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Part 11: Design Elements II: Canal Track & Canal Channel

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11 Design Elements II: Canal Track & Canal Channel

11.1 Canal Track: Structure

11.1.1 The Canal Track is the route of the existing canal or, where new construction is required, the proposed route.

11.1.2 The ideal canal track in open country consists of the following elements:

- | | |
|-----------------|--|
| ● Towpath Side | Boundary (fence or hedge)
Towpath
Verges |
| ● Canal Channel | Towpath Bank
Main Channel
Reedsheaf (if width available)
Offside Bank |
| ● Off Side | Bank Margin & Verge
Boundary (fence or hedge) |

11.1.3 An idealised cross section (Figure 10.2) shows the arrangement of these elements in an open country setting. The design of the restored canal track is intended to maximise local biodiversity by providing a suite of different niches and habitats however, given local constraints, notably in urban settings, not all these elements will be present at all locations along the canal.

11.1.4 The overall width of the canal track must make due allowance for structures (e.g. locks), and for any land which will be required to provide permanent access to undertake routine maintenance, including dredging, of the canal channel. The exact width of the Canal Track therefore varies according to location and the nature of the canal structures but will generally average 15 metres.

11.2 Canal Track: Historic Appearance

11.2.1 The Chesterfield Canal from Retford to Chesterfield was built as a narrow canal, for boats up to 72 ft long and 7 ft beam. The original (1777) canal track was between 40 and 50 ft (c.12-15 m) in width and included a canal channel with a width of around 30 ft (c.9 -10 m) and with a minimum depth of 4 ft (1.2 m).

11.2.2 In common with many first generation canals the route follows the contours - winding around obstacles rather than by crossing them with cutting and embankment.

11.2.3 The cross sectional profile of the original 1777 canal was trapezoidal and featured soft sloping banks on both towpath and off bank sides. Vertical walled banks (“wash walls”) were to be found only at wharfs and bridge narrows (bridge holes) and on the short pound between lock staircases on the Norwood Flight. Several extant dry sections in open country, such as that near Moorhouse Farm, Killamarsh (SK 4472 7855), show the original “u” profile very clearly. In some cases a more

“dish” shaped cross section can be observed but this appears to be a consequence of erosion and infilling.

- 11.2.4 The original channel was largely formed by cut and fill. A cut being excavated into the hill slope along the contour and the up-cast piled on the downhill side to create an earth bank. Both sides (banks) of the resultant channel were sloping with a batter of 1 in 2½ to 1 in 3. The channel was lined with puddle clay. Differential settlement between the constructed soft bank and the usually solid floor of the excavated cutting is a problem shared with many other “Brindley” canals and can cause cracking of the puddle and leakage along the centre line of the canal bed.
- 11.2.5 Unlike many other early “Brindley” waterways, such as the Trent and Mersey, the Chesterfield was never extensively remodelled to introduce a continuous wash wall on the towpath bank. Where short lengths of wash wall are evident these were introduced at busy locations when much of the canal was refurbished in the 1830’s after a half century of intensive use. The general retention of the soft banks on both sides encourages a diversity of plant growth and gives the canal much of its bucolic character.
- 11.2.6 Between Killamarsh and Kiveton Park wash walls are absent but there are good examples of colliery loading wharfs at Norwood Colliery and at West Kiveton Colliery. Both wharfs are on the towpath bank and are built of lime mortared rough stone in the form of snecked rubble (mostly yellow and buff coloured coal measures sandstones) brought to courses. The Norwood Colliery Wharf is 6 to 8 ft high (1.8 to 2.4 m) and would have stood at least 3 ft (0.9 m) above water level. The wall is topped with a series of four pairs of projecting stone beams which evidently held tramway rails or plates and would have enabled the rapid tip loading of boats moored beneath. The West Kiveton Colliery Wharf is of similar construction but stands only 1 to 2 ft (0.3 to 0.6 m) above water level and lacks any evidence for projecting beams (see archaeological reports).
- 11.2.7 The diversions of the canal line built in 1880 by the Manchester Sheffield and Lincolnshire Railway (later renamed the Great Central Railway) generally had a narrower channel cross section with steeper banks (at 1 in 2 or 1 in 1½), a narrower channel width (6m or less in places) and a deeper channel (5ft or 1.5 m) to reduce the need for dredging. In places, such as the outside of sharp turns, the banks were armoured with a layer of coarsely laid cobbles to reduce erosion. By the time of the railway diversions traffic had fallen away and wash walls were not required.
- 11.2.8 The original waterproof lining of the canal channel was clay “puddle”. This consisted of an 18 to 24 inch (c.0.4 to 0.6m) thick layer of clay trampled or “puddled” into place. This had the virtue of being inert and to some extent self sealing. The 1777 lengths generally have excellent puddle with an adequate depth of good quality clay, those “railway diversion” lengths built in the 1880’s are, however, known to have poorer quality, thinner, linings and were prone to leaking.
- 11.2.9 The restoration on the Chesterfield to Staveley section undertaken by Derbyshire County Council between 1996 and 2003 closely followed the original – 1777 - channel dimensions in both restoration and reinstatement. The works used a channel profile approximately 8 to 10 m wide and 1.6 m deep at centre. Soft 45 degree slope banks were used except at bridge holes and wharfs. Waterproofing was achieved by clay puddle in the traditional manner.

- 11.2.10 The earth outer bank was the location where leaks were most likely and the need for maintenance greatest. In consequence the towpath (which also provided access for inspection and repair) was generally carried along the top of the outer bank. As originally built the towpath appears to have been between 6 and 9 ft (1.8 to 2.7 m) width (sufficient for two led horses to pass without difficulty) and was not surfaced. Over time some heavily trafficked sections of the towpath were surfaced with gravel or more commonly cinders. Only at the wharfs and some bridge holes were cobbles or brick setts used to form a walking surface.
- 11.2.11 When built the canal track in open country was fenced on both banks with a continuous post and rail fence supplemented by a laid hawthorn hedge. The hedge seems to have been intended to replace the post and rail fencing over time. There were exceptions on the off-bank where landowners stipulated livestock access to the waters edge. In towns the boundary treatment showed more variation and depended more upon local building styles, adjacent landowner attitudes and the nature of canal side activity. A good example of urban canal side walling can be seen at Worksop on the former Canal Wharf.

11.3 Canal Track: Current Condition

- 11.3.1 The current condition of the channel and the nature of the infill – or where new channel is to be constructed the nature of underlying substrate – is given in **Appendix D, Table D1**. A summary is given in Figure 11.2 below.
- 11.3.2 The canal channel between Killamarsh and Kiveton Park is in a very variable condition. Some lengths are in water, some are intact but dry, some infilled and some require complete replacement by new construction.
- 11.3.3 The total length of canal to be restored is around 6442 m or just over 4 miles. Of this 3407 m is original channel to be reinstated and 3035 m is new construction. Approximately 730m of original canal channel is currently infilled and a further 3035m is to be excavated on a new alignment. The nature and condition of the fill is known over some 1687m and, at the time of writing, the condition of the fill over 2069m remains to be established.

Fill of Existing Channel

- 11.3.4 The majority of the channel works will involve the re-excavation and clearance of existing canal channel.
- 11.3.5 Where the channel has been deliberately infilled (such as through the centre of Killamarsh) the infilling material is largely known. Materials include building demolition debris (brick, concrete, tile, slate and cement) and industrial waste products (ash, slag, clinker and foundry sand). These are capped with a layer (of variable depth) of imported agricultural soil.
- 11.3.6 None of the known fills are contaminated and there are no known hazards associated with them. It is proposed to dispose of the arisings on site. Actual uses will depend upon engineering suitability for purpose but may include improvements to access, creation of required earthworks, repairs to damaged sections and the infilling of mining subsidence.

- 11.3.7 Topsoil & agricultural soil which has been deliberately emplaced as a capping on channel fills or has been ploughed or washed into the channel will be removed and stored separately from the main fills and will be used on site for landscaping purposes.
- 11.3.8 Where the original channel is infilled and the fill is unknown, analysis will be undertaken prior to planning application. It should be noted that these sections are short, recently infilled and in urban locations with no evidence for disposal of contaminated material. Notwithstanding, the precautionary principle shall apply until demonstrated otherwise. If contaminated material is located then appropriate treatment, handling and disposal regimes will be instituted.

Figure
11.1



Canal Channel

Original 1777 Canal
Channel near
Moorhouse Farm,
Killamarsh .

View from towpath
looking South.

Ground Conditions for New Channel

- 11.3.9 Substantial lengths of new canal channel will need to be created in the Killamarsh Town, Wales and Kiveton Park sections. The former because of the need to create a diversionary channel to avoid houses built on the original canal line in the 1970's and the latter to replace the partially collapsed Norwood Tunnel.
- 11.3.10 Figure 11.2 below shows the length of new channel which will be constructed in each section. It differentiates between shallow and deep overburdens based on existing borehole and test pit data. The overburden being the loose and relatively unconsolidated soil and sub-soil which as to be removed to reach a stable and cohesive substrate suitable for foundations. Where there are deep overburdens of unconsolidated material it will be necessary to employ techniques such as piling to stabilise the new works.
- 11.3.11 The existing borehole and test pit data is an initial estimate and will be refined by further geotechnical survey during the final design process, however sufficient is known to indicate that:

- 11.3.12 The Killamarsh Flight which takes the canal down into the Rother Valley is situated on Coal Measure Sandstones. The overburden here is relatively shallow and the dip and strike of the coal measures is relatively low and favourable. Extensive piling will not be required.
- 11.3.13 The Sheffield Road crossing and Nethermoor Lake Floodgate/Lock are both founded on the same coal measure sandstones with relatively shallow overburdens. Again, only limited piling is required.
- 11.3.14 The area around Nethermoor Lake up to the site of Barber’s Lane Bridge is largely composed of reclaimed open-cast coal workings. While it is likely that only limited mechanical compaction was undertaken, the site has had over twenty years of natural consolidation and, based on repeated surface measurements, is now stable. There are no major structures proposed in this area.
- 11.3.15 Barbers Lane Bridge and the Moorhouse Flight are situated on Coal Measures Sandstones which are moderately deeply weathered and overlain by a deep overburden of solifluction (head) deposits. The resultant slope is relatively unstable and will require piling of all major structures.
- 11.3.16 The Norwood High and Top Treble Locks are situated on the Coal Measure Sandstones escarpment. The sandstones are well weathered and there is a moderately deep overburden of solifluction deposits. The slope will require piling of major structures.
- 11.3.17 The canal channel from the M1 Motorway to the entrance to the former Kiveton Colliery Site is situated on the dip slope of the Coal Measures Escarpment. The overburden along this length is relatively shallow and the underlying bedrock is solid with favourable dip and strike. There is no immediate geological requirement for the piling of the foundations of the Coalpit Lane or Wales Locks.
- 11.3.18 The canal channel within the former Kiveton Colliery has already been formed and is stable. The location of the Hard Lane Locks will be in a cutting leading down to the surviving fragment of the Norwood Tunnel. This location will require underpinning / reinforcement as it is above the line of the partially collapsed Norwood Tunnel.
- 11.3.19 The cutting will be in Coal Measures Sandstone. At present a broad cutting with rest angles considerably greater than 1 in 3 is proposed and there would appear to be no requirement for rock bolting or similar treatments of the cutting sides.
- 11.3.20 Examination of extant mineral working records, heritage and archaeological survey records and surface inspection has so far failed to locate any evidence for surface mineral workings on the actual line of the new surface routes.
- 11.3.21 It is possible that there are unrecorded early (pre 18th century) coal mines (bell pits) on the route but there is no evidence for them at this time. Additional ground penetrating radar surveys are proposed to confirm the absence of workings. Should

Proposed Working Sections						
Proposed Length by Section of Channel :	Killamarsh Town	Killamarsh East	Norwood	Wales	Kiveton Park	TOTAL LENGTH
Length of Section *	1354 m	1714 m	654 m	875 m	1845 m	6442 m

Design Elements

CONDITION						
Infilled Original Channel, of which;	656 m	0 m	74 m	0 m	0 m	730 m
• Known Fill	441 m	0 m	74 m	0 m	0 m	515 m
• Unknown Fill	215 m	0 m	0 m	0 m	0 m	215 m
Open Original Channel, of which;	175 m	1430 m	580 m	0 m	492 m	2677 m
• Dry	175 m	385 m	0 m	0 m	0 m	560 m
• In Water	0 m	472 m	580 m	0 m	492 m	1544 m
• Shallow Ponds	0 m	573 m	0 m	0 m	0 m	573 m
New Channel, of which substrate is;	523 m	284 m	0 m	875 m	1353 m	3035 m
• Known	29 m	0 m	0 m	494	658	1181 m
• Unknown	494 m	284 m	0 m	381	695	1854 m
PROFILE						
Structural *	361 m	184 m	328 m	307 m	612 m	1792 m
Open "U" Soft Banks	603 m	741 m	276 m	192 m	830 m	2642 m
Reed shelf on off bank	170 m	647 m	0 m	376 m	403 m	1596 m
Wash wall one side	95 m	142 m	50 m	0 m	0 m	287 m
Wash walls both sides	125 m	0 m	0 m	0 m	0 m	125 m
LINER						
Clay Puddle	383 m	1530 m	326 m	100 m	1233 m	3572 m
Bentonite/Block	485 m	0 m	0 m	468 m	0 m	953 m
HDPE/Concrete	125 m	0 m	0 m	0 m	0 m	125 m
Structural (integral) *	361 m	184 m	328 m	307 m	612 m	1792 m

Figure 11.2 Summary of Channel Conditions, Fills and Proposed Channel Works (based on Appendix D, Table D1). (* = integral parts of major structures e.g. bridge holes, locks, etc).

workings be encountered these are likely to be shallow and not extensive. DCC Consultancy and Contracting has considerable experience in the remediation of this type of mining feature and conventional treatments (infilling, compaction and capping) will enable the route to be maintained on its currently proposed line. There

is no value in building the entire surface route in reinforced concrete as this is not required to deal with these minor features.

- 11.3.22 There is extensive documentary and physical evidence for deep mining across the entire proposed route. This has been summarised in the report on the condition of the Norwood Tunnel by Structural Perspectives (2004). Deep mining under the site ended with the closure of Westthorpe Colliery in 1987 and Kiveton Park Colliery in 1994.
- 11.3.23 Detailed levels surveys of the landscape along the proposed routes were undertaken in 1998, 2004 and 2008. Comparison of these surveys show no change in the relative levels along the route and indicate that the landscape is now stable.

Treatment of Arisings

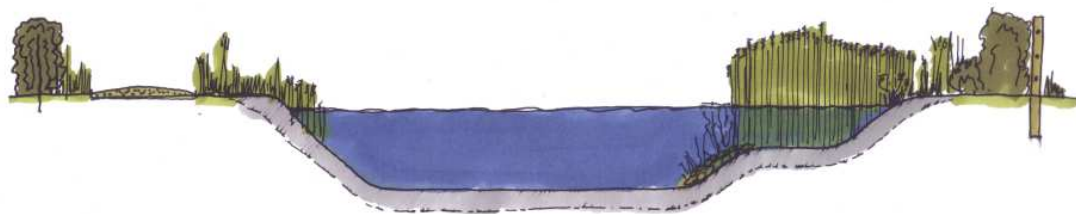
- 11.3.24 Sufficient it known of the general nature of channel infill's and new channel arising to make an estimate of the likely hazards at this preliminary stage. Additional testing will be undertaken prior to implementation of each stage. This will form part of the individual planning applications as they come forward.
- 11.3.25 Where arisings are not contaminated they will generally be disposed of on site through incorporation into new earthworks, access improvement works, repair to existing subsidence damaged earthworks or landscaping.
- 11.3.26 Where arisings are contaminated they will be disposed of in accordance with the appropriate legal requirement. In most cases this will involve disposal to deep landfill, although were appropriate bio-remediation may also be employed.

11.4 Canal Channel Dimensions & Cross Section Profile

Profile

- 11.4.1 Where the original canal channel survives and is capable of being restored then care will be take to ensure that the restoration profile follows the original. The original profile having been determined by site investigation. All surviving sections of canal channel in open country employ an open trapezoidal cross section (see 10.5 above). Restoration will employ compatible traditional materials.
- 11.4.2 Where new sections of canal channel have to be constructed they are designed to resemble the historic trapezoidal profile with the addition of an off bank "step" to provide several different water-depths and resultant habitats. As with the original channel sloping soft banks (rather than hard vertical wash walls) are employed. These have the advantage of being relatively simple and cheap to construct and have particular value in providing habitats for plants and animals including water vole.

Figure
11.3

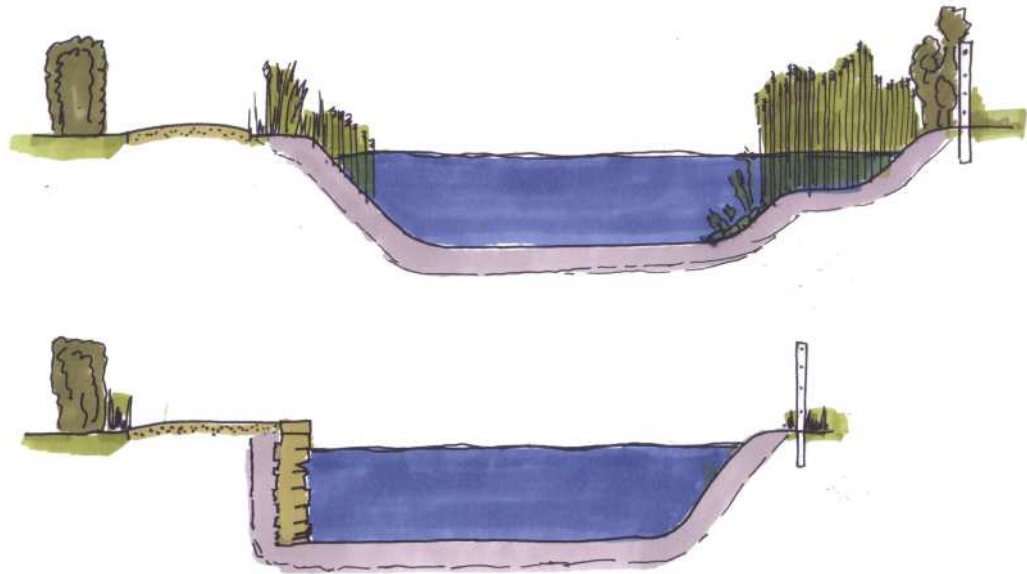


Idealised cross section through the reinstated canal track in open country.

Showing - from left to right – Towpath Bank Boundary (hedge), Towpath with verges, Towpath Bank, Channel, Reedshelf, Off-Bank, Off-bank margin and Off-bank Boundary (shrubs & fence).

- 11.4.3 The dimensions of the canal channel are specified below. The main elements of the channel in open country are as follows:
- 11.4.4 Towpath Bank Channel Side: This side of the channel will show the greatest variation. Where there is no restriction in width (generally in open country) soft engineering will be employed and the bank will be lined with puddling clay at a rest angle of less than 45 degrees. Where bank protection is required soft reinforcement (e.g. willow spilling or “grow through” geotextiles) will be employed.
- 11.4.5 The use of gently sloping banks will encourage “natural” crossing from wildlife and provide egress for animals accidentally immersed. Where steeper banks have to be employed “animal ramps” will be provided at intervals along the canal.
- 11.4.6 In areas where the canal narrows (usually in more urban settings) or where there is a need for moorings, the towpath bank will be reinforced with a wash wall. The structure will be dictated by engineering considerations but all visible surfaces (i.e. waterline and above) will be faced with stone or brick cladding, depending upon location and context. As noted above the original character of the canal dictates these sections with wash or wharf walls will be kept relatively short and will have a distinct identity as stopping and mooring places.
- 11.4.7 Main Channel: The main channel will normally be 9 to 10 m in width with a navigable depth of 1.5 m over a minimum width of 6 m. The normal waterproofing will be clay puddle with a depth of no less than 0.4 m (400 mm) (see notes on waterproofing below).
- 11.4.8 Off-Bank Channel Side (including Reed Shelf and “On-line” reserves, where possible): Where the canal is restricted to a narrow track this bank will mirror the construction of the Towpath Bank Channel Side (above). Where a wider track is possible then a stepped profile will be adopted to create a “reed shelf” along the off bank. The width of this shallow shelf will vary according to location but here we have assumed an average width of around 2 metres.

Figure
11.4



Idealised cross section through the reinstated canal track without reedshelf and with wash wall on towpath bank only (e.g. mooring or wharf).

Showing - from left to right – Towpath Bank Boundary (hedge), Towpath with verges, Towpath Bank or Wash Wall, Channel, Off-Bank, Off-bank margin and Off-bank Boundary (fence).

- 11.4.9 Mooring on the off-bank will be prohibited and warning signs will alert boaters to the shallow draught. Where experience demonstrates necessity a wooden bumper rail may be provided to segregate water bourn activity from reedswamp. The reedbeds will play an important role in dissipating boat and wind wash and thereby reduce wildlife disturbance and erosion of the off-bank.
- 11.4.10 Where additional bank protection is required soft reinforcement (e.g. willow spilling or “grow through” geotextiles) will be employed.
- 11.4.11 Offside Bank: Historically, the offside bank is usually located on the up-slope side of the canal and often takes the form of a shallow cutting no more than 1 to 1.5 m (3 to 4 ft) above water level. The borrow from the shallow cutting formed the towpath bank.

11.5 Wash Walls

- 11.5.1 While the vast majority of new channel works will be engineered with soft banks there are locations such as bridge holes, wharfs, stop plank narrows and lock approaches where it is necessary to construct vertical wash walls.
- 11.5.2 The construction of the wash walls was traditionally in cemented stone (on the Chesterfield usually snecked rubble brought to courses) with puddling clay (see waterproofing, below) packed behind the wall to create a seal. At wharfs and at

bridges the top of the wash wall was capped with broader, flat, coping stones. These have traditionally been of stone (here coal measures sandstones, millstone grit or similar) and a similar quality of material will be employed here.

- 11.5.3 Later wharfs and the railway company built replacement basin at Chesterfield employed a combination of hard red brick and engineers blue brick with stone coping stones.
- 11.5.4 Recent restoration at Mill Green Wharf Staveley has used poured mass concrete to form the functional wall with a cosmetic cladding composed of kerbstone (below water level) and salvaged coarse stone from just below water level to the salvaged original coping stones. The end result is a far stronger wall with lower maintenance costs which, when the canal is in water, appears identical to the original structure.
- 11.5.5 In other locations vertical sheet piling has been used to form banks and wash walls. This has structural and cost advantages but is not aesthetically pleasing and does not sit well in a rural environment.
- 11.5.6 Should sheet steel piling be dictated by engineering and geotechnical considerations then methods will be explored for disguising the piling. This could take the form of pre-cast concrete stone pattern cladding or a single skin of cladding brick resting (below planned water level) on a mass concrete foundation.
- 11.5.7 The wharf will require moorings bollards and mooring rings. Mooring bollard/rings should be located at no more than 4 m intervals along those sections where mooring is permitted. This “canal furniture” is integral to the waterside image and is essential to setting the tone and character of the site.

11.6 Lining & Waterproofing

- 11.6.1 There are several methods for rendering a canal channel waterproof in current use. Each has its own merits and all have been considered for use on the Killamarsh to Kiveton Park section. The methods are:

Clay Puddle

- 11.6.2 The traditional method was to form the channel and lay a 0.4 to 0.6 m deep layer of suitable clay. The layer was rendered waterproof by trampling into position (either by foot or by the use of a herd of cattle!) until an even consistency had been achieved.
- 11.6.3 The main advantage is that it is a proven technology; properly maintained clay puddle can function for hundreds of years. Patching and repair is relatively straightforward and to a limited extent the puddle is self sealing. It is a reasonable growth medium for aquatic plants and relatively forgiving of root system disturbance. It can be laid by non-specialist labour. The major disadvantages are that it is increasingly difficult to source suitable puddle clay at reasonable cost and that it is time consuming to lay and render water proof effectively. Further if clay puddle dries out it is prone to cracking and may not re-hydrate upon wetting leaving the canal prone to excessive leakage.
- 11.6.4 Where clay puddle is used it will fulfil the British waterways standards set out in the design specifications, Table D4 (part 2).

Composite HDPE and Concrete Liner

- 11.6.5 A 0.05 m (50 mm) to 0.1 m (100mm) layer of sand is placed over the formation to stop sharp stones migrating upwards. On silty clay soils the sand binding is not required.
- 11.6.6 A protective geofabric is then placed over the sand layer as the main liner protection material. This is usually High Density Poly-Ethylene (HDPE) but there are a number of other alternatives such as Polypropylene. Both types of liner are around 1mm thick and are laid from a roll. The sections of liner are stitched together in situ by heat joining which is then tested by machine controlled air pressure. Finally a 0.1 m (100mm) layer of protective concrete is placed on top of the lining. The technique requires specialist contractors and can only be laid in fine weather. Specialists normally give a 25 year warrantee on liner installation. The major disadvantage is that the concrete surfacing is a very poor growth medium for plants. This may be overcome by the use of gabion walls and rubble fill in “reed ledges” to promote plant growth and provide improved vole habitat (e.g. Project Atlas, Cotswold Canal Renaissance Phase 1, 2005).

Bentonite and Bentomat Liners

- 11.6.7 This is a layer of clay powder sandwiched between two protective geofabrics. It is laid over a sand bed as described above. The liner can be laid by non-specialist labour and is simply sealed by overlaps and pouring a clay seal. The liner must be kept compressed by a minimum of 0.3m (300mm) cover of earth or stone. The system can be laid in inclement weather. Bentonite systems have been in use for several years on the Kennet and Avon Canal without problems. The system is relatively wildlife friendly and appears to provide a suitable growth medium for aquatic plants without additional intervention.

Composite Bentomat and Concrete Block Liner Systems

- 11.6.8 The most recent arrival. This system has been developed for, and is now used on, the Wendover Arm of the Grand Union Canal.
- 11.6.9 The canal channel to be treated is cleaned and its profile brought to a rest angle of 1 in 2½. The channel sides must be free of significant sharp stones – should there be a significant angular stone content to the soil a thin sand layer (0.1 m) may have to be emplaced before the Bentomat is laid to prevent their migration. A shallow notch is cut at the very top of the channel slope (above water level) to enable the Bentomat to be eventually secured by overburden.
- 11.6.10 Pre-cut lengths of Bentomat are then used to line the sides of a prepared and cleaned canal channel and pegged loosely in place. A cast concrete footing is laid over the bottom of the Bentomat and along the joint between the base of the channel and the slope of the channel sides. The top of the shaped footing supports high density concrete blocks at the same angle as the slope of the cutting. The Blocks are then laid dry (no cement) in a simple overlapping bond to form a sloping wall-like covering for the Bentomat extending from the base of the channel to a point circa 0.25 m below the local pound level.
- 11.6.11 Along the top of this “wall” of concrete blocks is laid a coir matting roll circa 0.5 m in diameter. This acts as a buffer to protect the overlying soil from erosion.

- 11.6.12 Above the coir matting roll is laid soil and reclaimed bank materials stored from when the bank was cleaned and graded. The coir roll and this material overlays the Bentomat. The soil layer must be greater than 0.3 m deep to compress the Bentomat satisfactorily – the designed thickness is 0.4 m. This upper spoil layer fills the shallow notch and anchors the upper edge of the Bentomat sheet and grades the channel edge into the surrounding landscape.
- 11.6.13 Once both banks have been laid in this way the base of the channel (which has been in use as site access for the walling works) can be given a final clean and a further sheet of Bentomat laid along the bed. The sheet is wide enough to overlay the loose “tails” of Bentomat poking out from beneath the foot of each protected bank. The joints between Bentomat sheets are reinforced with copious amounts of loose Bentonite crystals.
- 11.6.14 The Bentomat is then covered with either (1) a 0.3 to 0.4 m deep layer of spoil and reclaimed clay from the clean up of the channel or (2) a 0.2 m deep layer of low grade ready-mix concrete.
- 11.6.15 The use of spoil and reclaimed puddle clay is a relatively low cost solution (and provides a suitable growth medium for aquatic plants) but has the considerable disadvantage of leaving the Bentomat liner susceptible to damage during subsequent dredging. To overcome this problem it is intended to “armour” the upper surface of the spoil with a layer of cobbles. In addition a series of upstanding concrete bunds the full width of the canal and the depth of the spoil covering every thirty metres will provide additional guidance to dredging crews.
- 11.6.16 Concrete has the advantage of providing very good protection for the Bentomat but with a higher carbon footprint and at considerable additional cost.
- 11.6.17 It is likely that both spoil and concrete capping will be used as is appropriate to the setting and the requirements for dredging and access.
- 11.6.18 Overall the Composite Bentomat and Concrete Block method appears to have several advantages. First, the majority of the liner below water level is laid in concrete blocks – this reduces the rooting of aquatic plants and thereby automatically keeps the navigation channel free of vegetation growth. Second, the presence of the Coir Roll and earth overburden from just below water level to the top of the bank provides a soft rooting and burrowing medium ideally suited to marginal aquatic plants and water vole. Third, the method is self contained and short sections of channel can be constructed and then protected from drying out in a short space of time making it very suitable for delivery by volunteer groups.

Water Losses from Puddled and Lined Lengths

- 11.6.19 The overall rate of leakage from a clay puddle lined canal is higher than for other methods. The typical average depth of operational water loss on the UK system is around 160 mm (0.16 m) per day (i.e. a depth of 160 mm of water is lost over the entire length). This compares with 50 mm (0.05 m) per day on a length lined with geomembrane liner.
- 11.6.20 This figure is based on a typical water loss values of 10 mm for evapotranspiration, 10mm through the lining itself and 30mm through the joints between liner and structures.

11.6.21 It is concluded that a lined canal will help to minimise water loss. This attribute will be useful in locations where minimising down-slope soil wetting is a priority (for example in the passage of Killamarsh).

Selection of Waterproofing System on the Killamarsh to Kiveton Park Section

11.6.22 While the liner systems may have some advantages in terms of preventing water loss they can have significant disadvantages. Most notably they have a limited proven lifespan (25 years as opposed to 200 years), some require specialist contractors to lay and their environmental impact (especially that of the composite HDPE and Concrete liner system) can be poor. Further, the installation of liner systems into existing channels will require the removal of historical material and will have an adverse, and unacceptable, impact on the archaeology of the canal where the original channel survives.

11.6.23 No single system is therefore suitable for use throughout the Killamarsh to Kiveton Park reinstatement. In consequence it has been decided that:

- Where there is an extant historic channel this will be repaired and relined wherever possible using traditional puddle clay.
- Where there is a new channel in a low lying location where water loss is not an issue (for example in the traverse of the floor of the Rother Valley) clay puddle will also be used.
- Where there is a repaired channel where retention of maximum biodiversity is essential clay puddle will also be used.
- Where new channel is constructed in open country and potential water loss is an issue (for example the new summit pound on the Wales Length) the new composite Bentomat and concrete block method will be used. This will reduce water loss and promote fringing aquatic and semi-aquatic plant growth.
- Where new channel is constructed in a constricted location (Killamarsh Town) where clearances and nearby structures dictate a hard edged solution and leakage must be reduced to a minimum the composite HDPE and concrete liner or composite piling/HDPE and concrete liner methods will be employed. Current designs calls for very limited lengths of hard engineered channel.

11.6.24 The liner system proposed for each section is summarised in Table D1.

Figure 11.5



Composite Bentomat and Concrete Block Channel Lining Method

Stage One: Channel cleared and accurately profiled. Profile swept and Large stones removed by hand.

Figure 11.6



Composite Bentomat and Concrete Block Channel Lining Method

Stage Two: Bentomat rolls are laid on each bank and temporarily pegged into place.

Figure 11.7



Composite Bentomat and Concrete Block Channel Lining Method

Stage Three: Plank shuttering used to build concrete form over lower edge of Bentomat. At same time hollow concrete blocks packed with cement used to set angle for first layer of blockwork.

Figure 11.8



Composite Bentomat and Concrete Block Channel Lining Method

Stage Four: concrete blocks laid (no cement) over Bentomat below water level and coir roll installed along waterline.

Figure 11.9



Composite Bentomat and Concrete Block Channel Lining Method

Stage Five: Earth & reused puddle clay is machine packed over Bentomat above water level. Boards protect concrete blocks.

Figure 11.10



Composite Bentomat and Concrete Block Channel Lining Method

Stage Six: Bentomat is laid along the floor of the channel – overlapping the lower edges of the side layers and the concrete footings. Earth and reused puddle clay is laid over the Bentomat to a depth of 0.4 to 0.5 m. waterline.

11.7 Canal Channel: Winding Holes, On-line & Off-Line Reserves

Winding Holes

- 11.7.1 A Winding Hole is a location where it is possible to turn a boat which is substantially longer than the canal is wide. They usually take the form of a small side cut which allows the boat to execute a “three point turn”. Winding can also be executed at the junction of a canal and a side arm or basin.
- 11.7.2 A winding hole (pronounced “wind-ing” as the term derives from the use of the wind to assist pushing the boat around) was required at locations where boats are likely to require turning and were usually sited near wharfs. As the canal fell into disuse the winding holes were often the first locations to silt up and were easily lost to landowner encroachments.
- 11.7.3 In the reinstatement of the canal winding holes will be located at:
- Above Old Farm Lock, Killamarsh (the end of the long pound from Staveley and thus a point where boats will turn if they do not wish to descend to Nethermoor Lake)
 - At the end of the mooring arm on the original canal line at Moorhouse Farm (enabling boats to turn before the Moorhouse Flight)
 - Between Norwood Bridge and the foot of the Norwood Flight (site of an original, and still visible, winding hole)
 - Between Coalpit Lane Double Locks and the M1 Motorway underpass.
- 11.7.4 In addition it will be possible for boats to be turned in Nethermoor Lake and at the entrance to Kiveton Waters Marina. Taken overall this yields a winding hole approximately every half mile which is considerably better than their average frequency of every 1½ to 2 miles between Kiveton Park and West Stockwith.
- 11.7.5 Where new winding holes are constructed they will be designed to provide additional shallow water wetland habitat. A typical winding hole design is shown in the accompanying drawings.

On-Line Reserves (Reed Shelves and Silt Screens)

- 11.7.6 Where there is sufficient pace within the available track the opportunity will be taken to wide the water channel and create a stepped profile will be adopted to create a “reed shelf” along the off bank. The width of this shallow shelf will vary according to location but on average will have a width of around 2 metres.
- 11.7.7 Mooring on the off-bank will be prohibited and warning signs will alert boaters to the shallow draught. Where experience demonstrates necessity a wooden bumper rail may be provided to segregate water bourn activity from reedswamp. The reedbeds will play an important role in dissipating boat and wind wash and thereby reduce wildlife disturbance and erosion of the off-bank.
- 11.7.8 Where there are established wetland habitats within the surviving canal channel (for example west of Rotherham Road Bridge No.29 in Killamarsh) it is desirable to protect part of that community while off-line reserves (below) mature. Experiments on the Rochdale Canal have shown that a fine nylon mesh screen supported by

vertical posts can make an effective silt screen. This enable dredging and boat movements in the main channel while retaining relatively clear water behind the screen.

- 11.7.9 During the initial development silt screens of this type will be used from the stop plank narrows at Norwood Industrial Estate to the site of Ellison’s Cottages. These will also help to filter the water flowing into the new off-line reserves (Gannow Ponds) running parallel to the canal.

Off-Line Reserves

- 11.7.10 Following abandonment several lengths of the historic canal have become shallow and have developed relatively diverse wetland habitats. In order to mitigate for disturbance to these habitats resulting from restoration it is proposed to create a number of “off-line” reserves. The reserves are “off-line” in that they are not intended for navigation and will be sited on the off-bank so as to minimise disturbance from towpath users.
- 11.7.11 Further reserves will be created on the new sections of the route which currently have no aquatic habitats. This will increase the overall biodiversity of the canal and will provide wildlife refuges along the route
- 11.7.12 The off-line reserves are in addition to the in-line mitigation measures such as the creation of reed shelves and shallow “broads” in the canal channel previously described.
- 11.7.13 The proposed off-line reserves are
- Gannow Side Ponds
 - Lower, Middle and Upper Norwood Ponds
 - Summit Pound Side Ponds
- 11.7.14 The **Gannow Side Ponds** are located adjacent to the partially watered section from Ellison’s Cottages to Rotherham Road Bridge. This section is designated as a (Derbyshire) County Wildlife Site on the basis of its reedswamp flora.
- 11.7.15 The Gannow Side Ponds will occupy ground on the off bank to the south and west of the existing canal line and will take advantage of confused topography created by mining subsidence to form a chain of linked but somewhat irregular and variable depth ponds. Water will be admitted to the ponds by a small take off weir and culvert at the eastern end of the pond chain and will be passed back into the canal by a similar culvert at the eastern end. The culverts will be used to regulate waterflow and prevent flooding on adjacent land. These ponds will be lined with puddle clay to simulate the substrate found in the existing channel.
- 11.7.16 When the ponds have been formed they will initially be watered by pumping and then vegetation will be transplanted from the main channel. This will be allowed to establish before the main channel is partially cleared, restored and water levels raised to operational levels. This follows the methods successfully used on the Montgomery Canal to create alternative habitats prior to restoration.
- 11.7.17 Once the canal becomes fully operational elements of the parallel inline off-bank flora will be protected by a silt screen as described above.

- 11.7.18 The **Lower, Middle and Upper Norwood Ponds** are situated on the Norwood Flight. All three ponds are currently extant and have been dredged to create ornamental lakes by their current owners.
- 11.7.19 The Lower and Middle Ponds are true side ponds and lie off the main canal line. Both ponds have navigable entrances and it appears that when the Norwood flight was in operation they were used by maintenance boats making deliveries to the Norwood yards and saw mill. There is no requirement to return navigation to these ponds and it is intended that the Lower and Middle Ponds become off-line reserves.
- 11.7.20 The Upper Pond form part the canal route and is technically an on-line reserve but is dealt with here for simplicity. As note above experiments on the Rochdale Canal have shown that in-line reserves may be created by the erection of silt screens in the canal channel (Inland Waterways Advisory Council/English Nature 2008). It is proposed that the south-western half of the upper pond be divided from the navigable channel in this way and the protected area created be treated as an off-line reserve.
- 11.7.21 The **Summit Pound Side Ponds** are situated on the off bank of the summit level between the M1 Motorway underpass and the top of the Wales double locks. These ponds are intended to (a) provide greater biodiversity on the summit pound by offering off-line reedswamp and shallow water habitats and (b) increase the overall water capacity of the summit pound and thus increase the resilience of the pound when locks are operated simultaneously at both the east and west ends of the pound.

11.8 Water Level and Regulation

Pound Levels

- 11.8.1 The **pound level** (water level) at the tail of Dixon's Lock near Staveley once formed the start of an uninterrupted six mile "long pound" to the foot of Belk Lane Lock in Killamarsh. In the restoration proposals this long pound will now end at Old Farm Lock on the western edge of Killamarsh. Old Farm Lock marks the start of the diversion works required to take the canal through and around Killamarsh.
- 11.8.2 At Old Farm Lock the canal will descend by 2m to gain sufficient clearance for bridges within the centre of Killamarsh. The canal then reaches the top of the Killamarsh flight where it will descend 15.8 metres to pass under Sheffield Road. Its final descent is 1.2 metres to pass through Nethermoor Lake flood barrier and reach the normal lake level at 36.9 m AOD.
- 11.8.3 Nethermoor Lake Lock and Floodgate will make allowance normal season fluctuations in the level of Nethermoor Lake by the provision of a deep lock chamber and lowered sill. The lock will be linked to the lake by a deeper than normal channel.

Proposed Pounds

Key Elements	Lowgates to Old Farm Lock (No.6a)	Old Farm Lock to Top of Killamarsh Flight	Bottom of Killamarsh Flight to Nethermoor Flood gate	Nethermoor Lake*	Top of Moorhouse Locks to foot of Norwood Flight	Top of Original Norwood Flight (West Portal Old Norwood Tunnel)**	Top of Norwood Flight to Coalpit Lane Locks (Summit pound)***	Coalpit Lane Locks to Wales Locks	Wales Locks to Kiveton Locks (Including Kiveton Waters Marina)	Kiveton Locks to Norwood Tunnel East Portal**
Canal Towpath (Bank Level)	56.1	54.1	41.7*	37.4	57.3	78.3	98.3	90.3	86.3	78.3
Water Level (Pound Level)	55.8	53.8	38.0	36.9	57.0	78.0	98.0	90.0	86.0	78.0
Base of Channel (Invert Level)	54.2	52.2	36.4	<i>sill level*</i> 33.8	55.4	76.4	96.4	88.4	84.4	76.4

Figure 11.11 Proposed Pound, Invert and Towpath Levels for reinstatement of the Chesterfield Canal from Killamarsh to Kiveton Park. (Note that the very short pounds between the locks on the Killamarsh & Norwood Flights omitted).

Notes:

- * = Sill level lower to allow for seasonal change in lake level of up to 1.5 m.
- ** = Former summit pound level & current top pound on restored BW canal.
- *** = Level assuming use of unmodified underpass (see underpass options above).

- 11.8.4 The diversion will then leave Nethermoor lake via a short channel at lake level (again with a deeper than normal channel to account for seasonal fluctuations in level) which gives access to the foot of the Moorhouse Locks. The Moorhouse Locks will raise the canal by c.20.1 metres back to the original line of the canal near Norwood Industrial Estate (57.0 m AOD). The diversion rejoins the canal to the north of (or uphill from) Belk Lane Lock – thus the rise on the diversion is greater than the fall.
- 11.8.5 The original canal line remains at this level until the foot of the Norwood flight. It then rises in stages to reach the old summit or Norwood Tunnel level at 78 m AOD.
- 11.8.6 From that point it then rises a further twenty metres to pass through the existing Poplar Farm underpass at c. 98 m AOD.
- 11.8.7 Note that It may be possible to greatly reduce the ascent at this point by deepening the farm underpass foundations and creating a box culvert below the level of the current floor of the underpass (i.e. the roof of the culvert forming the roadway through the underpass). This has the advantage of reducing the ascent (and thus saving on locks), retaining vehicle access through the underpass and creating a slightly longer summit pound with consequent water storage benefits. While this option reduces lock construction costs it will increase construction costs on the underpass and this balance will need to be taken into account in determining the final summit level. If this option is possible it may be possible to reduce the summit level to c. 92 m AOD with a saving of four locks – two each side of the motorway.

- 11.8.8 The box culvert in underpass option was considered feasible by Arup but they had insufficient time to explore it in detail. Discussions are now underway with the Highways Agency to see what may be possible given the planned widening of the M1 motorway. It should be noted that any level changes **will not affect the route** – the same alignment will be used whether the canal passes under the motorway at c. 98 m AOD or at c. 92 m AOD.
- 11.8.9 Once on the eastern side of the Motorway the canal will descend via two sets of double locks following the slope of the landscape to c. 90 m AOD and thence to c. 86 m AOD – the level of the existing Kiveton Waters ponds (destined to be Kiveton Waters Marina). From the Marina level the canal will descend to 78 m AOD at the entrance to the remaining tunnel fragment – this is the level in the current summit (Norwood Tunnel Level) pound.

11.9 Managing and Regulating Water in the Canal

Water Control and Management

- 11.9.1 The control and management of water on the canal requires ancillary structures to deliver water to the canal, maintain navigable pound levels, deliver adequate through flow and oxygenation of water and prevent flooding under storm or other exceptional conditions (See Figure 11.12, below). Water management and supply is discussed further in parts 14 and 15, below.

Water Inflow

- 11.9.2 Conventional stilling pond inflow weirs and inlets will be located at the head of the Norwood Flight and at Kiveton Waters. Reed bed filtered inflows will be located below Wales Double Locks and in Killamarsh (Sheffield Road).
- 11.9.3 The design of reed bed filters follows the designs recommended by the Environment Agency.

Water Level (Pound Level) Control

- 11.9.4 Pound level is maintained by **Regulating** and **Side Weirs**.
- 11.9.5 Pound level is maintained by **Regulating Weirs**: These regulate the amount of water passing along the waterway and govern its rate of flow. The crest of the regulating weir being at the required pound water level. Any water over this level will spill over and drain into the next lower pound. The regulating weirs in this case are integral to the Lock and Floodgate structures (see locks and by-weirs, below).
- 11.9.6 Excess water is removed by **Side Weirs**: The crest of the side weir is set slightly above that of the regulating weir. Should water levels rise above the discharge capacity of the regulating weir then excess water will flow over the side weir and discharge via a leat back to an adjacent natural watercourse. In some cases intermediate balancing ponds are used to store storm flow. The majority of side weirs along the canal are designed to have long crests which rise very slightly either side of the regulating notch height. This allows for gradually increasing flow as water depth increases to cope with storm surges. Some side weirs also have either

a penstock or a series of removable planks to permit the gradual drawing down of a pound to a particular level for maintenance purposes.

- 11.9.7 Each basin or short pound not on the river itself will be designed so it can be drained to permit essential maintenance and occasional cleaning. This can be facilitated by using lock gates and differences in level or through draw down penstocks or removable weir planks on the side weirs.

Water Length (Maintenance Length)

- 11.9.8 Structures are also required to permit the controlled de-watering of lengths of the canal for maintenance purposes and to enable lengths of the canal to be isolated should a catastrophic breach or other emergency occur. For that reason the canal is divided into a series of pounds and each pound is subdivided into a maintenance length.
- 11.9.9 Each length can be sealed with stop planks (sometimes called stop logs). Stop planks can be dropped into grooves or slots which are integral to bridge narrows and to the up and downstream ends of the locks. Where there is a long pound it may be subdivided by a stone or brick built narrowing of the canal channel with integral slots called a “stop plank narrows”.
- 11.9.10 The lengths between each set of stop planks must be capable of being dewatered using (1) a drawn down penstock or (2) a regulating weir with a lower-able crest or (3) the paddles of the lock immediately down stream.

	Proposed Working Sections					
	Killamarsh Town	Killamarsh East	Norwood	Wales	Kiveton Park	TOTAL
Water Inflow Points (field drains with bio-filters)	1	1	2	3	1	8
Regulating or Side Weirs	1	1	1	1	1	5
Stop-plank Narrows – Integral to Bridge	5	5	0	2	2	14
Stop-plank Narrows – Isolated Structure	0	1	0	0	2	2
Maintenance Lengths	6	7	9*	8*	4	na

Figure 11.12 Water Control: Summary of Extant and Proposed Inflow Points and Regulating and Side Weirs (* = Maintenance lengths using locks for stoppage)

