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KILDARE TOWN BYPASS
DESIGN AND CONSTRUCTION

JOHN COPPINGER, Kildare County Council.
ERIC R FARRELL, Trinity College, Dublin.

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SYNOPSIS

The 13.2 km long Kildare Town Bypass generated considerable public interest during its design arising from the possible impact of dewatering for a cut section on the internationally significant Pollardstown Fen which was about 5km from the proposed route. Apart from this aspect, the Bypass also included several major cuts, a 3.2km embankment section that crossed the Monasterevin bog and major drainage works. This paper discusses the design and construction aspects of the project and describes the innovative engineering concepts that were developed to overcome environmental and engineering challenges.

INTRODUCTION

The Kildare Town Bypass is part of the N7 which links Dublin, the capital of Ireland, with two important regional cities, Cork and Limerick. The existing road runs through the town of Kildare and this gives rise to long traffic delays at peak hours. The improvement of this section of the route by bypassing the town is, therefore, long overdue.

Kildare County Council has been heavily committed to and affected by the increased pace of National development and has years of experience in bringing a series of major road projects to construction. This Bypass represents the latest on their programme.

The Kildare Town Bypass generated considerable public interest during its planning stages due to the possible impact of the road drainage on Pollardstown Fen, which was about 5km distant. Apart from this aspect, the Bypass included a large embankment over a bog, structures and major drainage works. This paper describes these various aspects, along with the innovative concept of a 'tanked' section that was developed to overcome the environmental challanges.

NEED FOR THE KILDARE TOWN BYPASS

Over the years various projects have improved or by-passed sections of the original single carriageway N7 National Primary Route. The Naas to Dublin road was improved in the 1960's and 1970's. The Naas Bypass, Newbridge Bypass, and Portlaoise Bypass have also been constructed.

From 1989 onwards, Kildare County Council, through a combination of its own engineering experience and the expertise of various consultants, began to formally identify the need for a road of dual carriageway dimensions to bypass Kildare Town. The need to bypass the town with a road to motorway standards had been identified from traffic records and from traffic projections combined with an analysis of accidents and reports on noise and air pollution.

TRAFFIC

In 1989 comprehensive traffic counts and origin/destination surveys were conducted. The resulting analysis showed that if no action were taken 29,336 v.p.d. would be trying to use the town centre by 2017. The vast majority of this traffic was identified as by-passable traffic in the assignment process. This was on the basis of a 3% annual growth in traffic. That rate was considered conservative and prudent at the time. In 1999, 20,835 v.p.d. passed through Kildare Town. Accidents were examined and between 1977 and 1991 they averaged one fatal accident and six serious injury accidents per annum on the route between the townlands of Mayfield to Ballymany and which represent the limits of the Bypass.

HISTORY OF THE DESIGN

Kildare County Council, through its 1985 County Development Plan, required the council to identify possible routes for a by-pass of Kildare Town. In 1989 Kildare County Council set about formally selecting a route. The council used its own expertise and specialist advice from outside bodies to complete the selection process.

In September 1991 the elected members accepted the recommended route which is now being constructed.

The EU has provided monies to assist in the design and construction of projects such as Kildare Town Bypass. The fundamental objective of this is to reduce the negative impact of Ireland's peripherality on economic activity.

A public enquiry was held and the Minister for the Environment approved the scheme in early 1996. A significant section of the Bypass is in a cut which penetrates the Mid-Kildare Aquifer. There was some discussion between experts at the Public Enquiry regarding the risk of the groundwater level drawdown resulting from the road drainage impacting on the Pollardstown Fen which was some 5km from the road. Because of this, the Minister required that Kildare County Council, in consultation with the Office of Public Works (Duchas), Irish National Stud, Japanese Gardens Management, private well owners and fishery interests, etc., immediately design and implement a groundwater monitoring programme. This programme was designed to allow for evaluation of the existing groundwater regime and dependant flora and fauna in the area that might be affected by the proposed cutting through the aquifer. Kildare County Council were also instructed to implement any remedial measures shown to be necessary. The profile of the Motorway was also raised by 2 metres at one point on the alignment on the basis of the Public Enquiry.

ROUTE ALIGNMENT

Kildare Town is located about 55km south west of Dublin and is one of the principal towns of Co. Kildare. The population of the town was 4,200 in 1993 and is predicted to rise to 12,500 by 2006.

The Bypass extends from the townland of Mayfield just east of Monasterevin to the Curragh on the east of Kildare Town where it ties in to the existing Newbridge Bypass – see Figure 1. The ground is generally gently undulating glacial topography to the west and south of the town with a surface elevations of between 67mOD and 93mOD (Poolbeg). The ground rises to about 120mOD to the east were it crosses the Curragh Plain.

There are two interchanges in the project. The first interchange is at Mayfield and this will serve Monasterevin when the M7 Heath/Mayfield scheme (the next project to the west) bypasses Monasterevin. The second interchange serves Kildare town and is located about 0.75 km south of the town centre.

13.2km of motorway will be constructed under this scheme.

There are approximately 12 km of minor roads associated with the project along with nine bridges and Storm Water Holding Tanks to serve Kildare Town.

The horizontal alignment of the main motorway consists of five straights and four curves. Curve radii vary from 4000 m to 9500 m. The vertical alignment consists of seven curves with six straights. The cross section of the mainline consists of 2 x 7.3m wide carriageways as shown on Figure 2. A one metre inner hard

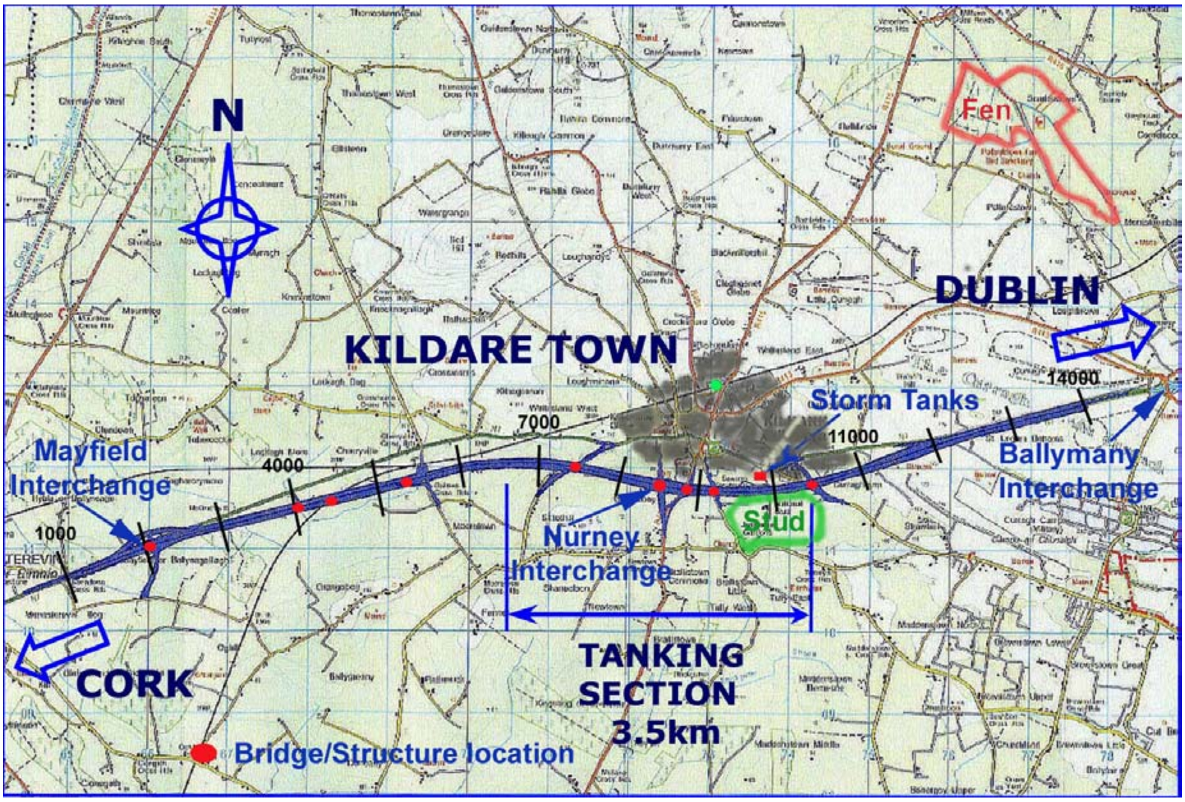

Figure 1 – Site Plan

shoulder and a three metre outer hard shoulder bound each carriageway. The grass median strip is seven metres wide.

The cross section is in line with RT180 Geometric Design Guidelines (An Foras Forbartha). The minor road carriageway widths vary from 5.5 m to 7.3m.

DRAINAGE

All drainage discharging from the project is routed to the Barrow either directly through a dedicated piped outfall or indirectly by discharging to Simpsons Stream (tributary of the Blackwater) which enters the Barrow north of Monasterevin. Drains within the site between Ch 3940 and Ch 12500 run to a central carrier pipe which is 6.5km long and 1.8m in diameter. The vast majority of the discharge into this pipe is from road surface drainage on the mainline and minor roads. The tender drawings show that the carrier is a significant structure with over 20,000m^3 of concrete surround.

A special form of construction, generally referred to as the Tanked Section, was adopted for the section of the Bypass which penetrates the Mid-Kildare aquifer between Ch 6900 and Ch 10400 – see Figure 1. This construction involved a complex system of drainage with a total length of pipework of about 60km. Details of the construction of this section are discussed later in this paper.

The road drainage system outside these chainages is similar to that normally adopted for roads to motorway standard with the exception of a concrete channel section along the road edge at areas where the longitudinal gradient is small. There are approximately 40km of drains through this 9.7km of motorway and 12km of minor road.

The surface water discharge was designed using the Wallingford procedure.

STRUCTURES

The bridge structures on the Kildare Town Bypass separate the local road network from through traffic on the motorway. There are nine major bridge structures along the route of the project, two at interchanges, three underpass bridges and four overpass structures – see Figure 1. In total, six different Consulting Engineering firms are involved in the design and supervision of bridges and other reinforced concrete structures.

The various Consulting Engineers used a number of different bridge styles. This means individual bridges vary in design leading to variation in construction methods from bridge to bridge. Reinforced Earth abutments were used for 1 bridge and cast in-situ concrete for 7 of the remainder. Piers vary in shape and number.

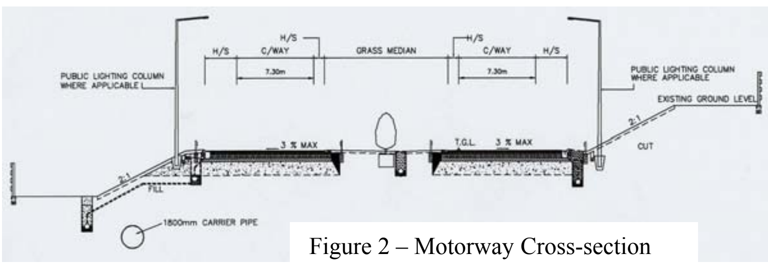

Figure 2 – Motorway Cross-section

Decks are cast in-situ as either post tensioned voided slab, box girder or reinforced slab on precast concrete beams. One bridge was a precast concrete arch.

There are a number of bridges within the tanked area and this complicates the construction of those structures.

Structure 10 is a series of four storm water holding tanks to contain sewage from the Kildare Town's partly combined foul sewer system. These tanks are located north of the motorway near the town – see Figure 1. The sewage is pumped underneath the motorway to the Sewage Treatment Works south of the motorway.

GROUND INVESTIGATIONS

A preliminary ground investigation was carried out in 1991. This comprised of a desk study and some light cable percussive holes (Shell & Auger), trial pits, along with some mackintosh probes to give an initial estimate of the depth of the soft soils in the bogland areas.

The main ground investigation was carried out in two phases by Irish Geotechnical Services Ltd (IGSL). The majority was carried out in the first phase between December 1991 and September 1993. The second phase from March to June 1994 concentrated on the bridge locations, which had been finalised at this stage, and in obtaining further localised earthworks information. Some supplementary piezocone probes (CPTus) and deep trial pits were carried out in 1997 to get additional information at specific locations. These ground investigations included light cable percussive boreholes, rotary drill holes, 4 No. pumping tests, geophysical investigations, trial pits up to 4.5m depth, dynamic probes and laboratory testing. Boring using the light cable percussive methods to depth through the glacial deposits was generally very difficult due to the presence of boulders. Pressuremeter and Marchete dilatometer testing was carried out in an attempt to determine the strength and compression characteristics of soft glacial deposits under peats in the bogland area, however these proved in general to be of limited success.

A factual report on the finding of the preliminary and main investigations was prepared by IGSL. An interpretative report with engineering recommendations, prepared by Dr Eric R. Farrell, was included in the tender documentation.

GROUND CONDITIONS

The geological strata encountered on the project generally comprised a complex series of glacial deposits overlying limestone bedrock. Recent organic soils, marls and soft postglacial inorganic deposits overlay the glacial soils in the bogland areas.

The bogland areas were made up of very soft organic soils and calcareous marls up to about 3m thick, over postglacial and glacial inorganic soils. The geotechnical properties of these postglacial silts and clays are discussed in the embankment section later in this paper. Piezometers installed at depth in the glacial soils showed that there was an upward flow of groundwater in these bogland areas. For example, the water level in the piezometers at 8m and 10m depth at the Railway Bridge site at about Ch 4500 – see Figure 1, rose to about 0.5m above ground level.

The glacial deposits are about 6m to 15m thick on the western end of the route, increasing to over 35m immediately south of Kildare Town. These comprise a complex series of sand, gravels and sandy gravelly Clays and Silts, along with local areas of glacial lacustrine deposits. These glacial soils are predominantly granular in the area of the Mid-Kildare Aquifer, which extends eastwards from approximately Ch 6900. This aquifer is considered to have been formed by glaciofluvial and glaciolacustrine processes which lead to depositional outwash deposits, including extensive deltaic fan deposits (Glanville, 1997). However, significant till deposits were also encountered. Generally the upper 3 to 6m had significant fines and would typically be referred to as a 'cohesive' till.

The bedrock in this area comprises Carboniferous Limestones of the Waulsortian, Boston Hill and Richardstown Formations (Geology of Kildare-Wicklow, 1995). Although relevant to the hydrogeology of the area, rock was only actually encountered in the works during the construction of the 1.80m carrier pipe between Ch 5100 and Ch 5900.

HYDROGEOLOGY

The hydrogeology was an important aspect, both in relation to the potential environmental impact of the scheme on the groundwater and in relation to the construction dewatering requirements.

An extensive hydrogeological study of the Mid-Kildare Aquifer was carried out on behalf of Kildare County Council by KT Cullen & Associates and Entec Ltd. This study included water head readings at various depths and at various locations within the aquifer, special studies of the hydrogeology and ecology of the Pollardstown Fen, the estimation and measurements of flow from the aquifer and extensive 3-D numerical modelling of the aquifer by Entec Ltd. under the direction of Prof. K Rushton, Chairman of the Monitoring Committee.

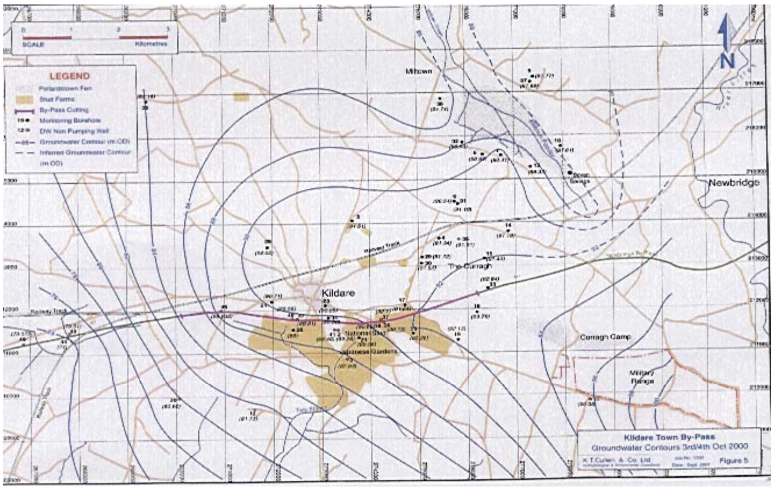

Figure 3 – Typical Groundwater Contours

and of the road cutting, both during and after construction.

The general groundwater level contours for the Mid-Kildare Aquifer recorded in these studies are shown on Figure 3. These water levels do vary with time, depending on the rainfall and evaporation rates. The water level variation recorded along the line of the Bypass prior to construction was generally between 1m and 2m, depending on the location of the piezometers. The particular conditions that make the ecology of Pollardstown Fen special is that it dips below the general water table of the aquifer and has a low permeability base.

Thus water, which is highly carbonated in this area, spills over the edges in the form of springs. The carbonate is deposited from the water in the form of tufa when exposed to air, to form the special ecological environment. The water under the central area of the fen is under artesian pressure, thus giving rise to a slow upward flow of water. The water from Pollardstown Fen is used to feed the Grand Canal and a reduction in this supply was also of concern.

There was a concern by some that the road drainage system for the Kildare Town Bypass, which would lower the water level along the route, would cause a significant change in the hydraulic divide and consequently have an effect on the flows into Pollardstown Fen. This concern led to the adoption of the Tanking System for a section of the route.

EARTHWORKS

Fill criteria

The main cut sections were at Mayfield (Ch 1300 to Ch 2550), between Ch 6250 and Ch 10400 and at the Curragh (Ch 11070 and Ch 12540). The ground conditions were very variable, containing fine grained ‘cohesive’ tills as well as a variety of glacio-fluvial and glacio-lacustrine deposits.

The plasticity index of the fine grained till was low which is typical of most of the Irish tills – see Figure 4. The compaction results indicated that the MCV was an appropriate test for limiting the engineering

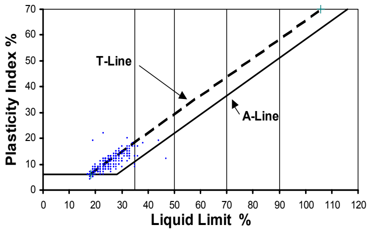

Figure 4 – Atterberg Limits

properties of these soils. The CBR versus moisture content relationship developed from the laboratory tests conformed to that published by Davitt (1984) – see Figure 5. On the basis of these results, and on an analysis of the compaction characteristics, an MCV of 8 was selected as the lower limit for acceptable fine grained till for general fill.

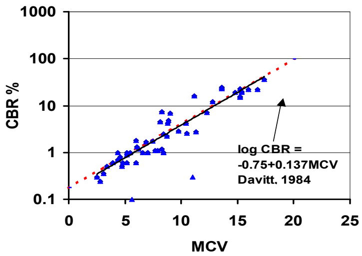

Figure 5 – CBR versus MCV

Embankments

The section of the bypass between about Ch 2500 and Ch 5000 is on an embankment of up to 13m in height, most of it over bogland. The peats/organic soils and marls are generally up to 2m in depth with local deeper spots. These very soft compressible soils are underlain by variable post glacial and glacial deposits comprising sandy gravely Clays, laminated clays, silts and very clayey sandy Gravels.

The moisture contents in the peats were between 400 and 700%, which were to be expected in these soils. The assessment of the in-situ strength of the underlying post glacial or glacial fine soils was difficult to determine due to sample and borehole disturbance. As stated previously, pressuremeter and Marchetti dilatometer testing proved to be inconclusive due to site difficulties and due to the stone content of the soil. These soils have a very low plasticity index, generally being between about 6 and 18%. The moisture contents recorded from boreholes samples were between 8% and 18% with no significant trend of reduction with depth. The fines content for most of these soils were above 35%. These soils are easily disturbed when sampled and undrained shear strengths determined in laboratory UU tests on samples recovered were considered to be unrepresentative of the in-situ strength. A sample reconsolidated under an effective stress of 20kPa in a CUD triaxial test recorded an undrained shear strength of 35.7kPa.. Although N values recorded in the boreholes where low at about 2 to 4, CPTus indicated that the in-situ undrained shear strength below about 4.0m was in excess of 60kPa – see Figure 6 which shows the undrained shear strength estimated assuming an N_k coefficient of 15.

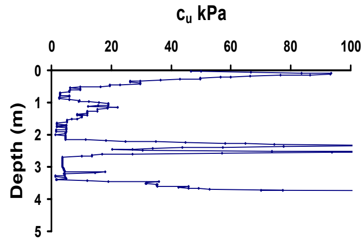

Figure 6 – c_u from CPTu

The strength of the inorganic soils above that depth was more variable, however consolidation tests indicated that these soils had a relatively low compressibility with $(C_c/(1+e_o))$ values of between 0.031 and 0.048, (where C_c is the compression index and e_o is the initial void ratio of the soil) and a relatively high coefficient of consolidation of about $20m^2/yr$. These soils were to be left in place beneath the embankment and a provision was made to allow a 6 month consolation period when the embankment was at 10m height. A 1m free draining granular layer was to be placed on a geotextile to form a working platform and to act as a drainage layer. Water percolation through the ground would not be significant.

TANKED SECTION

The term ‘tanked section’ is given to the form of construction, devised by Dr Eric R. Farrell, which was adopted between Ch 6900 and Ch 10400. This section of the Bypass penetrates the Mid-Kildare Aquifer.

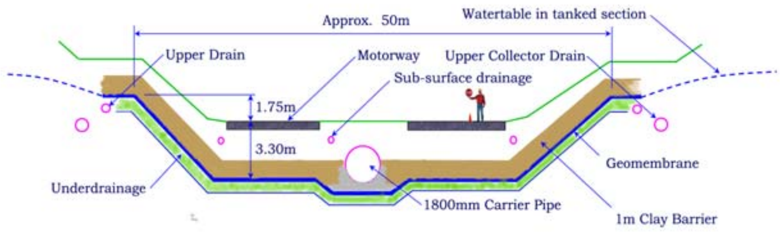

Figure 7 – Tanked Section

The concept

The basic function of the tanked section is to minimise the groundwater drawdown from the permanent drainage system of the motorway. In traditional road construction, the road subsoil drains lower the watertable by about 1.5m below road level. In the tanked section, the water level is 1.75m above the road level – see Figure 7. In relation to the water levels along the motorway prior to its construction, the tanked section will generally maintain the groundwater at about the seasonal low level. The tanked section could not be economically constructed to prevent uplift under the extreme high water levels recorded along the line of the motorway during the high water level season. Furthermore, a tanked section alone would form an impermeable barrier that could significantly affect the groundwater flow conditions. An underdrain system was therefore constructed to ensure that excessive water pressures could not build up beneath the tanked section and to maintain flow around the motorway – see Figure 7. This underdrainage system maintained the groundwater levels at a height of 1.75m above road level, thus reducing the drawdown by at least 3.25m. This meant that the water levels in the aquifer along the line of the tanked section were maintained at about the recorded seasonal low levels. The flows that would be taken from the aquifer when the Bypass is completed are estimated at about 10 l/s at seasonal low water levels to 150 l/s at high water levels. These estimates were based on the findings of the numerical model by Entec Ltd.

Normal road construction was adopted within the tanked section. This included a requirement for subsoil drains to protect the subgrade.

Design against uplift

The tanked section was designed in accordance with the ENV 1997-1 (1994) Eurocode 7, Pt 1, Geotechnical Design. This enabled the concept of characteristic parameters to be adopted in design and quality control monitoring. The basic relationship to be satisfied in relation to uplift is

$$\gamma_g(\gamma_k D) \geq \gamma_w(D + h_w + \Delta h)$$

where γ_k and γ_w are the characteristic unit weight of the soil and water respectively and γ_g is the partial factor on the actions, D is the thickness of the material above the base of the impermeable barrier and h_w is the additional head of water above the road surface. A partial factor of 0.9 was adopted as recommended in EC 7. The Δh term is to allow for the seepage water pressure required for the water at the centre of the road to flow to the upperdrains and a value of 0.25m was used in the design. The underdrain comprised a central 250mm thick granular layer of 10mm to 37.5mm crushed stone with a 10% fines value greater than 130kN with a 100mm filter layer underneath and a blinding layer on top to avoid high point contact stresses on the overlying geosynthetic. Drainage pipes, 75mm diameter and perforated on the top half circumferences, were installed transversely in the stone layer at 5m centres to ensure that head losses in the underdrain were kept to a minimum.

The characteristic unit weight, which is critical to the stability of the tanked sections, was specified in the tender documents as the lowest of the following:-

$$\gamma_k = 9.81*(\rho_{av}-0.06)$$

or

$$9.81*(\rho_{av} - 1.64*\sigma) \ Mg/m^3$$

where ρ_{av} = average of 4 No. density readings measured using nuclear density gauge at corners of 1m square and σ is the standard deviation.

A characteristic weight of 21kN/m^3 was selected for use in design based on an analysis of density tests on compacted well graded glacial soils.

The design of the central carrier drain and of the manholes against uplift required special consideration and an extended base slab was constructed to use part of the weight of the soil within the tanked section to resist the uplift water pressure. A characteristic unit weight of 22.5kN/m^3 was adopted for the concrete.

Tanking layers

The sealing of the tanked section is achieved by a composite geosynthetic/low permeability clay barrier. The design of the clay section of this 1m thick barrier, called the Low Permeability Material Barrier (LPMB) is based on a coefficient of permeability of less than 10^{-8} m/s. Research into the permeability of well graded glacial soils has shown that this could readily be achieved provided the soil has more than 35% fines (percentage passing 63μm sieve), Swartz et al (2003). Tests on material from the Bypass confirmed this, provided it was compacted wet of optimum and to 95% of the maximum dry density achieved using the 2.5kg compaction level ($\rho_{max2.5kg}$). The specification required the LPMB to have an MCV of between 4 and 8 for the first 0.6m and 5 to 12 for remaining 0.4m, 35% or more fines and to have a characteristic unit weight of 21kN/m^3 or greater. Based on the results of laboratory tests on the material used on site, the specification for the upper 0.4m of this low permeability barrier was relaxed to allow the use of material with 30% fines or more.

The project was initially designed for a composite geosynthetic barrier comprising of a geosynthetic clay barrier, a polymeric geomembrane and a non-woven geotextile. The Contractor subsequently proposed an alternative single 4.8mm thick layer of Coletanche NTP 3 bituminous geomembrane. Extensive field and laboratory testing showed that this liner met the design requirements and also had the advantage of being relatively robust. As a precaution, stones greater than 37.5mm were screened from the low permeability material placed within 200mm of the liner and stones greater than 100mm for the next 400mm The size of the compaction plant to be used to form the LPMB was also restricted. Details of the design of the composite geosynthetic/low permeability clay material barrier is given in Coppinger et al (2002).

The materials on top of the low permeability barrier were in accordance with the normal specification for acceptable material, capping and road pavement with the additional requirement that these materials have a characteristic unit weight of 21 kN/m^3.

Prevention of clogging

The waters within the Mid-Kildare aquifer have a high carbonate content with the result that calcium carbonate deposits can be formed when the water is exposed to the atmosphere. This process gives rise to the tufa mounds within the Pollardstown Fen, however in the context of the upperdrainage system, such deposits could clog the drainage system. The design prevents this by requiring the water to flow over a weir within a manhole such that the upperdrain is permanently 0.5m below the water level

Prevention of longitudinal drainage

The alignment of the Kildare Town Bypass along the tanked sections is on a vertical curve, consequently the underdrain could act as a longitudinal drain and lower the water level to the lowest point. Transverse barriers were constructed using low permeability clay material to prevent this longitudinal flow – see Figure 8. A geohydraulic analysis showed that it was prudent to limit the head difference across the barriers to 0.1m in order to prevent local excessive flows beneath the barriers themselves. In practice, this resulted in transverse barriers at 50m centres, with a reduction to 25m centres at the steeper sections of the vertical alignment.

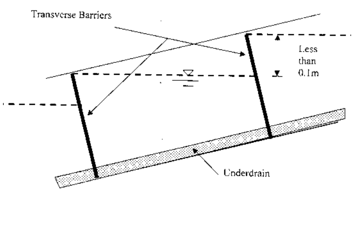

Figure 8 – Transverse barriers

EARTHWORKS BALANCE

The final design involves 3 million m^3 of cutting with 1.44 million m^3 of embankment fill required. A surplus of 75,000m^3 of suitable material was estimated from an analysis of ground investigation.

In addition, the contract required the importation of 116,000m^3 of Low Permeability Barrier Material though some of this may be available on site. The site investigation indicated only a small quantity of rock present in the works. This has proved correct.

SITE ORGANISATION

The Engineer is Mr. J. Lynch, Director of Services and County Engineer, with the various consultant engineering firms acting as the Engineer for their respective structures. The Engineer's supervision team were recruited and employed by Kildare County Council.

It can be seen that the Tanking Construction requires high levels of supervision. It is also worth noting that significant resources have had to be dedicated to design at varying times.

In addition the contract includes for the appointment through the Contractor of an independent chartered engineer to oversee the Certified Quality Assurance associated with the Tanking Construction.

GROUNDWATER MONITORING COMMITTEE

Kildare County Council formed a Groundwater Monitoring Committee to satisfy those requirements of the Minister of the Environment relating to consultations with relevant bodies and to groundwater monitoring. This committee has also been working in parallel with the project team in accordance with the requirements of the ministerial order. While the committee have no direct control over the contract or site activities their opinion weighs heavily in any decision by the Engineer. The numerical groundwater model developed for the committee has been used to compare the effects of various scenarios proposed by the Contractor. These scenarios involve modification of the constraints on groundwater extraction associated with Tanking. In evaluating and comparing any output it must be remembered that the model was designed to reflect the worst case scenario and as such, the Engineer does not use the output to calculate flows and levels but rather compare scenarios.

The results have helped to maintain and increase confidence in the construction methods and the design solution to difficult environmental challenges.

CONSTRUCTION

Kildare Town Bypass is being constructed through a series of two preliminary contracts and one main contract.

The first preliminary contract involved the construction and improvement of two outfalls. The first outfall drains water directly from the west end of the project to the Barrow in a 1.2m diameter pipe. The second outfall drains into Simpson's Stream which is also a tributary of the Barrow. The cross section of Simpson's Stream was enlarged for a portion of its length immediately down stream of the point where it crosses the site at Ch 3940. The Contractor was Wills Brothers and the contract was completed in October 1999.

The second preliminary contract involved the construction of Structure 3a bridge over the railway (Athy Branch line). This was to enable the transport of fill over the railway and greatly facilitated the main contract. The Contractor was Ascon and the contract was completed in August 1999.

The main contract is for the completion of the main carriageway including cuttings, embankments, tanking and surfacing. It also includes the completion of interchanges, bridges, minor roads and storm water holding tanks. The Contractor is Pat Mulcair Civil Engineering and Building Contractor. The project was awarded in February 2001, and runs for 39 months.

The Contract began with the construction of the first part of the main carrier pipe between Ch3940 and Ch 6900 and included a thrust bore pipe beneath the railway embankment at Ch 4550. This 1.8m diameter outfall ultimately extends to Ch 10400.

The first earthworks season began with the removal of the peat and some of the soft material between Ch 2500 and Ch 5700. The main point of interest was the decision to leave most of the inorganic soils in place under the embankment, even where the ground investigation indicated that the upper layers of these soils were very soft. This decision was based on the results of site and laboratory tests. It is also worth noting that the contract documents detailed the temporary works associated with construction of the embankment. This is a reflection of the level of difficulty expected during its construction.

Filling of embankments began immediately with the excavation of material from the cutting at Mayfield. The Contractor worked hard to maximise the suitable material from Mayfield as the haul distance was short. The large area of embankment facilitated the maximum use of these materials.

Bridges began early in the Contract and are being completed in the following order: Structure 9, 8, 1, 2, 5, 6, 4, 7,10.

Tanking began in late 2001 at Ch 6900 with dewatering of a 300m trial section. This was later extended to 500m to include the bridge site at Structure 5. The contract confined tanking to a 500m section of dewatered cutting at any one time. However, bridge sites could be dewatered separately. The novelty of the tanking construction meant that everyone involved had to go through an initial learning period. For instance, while dewatering of cuttings is common practice, the minimisation of dewatering over a period of 3 earthworks seasons requires the Contractor to develop a way of reducing the volume extracted and associated cost. The intensity of the overall construction within the 500m section was also a major challenge.

The Contractor used excavators and dump trucks for the movement of materials within the tanking cutting and for the long haul from about Ch 11800 to Ch 4500.

The second season (year 2002) has seen the completion of much of the bulk excavation outside of the tanking. Bridges and surfacing have also continued. However tanking has been the most critical activity in 2002.

Groundwater monitoring on site

It was stated above that the dewatering associated with the tanking and indeed with all of the works between Ch 6900 and Ch 10400 were initially curtailed to 500m lengths of the cutting. In addition the contract required a four-month break in dewatering to allow recovery of the water table generally. During 2002 the length of cutting was extended to 1000m and the four-month break has been waived this winter. This is done to reduce the overall length of time for dewatering and consequently to minimise the effect on the groundwater regime. This was possible because of the close co-operation between the Engineer and the Groundwater Monitoring Committee and the confidence in the groundwater monitoring taking place on and off the site. The groundwater model was used to compare the various scenarios based on the experience of the 2001 season.

The Monitoring Committee controls the off-site monitoring while on site monitoring forms part of the contract. On site groundwater levels are recorded at monitoring boreholes located at 50m centres along the cutting between Ch 6900 and Ch 10400. The flow of all water from the cutting is monitored with continuous measurement, if possible, or else with frequents spot measurements. This involves continuous dedicated manpower as pumps are often changed around and/or diverted to alternate outfalls. As the cutting proceeds and surfacing begins within the tanked area, it is intended to separate the groundwater flows leaving the dewatered cutting (Active Flows) from the surface run-off and also to measure the groundwater extracted via the upper drainage system.

Tanking

The tanking construction is a new phenomenon and is consequently the most interesting and challenging part of the project.

The first stage of this activity is dewatering of the ground to be excavated. While some deep wells were installed, the main method involves using drains and sumps to draw down the water initially. Slim line pumps are then used to maintain the water levels just below the excavated outline. This is attractive to all involved as it minimises the volume extracted. The total flows including discharges from structures sites and 1km of dewatered excavation ranges between 160 l/s and 220 l/s.

Once the initial dewatering is under way, the contractor begins excavation of the cutting above the drawdown level. The slim line pumps are then placed just behind the side slope.

The upper drains and upper collector drains (all consisting of HDPE pipes) are placed at this time and are followed by the installation of the underdrainage. This is done in sections. Typically the first phase extends from the left-hand side upper drains to the right hand side of the Carrier pipe located in the median.

The Coletanche NTP3 bituminous geomembrane liner is laid out on the finished underdrain filter material and welded together. All the horizontal welds are then checked using an ultrasound device (CAC) connected to a computer. This can detect the weld width and leaks in the welds even where these extend along the weld. The welds on the side slopes are checked using a vacuum box and weld width is measured using a hand held ultrasound device. The liner is initially laid under the line of the carrier pipe to allow it to be constructed. The remainder of the area is then covered.

When the first section of liner is installed the construction of the carrier proceeds. This involves placing a structural concrete slab followed by the concrete pipe and in-situ concrete cradle or full surround where necessary.

Backfill over this area begins when the liner and carrier pipe have been completed and checked. The first five layers of material consist of Low Permeability Barrier Material which has an MCV in the range 4 to 8, to ensure density and low permeability. The material must be in intimate contact with the liner to ensure the required combined permeability is achieved. The first layer is 200mm thick fine material. It is processed (screened) to remove all stone greater than 37.5mm. It is difficult to screen these fine materials when they are this wet. The second and third layers are similar but only stone greater than 100 mm is removed. The fourth and fifth layers are similar but can contain fewer fines.

It must be compacted to a density equal to 21 kN/m^3 and this is checked using a nuclear density gauge. There is significant movement of this material during compaction and it can be hard to maintain its shape when placing and compacting material immediately above it. The material is sensitive to small changes in moisture content and care is needed to maintain its MCV.

Selected suitable material is next placed over the low permeability barrier material. Again the density must be equal to 21 kN/m^3. This is important to ensure sufficient weight to prevent uplift, especially at the critical points such as the back of verge and through the median. Backfill then continues with the placing of lower sub-base and low permeability barrier material in the side slopes. The density equal to $21kN/m^3$ continues to be a density requirement up to the underside of sub-base and underside of topsoil. Selected and processed unsuitable material can be used in certain areas.

When the fill reaches a certain specified level and all services and other works are complete to that level then the groundwater can be allowed to recover. This allows the water rise to the control level that is 0.5m above the upper drains. It will then be maintained at or below that level with excess water being removed through the upper collector drain system.

Roadside drains, ducts, manholes and gullies, public light foundations and sign foundations must all be completed before the water is allowed rise. In the design, all those items with voids have been provided with concrete surrounds or concrete bases to ensure sufficient weight exists to prevent uplift. The concrete is compacted to a density equal to $22.5kN/m^3$ as opposed to the $21kN/m^3$ of the surrounding soil.

If possible all fixings for road furniture that might need replacing are detailed so that no excavation is required in the future. Otherwise a large area of the cutting would have to be dewatered again at enormous cost.

Certified Quality Assurance

The tanking activities are all subject to a certified quality assurance (CQA) system included in the contract. An independent chartered engineer (CQA engineer) is engaged to plan and supervise the CQA system. The progress of this is reported to both the Contractor and the Engineer on a weekly basis.

CONCLUSION

The design and construction of the Kildare Town Bypass presented many engineering challenges which were successfully overcome. One of the most significant aspects was that an engineering solution was found for an environmental concern through the co-operation of the engineers and environmentalists involved and under the guidance and experience of the NRA. The successful construction owes much to the excellent working relationship between Kildare County Council and the Contractor's site teams and their ability to develop pragmatic solutions.

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STRUCTURE CONSULTANTS

The Consulting Engineering firms are:
HGL O'Connor & Co. (Str. 1 & 2)
W.S. Atkins & Co. (Str. 3)
Molloy Pollock Punch (Str. 4 & 5)
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Ove Arup (Str. 8 & 9)
Nicholas O'Dwyer (Str. 10)

GEOTECHNICAL CONSULTANT

AGL Consulting

MAIN CONTRACTOR

Pat Mulcair Civil Engineering and Building Contractor

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