in the Kurdistan Region of Iraq by the United Nations High Commissioner for Refugees (UNHCR) with Water, Sanitation and Hygiene (WASH) installed as a matter of course. However, in general, little account is taken of surface-water drainage or greywater management until the camp floods or greywater streams become an environmental or health issue. This article reports on the construction of a sustainable drainage systems (SuDS) management train in a refugee camp with the community and local non-governmental organizations to address excess surface water and lack of greywater management in this most challenging of environments. There is thus potential to influence policy, at the first stages of planning, to encourage the installation of drainage as well as WASH. SuDS mimic nature by percolating water into the ground, storing it and allowing slow conveyance to reduce the storm peak, improve water quality and provide space for amenity for residents and for biodiversity. By encouraging the water to infiltrate, polluted standing water between dwellings and on the street is reduced, so that human and environmental health is improved, with the potential to address nuisance-insect-breeding sites. Site walkovers, workshops and meetings engaged residents in the design process from the very beginning. The design produced by the community was professionally drawn up and passed to the UNHCR and local management engineers for comment and approval; this article describes the process of designing and constructing the first SuDS-management train to be built in a humanitarian setting.

Keywords: Sustainable drainage, storm water, greywater management, Kurdistan Region of Iraq, community engagement, flooding

Introduction

Increasing urbanization associated with population growth, exacerbated by ageing drainage infrastructure in cities worldwide, have caused flooding problems, contamination and negative impacts on human and environmental health, regardless of the stage of development of the city. However, in developing countries, whilst the provision of drinking water and the disposal of human waste are prioritized, the management of excess surface water and greywater or sullage (from personal bathing, preparation of food in the kitchen, etc., but not what is disposed of in the toilet), in general, is not (Charlesworth *et al.* 2018). This is particularly true for temporary, informal settlements and refugee and internally displaced person (IDP) camps. This is particularly true when relocating those fleeing crises, such as IDP camp Protection of Civilian Camp 1 in South Sudan, where inadequate drainage was acknowledged to be an issue (Munive 2019), leading to residents facing 'numerous obstacles'. Where settlements are initially set up as a temporary measure for refugees, if neither storm water nor greywater is adequately managed, they are disposed of between shelters and on the street. This results in contaminated streams running through the camp, standing water between shelters and rank pools forming at camp boundaries (see Figure 1). Excess storm water and greywater can be managed in combination, such that 'drainage' in this context can include both, however, 'black water' or effluent from the toilet is assumed to be taken care of separately and is therefore not considered further here.

In the Kurdistan Region of Iraq (KRI), camps are set up by the Kurdistan Regional Government and the UNHCR with Water, Sanitation and Hygiene (WASH) installed as a matter of course (Sphere Association 2018). In a history of UNHCR classifications, Glasman (2017) does acknowledge that 'drainage' was included in the setting-up of rural camps in Africa in the 1960s. However, drainage is now generally considered to be a component of WASH and is often listed amongst the provision of toilets for the community, supply of water and its purification (Ahmed 2016) or specifically under 'sanitation' as 'excreta disposal from toilets to final deposit site or treatment; solid waste management; drainage and vector control' (Bastable and Russell 2013: 1). Reed (2017) identifies this as a possible explanation for confusion over the management of surface water in that the sources are not individually identified. However, treating them separately would require separate infrastructure, increasing complexity and potentially cost. As long as

Figure 1
Accumulated Greywater and Storm Water, Gawilan Refugee Camp, Kurdistan Region of Iraq

black water is not allowed to pollute surface flows with faecal contamination, it is possible to deal with standing water altogether, regardless of source.

A WASH gap analysis by Bastable and Russell (2013) found that 'general drainage' was raised several times as an important issue, albeit mostly in relation to showers and areas associated with bathing; although 'poor drainage' in terms of concerns with environmental quality was mentioned, 'better rainwater capture' was also recommended.

The provision of potable water, showers and toilets is prioritized as illustrated by van der Helm *et al.* (2017) in a study of one of the biggest refugee camps in the world—Za'atari, in Jordan, in which 'storm water drains' are mentioned, mainly as a conduit for wastewater. These would appear to be based on pipes and hard infrastructure, which they state may overflow during storms. If drainage is considered at all in the planning and building of a camp, it is constructed last, which can result in expensive retrofits that may still be ineffective once flooding occurs. The flows themselves are directed 'to another environment' (Tota-Maharaj 2016) via large drainage ditches, open concrete drains (see Figure 1) and pipes that can then exit at the camp boundary. This infrastructure needs dismantling when or if residents return home—another expensive exercise for the non-governmental organizations (NGOs) to undertake. Bastable and Russell (2013) raised this issue in their gap analysis as the importance of planning an 'exit strategy' as well as concerns with the general environment of the camp.

The lack of drainage is also recognized in the proliferation of disease vectors and nuisance animals such as mosquitoes. The Sphere Association (2018: 121) states that 'Vectors can be symptomatic of solid waste, *drainage* or excreta management problems' (emphasis added); the regular appearance of solid waste, greywater and storm water together is illustrated in Figure 1. Where solid waste accumulates in the drainage infrastructure, it can become blocked, encouraging stagnation and providing breeding sites for vectors, similar to what was shown by Charlesworth *et al.* (2018) in favelas in Brazil.

Encouraging the water to infiltrate into the ground, should conditions permit, would effectively remove it and reduce surface-water flows, suggesting that Sustainable Drainage Systems, or SuDS, have the potential to address these issues. SuDS mimic nature by encouraging the water to infiltrate, storing it and conveying it slowly to a receiving waterbody (Woods Ballard *et al.* 2015; Charlesworth and Booth 2017; Arup 2019). It does this by balancing a reduction in water quantity (i.e. attenuating the storm peak, reducing flooding), improving water quality (by a variety of means including filtration, settling of particulates, uptake by biota and adsorption), provision of amenity potential and space for biodiversity. This is encapsulated in the SuDS square (see Woods Ballard 2015; Charlesworth and Booth 2017). However, the system needs to be designed appropriately and take account of local conditions.

Problems associated with the lack of drainage in refugee camps have been investigated by a few authors; for example, in Lebanon, Davey and Maziliauskas (2003) found the storm water drainage infrastructure to be 'inadequate', with flooding common and contamination a problem. However, their subsequent drainage design was based on hard engineered infrastructure around pipes, manholes and open channels. Very few have considered using SuDS, although Ajibade *et al.* (2016) based their SuDS recommendations on a literature survey, and Ajibade and Tota-Maharaj (2018) constructed experimental models of filter drains and engineered wetlands that could be used in a refugee camp in the laboratory. In contrast, this article presents the design and actual construction of a SuDS management train in a refugee camp environment for the first time to the authors' knowledge. Funded under the 'Surface Water Drainage' challenge by the Humanitarian Innovation Fund, the aim of this article is to investigate the potential of using SuDS to address excess surface water flows and manage greywater in the challenging environment of a refugee camp. It shows how engagement with the refugee community led to the design and construction of a SuDS demonstration site at the Gawilan refugee camp, KRI.

Gawilan Refugee Camp, KRI

The specific camp (Gawilan) where SuDS was to be trialled was agreed with the UNHCR. It is located in Ninewah Governate, Al-Hamdaniya, KRI (location shown in Figure 2). The Gawilan refugee camp opened on 29 September 2013 with 2,810 individuals and a total planned capacity of 29,000. According to the UNHCR (2018), there were 8,607 people registered, mostly Kurdish, from Aleppo and Hassakeh in Syria.

Historically, the camp has had problems with flooding due to inadequate storm-water drainage and lack of greywater management. The latter was addressed with open V-shaped concrete channels where residents deposited

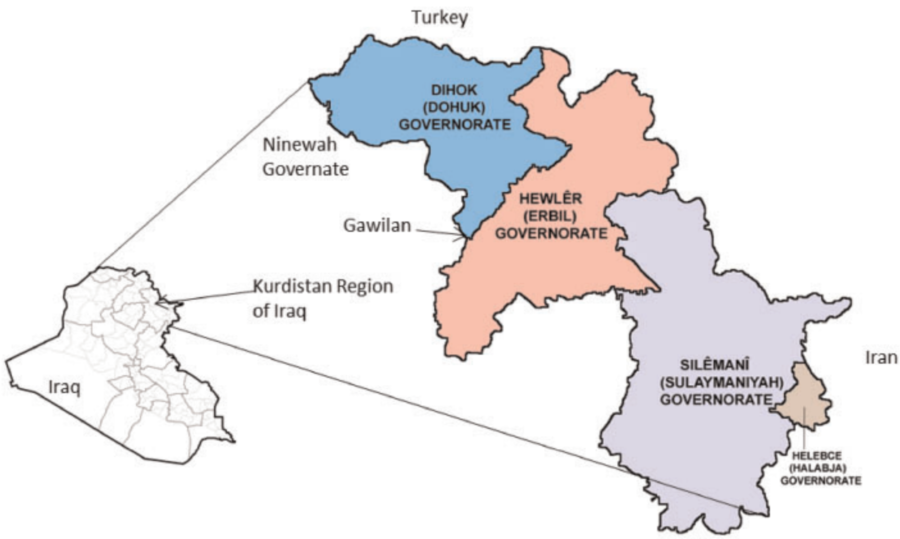

Figure 2
Location of Gawilan Refugee Camp

their greywater from personal bathing, clothes washing, food preparation, etc. The water carried in the concrete channels was discharged downstream of the camp, but within its boundary (see Figure 1). Greywater is produced constantly in the camp due to daily personal and food-preparation activities, so the flows are continuous and constitute a long-term problem. Flooding, on the other hand, is seasonal and therefore relatively short-term, mainly occurring between November and March in KRI. Flooding is far more problematic, as shown by the severe event that occurred between 22 and 23 November 2018, in which 28 people were killed and up to 250,000 had to leave their homes, including those living in refugee camps (OCHA 2018). Ninewah and Salah al-Din Governates were the worst affected.

Methodology

In consultation with camp officials and local management, an area of the camp was identified that had flooding and greywater-disposal problems. Figure 3 shows the area that was to be the site of a SuDS-demonstration management train, using native vegetation, local topography, infiltration, retention and slow conveyance (see Woods Ballard *et al*. 2015; Charlesworth and Booth 2017). The overall ambition was that no surface water would leave the site.

Three approaches were taken:

1. Composite water samples were taken at the three sites shown in Figure 3 to establish a before-construction baseline of contamination as well as that of

Figure 3
The site of the SuDS-demonstration Site at Gawilan
Numbers 1, 2 and 3 indicate where water samples were taken for analysis

flows and volumes; it is planned to monitor seasonally after construction has been completed to assess the performance of the system. All collection, analysis and interpretation of samples were undertaken as recommended by Rice *et al*. (2017). Thus, depending on the analyses to be conducted, samples were collected in clean polypropylene, clear-glass or brown-glass bottles. Temperature, pH, conductivity, salinity and total dissolved solids analyses were undertaken *in situ* by MapCom, KRI, using standard hand-held environmental probes. All of the metals were analysed using ICP-OES apart from mercury (Hg), which was measured using fluorescence spectrometry. Metal element and microbiological analyses were undertaken in the Czech Republic by ALS laboratory adhering to relevant USEPA and CSN standards. Tables 1 and 2 list the measured parameters. Permission had also been obtained locally to overfly the area with an unmanned aerial vehicle (UAV) to survey the site and monitor water flows.

2. In order to establish water usage at the household level, cleaning product use and subsequent greywater generation and management, as well as WASH

Table 1

Results of Chemical Analysis of Water Samples

Chemical analyte	World Bank Standard[1]	LOR	Sample 1	Sample 2	Sample 3 outflow
As	0.1	0.01	<0.01	<0.01	<0.01
Cr	0.1	0.02	0.0219	0.0126	0.013
Co	Nd	0.002	<0.002	<0.002	<0.002
Fe	3.5	0.05	3.16	1.39	2.4
Pb	0.1	0.01	<0.01	<0.01	<0.01
Mn	Nd	0.0005	0.123	0.505	0.333
Hg	0.01	0.02	<0.02	<0.02	<0.02
Ni	0.5	0.005	0.0144	<0.005	0.124
Zn	2.0	0.003	0.271	0.305	0.0518

Units = all mg l^{-1} except Hg = μg ml^{-1}. Nd, no data; [1]Ackerman *et al.* 1999; LOR, Limits of Reporting.

practices, a questionnaire was distributed to the 10 households that overlooked the proposed SuDS site (see Figure 3). Ethical procedures of Coventry University were followed at all stages of community engagement, with participants informed of the reason for the project, their part in it and that they could withdraw at any time. Of the 10 households included in the survey, none chose to withdraw. To ensure understanding, an interpreter accompanied the researchers at all times.

3. 'Technical solutions are available, but in the absence of adequate social and institutional planning and support, success is rare' (Winter 2015). Winter (2015) called this 'socially responsive SuDS' in which the community would have to be involved for such projects to succeed. This is also identified as a priority by Bastable and Russell (2013), who recommended the use of low-technological approaches that are sustainable and simple, and that involve the community and can be maintained by them. The Gawilan SuDS project thus engaged with the community from the beginning by undertaking walk-overs of the site with groups of residents, conducting workshops to explain the SuDS concept and also to encourage residents to be fully engaged in the design process (Figure 4). The identification of a potential site was in consultation with the UNHCR; several camps were visited and the Gawilan camp was proposed as it had an appropriately sized area of land below the camp that was unused and was currently problematic due to the accumulation of rubbish and wastewater. In order to properly design the SuDS-management train, site characteristics were determined as shown in Figure 4 to include soil properties, water quality, hydrological pathways, etc. A local plant inventory was also undertaken. UAV overflies of the site mapped wet areas and where vegetation had already established. To ensure explanations

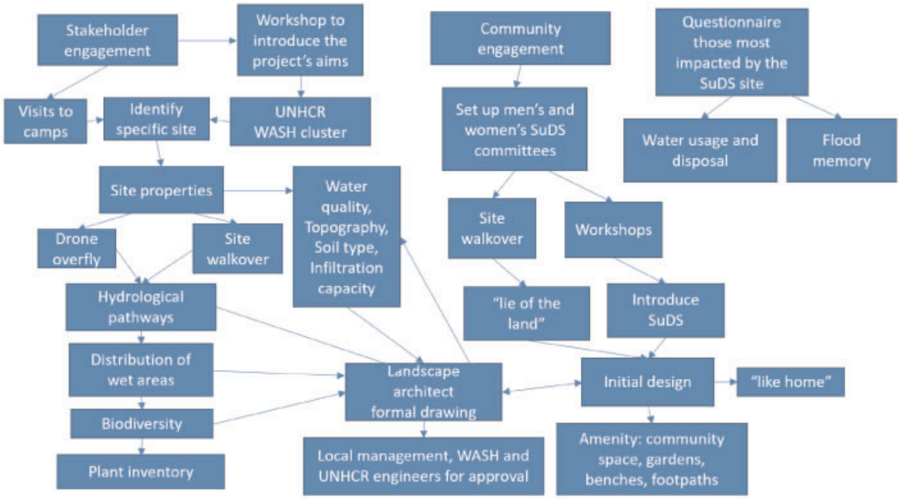

Figure 4
The Processes Undertaken to Identify a Suitable Site, Collect Information Required, Engage with the Community and Design the Site

were clear, an Arabic/English translator was engaged in the process and images of SuDS devices used to illustrate the concepts being introduced.

Results and Discussion

Water Quality

Water-quality analysis indicated little concern regarding many of the chemical parameters. As shown in Table 1, arsenic (As), cobalt (Co), lead (Pb) and Hg were all below the limits of reporting, with chromium (Cr), manganese (Mn), nickel (Ni), zinc (Zn) and iron (Fe) all below the threshold for World Bank environmental guidelines (Ackermann *et al.* 1999). These parameters are therefore not discussed any further.

However, there were concerning levels of 5 Day Biochemical Oxygen Demand (BOD5) and Chemical Oxygen Demand (COD) (Table 2), both of which were well above World Bank environmental guidelines (Ackermann *et al.* 1999), although, in comparison with the two inlets (Samples 1 and 2), both had reduced at the outflow. Bacterial counts were concerning at all three sampling sites; in comparison with USEPA (2015) and UK EA (n.d.) standards for bathing waters, bacterial counts exceeded all measures and were far worse than 'poor'. This may be an indication of blackwater being mixed into the wastewater streams, where it flowed in the open concrete channels through the camp and on into the environment beyond the camp boundary. Turbidity was also extremely high in comparison with other standards, which may be a reflection of the relatively high bacterial counts (Ackermann *et al.* 1999).

Table 2

Results of Physico-chemical and Biological Analysis of the Water Samples

Physical parameter (units)	World Bank standard[1]	LOR	Sample 1	Sample 2	Sample 3 outflow
Turbidity (NTU)		1	213	468	473
pH	6–9		7.68	8.67	7.99
EC (μS cm^{-1})			1,010	660	1,030
Salinity (ppt)			0.49	0.33	0.51
Temp (°C)			17.2	17.5	13.2
BOD5 (ppm)	50	1	353	470	59.1
COD (ppm)	250	5	668	966	202
Discharge (L s^{-1})			0.0204	0.0067	Nd
Bacteria	USEPA standard[2]	UK EA standard[3]			
Coliform bacteria (CFU/100 ml)	<33 30-day mean 61–151 single sample	Poor: >330	2,000	1,800	2,300
E. Coli (CFU/100 ml)	<126 30-day mean 235–575 single sample	Poor: >900	1,700	1,000	2,000

Nd, no data; [1]Ackerman *et al.* 1999; [2]USEPA (2015); [3]UK EA (n.d.); LOR, Limits of Reporting.

Table 3

Greywater Production and Reuse at the Household Level ($n = 10$)

	Percentage of households
Detergents used	
Bath soap	100
Washing powder	100
Dish washing liquid	100
Shampoo	100
How often clothes are washed	
Daily	10
Twice a week	70
Other	20
Volume of water used for each wash	
100–150 L	20
>150 L	80
How frequently family members take a shower	
Once daily	40
Less than once daily	60
Volume of water used per bath	
100–150 L	20
>150 L	80
Disposal of greywater	
Throw away	100
Water plants	40
Any other sources of water in addition to the usual ones	
Reuse of greywater	10
None	70
No answer	20

Questionnaire Survey Results

As shown in Table 3, all camp residents in the survey were able to access a toilet and shower, and had water for the kitchen; once used, the latter was either sent to an open concrete drain or underground via a pipe. Nine of the households had an inside tap and one had a roof tank. Of the 10 households surveyed, four collected some of their greywater to irrigate plants, but the remaining households disposed of it immediately after use. All of the households in the survey were aware of the drainage system, stating that it rarely overflowed—probably once a year—but did smell at least once a month. Most excess surface water was noticed in the winter, with one respondent noting its presence on the roads and drains at all times.

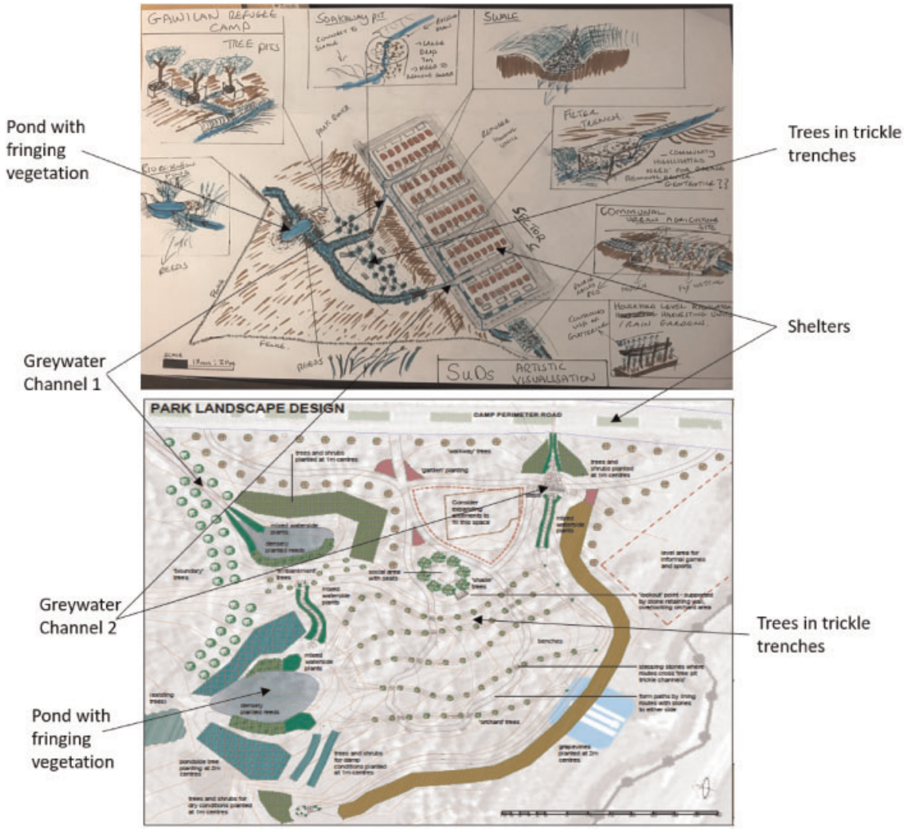

Figure 5
Comparing the Community's Design (Top) with that of the Landscape Architect's Drawing (Bottom)

Design of the SuDS-management Train

Both men's and women's SuDS committees were set up by the community. Separate site walkovers were held and a combined workshop of six women and four men discussed their initial thoughts on drainage, which were mainly focused on pipes and concrete. Following an introduction to the concept of SuDS, the committee was encouraged to design a management train based on sustainable principles. Interestingly, a common theme throughout the discussion was that the area should be 'like home'—that is, it should reflect where they had originally come from in Syria. They therefore asked for community spaces, footpaths around the site and an area for sport and also for gardening. Their design was drawn up by a professional architect and passed to the UNHCR, WASH and local management engineers for comment and approval. Figure 5 compares the design finally produced by the community

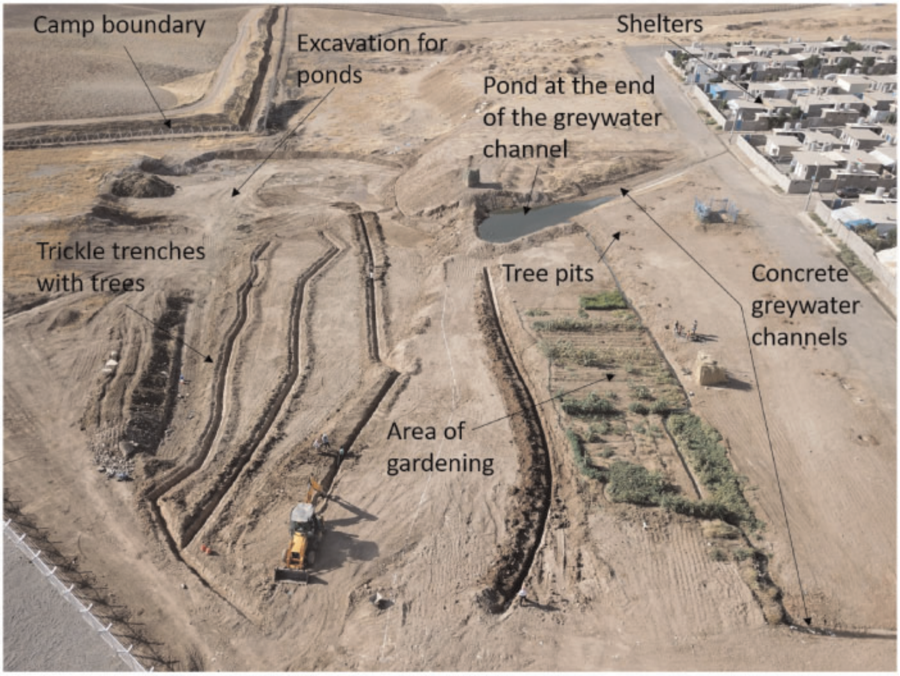

Figure 6
Aerial View of SuDS Site under Construction

with that of the landscape architect who interpreted it in terms of a SuDS-management train.

The final design included provision of ponds and wet areas, or blue infrastructure, and incorporates vegetation or green infrastructure in fringing native plantings and the many trees around the site. Two greywater channels entered the site. The channel to the west (greywater channel 1 in Figure 5) directed flow through a wetland/pond area to allow any solids to settle out and treat the water via biofiltration through the vegetation. Greywater channel 2 to the east of the site directed flow through a broken pavement of aggregates to trap solids carried in the greywater.

As shown in Figure 6, gardening had already begun in the area proposed for the SuDS demonstration area. This was not unsurprising given the importance of this activity to Syrians, who have historically created gardens (Millican *et al*. 2018). This area was therefore left alone in the subsequent SuDS design. Construction began in November 2018. To date, 2,000 trees have been planted around the site, in the trickle trenches and in tree pits. Grapevines have also been planted in the south of the site and the landscaping is almost complete.

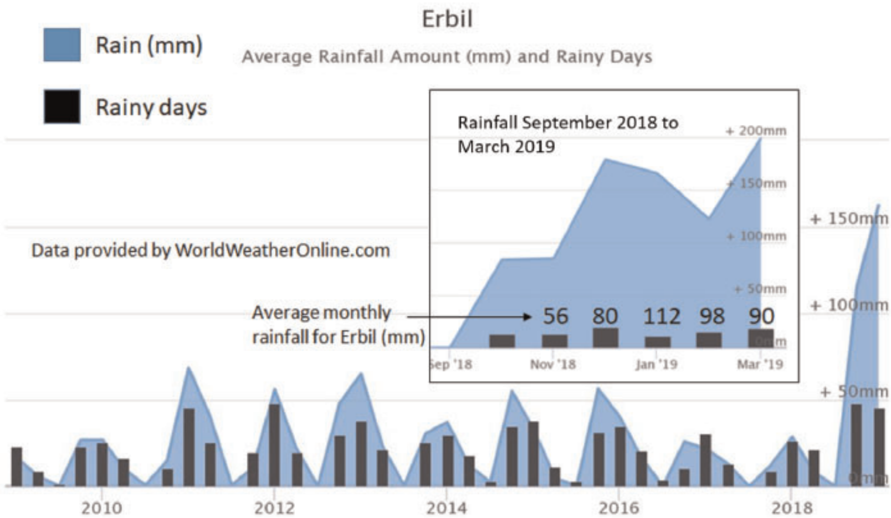

Figure 7
Yearly Rainfall Amounts (mm) and Rain Days for Erbil from 2010 to 2019 and (Inset) Focus on September 2018 to March 2019 with Average Monthly Rainfall (mm) and Rain Days

Modified from https://www.worldweatheronline.com.

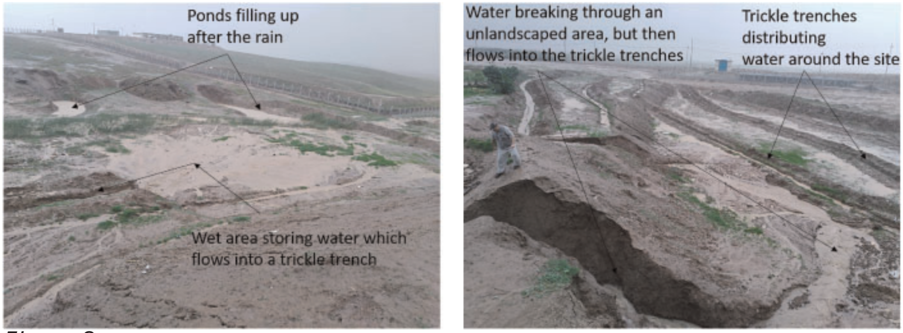

Figure 8
The SuDs-demonstration Site during the Floods of 22 and 23 November 2018

Flooding from 22–23 November 2018 to March 2019

As mentioned in the introduction, KRI was initially struck by extensive and severe flooding due to a storm event on 22–23 November 2018. Figure 7 illustrates the severity of the storms, which lasted until the end of March 2019, where amounts were twice the average expected in Erbil during the winter; the previous highest rainfall since 2010 was about 70 mm in 2011.

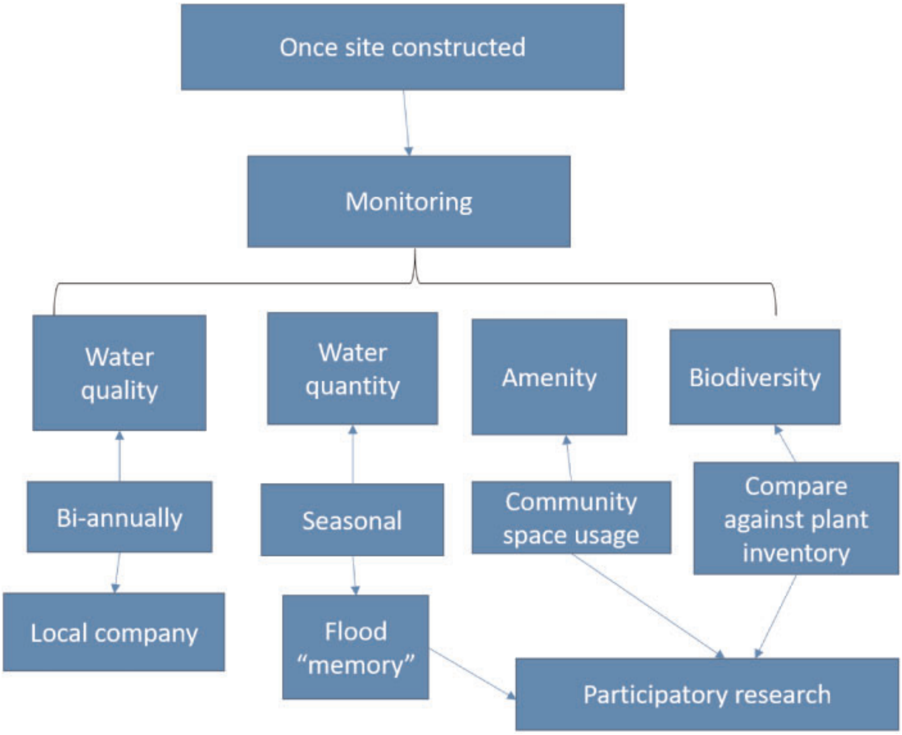

Figure 9
Future Plans to Monitor the Performance of the Site Based on the SuDS Square (Woods Ballard *et al.* 2015)

However, even though the SuDS demonstration site was incomplete, the devices behaved in the way in which they were designed: the trickle trenches moved the excess water around the site, slowing the flow and allowing time for it to infiltrate into the ground; the ponds filled and stored the water (Figure 8).

It is likely, therefore, that, once the site is fully complete, it will perform even better. The following section given details of plans for the future.

Plans for the Future

Once any damage from the flooding has been addressed and the site is completed, it will be regularly monitored according to the SuDS square (Woods Ballard *et al*. 2015). A focus will be on reduction in water quantity, with the ambition that no surface water will leave the site; improvement in water quality, in particular a reduction in bacteria; and the provision of amenities and providing space for biodiversity, as shown in Figure 9. Collecting this information will mainly be focused on Participatory Action Research with the community, who will be trained to monitor the use of amenities designed into the site, such as whether residents use the footpaths, community area, sports pitch and gardening. Biodiversity will also be monitored in this way, but water quality will be monitored by the same company as before.

Conclusions

This project has shown that a management train of sustainable drainage devices can be designed and built by the community in a humanitarian context. Once the technique had been explained, residents engaged with the potential of the site to remind them of their home: Syria. They were therefore proactive in its design and construction, which can instil a feeling of ownership in the site. Future plans include training residents in the operation and maintenance of the site to ensure its sustainability. By including soft green (vegetation) and blue infrastructure (open water), if the site is dismantled, the trees etc. can be left *in situ*, making the NGOs' exit plan less onerous and expensive.

The almost complete site was severely challenged by an intense storm event at the end of November 2018, but performed in the way that was expected, by slowing the flow of water and reducing its volume, showing its potential to be utilized in similar sites worldwide.

There was some concern over water quality, in particular turbidity and the presence of bacteria in the water entering the site, and this will be monitored as well as other biological and physico-chemical properties to determine whether there is improvement in water quality over time as the site matures.

Principally, however, the site has been developed to demonstrate the concept of SuDS in order to encourage the inclusion of drainage in the future when planning and constructing refugee and IDPs camps. Whilst it is still at the early stages of development, the initial signs are clear that managing storm and greywater together using the SuDS approach is a genuine proposition in these challenging environments.

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