Nature-based-solution for flooding, pollution and droughts of Haigh Beck

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Abstract

A nature-based solution (NBS) is proposed to deal with the Haigh-Beck surface-water flooding in the Apperley Bridge neighbourhood close to the River Aire, which is lying between the river and Leeds-Liverpool canal. The solution consists of separating the beck flood waters from the CSO/sewage-overflow waters, letting the then clean beck waters flow into the canal, such that a beck-flood can never reach the low-lying neighbourhood, and diverting the CSO-water via a closed 60cm diameter pipeline to the Carr-Beck-canal overflow through extra debris filters. Additional rewilding of the beck further enhances the water quality and avoiding construction, operation and maintenance of a pumping station near the river reduces our carbon footprint and localized pollution by such an industrial station. The NBS thus prevents/limits drought, pollution as well as increased rainfall threats and offers more robust protection against uncertainties/unknowns involved in extreme events.

Background, overview and challenges

Haigh Beck is a beck in the city of Bradford, UK. Haigh Beck streams from circa 150m height above sea level near the Idle Cricket Club (at what-3-words location: *drives.prices.miles* [0][1]) to its mouth or confluence with the River Aire (at 3-words location: *among.plant.dogs*) at circa 50m above sea level. Haigh Beck has a birds-eye-view-estimated length of circa 1500m, see Figs. 1 and 2. On older maps from circa 1903 and 1914, displayed in Fig. 3, it may be discerned that its source seems to lie further upstream from this cricket club, likely at "Springfield". One observes that Haigh Beck ran past numerous mills, with several of those mills remaining to date as appartement blocks. The beck runs partially underground in culverts: a long one from Old Park Road (3-words location: *cost.dish.crowned*) to just NE of Robin Mills (at 3-words location: *maker.eagles.royal*) and a second long one from the Leeds-Liverpool canal (at 3-words location: *maps.spins.vibrate*) to its confluence with the River Aire next to Harrogate Road (at 3-words location: *among.plant.dogs*). From its re-emergence NE of Robin Mills to the Leeds-Liverpool canal it runs mainly in an open, concrete channel. At that location near Robin Mills, a Combined-Sewer-Overflow (CSO), with an outflow pipe of circa 55cm to 60cm in diameter, flows into Haigh Beck, see the photo in Fig. 4 (at 3-words location: *maker.eagles.royal*).

At the Dyehouse Mill near the canal (at 3-words location: *divide.undulation.jets*), there is a an old splitter-gate (next to the existing Dyehouse Mill marked in Fig. 3; at 3-words location: *riots.total.handle*), dividing the combined CSO-beck flow:

(a) either into an open channel of circa 20m to near the canal and then in a culvert under the Leeds-Liverpool canal and further underground to its mouth into the River Aire, or
(b) via a wider open channel-bed into the Leeds-Liverpool canal, or via both routes.

The splitter-gate is locked and seems to be operated by the Canal-and-River Trust.

Intermittently, beck water is adjusted to flow into the canal as one can sometimes observe from the canal or its tow path. Intermittently, the CSO flows into the beck. At high levels of CSO-beck waters, the splitter-gate cannot handle the flow rate and CSO-beck waters (over)flow into both culvert and canal (as shown in footage on 20-10-2022 on the Facebook page of Friends-of-Bradford's-Becks (FoBB) and OB's *YouTube* channel [4]).

Since 1903, the following housing developments emerged:

i. next to the River Aire between the canal and river with Fig. 3 revealing older dwellings and a hotel at this location; and,

[1] References are found near the end of this document and indicated by [0], [1], etc.

ii. the 1980's/1990's Apperley Bridge neighbourhood South of the Leeds-Liverpool canal, including the converted mills (see Fig. 3 with the named Dyehouse Mill, Valley Mill and Canal Mills).

Around 2000, local flooding of Haigh Beck in the late '90's over and at the current Tenterfields road, involving various houses between the beck and the Apperley Bridge marina, was solved by building a modern culvert (at 3-words location: *roofs.lines.circle*) with grating holding back debris (source: online newspaper article [5]). The debris has been regularly cleared by council, as well as by local citizens who noticed it is or was not cleared sufficiently often.

The houses along the entire culvert North of the canal have faced intermittent flooding of cellars and gardens with polluted CSO-beck waters over two to seven (or more) decades due to culvert collapse, blockages and such. Also, the outflow of CSO-beck waters into the river is blocked at higher River Aire levels, due to a valve which automatically closes, even at intermediately high River Aire levels. In that case the houses along the beck culvert can flood from the combined CSO and beck waters without the River Aire levels flooding these properties. The reason is that the CSO-beck waters have sunk to a level that is too low relative to some river levels once the beck has crossed the Leeds-Liverpool canal. An obvious solution is to let clean beck waters flow into the canal, such that these do not reach levels too low to require pumping. The Leeds-Liverpool canal has several wide overflows towards the river to deal with excess canal water, notably one circa 200m east of Dyehouse Mill (i.e. at 3-words location: *riots.total.handle*), where it joins the Carr-Beck culvert under the canal, and circa 3 miles downstream along the Leeds-Liverpool canal at Rodley, and a further 4.5 miles downstream at the Newlay Three Rise Locks at Brambley. Several instances of surface flooding North of the canal in Apperley Bridge have been filmed and reported since 2020. Both in person and online, locals have reported decades of intermittent surface flooding by CSO-beck waters, again noting that surface flooding can occur when intermediate-high River Aire water levels close off or block beck flow into the River Aire.

In summary, the following challenges posed by the combined CSO-beck flow have arisen in the last few decades:

A. Surface-water CSO-beck flooding along the Haigh Beck culvert in the Apperley Bridge neighbourhood between canal and river, for which emergency services have been called in numerous times to pump away the polluted CSO-beck flood waters. A new pumping station has recently (2022- January 2023) been proposed with storage space and additional culverts, given that new FAS-II flood-defence walls along the River Aire will further trap CSO-beck waters and induce flooding from within these new flood-defence walls [1]. Unresolved issue.
B. Pollution, odours and rat infestations in the neighbourhood South of the canal and the neighbourhood North of the canal along the Haigh Beck, due to and downstream of the Haigh Beck CSO. Unresolved issue.
C. Climate-change induced intense rainfall causing future flooding in the neighbourhood North of the canal, dealing with "*known unknowns and unknown unknowns*" [6,7]. Unresolved issue.
D. Drought in the canal during (climate-change enhanced) drought periods. Unresolved issue.
E. Deposition of solid debris, including wet wipes, sanitary pads and such along the beck downstream of the CSO. Such solid debris over years is found in heaps next to the beck culvert under Tenterfields Road (at 3-words location: *roofs.lines.circle*). Unresolved issue.
F. The short, somewhat hidden circa 20-m open channel of Haigh Beck along Dyehouse Mill is a danger to life since animals and humans can fall in and be sucked into the culvert under the canal during high flow rates (see 20-10-2022 footage on OB's *YouTube* channel [4]), since it is uncovered. Unresolved issue.
G. Due to both the CSO and the beck flowing in a concrete channel, natural life within the beck is minimal downstream of the CSO flowing into Haigh Beck. Further issues hampering natural life are the strong ochre-content of the beck (see Fig. 5) and known and unknown storm drains with

misconnections. One storm drain with a misconnection flows into Haigh Beck in the beck South of Old Park Road (roughly at 3-words location: *loaded.evenly.them*), see Fig. 6. Unresolved issue.

Proposed nature-based solution (NBS)

Challenges A-to-G can be readily resolved by combining two measures, based on the main principle that CSO-beck waters should not enter the low-lying flood-prone area between canal and river, in combination with rewilding the beck:

(i) By avoiding the CSO to overflow into the beck via the construction of a separate declined pipeline (diameter 55cm to 60cm) from the current CSO to the canal and then via another declined pipeline (diameter 55cm to 60cm) leading CSO waters along (in/above) the South side of the canal till under and past Harrogate road and then along (in/above or onshore-next-to) the canal to the Carr-Beck overflow (at 3-words location: *party.jazzy.grew*); and,

(ii) By letting the new clean, no longer CSO-polluted, Haigh Beck waters flow into the canal, using the existing wide channel and noting that excess canal water has existing and automatic overflows in Apperley Bridge and Rodley to the River Aire, and downstream to the next canal segment.

(iii) By rewilding of the beck at least at two spots downstream of the current CSO:
(a) Wildlife in Haigh Beck downstream of the CSO can be enhanced by breaking through the vertical concrete side-wall on the NW side just upstream of the Tenterfield grating at the depression on the park side (i.e., at 3-words location: *equal.frame.quit*). Meandering can be enhanced by placing obstacles in the flow. By preserving the East wall (and bottom) of the concrete channel, channel erosion on that side will be prevented. Similarly, erosion on the Western, park side can be avoided by introducing stone shores or steps, thus limiting erosion due to dog access. Such reintroduction of a meandering beck also will increase flood-water storage. Keeping one side of the concrete wall prevents erosion of the steep slopes.
(b) Opening the shores on the East side of the beck into the low-lying area between the current CSO exit and the path via one dam or more leaky dams in the larger private-property area will enhance wild-life and flood storage (i.e., at 3-words location: *sides.violin.undulation*).

Remarks:

- Note that solution (i)-(ii) exclusively uses gravity to drive the flows, naturally, with no pumping station required, using the design principle that the CSO-beck water should never enter the low-lying area between canal and river which often requires pumping or causes local surface flooding. The solution (i)-(ii) would have been easiest to implement before the neighbourhoods at the river and just south of the canal were built circa 70 and 30 years ago[2]. Avoiding construction, operation and maintenance of a pumping station near the River Aire reduces our carbon footprint and localized pollution by such an industrial station.
- Note that another proposed solution by Mott MacDonald/Bradford City Council involving a pumping station, storage tanks and more culverts [1] near the River Aire requires long-term maintenance and energy use, and only deals with challenge A, and not with any of the other identified challenges B-to-G. The solution of Mott MacDonalds/Bradford City Council thus appears to be more expensive, involves more maintenance, and is less sustainable and climate-change resilient, and is less able to deal with "*known and unknown unknowns*" [6,7]. It does not use a holistic approach considering the entire Haigh-Beck catchment, in contrast

[2] The suggested solution was inspired by Robert Hellawell's comment that in modern neighbourhood a concrete channel for combined CSO-beck flows would no longer be permitted.

to the proposed NBS-approach, which builds on earlier and reported suggestions made in 2021.

- The pumping station is mainly required because the high volume of CSO-beck waters reaching the low-lying area between canal and river, with flows over $1m^3/s$ mentioned for two hours [1], which equals a volume or reservoir of circa $85x85x1m^3$ after two hours.

(iv) To deal with potential siltation of the canal by inflowing beck waters, a siltation screen can be placed, either in the canal or in the wide inflow channel, or both, such as to avoid or limit dredging of the main canal channel.

CSO-pipeline construction options and estimates of construction timeline

Various options for the CSO-pipeline to the canal and along the South side of the canal to the Carr-Beck overflow can be considered (see Fig. 7, red line indicating the pipeline):

- South of the path from the CSO to the path a pipe of matching diameter is dug into the soil on the East side of the beck, crosses the beck with its culvert under the path and continues between beck and path dug into the soil toward the Tenterfields culvert.
- Alternatively, the pipe gets laid under and into the floor of the beck, of which there are examples in other cities.
- At the culvert under Tenterfields road (at 3-words location: *equal.frame.quit*) the pipe is put into the existing culvert, i.e. within the pipe separated from the beck waters, since it has been designed to have ample space for both beck and CSO waters.
- Depending on the size of the culvert to the splitter-gate the pipe continues in the culvert or a separate trench is dug along the edge of the car park for the CSO pipe.
- The splitter-gate is modernised with the pipe continuing to the canal using the space of the current open channel directly adjacent to Dyehouse Mill.
- The existing culvert at Dyehouse Mill and its passage under the canal are closed off.
- The pipe continues at the edge of the canal till past Harrogate Road where it either is cut through the canal border and continues in a trench dug into the existing green strip or it continues along the edge of the canal to the Carr-Beck overflow, to finish into Carr Beck with its intermittent Greengates-CSO waters.
- There are several pipe options: concrete, steel or light-weight plastic/PVC.
- The entire pipeline is laid under a (slight) decline such that no pumping station is required since the flow is thus gravity driven.
- Clean-up consist of water being flushed through the pipes, driven by gravity. Additional filtering or screening at the Carr-Beck overflow can be used to catch solids, since there is some space with a larger vertical drop. Note that the current CSO does regularly release solids, as evidenced by heaps of debris in the concrete beck channel (e.g., see Fig. 4), next to the channel at the Tenterfields culvert-grating (at 3-words location: *equal.frame.quit*), the entire concrete channel and in the existing wider beck channel flowing into the canal at Dyehouse Mill.

21st-century future extensions

(a) Modernisation of the sewage network in Haigh Beck catchment by splitting rainfall drainage from sewage drainage will diminish or eliminate CSO releases. An emergency CSO will remain necessary to avoid sewage entering homes in emergency situations but the latter emergencies can be reduced.

(b) BBC Futures highlights novel yet already existing treatments of sewage at in-situ micro-plants, which could become a way of dealing with sewage and is already in use in some various cities [3].

Questions

- There do not seem to be data or estimates thereof made available on the volume of beck water and the volume of CSO-water released during higher water levels.
- Data of volume estimates of each release of the Haigh Beck/Stockwell CSO over the years are required, e.g. in 2021 and 2022 have not been made available by Yorkshire Water, despite FOI requests and despite Yorkshire Water's open data policy. Such data are relevant to estimate expected CSO flow rates, in order to use these in any design.
- Total existing combined CSO-beck water flow rates are stated in the Mott-MacDonald/Bradford City approach at a maximum of 1.53 m^3/s with CSO-beck discharges above 1.0m^3/s for over two hours in certain scenarios, with a peak flow pump action at 0.245 m^3/s required, possibly over 5 to 10 hours [1]. The pumps are also required to alleviate locally trapped rainfall amounts.
- Note that two hours of flooding at 1.0m^3/s concerns a volume of 7200 m^3 (2 hours being 2x3600s), equating to a lake or reservoir of circa 85x85x1m^3. Note that the quoted [1] 10 hours of pumping at 0.245 m^3/s concerns a volume of 8820m^3 (10 hours being 36000s), equating to a lake or reservoir of circa 94x94x1m^3. These are substantial volumes caused by the CSO-beck water flowing into the area between canal and river during intense rainfall events, which fact triggered the NBS-approach principally avoiding those waters to flow into that low-lying area and hence avoid pumping to be required. (The data of Table 3 in [1]b should preferably be displayed graphically and the cumulative volume per case calculated, for clarity's sake.)

References

[0] https://what3words.com/

[1] (a) Main site with planning documents: https://planning.bradford.gov.uk/online-applications/applicationDetails.do?activeTab=documents&keyVal=RJOL49DHGQQ00

(b) In particular document (Table 3):
https://planning.bradford.gov.uk/online-applications/files/D647059F07FAA8715E84FCCB1018042E/pdf/21_00249_SUB04-COMPARISON_OF_POST_SCHEME_AND_BASELINE_PEAK_FLOOD_LEVELS-7134928.pdf
mentions engineered solution with pumps, while the NBS-solution avoids the entry of CSO and beck waters South of the canal altogether.

[2] Friends of Bradford Beck (FoBB): https://www.facebook.com/groups/BradfordsBecks

[3] The secret science of sewage. https://www.youtube.com/watch?v=D6HnBQ-qJMA

[4] YouTube channel: https://www.youtube.com/user/onnobokhove

[5] https://www.thetelegraphandargus.co.uk/news/8065424.estate-may-see-breakthrough-in-long-battle/

[6] Poortvliet et al. 2019: On the communication of statistical information about uncertainty in flood risk management.
https://www.sciencedirect.com/science/article/abs/pii/S0925753518309755

[7] Di Baldasarrre et al. 2014: On the communication of statistical information about uncertainty in flood risk management.
https://www.tandfonline.com/doi/full/10.1080/02626667.2015.1091460

Supporting figures

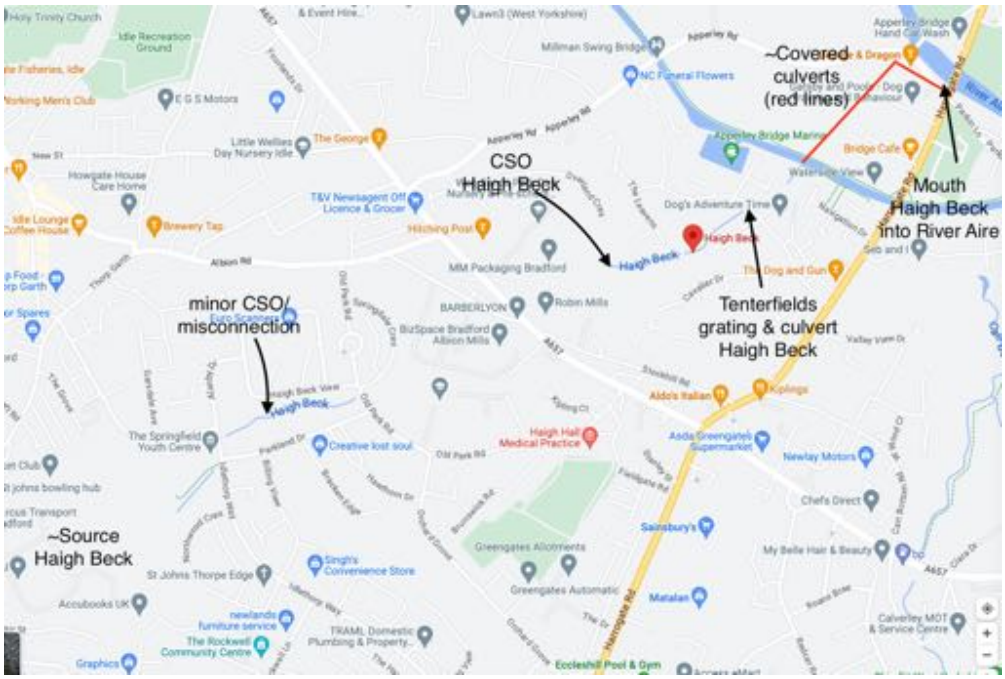

Fig. 1 Haigh-Beck catchment from Google maps annotated with indicated locations.

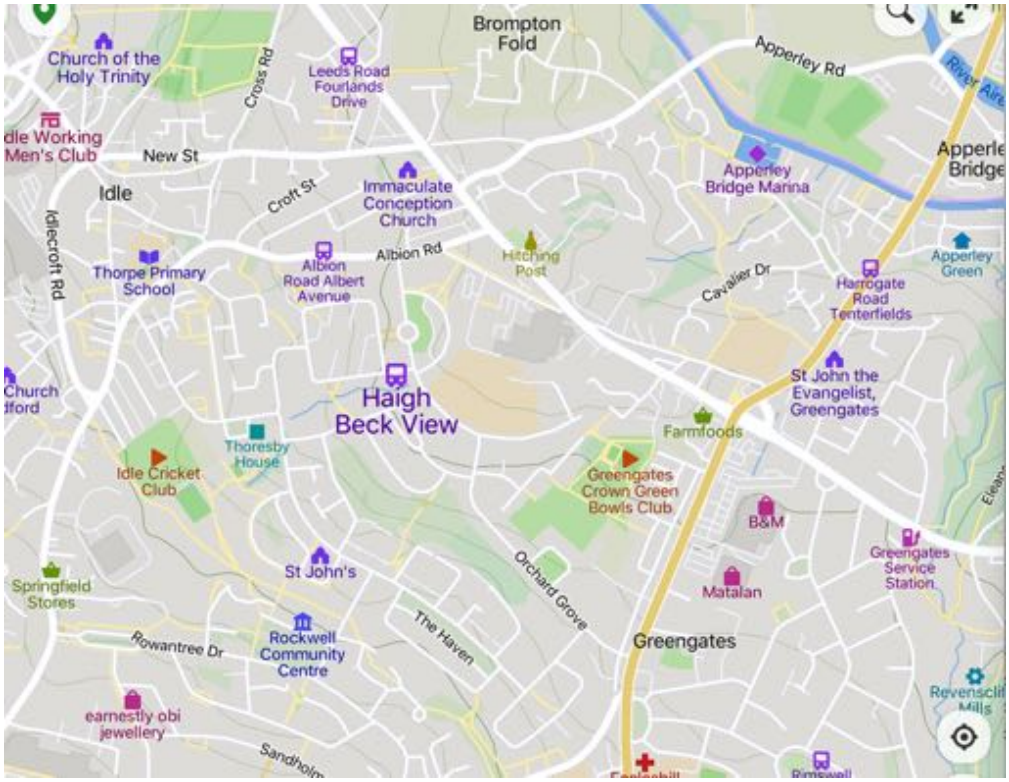

Fig. 2. Haigh-Beck catchment on Mapcarta. Note that Haigh Beck streams from circa 150m height above sea level near the Idle Cricket Club to its mouth or outflow into the River Aire at circa 50m above sea level with a birds-eye-view-estimate length of circa 1500m. The 150m, 100m, 50m contour levels can be found at: https://mapcarta.com/N496738883

a)

b)

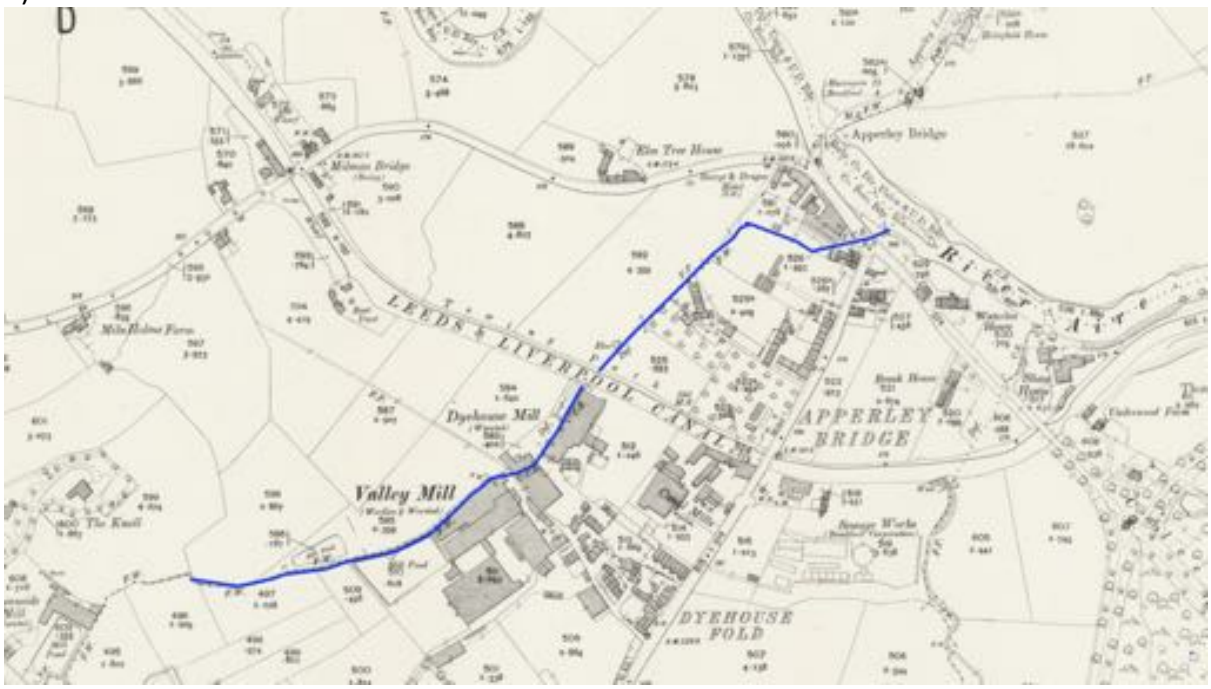

Fig. 3. Haigh-Beck area: a) 1906-1909 https://maps.nls.uk/view/100946516 and b) 1914 with beck highlighted in blue: https://maps.nls.uk/geo/explore/#zoom=17.8&lat=53.83434&lon=-1.71268&layers=168&b=1

Fig. 4. Combined-sewer-overflow (CSO) permit number 1862 of Haigh Beck with CSO-debris (rags and wet wipes) on the foreground. "Stock Hill Fold No 2 Cso (Yorkshire Water)"; "In 2021, this sewer storm overflow spilled 45 times for a total of 174 hours, discharging into the Haigh Beck"; "In 2022, this sewer storm overflow spilled 36 times for a total of 64.92 hours, discharging into the Haigh Beck", sewage map: https://theriverstrust.org/sewage-map Photo OB 08-04-2023.

Fig. 5. Ochre-coloured waters of Haigh Beck near the CSO (at 3-words location: *maker.eagles.royal*)). The low water quality on 08-04-2023 was apparent since "*the absence of certain pollution sensitive families of aquatic invertebrates, such as upwinged flies, and the abundance of invertebrates which are more pollution tolerant, such as freshwater hoglouse, is indicative of low water quality*"; in addition: "*the ochre found in the stream, whilst naturally occurring, is also a serious pollutant and will be detrimental to the water quality*" (Robert Hellawell). Photo OB 08-04-2023.

Fig. 6. Surface-water storm drain with misconnection into Haigh Beck, North of Old Park Road (at 3-words location: loaded.evenly.them) during a dry day. "*It is [likely] a surface-water drain into which a sink, shower, bath or dishwasher has been misconnected: http://www.connectright.org.uk/*" (Robert Hellawell). Photo courtesy: Barney Lerner, taken during the FoBB clean-up on 08-04-2023.

Fig. 7. Haigh Beck ~1900 course overlaid in blue and prospective CSO-pipelines overlaid in red on google maps.