Exploring Greater Manchester

a fieldwork guide

MANCHESTER GEOGRAPHICAL SOCIETY

Series editors: Paul Hindle
and Cathy Delaney

Urban floodplains and slopes: the human impact on the environment in the built-up area

Ian Douglas

University of Manchester

ian.douglas@manchester.ac.uk

Aims: This excursion covers the Mersey Valley through south Manchester from Didsbury to Urmston, the Manchester Ship Canal and the Bridgewater Canal up to Worsley and then the River Irwell at Lower Kersal and Salford Quays. Originally, in the late 1980s, it was a first year University student field trip by bus led by the author to encourage students to look at the multitude of ways the impact of human activities, especially those in the urban environment affected the hydrological cycle, water quality, the stability of river channels and the vegetation of areas with little n human intervention. This present excursion may be made by car, or bus, but could also be done as separate walks: along the River Mersey; from the Barton swing aqueduct to Worsley; around Lower Kersal and The Cliff in Salford; and around Salford Quays and their dock basins.

Because it was a student excursion, I have retained exercises to be done at four of the stops in the hope they will encourage students and others to look at things for themselves and to think more deeply about the issues raised at the different stops. I hope this may also be helpful to A-level students studying the urban environment.

Four main themes are addressed in this excursion:

1: How geomorphological processes can be intensified by human activity and can disrupt built domestic and utility infrastructure;
2: Urban hydrology and the impact of urban development on rivers, including flooding and water pollution;
3: The value of urban green infrastructure and its contribution to managing environment change by implementing nature-based solution;
4: How invasive species threaten urban ecosystems and create problems for public greenspace, river and canal management.

Starting point: Millgate Lane, Didsbury.

Finishing Point: The Lowry Centre, Salford Quays.

Estimated time: 3-4 hours by car, or 6+ hours in a bus with students (this excursion is based on a student field trip first organised in the late 1980s).

Related Walks: This excursion links to six urban walks in south Manchester: in the Manchester Geographical Society's 'Exploring Greater Manchester' Series:

- Discovering history, spiritual peace and tranquillity in Didsbury: West Didsbury and Albert Park (PDF, 8670KB).
- Chorlton-cum-Hardy: From village to lively, diverse suburban centre in 150 years. (PDF, 6000KB).
- Discovering history and conservation in East Didsbury. (PDF, 3440KB)
- Sale Water Park, the River Mersey and Bridgewater Canal Aqueduct (PDF, 7930KB).
- The Mersey Valley from Didsbury to Chorlton Water Park and Jackson's Boat: transformed landscapes in an urban green/blue corridor (PDF, 9860KB).
- Stretford Meadows and Urmston Meadows: landscapes of the Anthropocene (PDF, 5790KB).

All are available at: https://www.mangeogsoc.org.uk/publications/exploring-greater-manchester/

Maps: Geographers' Greater Manchester A-Z Street Atlas (4.25 inches to 1 mile), Ordnance Survey Explorer (1:25,000) no 277 Manchester and Salford; Google Maps.

Date of Last Revision: 21 November 2023.

Introduction: the four main themes explained

This excursion traverses varied urban landscapes and greenspaces from the golf courses, sports grounds and water parks along the Mersey from Didsbury to Urmston, the former industrial landscapes around Trafford Park, Patricroft and Worsley, the low-lying housing and former horse racing track in the meanders of the lower Irwell, evidence of disappeared tram lines, and the second life of the former Salford Docks (Figure 1).

1: Geomorphological processes and the urban environment

Greater Manchester sits in a young landscape in which the legacies of glaciations, river development, human settlement, including extraction of materials, river regulation, farm and urban drainage, and construction in inappropriate places, have created or accentuated issues of landscape instability through migrating meanders, sliding cliffs and subsidence.

Figure 1: Generalised map of the route, showing the suggested stops.

In this part of Britain, the retreat of the Irish Sea ice glacier, part of the British-Irish ice sheet, at the end of the last glaciation left a depositional landscape of material dropped by the ice, periglacial slope deposits and river sands and gravels across which rivers such as the Mersey and Irwell had to establish new courses. On the Cheshire plain, the antecedents of the modern rivers meandered among the varied sediments. Those meandering channels still exist today, the Bollin and Dane being good examples (Hooke, 1996). The Greater Manchester rivers began to be embanked and constrained in the 17th century and in most of the county are now fully embanked, except downstream of Ashton Weir on the Mersey, as will be seen on this excursion. Embankments constrain the natural tendency for a river to deposit some is load on the inside of meander bends and acquire more sediment by eroding the outer bank of the meander. Thus, when a river reaches a zone of unprotected banks, it has extra energy to erode the soft banks rapidly. This will be seen at the Urmston meander of the River Mersey.

Another legacy of glaciations are major sequences of fluvioglacial deposits, where glacial boulder clays were dissected by meltwater channels carrying silt and sand. Where rivers have carved channels through such material valley side slopes may have many seepages where water flows out of former meltwater channels, carrying the fine silt and sand. Sometimes, the valley side slopes are mantled by postglacial periglacial deposits, seepages from the fluvioglacial material may move downslope beneath those periglacial materials which then can slide, sometimes affecting housing developments, such as at Ewood Bridge in the upper Irwell valley above Rawtenstall (Douglas, 1985b, Lee and Giles, 2020). The consequences of water seepage through fluvioglacial deposits will be seen at The Cliff on this excursion.

The consequences of human disturbance of the ground must be added to this natural instability. Just south of Greater Manchester many instances of subsidence caused by salt mining occur, such as around Northwich and along the railway between Sandbach and Crewe. In Greater Manchester coal mining subsidence has been widespread north of the Mersey, Pennington Flash being an excellent example of a mining subsidence lake. Elsewhere, the draining of the peat moss lands has lowered the ground surface, many older farmhouses around Chat Moss for example are lower than road levels.

2: Urban hydrology and the impact of urban development on rivers

When the land is covered with hard surfaces in towns and cities, less rainfall soaks into the ground and much moves quickly to storm drain and rivers. Over much of Greater Manchester the rainwater from the streets enters combined sewers that also carry wastewater from homes and other buildings. The net result is more storm rain entering rivers more quickly and sometimes also more pollutants being washes into local streams. Such modification of runoff to rivers (Figure 2) produces changes in flood behaviour, sometimes leading to local flash flooding and at other times to widespread flooding across the region.

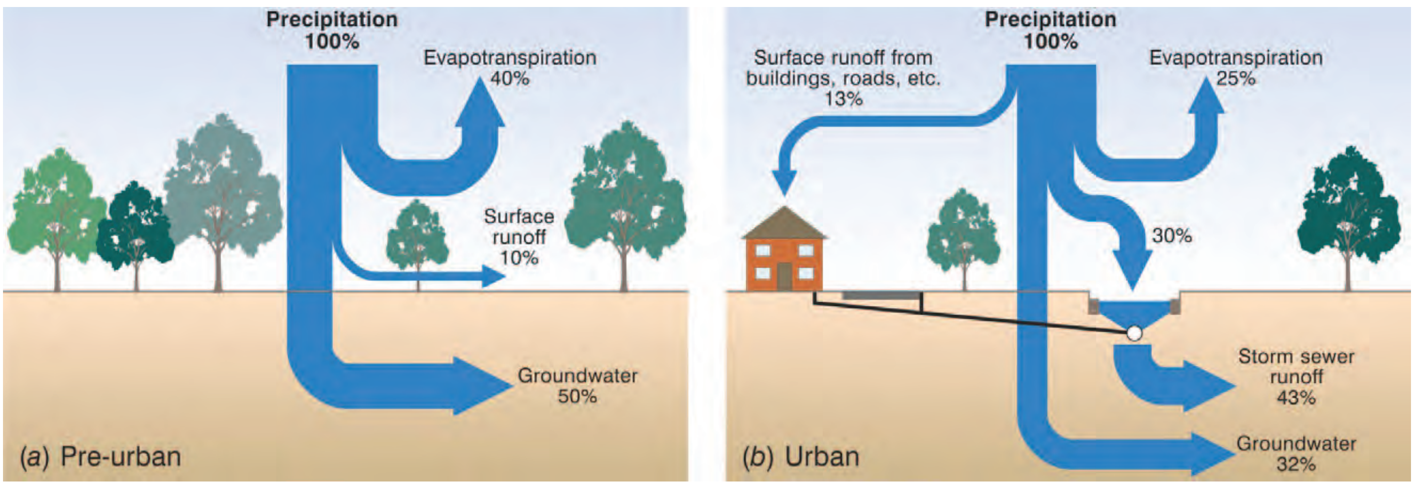

Figure 2: The changes to water flow paths caused by urban development: note less evaporation from fewer green areas and more surface runoff from paved and roofed areas.

To cope with the more frequent major flooding associated with global heating and changes in storm magnitudes and frequency, the key task is MAKING SPACE FOR WATER which is shown on this excursion by both the Didsbury Flood Basin with its inlet weir in Didsbury and outlet weir at Northenden and the flood basins on the River Irwell at Lower Kersal in Salford. The flood basin is part of a series of control structures and interventions in the Mersey basin that slow down the flow of water and reduce the peak stormwater discharge of the river. The main components are: treatment of moorland streams; potential to store storm runoff in upland water-supply reservoirs; storm runoff tanks at combined sewer overflow points along the rivers; flood defence embankments, and flood basins (Figure 3).

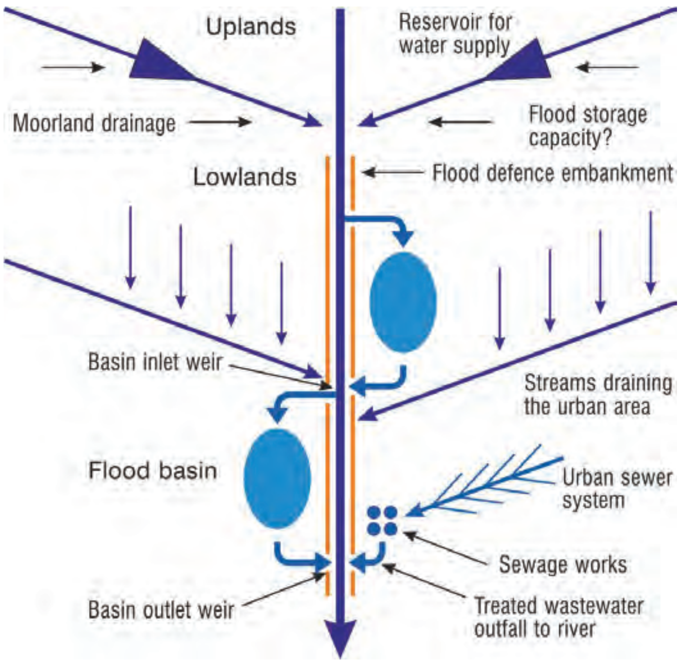

Figure 3: Some of the components of the Mersey and Irwell catchments that must be considered when making space for water.

The climate crisis and flooding on Manchester's rivers

The current global heating is testing our ability to cope with flooding. For centuries the River Mersey in Manchester and Trafford has been embanked. Landowners built river embankments to prevent the river flooding their lands. The last major improvement to the embankments in this part of the River Mersey occurred in the 1970s when the M60 motorway was built and the Didsbury flood basin and, further downstream, Sale Water Park were created. By 2009 there were over 67 km of raised flood defences in the Upper Mersey catchment management area, which includes the headwaters drained by the Tame and Goyt, the urbanised region from Stockport to the Manchester Ship Canal and the sectors drained by the Sinderland Brook and Bollin separately to the Ship Canal. The three Upper Mersey flood storage areas are at Sale and Didsbury on the Mersey and at Timperley on the Sinderland Brook (Environment Agency, 2009).

While an embankment is an obvious defence of a particular area, it does not reduce the overall flood problem, it merely pushes the floodwater to somewhere else downstream. It shifts the problem onto to someone else. Flood mitigation must consider the river catchment as a whole and to make space for water (Figure 3). The upland headwaters include the peat covered moorland within the High Peak area. In the past, the peat was drained and burnt, thereby lowering its water retention capacity. In many places the peat became severely eroded and deep gullies developed. This erosion and gullying speeded up the runoff of storm water to local upland rivers. Since 2005 there has been a concerted collaborative effort by organisations, including the Moors for the Future Partnership, United Utilities and the University of Manchester, to restore these eroding peatlands by blocking gullies and thereby regulating storm flows to downstream areas (Shuttleworth *et al.*, 2019; see Fig. 95 in Anderson, 2021 for excellent photos of ways of gully blocking). Moorland areas feed the reservoirs in the Goyt and Etherow headwaters of the River Mersey. While basically for water supply or to maintain water levels in canals, the reservoirs may have some extra storage capacity for runoff from major storms. If available, such storage would also reduce the amount of water entering the Mersey tributaries above Stockport.

Once the tributaries enter the urban area, they receive some runoff from compacted urban surfaces. Many of these little streams, such as the Chorlton Brook, have been diverted through culverts under roads or buried in large pipes for parts of their courses. Such culverted or piped sections have restricted capacity for high flows. Culverts also tended to become partially blocked by debris. Such conditions create a risk of localised flooding. However, most of the runoff of rainwater from the paved and roofed sections of the urban area goes into drains, which may be storm drains or combined sewers. Both may feed into sewage works, such as that at Davyhulme, but they may have provision for stormwater overflows direct into the Mersey. Whichever path the water takes, the rate of runoff from the impermeable surfaces of the built-up areas is far higher per unit area than that from vegetated surfaces. Space for such runoff is limited, due to sewer, culvert and bridge capacities. If we are to avoid properties and other assets being inundated, we must find more space for water, whether by allowing more of it to infiltrate into the ground, by slowing the rate of runoff to rivers, or by creating opportunities for water to move out of the river and be held somewhere else (Douglas and Douglas 2022).

3: The value of urban green infrastructure and the implementation of nature-based solutions

In 1994 the Florida Greenways Commission coined the term green infrastructure (GI) in a planning report that advocated nature conservation by using a system of greenways, or GI, that were as well-planned and financed as traditional built infrastructure (Elliot *et al.*, 2020).

Now, the term green infrastructure is widely used to describe networks of green spaces, including natural areas such as waterways and woodlands, and built areas such as parks and community gardens – all of which provide ecosystem services to humans and the environment. Among the most pressing roles for green infrastructure is reducing urban stormwater runoff. Research in Greater Manchester has shown that green infrastructure landscapes already provide valuable flood risk management functions and will help in adapting to the changing climate. However, it also appears that the loss of green infrastructure cover can act to increase runoff volumes and associated flood risks, even if that loss is some distance from local rivers and streams (Carter *et al.*, 2018).

Urban greenways are linear open spaces such those along canals, rivers, streams or abandoned railways. They protect environmental values and provide routes for non-motorised traffic, on foot, horse or bicycle (Horte and Eisenman, 2020). In Salford, the 7 km Swinton Greenway connects neighbourhoods in Swinton and Monton, mostly following a former railway line, while the 3 km Port Salford Greenway between Worsley Village and Peel Green, which is seen on this excursion, Is mainly along the Worsley Brook.

These greenways and other types of green infrastructure help to provide nature-based solutions (Figure 4), about which the international Union for the Conservation of Nature (IUCN) states that "nature-based solutions leverage nature and the power of healthy ecosystems to protect people, optimise infrastructure and safeguard a stable and biodiverse future". The large Didsbury and Sale Water Park flood basins are excellent examples of multi-functional nature-based solutions, with their flood storage spaces being used most of the time for multiple recreational and wildlife conversion purposes. For example, the Mersey Valley in South Manchester contains several Local Nature Reserves including Stenner Woods and Chorlton Ees.

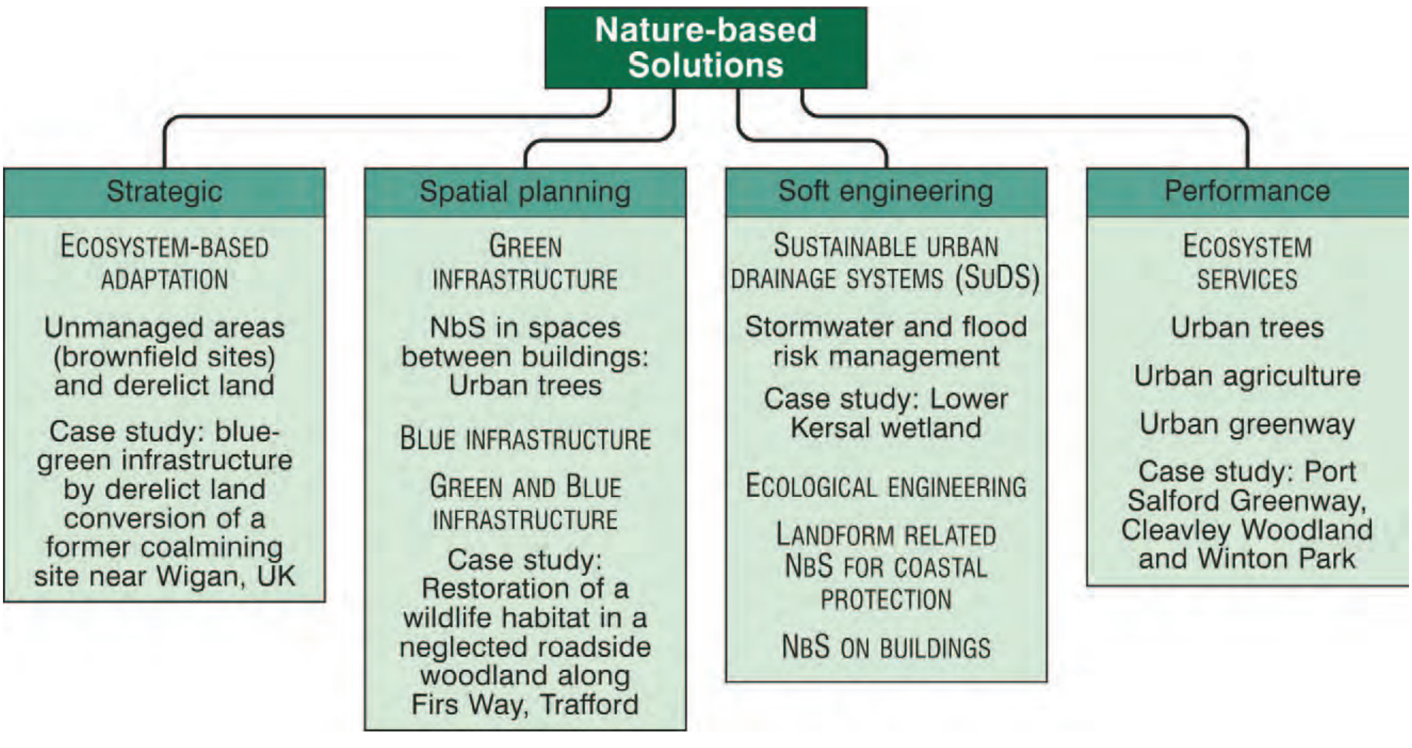

Figure 4: Various types of nature-based solutions classified according to their main purposes, with some specific examples either examined in this excursion or in the neighbourhood.

4: Invasive species and urban green infrastructure management

The Greater Manchester Combined Authority's Local Nature Recovery Strategy (https://www.greatermanchester-ca.gov.uk/news/new-plan-for-nature-to-help-make-a-greener-greater-manchester/) includes undertaking surveys of all the main rivers and surrounding areas within the River Irwell catchment to understand the impact of invasive, non-native species and propose measures to tackle them. Plants such as Himalayan balsam and Japanese knotweed cause major problems on riverbanks throughout the region. A severe infestation by Himalayan balsam occurred along the Mersey at Urmston in the summers of 2022 and 2023. These plants out-compete native wildlife, damage ecosystems and spread disease. Every year the Canal and River Trust spends hundreds of thousands of pounds to clear away unwanted vegetation and manage delicate waterway ecosystems.

Himalayan balsam does not need much light and will grow in a wide range of habitats. However, Himalayan balsam tends to shade out other plants and when it dies back in autumn its destructive legacy lives on. Riverbanks are left bare and thus vulnerable to erosion. Elsewhere on sections of the Mersey floodplain, it has been removed by balsam bashing which involves pulling the shallow-rooted plant up before it flowers in June. Bashing can eradicate the plant from an area within a few years. [Find out more

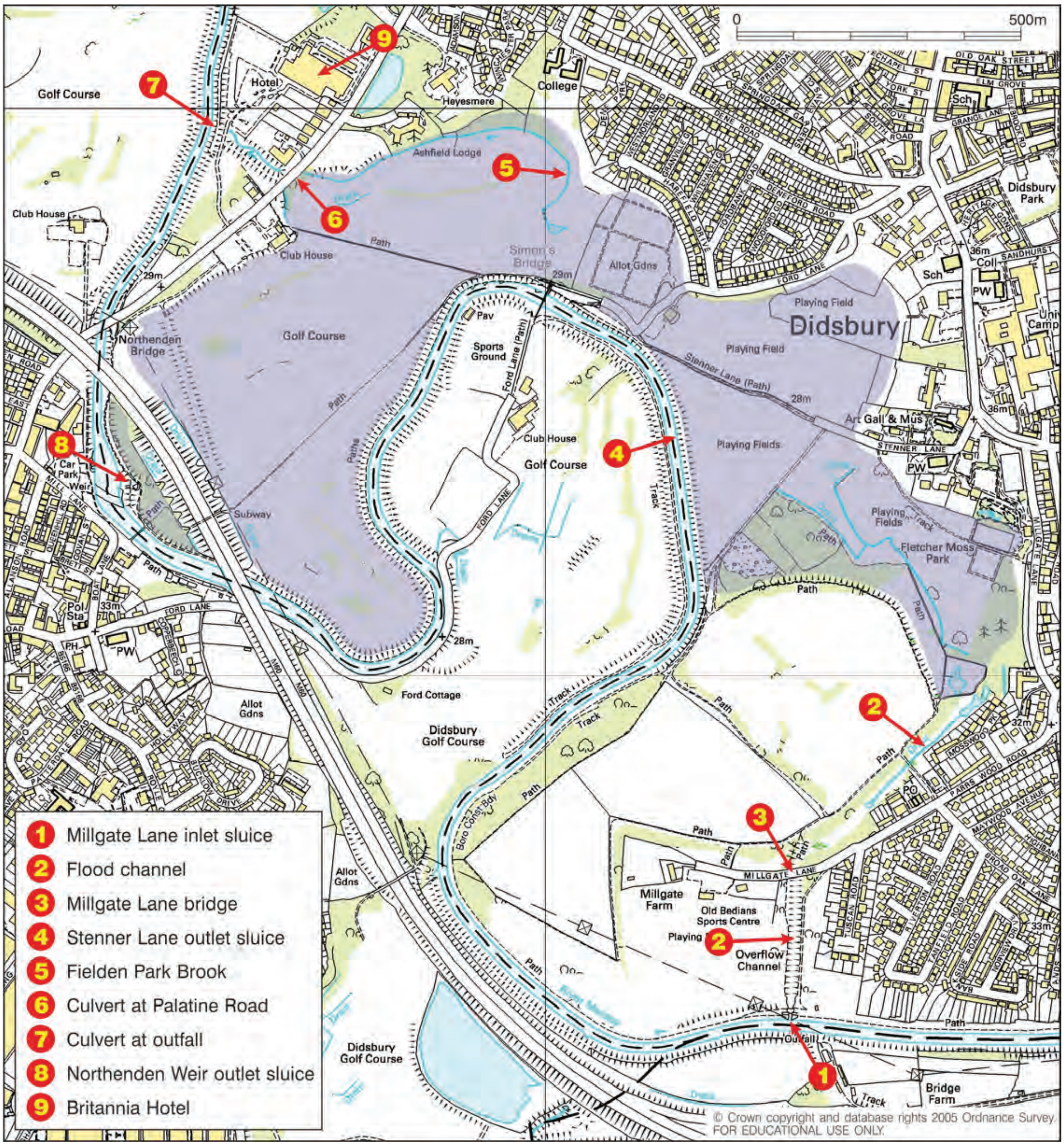

Figure 5: Flood plain map of the River Mersey between Northenden and Didsbury showing the inlet sluice at point 1 and the outlet at point 7.

at: https://canalrivertrust.org.uk/enjoy-the-waterways/canal-and-river-wildlife/canal-and-river-invasive-species-eradication-project-2021-2025]. When the new wetlands were established at Lower Kersal on the Irwell (Stop 8 on this excursion) a strategic plan to manage the threats of invasive species was implemented.

The route and stopping places

A. The River Mersey

STOP 1: Millgate Lane, Didsbury

From East Didsbury station and the junction of the A34 and A5145, proceed south along Parrs Wood Road and into Millgate Lane, Stop at the bridge over the flood basin inlet channel at Grid Reference (GR) 844896 (a car can be turned round at the playing fields car park further on).

Looking south from here the inlet channel from the banks of the Mersey can be seen. At flood times the gates of the weir on the Mersey embankment can be opened to release water into the Didsbury flood basin that lies to the north. Here, and at other sites along the Mersey, evidence of multi-purpose use of the floodplain, for recreation and wildlife conservation as well as flood management can be seen (Figure 5).

STOP 2: Palatine Road (GR 835908)

Opposite the Britannia Ringway Hotel, stop 2 provides an opportunity to examine encroachment on to the floodplain of the River Mersey. Note how the golf club house and car park are on raised land well above the level of the golf course itself. The low-lying land is part of the Didsbury flood basin into which water is released during times of high river levels, to prevent overbank flooding. In 1991, the car park of the Britannia Ringway Hotel was flooded and cars had water up to their windows (Figures 5 and 6).

STOP 3:Northenden (GR 833902)

By the footbridge, near the disused Tatton Arms pub at the end of Mill Lane (GR 833902) examine the embanked channels and the provision for floodwater management with passages beneath the M60 embankment, which occupies the floodplain and control gates for the release of overbank water back into the Mersey channel. A flood wall was built on the Mill Lane side of the river. Looking upstream From the footbridge, a “trailer home” caravan park is visible on the south bank. Characteristically, such removable homes have been permitted on floodplains, on the assumption that they could be removed in the event of floods. Now the flood wall protects them, as well as the houses on Mill Lane.

Figure 6: Photograph of the Britannia Hotel car park after the flood of 27 December 1991.

Downstream from the footbridge on the north (right) bank is the outlet gate to release water from the Didsbury flood basin. Note the tunnels to carry floodwater underneath the motorway. The tree planting undertaken here by the Mersey Valley Warden Service is part of the creation of urban woodlands in river valleys as part of greater Manchester´s green infrastructure.

STOP 3 TASKS

1. What do you consider to be the likelihood of flooding of the area on the south side of the river (the bank on which the former Tatton Arms is situated)?
2. What alternatives would have been available for regulating floodwaters in the areas of the floodplain occupied by the motorway?
3. What examples of floodplain encroachment, other than the motorway, can be seen in the Northenden area?

4. Just below the weir, the banks of the river are eroding, loose blocks being seen at the foot of the bank. In the middle of the stream a gravel bar has formed (Figure 7). How do you explain this?
5. What are the benefits of woodland creation on the floodplain?
6. How many different uses are there in this part of the floodplain? Can it be described as an example of multi-functional, multi-purpose land use?

Figure 7: The embankments, weir and gravel bar on the Mersey at Mill Lane, Northenden in 2020.

Journey along the M60 to Urmston

From Mill Lane, return to Palatine Road and turn left. Continue to the Princess Parkway overbridge. Get in the righthand lane and turn at the lights on the access road up to the parkway. Keep left and take the fork off and enter the M60. Procced forward towards Junction 9.

As you join the M60, the motorway is at the southern edge of the floodplain, with playing fields to the north (right hand side) (Figure 8). After the next junction (Junction 6), Sale Water Park will be seen to the right. This was a gravel pit from which material for the motorway embankment was excavated. Now the water park provides for:

- Water-based recreation
- Wildlife conservation (an area is set aside as a reserve for wading birds)
- Flood mitigation (a weir allows water to flow from the Mersey into the water park and to be stored there until the floodwaters have passed (Figure 9)).

At the end of the Water Park, the motorway crosses the former Manchester South Junction and Altrincham Railway, now the Metrolink line from Altrincham to Bury, and the Bridgewater Canal from Manchester to Runcorn. The canal was built in 1760; it is carried over the river by an arched aqueduct. The arch form means that as the river

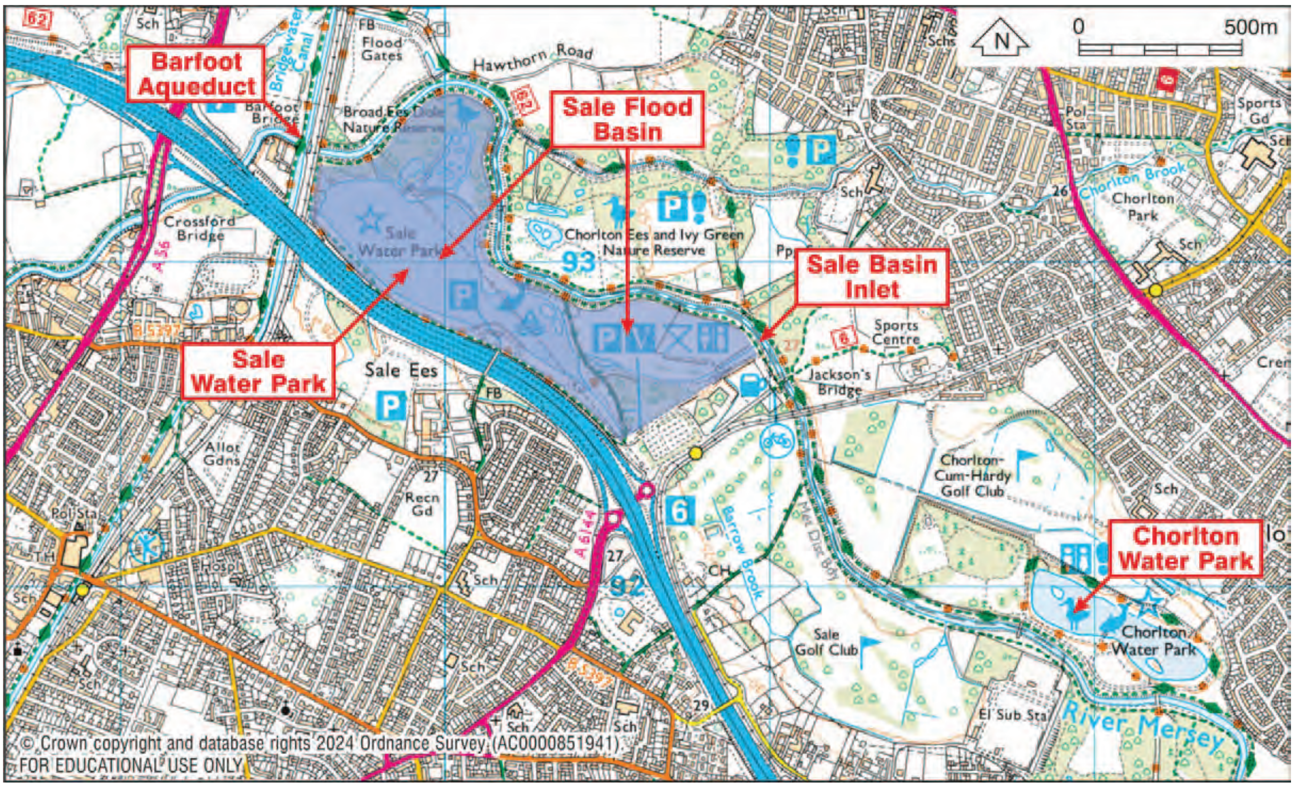

Figure 8: Flood plain map covering Chorlton Water Park and the Sale Flood Basin, again showing the basin inlet.

Figure 9: Floodwaters being released from the Mersey (behind the weir structure in this picture) into Sale Water Park through the basin inlet near the Jackson's Boat Public House.

level rises, there is less space for the water to pass under the arch. Backing up of the water against the canal threatened to undermine its embankment and thus in 1840, a diversion weir was built in the Mersey bank, to the north of the present motorway, and an overflow channel takes the floodwater under the canal at another point. The next junction is the A56, and the area to the south of the junction, known as Crossford Bridge, where the A56, the old Roman road from Chester to Manchester, crosses the Mersey. It used to suffer frequent flooding until the Mersey was embanked in the nineteenth century. Immediately after the junction you will see intensively used farmland to the south (left-hand side).

Just after the junction with the A56, the M60 passes on the northern (right) side, the Stretford Meadows, a former landfill site where domestic waste was dumped in the 1970's and 80's. Landfill gas was trapped and used to generate electricity: a good example of wise management of waste disposal. This raised green area is a landform created by urban waste disposal. The nature-based solution here is to allow it to become revegetated and eventually develop into woodland. Much of the floodplain area near Urmston has been used for landfill in the past.

The route leaves the motorway at Junction 9 and turns into Urmston.

This is a typical south Manchester suburban area. The nineteenth century node is the shopping area on both sides of the railway line, the original node, after crossing the railway line is near the church, on the top of the first terrace, just above the floodplain.

STOP 4: Urmston (GR 767937)

Here we investigate the dynamics of the the meanders downstream of Ashton Weir where the river is no longer embanked and has changed its course considerably in the last 25 years.

Proceed down Queens Road from the traffic lights at the junction of the B5213 and B5214 in Urmston, turn left (east) down Eeasbrook and right (south) along the narrow, unsealed lane behind the houses. Where the lane widens go left down the slope, cross the floodplain (yazoo) stream and go forward the bank of the Mersey. [A yazoo stream collects drainage from the floodplain and immediately adjacent areas but is at a lower level than the levees along the main river and so flows parallel to the river along the lowest axis of the back swamp (named after the Yazoo River on the lower Mississippi River floodplain in the USA). It is perhaps worth noting that such a feature occurs at a much smaller scale on the Mersey floodplain!].

Examine the deep channel and eroding banks. Flooding is more frequent here than further upstream because the river is no longer firmly embanked. Buildings on the floodplain are occasionally surrounded by floodwaters (Figure 10).

When the Manchester Ship Canal was built, it replaced the lower reaches of the Mersey's major tributary, the Irwell. The Mersey bed was lowered so that it could flow into the canal. This meant that the Mersey cut down into the floodplain more deeply than before. This explains why the Mersey bed is so far below the floodplain level at the point where you see it at Urmston. Some of the erosion of the bank here results from this deepening, but the main cause is that after being embanked and unable to erode for many kilometres above Ashton Weir, the Mersey is now free to erode and change its course. In about 1980, iron piling was inserted to

Figure 10: Floodwaters surrounding Willow Farm near Urmston in 1991.

Figure 11: The Mersey at Urmston in March 1983 (left) and Figure 12: in early 1986 (right) showing how shift to the channel caused the iron piling installed to protect the pylon on one bank ended up on the other side of the channel.

protect the opposite (left) bank of the river (Figure 11). This massive shift of the channel is a continuing process, and slumped pieces of turf are visible on the undercut banks. The National Grid (now National Grid Electricity Transmission) had to spend £ 500,000, in the late 1980s, moving a pylon from the top of the undercut bank to the point bar. To avoid further risk, a caisson was sunk down to bedrock beneath the river alluvium, so that whatever the river did, the pylon would be firmly anchored in position (Figure 12).

The shift has continued (Figure 13). The original pylon footings ended up in the channel and now, in 2023, the replacement pylon is threatened and boulders have been placed on the south bank to try to stop further shifts of the channel (further details of the behaviour of the channel here can be found in the Stretford and Urmston Meadows walk in Exploring Greater Manchester (Douglas and Harrop, 2023)).

Invasive species are a major problem here. In summer, Himalayan balsam is rampant here, occupying virtually all the riverbank and hiding much of the eroding banks of the meander (Figures 14 and 15). Help to avoid carrying seeds of the plant to other places by cleaning shoes and brushing clothing before re-entering your vehicle.

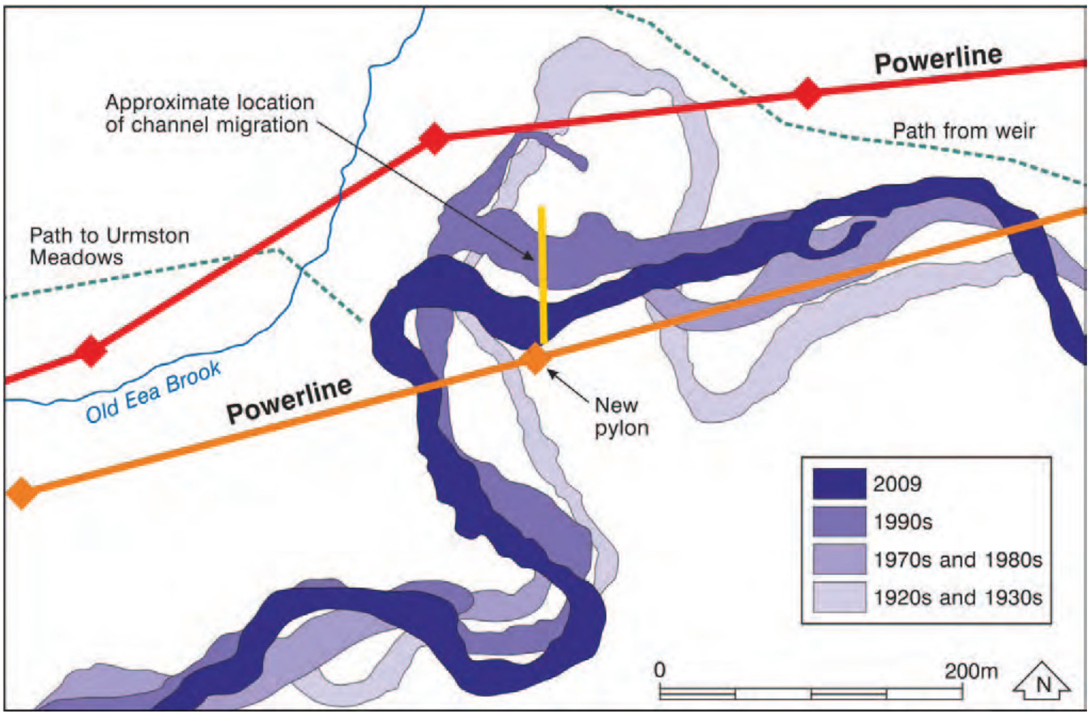

Figure 13: Changes in the position of the Meander of the Mersey at Urmston (adapted from Da Luz et al., 2015).

Figures 14 and 15: Himalayan balsam on the banks of the Mersey at Urmston in late August 2023. The only section of the riverbank on which the Himalayan balsam has not taken hold was the rapidly slumping section of the bank in figure 15, where lumps of turf sliding towards the river can be seen.

STOP 4 TASKS

5. Estimate the extent of the Himalayan Balsam infestation in the immediate area of the meander and suggest what can be done to manage it.
6. The pylon opposite the car park by the river appears to be reasonably stable at present. What changes by the river could affect it in the future?
7. There was a proposal to infill the abandoned 1971 meander on the Urmston side of the river by using it for dumping and landfill. Set out the arguments for and against the proposal.
8. List or sketch the signs of active bank erosion and sediment deposition that you can see in this area.
9. What type of material is the river cut into at this point? Describe its stratigraphy, texture and grain size composition.

Return through Urmston to junction 10 of the M60, go straight ahead beneath the motorway and keep to the nearside, continue following the signs for Eccles. After passing the entrance to the Trafford Centre (GR 769972) at the second roundabout, the older industrial buildings of Trafford Park, the earliest trading estate in the world, can be seen.

Trafford Park Development Corporation initiated many schemes to revitalise the area, which still contains a few major industries, including the Kellogg's cereal factory . The major Colgate-Palmolive works closed in 2007 and has been transformed into a centre for business, creativity and leisure activities. However, the heavy engineering has all gone. The last vestige of the former Metropolitan-Vickers electrical engineering plant, Alstom Turbine Generators, closed in 1999 and the power station design team was moved to offices in Knutsford. Problems of contaminated land abound in Trafford Park, particularly in old oil refineries and gasworks. Just after the roundabout, the route passes the site of the former Barton Power Station (now occupied by the B&Q Store). As with many other former power stations built in urban areas early in the twentieth century to supply electricity local factories homes, Barton Power Station became too old and too small for modern needs.

STOP 5: The Barton Swing Aqueduct (GR 767976)

Turn on to Redclyffe Road and immediately before the swing bridge turn into Old Barton Road to park. Turn back and cross Redclyffe Road (with care!) and follow the path up to the bank of the Bridgewater Canal. Turns left (north-westwards) and climb the ramp up to the bridge over the canal for a good view of the Barton Swing Aqueduct and the Manchester Ship Canal (Figure 16).

The Barton Road Swing Bridge (Figure 17) and the high level M60 bridge can be seen to the left-hand side. Here, in the early 1890's the ship canal engineers had to provide a means whereby traffic along the Bridgewater Canal could be maintained, while allowing for the passage of ocean-going vessels along the ship canal. The old stone aqueduct over the Irwell built by Brindley was replaced by the Barton Swing Aqueduct, a great feat of late nineteenth century engineering. The vegetation beyond the metal fence across the Bridgewater Canal from the access ramp is on the site of a vehicle depot, which replaced a former fuel oil depot. This is typical of the many industrial land use changes that continue to occur in Trafford Park.

Figure 16: The Barton Swing Aqueduct over the Manchester Ship Canal; and Figure 17: The Barton Swing road bridge over the Manchester Ship Canal (photo taken from the west side of the bridge).

Figures 18 and 19: Two views of the swing aqueduct opened; one from the opposite bank of the Ship Canal and the other from a vessel travelling up the canal towards Salford Quays (Figure 18 courtesy Cathy Delaney).

The Ship Canal is now used only by a few ships serving Irlam, but not usually passing through the Barton swing bridges. In recent years, the MV Coastal Deniz, carrying up to 260 containers, has operated between Liverpool's Seaforth Container Terminal, Ellesmere Port and the Irlam Container Terminal in Salford. A new inland terminal, Port Salford, is being developed just west of the AJ Bell Stadium, on north-western side of the M60 high level viaduct. The plan is that it will provide a localised logistics service, with the port of Liverpool intending to entice mainline operators to offer direct calls or feeder services from Europe into north-west England. Hopefully, the use of the canal in this way will reduce vehicle mileages (and thus greenhouse gas emissions) for containers that are presently delivered to the north of England from Felixstowe, London Gateway and Southampton.

STOP 6: Winton Park and the Cleavley Wetlands (GR 755990)

From Barton, follow the B2511, Barton Road across the Ship Canal alongside the Bridgewater canal to A57 at Patricroft, going straight ahead at the traffic lights on to Worsley Road.

Continue along the road passing under the railway bridge and continuing up to Sutherland street. Enter Sutherland Street and stop near the park on the left (GR 755990). The road just to the left just before the park is a good place to park.

The park (Figure 20) is a traditional formal urban greenspace established in 1906. It had a major refurbishment around 2022 which included the design of a new central grassed area, installation of public toilets and improvements to the bowler's pavilion. It is typical of the many such parks created in Greater Manchester and other UK cities in the period 1840 to 1950.

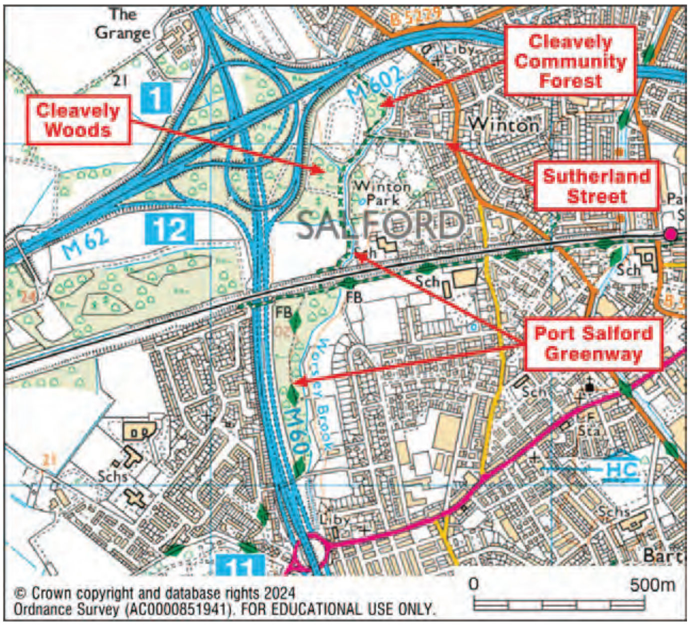

Figure 20: Map showing Winton Park and the Cleavely Woods area.

Figure 21: Worsley Brook from the Sutherland Street footbridge.

Walk further along Sutherland Street going straight ahead across a bridge over Worsley Brook (Figure 21), when you reach the tarmac track turn left.

The track is the Port Salford Greenway, a 3 km cycling and walking route between Worsley Village and Peel Green. In 2023 it was extended from Worsley to Peel Green, but it is intended that eventually it should reach the Ship Canal at Port Salford.

A balsam bash exercise was undertaken along Worsley Brook in spring 2023 as part of the Salford Small Streams project tackling invasive non-native species (INNS) in the Glaze and Irwell catchments as well as improving water quality, raising awareness of local environmental issues and reducing flooding through Natural Flood Management (NFM) techniques.

As you join the greenway track, you will see a notice giving information about the Cleavleys Community Forest Garden, which used to be a Salford City Council operated plant nursery until around the early 1990's when the site became redundant. It had previously belonged to Eccles Borough Council from around the 1950's. The Forest Garden grew rapidly after the COVID pandemic, with an education centre, social prescription service, green roof project, local food scheme and café amongst the many additions. The ambition of the Cleavleys initiative is to help strengthen the community and improve the participants' quality of life (Cappelli and Cini, 2020). The urban farm acts as a hub, with staff working with local schools, elderly societies, and other key organisations to generate further funding (Court et al., 2022). Turn right and follow the fence to find the entrance (but the opening hours were unclear in August 2023).

However, for this exploration, turn left at the junction of the track across the Worsley Brook and the Greenway and continue along the hedge on your right until there is an opening where you can see the Cleavely athletics track, one of the best in Geater Manchester. A little further on there is a track entering Cleavely Woods (Figure 22), once part of a Salford city tree nursery area, which are worth a short exploration. In the woods in late August 2023, there were signs of an infestation with ivy.

Figure 22: Cleavley Woodlands.

STOP 6 TASKS:

10. Examine Winton Park and assess the varied activities that can be enjoyed there. How relevant are those facilities in the present day?
11. How well does the Port Salford greenway meet the criteria of both protecting environmental values and providing routes for non-motorised traffic, on foot, horse or bicycle? What types of users did you see during your visit?
12. Cleavely Woods are a relatively small greenspace at the edge of the built-in up area. How valuable ae they to a) residents within walking distance and b) as part of the Greater Manchester Green infrastructure?

After inspecting the woods, return to Sutherland street and travel back to the main road turning left and on into Worsley. In the village, stop on the roadside near Farm Lane (GR 749002) and cross the road and proceed on to the footbridge over the canal.

STOP 7: The Bridgewater Canal at Worsley

Here is some fine industrial heritage and an opportunity to discuss the nature of the coal measures that the canal helped to exploit. Note the colour of the canal. It is due to the iron staining of the mine water that drains out the horizontal adits formerly used as undergoing canals to enable the mined coal to be loaded direct on to barges for transport to Manchester and elsewhere. Cross the footbridge and walk on to Worsley Green. Worsley Green is an area of public open space, bordered by a heavily trafficked road and by terraces of 18th century cottages and 19th century houses with elevations in black-and-white vernacular style. The Victorian ornamental fountain, an important feature of the Green, originally formed part of a chimneystack on factory buildings that stood on the site of Worsley Green. Worsley village was designated as a conservation area by the former Lancashire County Council. The boundary was drawn to include, at that time, approximately 40 listed buildings, together with some less attractive but historically interesting industrial buildings. The settlement originated in the last quarter of the 18th century as a group of industrial buildings, cottages, shops, inns and other community buildings at the Delph where the entrance to the Duke of Bridgewater's underground coal mining and canal system was situated.

Walk up the west side of Worsley Green on to Worsley Road (A572) cross the road, turn left (west) and stop just past Mill Brow and look at the rock face and water body visible to the north. This is the Delph where the underground canals begin. The Duke of Bridgewater commissioned James Brindley to design the Bridgewater Canal and then in 1760 he engaged the engineer John Gilbert to create 72 km of underground canals, together with a series of inclined planes that lifted loaded barges from one canal to another. The most interesting buildings of interest in this area are the Bridgewater Estate Offices, the Nailmaker's House, Rock House, Packet House, Court House and former Police Station (The Old Nick).

B. The fluvioglacial gravel ridges of Salford and flooding on the River Irwell

From Farm Lane, return to the B5211 (Barton Road and proceed up to the roundabout near the Delph. Take the A572 Worsley Road to the A580 (East Lancashire Road) and turn right, proceed to the turning for A666/M60/M66/Swinton/Kearsley/Bury with and take the A666 Bolton Road. After 400 m turn right on to the A6044 (Agecroft Road). Proceed downhill to the bridge over the River Irwell and take the 3rd exit at the roundabout on to Kersal Vale Rd that takes you southwards (downstream) along Kersal Vale following the river into the centre of the wide floodplain in the large meander at Lower Kersal (Figure 23). From Littleton Road you will see high banks on the left. These are the embankments around the Littleton Flood Basin.

Lower Kersal has a long history of flooding. These wide meanders of the Irwell have been kept mainly free of development. The area close to the river has major flood problems, with severe floods in 1866, 1946, 1954 and 1980. People are now not very aware of the floods, which occurred so long ago, and they make little attempt to protect themselves against future floods. The large council estate built here in the 1930s had many houses, which were seriously flooded in 1946 and 1980. Several houses in Lower Kersal had over a metre of water over their ground floors. The entrance doors of many houses on the estate are below the level of the road.

The residents facing the flood risk here are relatively poor, yet a 1 in 100-year flood would cause some £55 million damage to property (Penning-Rowsell, 1999). A large flood storage basin to alleviate the flood problem by protecting some 3000 properties against the 1 in 75-year flood to the west of Littleton Road (Figure 23) was completed by 2008 at a cost of around £ 11 million. A second major flood basin was created within the next meander bend downstream at Castle Irwell, which will be seen at the next stop. Although people might expect to be protected against less frequent (rarer than 1 in 100 years) floods, at the time the Environment Agency that higher flood embankments might change the landscape too much, reduce accessibility to the playing field inside the basin, and aggravate the existing sewer flood-

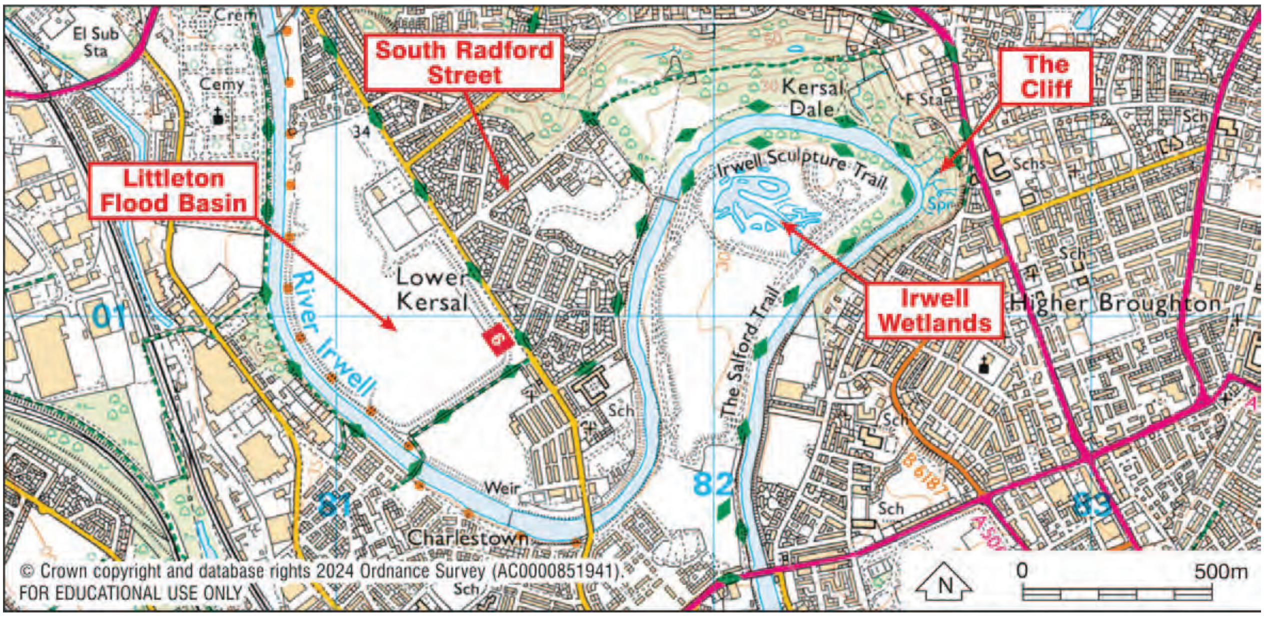

Figure 23: Map of key locations in the Lower Kersal and Cliff Areas of the Irwell Valley.

ing problems. Now, with daily evidence of increased climatic extremes, major floods are likely to be more frequent and more defences are need. The Lower Kersal flood basin is a twenty-first century start to the continuing effort to reduce flooding both here and downstream in the city centre.

Continue along Littleton Road and turn into South Radford Street on the right. Follow this slightly up hill until you reach Kersal Way, on the right running downhill towards some multistorey flats. Proceed to the very end and stop at the concrete blocks preventing you going any further. Park here and walk on past the concrete blocks until you come to a surfaced path leading off to the left (Figure 24). Follow the path to the gate at the end, turn right and go up the slope to the riverbank. Cross the river by the footbridge looking at the turbulence in some parts of the channel. (Figure 25).

From the riverbank go up the steps onto the further embankment in front of you which is the boundary of the Castle Irwell flood basin. From the top you can see both a good view of the Manchester-Salford skyline and the water-bodies of the Kersal wetlands (Figures 26 and 27).

Figure 24: Path through copse at Lower Kersal.

Figure 25: River Irwell at Lower Kersal footbridge looking downstream and showing some turbulence.

 

Figures 26 and 27: The Manchester–Salford skyline from Castle Irwell embankment and ducks on the Irwell wetlands (Figure 26 courtesy Cathy Delaney).

STOP 8: Kersal Wetlands (GR 823013)

This £10 million Salford flood scheme provides increased protection to more than 1,900 homes and businesses across Lower Broughton and Lower Kersal. Lower Broughton was affected by the devastating floods that struck the city on Boxing Day in 2015. It has also created more than 5 ha of urban wetland, bringing attractive landscapes for people and wildlife. This is another multifunctional riverscape, combining flood protection, recreation opportunities and nature conservation: a good example of a nature-based solution. The entire 28 ha flood basin sits within a meander loop of the River Irwell, protecting surrounding properties by holding up to 650 million litres of water – the equivalent of 260 Olympic-size swimming pools – during flood conditions.

However, the wetland is situated in a catchment that has significant infestations of invasive non-native species. Therefore an invasive control programme was included as part of construction work. Subsequently a long-term monitoring and control programme was initiated as part of the overall capital scheme maintenance (see: https://www.gov.uk/government/news/environment-agency-completes-10-million-flood-storage-basin-on-world-wetlands-day).

After visiting the wetlands, return to Littleton Road and turn left (south). Continue across the river to the roundabout and take the first exit on to the A675. Immediately after the bridge over the river, turn left at the traffic lights on to Lower Broughton Road.

As the road goes up the hill, early to mid-nineteenth century house built by industrialists on the edge of the then industrial town can be seen. The oldest house that now exists is Cliff House dating from 1817, which was the first of many large houses to be erected overlooking the River Irwell. In the mid-19th century most residents at The Cliff were members of the professional classes but several merchants also resided there. The Cliff was one of the earliest residential suburbs for commuters into Manchester and Salford. Whilst the layout of The Cliff was not as formal as areas such as Victoria Park, Manchester, it was a prototype for such later developments. The Cliff is a Conservation Area. The Grade II listed buildings on Lower Broughton Road are numbers 388 (Ivy Cottage), 390, 464, 466, 435 (Scarr Wheel House), 461 (Cliff House), 437, and 451/459.

STOP 9: The Cliff (GR 827013)

The junction of Lower Broughton Road and Great Clowes Street provides an excellent opportunity to study the effects of mass movement on the steep slope overlooking the river and to look for signs of subsidence affecting housing in the local area. The section of Great Clowes Street north of the junction had to be closed because of the mass movement on The Cliff. Signs of the former tram tracks are clearly visible in block paving of the road immediately in front of the fence round the wooded area of the Cliff itself (Figure 28) Look back down Great Clowes street at this point and you can see the alignment of the setts in the road where the tram tracks would have been (Figure 29).

Walk along the footpath in front of the houses and look over the fence where you can still see part of the old road (Figure 30). In the 1980s, the old rails of the tram tracks stuck out into the air from the top of the present street (Figure 31). Today (2023) you can see how the individual setts from the old road are about to fall out and roll downslope (Figure 30).

Go through metal gateway into the area at the top of the wooded slope. Turn back and look over the fence on The Cliff side at the exposed reddish-brown sands beneath the former street. These sands are part of the fluvioglacial sequences underlying this higher land. Water moves preferentially through lenses of coarser material with these

Figures 28 and 29: The old tram tracks at the top (28) and the tram track alignment down hill in Great Clowes Street (29).

Figure 30: The collapsing continuation of Great Clowes Street.

Figure 31: Tram tracks in the air in 1984.

deposits. By descending through the woods, evidence of mass movement, in the form of tilted fences and walls, and trees whose trunks have grown at different angles as they have slipped from the vertical, can be seen.

The issue here is why is this slope collapse occurring? Three possible hypotheses can be put forward:

1) It is a consequence of mining subsidence (Agecroft colliery was not far away);
2) It is because the river is undercutting the base of the slope;
3) It is something to do with the properties of the fluvioglacial sediments in the slope, perhaps irregular development of concentrated subsurface water flows.

To test hypotheses 2 and 3, follow the path down to the riverbank. Can you see any signs of undercutting of the cliff itself? Then explore downstream along the riverbank to see whether there is a small stream flowing from the Cliff to the river. Follow that stream back towards the Cliff. Is it carrying sandy material that descends from springs part-way up the slope? Could it be possible that headward erosion of these stream sources, (termed spring sapping) is responsible for the mass movement (hypothesis 3). It may be that that the land slipping at The Cliff is a natural process associated with ground water flows through the diverse materials beneath the slope. [Teachers may wish to use this example to illustrate the method of multiple working hypotheses in the field].

STOP 9 TASKS

13. What indicators of mass movement can be found on the slope below The Cliff? Draw diagrams to show the tell-tale features characteristic of areas suffering mass movement.
14. Look for seepages on the slope below The Cliff. Are there any signs of material being carried out of the ground by spring water? How do the springs relate to the level of the river? Does river undercutting affect The Cliff?
15. How has the opening of The Cliff to recreational use affected the stability of the slope?
16. Describe the stratigraphy and materials of the slope.

From The Cliff, the route returns via Great Clowes Street, Camp Street, Frederick Road, Albion Way, Trafford Road and Broadway into Salford Quays to the Lowry Centre to examine the problems of dealing with pollution in the enclosed basins and in the ship canal itself.

STOP 10: The Lowry Centre and Manchester Ship Canal Turning Basin (GR 803972)

Salford Quays is now a well-established commercial, entertainment and residential area with major attractions such as the Lowry Arts Centre and the BBC studios. The enclosed former dock basins are attractively lined with trees and the water in the basins looks clean. It was not always thus. Salford docks closed in 1982 and by 1985 local unemployment had risen to 30% of the potential working population. Redevelopment was driven by a range of government and private partnerships. The Trafford Park Development Corporation was established in 1987 and in the next 11 years it focused on environmental improvements, land assembly and new infrastructure (Robson, 2016). The BBC decided to relocate some of its production departments there in 2006, while, in 2013, ITV moved the studios for Coronation Street to a site close to the architecturally significant Imperial War Museum North across the Ship Canal from the new Media Centre. This is now a thriving cultural and entertainment area.

However for the re-development to succeed two major water pollution problems had to be resolved, one in the canal itself, the other in the newly enclosed dock basins. These water pollution problems were due to the Manchester Ship Canal acting as a drain transporting water from the Rivers Irwell and Medlock, including both licenced industrial wastewater releases and combined sewer overflows containing domestic and industrial sewage and road runoff. In the early 20th century, water treatment upstream was less effective than it is today and thus contaminated water with a high organic load was swept into the canal during high flows from major rainstorms. As Figure 32 shows, that polluted water was carried into the old dock basins as well as accumulating on the bed of the wide turning basin. In the turning basin, the canal is less steep and much wider than the rivers upstream, and thus solid matter gets deposited. Over more than a century, several metres of organic matter built up in the turning basin and on the dock floors. Conditions for aquatic life were extremely poor. Aesthetically unpleasant rafts of floating debris often floated on the canals surface. Sometimes bubbling gases were visible on the water surface. On hot summer days unpleasant odours sometimes permeated the air around the docks (Williams *et al.*, 2010).

Solving the enclosed dock basin problem

The transformation of the former docks involved three phases (Figure 34): post closure (premediation), remediation, and post-remediation. When the dock basins at Salford Quays were hydrologically isolated from the Ship Canal in 1987, the highly contaminated sediment on the floor of the basins was not removed (pre-remediation in Figure 34). In addition to the organic-rich urban sewer and run-off sediments already in the basins, detritus from demolition of dockside buildings sent a pulse of debris into the basins creating a layer of building dust and debris over the organic sediments (remediation - anthropogenic grains in Figure 34). The gradual decomposition of that sewage-rich sediment used so much oxygen, that there were periods of insufficient oxygen to support aquatic life in the water within the basins. To combat this oxygen deficiency. Helixor pumps were used to circulate compressed air through the water column. After remediation, the improved water quality and development of aquatic flora and fauna led to the deposition of clays and algal material, while the decomposition of some of the demolition debris released metals to the porewaters of the newly deposited clay and algal sediments in the basins (post-remediation in Figure 34).

Solving the turning basin problem

The Turning Basin (Figure 35) issues are more complex than in the enclosed dock basins as polluted water from upstream continues to flow through the basin. These continuing inflows and outflows of water and sediments, including sewer overflows and matter washed from the urban surface into rivers upstream present an ongoing problem. In2001, in the first stage of overcoming the problem of severe unpleasant odours during hot weather, a system of liquid oxygen injection was initiated. At that time, 15 tonnes of oxygen

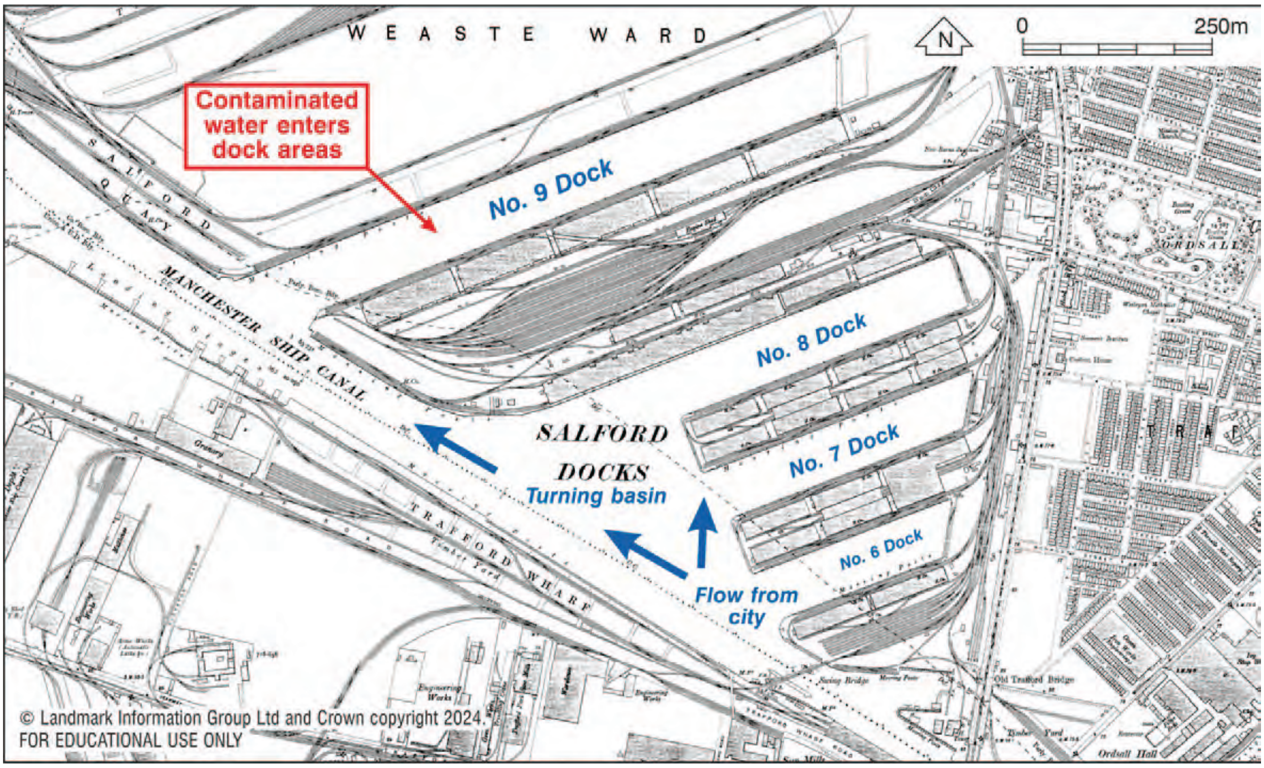

Figure 32: The original Salford Docks in the 1900s. The arrows show the directions of water flows derived from all the urban areas upstream on the Rivers Irwell and Medlock.

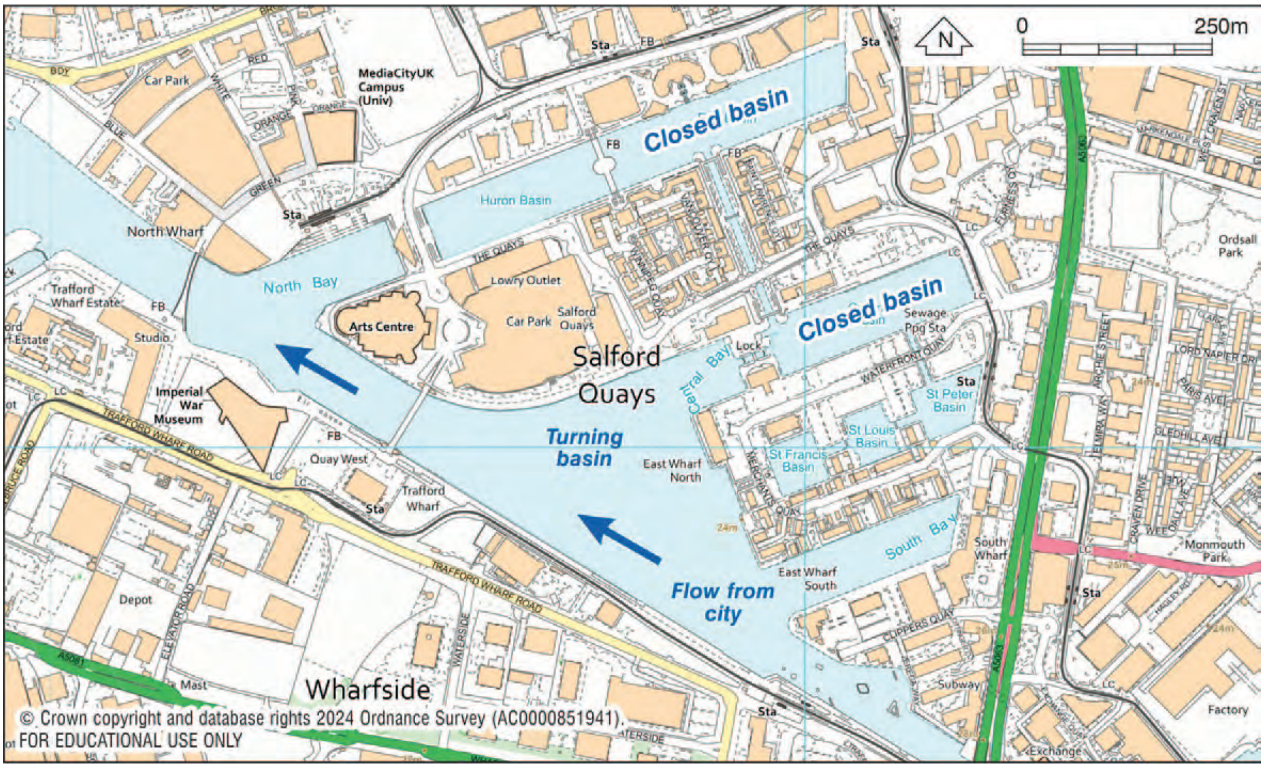

Figure 33: Salford Quays in the 2020s showing the closed basins in the former Docks 9, 8 and 7.

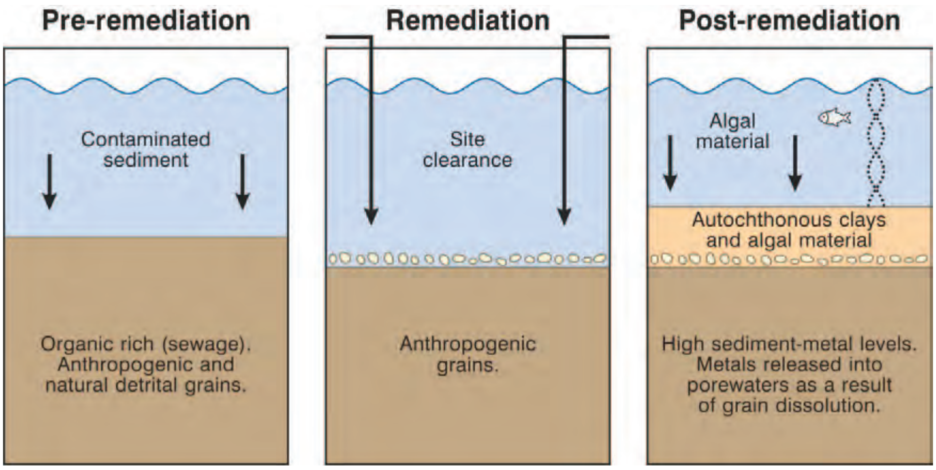

Figure 34: A schematic diagram of the changes in sedimentation within the enclosed Salford Quays basins (after Taylor et al., 2003).

were pumped each day into water near the Lowry arts centre and the Imperial War Museum North. When the equipment was turned on during hot periods, the dissolved oxygen in the water could increase by almost 300%. The scheme was highly successful improving conditions for fish and greatly reducing the odour issues. This initial raising of the oxygen levels was expected to take 12 years.

In 2012, it was decided that the now raised dissolved oxygen level in the water could be kept sufficiently high by adopting the Helixor pump method as used in the enclosed basins. These pumps keep the dissolved oxygen at a high enough level to sustain aquatic life. However, when water flows are low and there is little movement of water in the Turning Basin, as during hot days in summer, such as in June 2023, there is a risk of a fall in oxygen levels. For example, such an oxygen depletion led to a fish-kill in the Turning Basin on 14 June 2023 (reported by the BBC: https://www.bbc.co.uk/news/uk-england-manchester-65902910).

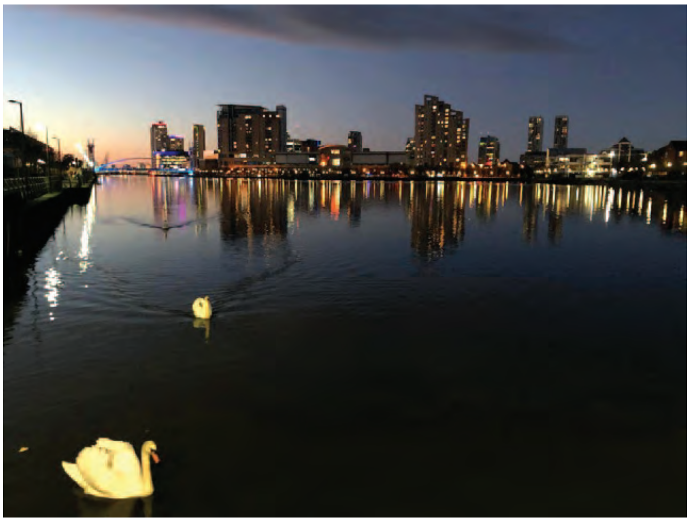

Figure 35: The Turning Basin on the Ship Canal at Salford Quays (photo courtesy Cathy Delaney).

These two sets of improvements in water quality have led to marked changes in the biology and sedimentology of the Salford Quays (Taylor *et al.*, 2003). Macroinvertebrate and zooplankton diversity steadily increased after the 1980s, indicating a healthy water body. Both fish and bird diversity has grown (For more details see: https://www.apemltd.com/a-lasting-relationship-salford-quays/). Not only were the enclosed basins used for the swimming part of triathlon events in the 2002 Commonwealth Games, but the enclosed basins have become a major water sports centre with open water swimming in the Dock 8 and Dock 9 basins being offered by two firms in 2023. Such ecosystem service provision is only possible through the skill of the water quality managers and the commitment of all the agencies involved. Nevertheless, with global heating bringing more hot days and continuing occasional sewage spills there will be occasional algal blooms and fish losses.

All these efforts to overcome some of the hangover effects of the past 200 years of urban and industrial development upstream show that even in the heart of this industrial area, environmental processes cannot be segregated from economic development and urban retailing, residential and leisure activities.

From Salford Quays access to Manchester city centre or the motorway network is easy via Regent Road or the M602.

Acknowledgements

The author thanks Maureen Douglas, Fiona Harrop and the late Nigel Lawson for help with both fieldwork and the text, Paul Hindle and Cathy Delaney for their editorial advice on successive versions of this exploration, and Cathy Delaney for supplying additional photos.

References and further reading

Anderson, P. (2021). The Peak District, London: Harper Collins

Cappelli, A and Cini, E. (2020) Will the COVID-19 pandemic make us reconsider the relevance of short food supply chains and local productions? Trends in Food Science and Technology, 99, 566. https://doi.org/10.1016/j.tifs.2020.03.041.

Carter, J. G., Handley, J., Butlin, T. and Gill, S. (2018) Adapting cities to climate change–exploring the flood risk management role of green infrastructure landscapes. Journal of Environmental Planning and Management, 61 (9), 1535-1552, https://doi.org/10.1080/09640568.2017.1355777

Court, A., Kelly, A. and Hardman, M. (2022). Exploring the need for innovation in greening urban environments: Reflecting on radical practice in Greater Manchester, UK. Cogent Social Sciences, 8 (1), 2109261. DOI: 10.1080/23311886.2022.2109261

Da Luz, R.A., Lawson, N., Douglas, I. and Rodrigues, C. (2015). Historical sources and meandering river systems in urban sites: the case of Manchester, UK. North West Geography, 15 (2), 1–2

Douglas, I. (1985a). Geomorphology and urban development in the Manchester area. In Johnson, R.H. (ed.) The Geomorphology of North-West England. Manchester University Press, Manchester, 337-352.

Douglas, I. (1985b). Cities and geomorphology. In Pitty, A.F. (ed.) Themes in Geomorphology. Croom Helm, London, 226-244.

Douglas, I. (1989). The environmental problems of cities. In Herbert, D.T. and Smith, D.M. (eds) Social problems and the city. Oxford University Press, Oxford, 81-99.

Douglas, I. (1989). The rain on the roof, a geography of the urban environment. In Gregory, D. and Walford, R. (eds) Horizons in Human Geography. Macmillan, London, 217-238.

Douglas, I. (1999). Physical Problems of the Urban Environment, In Pacione, M. (ed.) Applied Geography: Principles and Practice. Routledge: London, 124-134.

Douglas, I. and Harrop, F. (2023). Stretford Meadows and Urmston Meadows: landscapes of the Anthropocene Exploring Greater Manchester https://www.mangeogsoc.org.uk/egm/5_4_Stretford_Urmston.pdf

Douglas, I. and Douglas, M.A. I2022). Sale Water Park, the River Mersey and Bridgewater Canal Aqueduct, Exploring Greater Manchester, https://www.mangeogsoc.org.uk/egm/5_2_Sale_WP.pdf.

Elliott, R. M., Motzny, A. E., Majd, S., Chavez, F. J. V., Laimer, D., Orlove, B. S. and Culligan, P. J. (2020). Identifying linkages between urban green infrastructure and ecosystem services using an expert opinion methodology, Ambio, 49, 569–583, https://doi.org/10.1007/s13280-019-01223-9.

Environment Agency (2009) Upper Mersey Catchment Flood Management Plan Summary Report December 2009, https://www.gov.uk/.../upper-mersey-catchment-flood-management-plan.

Horte, O. and Eisenman, T. (2020). Urban Greenways: A Systematic Review and Typology. Land, 9 (2), 40. MDPI AG. http://dx.doi.org/10.3390/land9020040.

Lee, E. M. and Giles, D. P. (2020). Landslide and slope stability hazard in the UK. Geological Society, London, Engineering Geology Special Publications, 29 (1), 81-162. https://doi.org/10.1144/EGSP29.4

Penning-Rowsell, E. (1999). Floods. in Pacione, M. (ed.) Applied Geography: Principles and Practice, Routledge. London, 95-108. (Has a particularly important section on flooding on the River Irwell in Greater Manchester on pages 101-103 which should be read by all).

Robson, B.T. (2016). The resurgent entrepreneurial city, in Kidd, A. and Wyke, T. (eds) Manchester: Making the Modern City. Liverpool: Liverpool University Press. 347-396.

Shuttleworth, E. L., Evans, M. G., Pilkington, M., Spencer, T., Walker, J., Milledge, D. and Allott, T. E. (2019). Restoration of blanket peat moorland delays stormflow from hillslopes and reduces peak discharge, Journal of Hydrology X, 2, 100006.

Taylor, K.G., Boyd, N.A. and Boult, S. (2003). Sediments, porewaters and diagenesis in an urban water body, Salford, UK: impacts of remediation. Hydrological Processes, , 2049–2061.

Williams, A., Waterfall, R.J., White, K.N. and Hendry, K. (2010). Manchester Ship Canal and Salford Quays: industrial legacy and ecological restoration, in Batty, L.C. and Hall, K.B. (eds) Ecology of Industrial Pollution, Cambridge: Cambridge University Press, 276-308.