FIRST INDEPENDENT ENGINEERING EXPERTS' REPORT:

A REVIEW OF THE RAILWAY ORDER APPLICATION FOR DUBLIN METRO NORTH AND CONSIDERATION OF THE CONCERNS OF RESIDENTS AND OTHER INTERESTED PARTIES

VOLUME I: REVIEW OF THE ENVIRONMENTAL IMPACT STATEMENT AND OTHER RAILWAY ORDER DOCUMENTATION

1. INTRODUCTION

1.1 The authors of the report

1.1.1 This report has been prepared by a team of independent engineering experts commissioned (in August 2008) by the Railway Procurement Agency (RPA) on behalf of residents' groups and associations, and other stakeholders with interests in the effects of the Metro North scheme for Dublin. The team is managed and co-ordinated by GWP Consultants LLP and currently comprises the following experts:

Ruth Allington	**(GWP)** Project Manager, responsible for ensuring that the expert team's work is effectively communicated to residents and for ensuring a continued dialogue with, and flow of information between, the RPA and residents' groups.
Dr Michael DeFreitas	**(First Steps Ltd)** Lead expert, and expert on hydrogeology and ground response to tunnelling. Responsible for co-ordinating the work of the engineering experts.
Dr Alan Cobb	**(GWP and Blast Log Ltd)** Vibration expert.
Dr Paul Cockcroft	**(WBM)** Noise and groundborne noise expert.
David Donaldson	**(Donaldson Associates)** Tunnelling expert.

1.1.2 The range of expertise reflects the requirements set out in the terms of reference for the Independent Engineering Expert team. These were developed by the RPA in partnership with residents' representatives, who also participated in the selection process.

1.2 Purpose of the report

1.2.1 This report is the first formal output of the independent expert team and is intended to be available to residents as a resource to assist them in their consideration of the Railway Order application for Metro North, and in participating in the consultation process (including, as appropriate, making written and oral submissions to An Bord Pleanála).

1.2.2 The Railway Order application, which was submitted to An Bord Pleanála on 17th September 2008, comprises the following elements:

- a draft of the proposed Railway Order;
- plans showing details of the proposed railway works;
- a 'book of reference' to the plan indicating the identity of the owners and occupiers of the lands described in the plan; and

- a statement of the likely effects on the environment (an "Environmental Impact Statement") of the proposed railway works.

1.2.3 Interested parties had until 29th October 2008 to make submissions to An Bord Pleanála. A draft of our report was issued for comment and discussion on 8th October 2008, followed up by open public meetings, meetings with the RPA engineering and environmental teams and meetings with groups of residents and others during the week commencing 20th October 2008. The draft report aimed to provide information and technical background to assist interested parties in framing their submissions and to record their concerns, questions and objections (communicated to us in meetings and in correspondence during August and September 2008). The meetings held during the week commencing 20th October 2008 allowed the experts to explain in more detail some of the matters covered in the report and to identify further questions, matters of concern, and objections from interested parties that should be covered in the final report. In addition, these meetings and associated correspondence provided an opportunity to receive feedback (comments, clarification, further points requiring consideration and suggestions as to amendments) from RPA and interested parties. A schedule of meetings held and attended by the Independent Experts is included at Appendix 1.

1.2.4 The comments and feedback on the 8th October draft resulted in an amended and expanded version of the report. A final draft report was issued on 20th December 2008, intended to incorporate the comments and feedback received on the draft and to bring up to date the schedule of interested parties' concerns, questions and objections (originally Section 5 in the October 2008 draft, now Volume II of this Report). This is a final version of our report incorporating feedback on the December 2008 final draft. The principal differences are as follows:

- **Volume I** Update of Section 1 to reflect changes in other parts of the document. Later sections left unchanged except for insertion of reference to the new Appendix 4.
- **Volume II** Expansion of some sections and addition of sections to reflect omissions in the final draft (drawn to our attention by several residents' groups), feedback from RPA on the final draft of Volume II and requests to express their concerns more clearly from some parties.
- **Volume III** Schedule of meetings extended to include meetings held in January 2009. Additional appendix (Appendix 4) added: *Document entitled "RfR tunnelling questions and answers for Independent Expert (Jan 2009)".*

1.2.5 To assist readers, we have made available marked up versions of elements of the report that have been amended and/or extended since the December final draft.

1.3 Scope and structure of the report

1.3.1 Our report is in three volumes:

- Volume I (this volume) provides an introduction to environmental impact assessment and the design process, together with a review of selected sections of the Environmental Impact Statement;
- Volume II (based on Section 5 of the October draft) provides a summary with comments and cross references of the particular concerns and questions of residents and other interested parties; and
- Volume III includes supporting appendices for Volumes I and II.

Volume I

1.3.2 Volume I of our report is based on a review of the Environmental Impact Statement (EIS), backed up by reference to the plans showing details of the proposed railway works. All of these documents (comprising the Railway Order Application for Dublin Metro North) may be found at www.dublinmetronorth.ie/. We have also had access to unpublished technical data and reports generated by and for the RPA design and environmental teams, but these have not been reviewed in detail. Our review has considered the adequacy and clarity of each of the elements of the EIS depicted in the sketch after paragraph 2.2.3, for topics of particular interest and concern to residents (see Volume II). We have also attempted to identify gaps or unanswered questions that arise from the Railway Order Application (especially the EIS and the drawings describing the scheme).

1.3.3 We have some specific reservations about the breadth of coverage and/or the way in which the results of the environmental assessment have been communicated for some topic areas. However, overall, we are satisfied that no major subject for concern has been overlooked in the EIS and we note that, in some respects, it goes beyond what is statutorily required to be covered in an EIS. The EIS is of limited usefulness to a non-technical readership without some additional guidance. Volume I of our report attempts to bridge this gap by presenting the findings of our review in three main sections following this introductory section as follows:

Section 2 – an introduction to the EIS, its structure and purpose.

Section 3 – background sections covering:

- How the final detailed design will be developed, and how it will be monitored and controlled; and
- How tunnels and underground stations are constructed.

1.3.4 Section 3 is intended to set the scene for residents to help them appreciate the stage that the engineering design of the scheme has reached and how it will be refined between now and the construction phase, as well as providing a non-technical introduction to tunnelling and associated works, such as station and shaft construction.

Section 4 – Consideration of key environmental impacts relevant to the project[3]:

- Airborne noise from construction works and railway operation (also referred to as "environmental noise");
- Vibration and groundborne noise from metro construction and operation;
- Influence of proposed works on surface water;
- Influence of proposed works on groundwater; and

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3 Some of the issues of particular interest to residents concern topic areas that were not anticipated in the original brief for our appointment (particularly for sections of the line that do not involve tunnelling). Particular examples are traffic and flood risk. Although we have included a section covering surface water (including flood risk) in Section 4 in this report (drawing on expertise and experience available within the team), other matters of concern that have been raised with us (notably traffic impacts and the feasibility of design changes to elevated and 'at grade' surface track to reduce impacts) are not covered in this report (although they are recorded as concerns in Volume II and comment is made where appropriate). We anticipate addressing these additional areas if appropriate in an addendum report drawing, where appropriate, on expertise within the expert team members' organisations (or elsewhere if necessary).

- Settlement of ground around tunnels and excavations.

1.3.5 Each of the scientific sections in Section 4 is structured as follows:

(i) Introduction to the subject - important concepts and terminology;
(ii) Reference to relevant sections of the EIS;
(iii) Description of the assumptions made in the Metro North assessments and the methodology used;
(iv) Summary of the results of the assessment; and
(v) Comment from the Independent Engineering Experts on the adequacy and clarity of the EIA (and other Railway Order documentation) in relation to the impact under consideration and identification of gaps and/or un-answered questions.

Volume II

1.3.6 Volume II records the concerns expressed and issues raised during meetings with, and in correspondence from, residents and other interested parties. Where possible, we have provided cross references to Volume I of this report and the Railway Order documentation (especially the EIS). We have also included our own comments and observations where appropriate and have recorded feedback from RPA as well as details of any further developments on specific issues since we issued our draft report for comment and discussion in October 2008 and since the final draft in December 2008.

Volume III

1.3.7 The report is supported by appendices in Volume III as follows:

- **Appendix 1** Schedule of groups of residents and other interested parties with which the experts have worked to date and a record of meetings held.
- **Appendix 2** Table summarising proposed and minimum depths from ground surface to the bored tunnel and inferred depths to rockhead.
- **Appendix 3** RPA comments on GWP draft report for comment issued in October 2008 (Version 3 (RJS/GFE))
- **Appendix 4** Document entitled: "RfR Tunnelling questions for Independent Expert (Jan 2009)". (First issued and circulated to residents, RPA and other interested parties February 2009).

1.3.8 We anticipate that our report (together with any future addenda required to cover further topic areas and our continued assistance) will provide a useful resource for residents in ongoing discussions and negotiations with RPA and during the Oral Hearing. In the future, it may be useful as a source of reference during the construction phase.

2. THE ENVIRONMENTAL IMPACT STATEMENT

2.1.1 Environmental Resources Management (Ireland) Ltd. (ERM) has co-ordinated the work of some 20 environmental experts to undertake an Environmental Impact Assessment. The findings of this assessment are reported in a 3-volume Environmental Impact Statement (EIS) for the Metro North scheme.

2.1.2 The objective of the EIS is to consider the likely impact that the proposed scheme described in the Railway Order application may have on the people who live close to it and their surroundings, and to describe the mitigating measures that can be taken to avoid (and, if not avoid, to reduce and constrain) hazards and disturbances to the local population, its resources and the natural environment. The EIS is a central part of the Railway Order documentation and records various conclusions reached by the ERM team. The EIS does not set out in full the basis upon which those conclusions were reached and it is therefore important to appreciate that behind it there are many other investigations and analyses that the ERM team used to support its work. We have had access to some of the supporting data and reports relevant to key topic areas, and also to the experts who prepared certain chapters to discuss details of their approach and methodology.

2.1.3 The Environmental Impact Assessment reported in the EIS was carried out generally in accordance with the standard methodology indicated in the sketch at Figure 1 below (after paragraph 2.2.3). Figure 1 provides references to the EIS volumes where relevant aspects of the environmental impact assessment are reported and more detailed guidance to navigating the EIS is provided for the specific environmental topics covered in Section 4 of this report.

2.1.4 In response to comments on the discussion draft from members of the public regarding the accessibility of the EIS, given its specialist vocabulary, we have added the following additional section in this report introducing important terms and concepts used in the EIS.

2.2 Important terms and concepts used in the EIS

2.2.1 This section identifies some of the specialist vocabulary and concepts that are used in the main parts of the EIS (describing baseline studies, impact prediction and impact assessment) to assist readers in navigating through the document and interpreting its findings. There is a helpful glossary of terms included at the end of each of the books and volumes comprising the EIS; this section aims to assist readers by putting into context some of the terms therein.

2.2.2 Environmental impact assessment is based on a simple source-pathway-receptor model where the "source" is the origin of the impact, the "pathway" is the transmission route of the impact to areas outside the source and the "receptor" is the natural and built environment, most notably people and the structures they occupy and use. In applying this model, the ***source*** of each impact arising from the scheme is identified (*e.g.* a train moving along the track at surface giving rise to noise and visual impact or a tunnel boring machine working at depth, giving rise to vibration and ground-borne noise). The location and magnitude of the source is also assessed (*e.g.* sound power level of particular equipment, numbers of vehicles on a particular stretch of road, amount of water to be discharged at a particular point *etc*) and the time for which it will be operating in a particular location.

2.2.3 In order for a source of impact to cause a detectable change (or effect) at any other location (*e.g.* noise or vibration generated at point A (the source) to be heard or felt at point B (the receptor)), there must be a ***pathway*** linking them together (*e.g.* noise is propagated through the air, vibration is propagated through the ground, the pathway for visual impact is a line of sight *etc*).

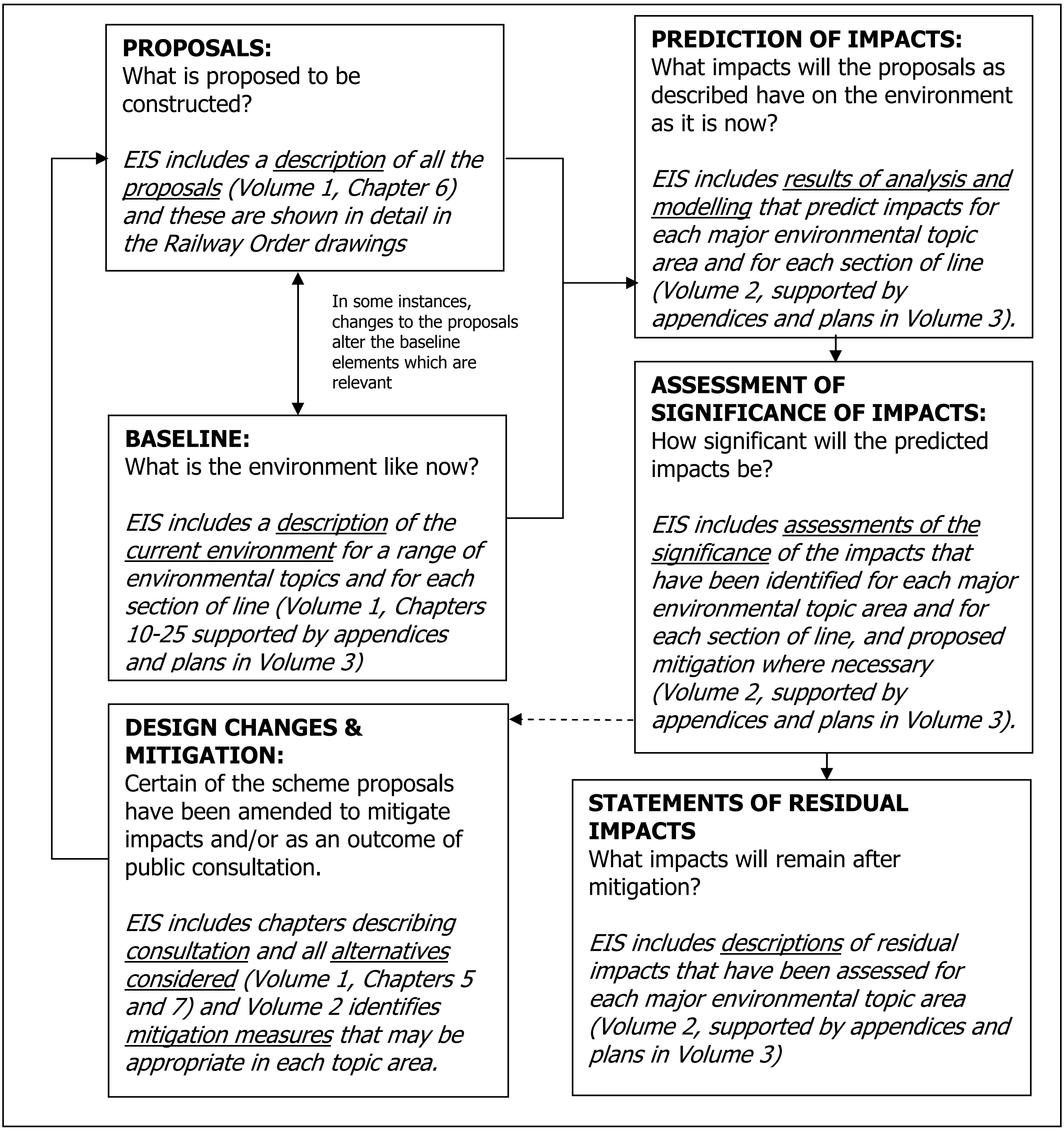

Figure 1: Environmental Impact Assessment methodology

2.2.4 People, sensitive environments and structures which may be affected by the impact of 'sources' of environmental change transmitted *via* 'pathways' are referred to as ***receptors***. Examples of receptors are: people who live close enough to a source of noise or vibration to hear it or feel it; structures that are within a zone where settlement could occur; landscapes that might be changed as a result of the structures to be constructed within them; or air quality that may be affected by increased traffic volumes. For each relevant environmental topic area, 'receptors' are identified that are linked to 'sources' *via* 'pathways'. The magnitude and significance of predicted effects on receptors is assessed taking account of the magnitude of the source, the nature of the pathway and the sensitivity of the particular receptor to the effect under consideration.

Baseline studies

2.2.5 As is indicated in Figure 1 above, description of the 'baseline' environment for each relevant environmental topic area, together with a description of the proposals, is an essential pre-requisite for predicting the magnitude and importance of impacts and assessing their significance. In Volume 1 of the EIS, each of the Chapters 10-25 describes the baseline environment for the range of environmental topics considered by the environmental assessment team. Each of these chapters is structured identically as follows:

Study area:	The study area is defined and the important considerations in that definition are set out. For example, in Chapter 12 (which is concerned with airborne noise) the study area has been defined based on examination of a corridor 500m either side of the proposed alignment. Within this corridor, sensitive receptors have been identified and some have been selected for baseline monitoring based on their proximity to the alignment (the source of noise). Similarly, in Chapter 17 (soil and geology) a corridor 500m wide has been defined as the study area within which to establish the baseline environment for soils, geology, landuse and ecology.
Baseline data:	This is generally provided as a table listing the information required for the baseline study and the sources of that information used by the environmental assessment team.
Baseline categorisation criteria:	The baseline environment is categorised by allocating ***functional values*** to selected areas within the study area; the areas selected are those which are likely to contain receptors of particular environmental effects. A 'functional value' for a particular element or area of the baseline environment is evaluated by reference to the ***importance*** and ***sensitivity*** of the area and the receptors within it, as well as the presence of ***existing adverse effects***. Importance is considered in relation to national or international statutory designations, best practice and regulations. Sensitivity considers the sensitivity of receptors to the particular environmental matter under consideration. For example, places of worship and educational facilities are considered to be highly sensitive noise receptors, whilst industrial premises are considered to be of low sensitivity. Existing adverse effects (such as existing high levels of noise) are also taken into account. Functional values are defined on a qualitative scale ranging from Very Low (I) to Very High (V). These are presented in each of the baseline chapters in Volume 1 in a table describing the criteria that have been used for categorisation and allocating a functional value in relation to the topic under consideration. For example, in relation to noise, 'locations that are highly sensitive during both day and night' are defined and given a functional value of Very High (V), whilst 'Locations that are only sensitive during the day and where the activities that are carried out can be carried out in the presence of some noise, but not high levels of noise' are given a functional value of Medium (III).
Description and categorisation of the baseline environment:	Using the terminology and methodology described above, the baseline environment is described and categorised for each element of the proposed line and its associated structures and activities (generally by reference to the numbered lengths of line MN101, MN102 *etc*).

Impact prediction and assessment

2.2.6 Volume 2 of the EIS comprises 7 books, one for each of the Metro North areas (MN101, 102 *etc*). Each book is structured identically and comprises 17 chapters considering each of the environmental subjects covered in the EIS, and an 18th chapter on interrelationships and cumulative effects. After a short introduction and a description of the study area (generally consistent with the study area descriptions in Volume 1), each of the 17 environmental topic chapters has the same basic structure as outlined below:

Impact assessment methodology	The impact assessment methodology is described in terms of the way in which impact ***magnitude*** is predicted. The assessment of magnitude of impacts takes into account the quality, type and range of impact that will occur when the project is implemented (construction and operational phase), as well as its duration (*i.e.* elapsed time and time of day or night) over which the impact will occur. For many topics, the assessment criteria are entirely descriptive (*e.g.* landscape and visual amenity criteria in tables 13.1 and 13.2, which are expressed in sentences such as 'Major changes in view….' or 'Clearly perceptible changes in views….'), whilst others have quantitative (numerical) criteria (*e.g.* noise criteria listed in table 4.1 are expressed in dB). Whether the criteria are expressed in a descriptive or quantitative manner, they are used to develop an impact magnitude scale from 'very low' to 'very high'. For example, where there will be a 'major change of view', the magnitude of the change in visual amenity is described as 'very high' (table 13.2). Where actual noise predicted at a receptor exceeds the relevant noise assessment criterion (table 4.1) by less than 1dB, the magnitude rating is given as 'very low'.
Impact assessment	Impact ***significance*** is determined on the basis of the expected ***magnitude*** of the impact and the ***functional value*** (see paragraph 2.2.5 above) of the receptor. Significance is expressed slightly differently in different chapters, but is generally expressed according to a scale: 'Not significant', 'Low significance', 'Medium significance' and 'High significance'. Impacts are assessed separately for the construction phase of the project and for the operation of the metro when complete. Mitigation measures are described and there is a section (and usually a summary table) at the end of each chapter summarising the ***residual impacts taking into account mitigation***. A residual impact is the degree of environmental change that will occur after the proposed mitigation measures have taken effect.

2.2.7 Within this basic structure, each chapter varies significantly in the way it is laid out and the background information that is provided (in Volume 3). This reflects the wide variation in topics considered, the fact that the investigation and analysis behind each chapter was undertaken by different specialist teams, and the way that each particular topic is assessed.

3. BACKGROUND SECTIONS

3.1 The design process for construction works

Evolution of the detailed design of the works

3.1.1 The scheme for construction and operation of Dublin Metro North described in the Railway Order application, currently the subject of public consultation, is extremely detailed and may appear to be beyond change, a *fait accompli*. This is not true, as we will explain in this section; the current proposals are an important but nevertheless intermediate stage in an overall design process.

3.1.2 The design process for an engineering project such as this is directed towards designing and implementing a scheme that meets its overall objectives whilst being acceptable financially, technically and politically. The design process for major schemes such as this (and this is a large scheme on the scale of engineering works) progresses in stages, starting with a simple idea, which, through a process of iteration and incorporation of decisions and additional data, is progressively fleshed out until a detailed design is complete and implemented. The 'generic' stages in the design process for the Dublin Metro North project are illustrated schematically in Figure 2 below. The double headed arrows signify iteration and feedback in the process, rather than progression from one element to the next.

3.1.3 The current design is known as a "***Reference Design***". It is sufficiently detailed to allow meaningful Environmental Impact Assessment and to be the basis for a Railway Order application (which, when granted, amounts to a detailed planning permission for the works). Whilst the proposed outcomes of the project are set out in detail in the Railway Order Application, there is less detailed information as to *how it will be done*; the development of programmes and detailed plans for the construction itself will be matters for the contractor (within the requirements of the contract between the contractor and RPA and compliant with legal obligations set in place by the granting of the Railway Order).

3.1.4 The Reference Design permits variations within defined limits to allow the selected contractor to vary certain aspects to achieve technical, financial, operational or environmental performance or to accommodate variations in actual conditions experienced during the works. In addition to variations that the contractor may make within these defined limits, the works are also subject to the Railway Order planning process that will give rise to environmental and other conditions being applied (which will have to be incorporated into the final design, such that it may differ from the Reference Design). Limits of deviation are further described and discussed at paragraph 3.1.11 below). In addition to the limited permitted variations built into the Reference Design, it is possible that, in the course of consultation on and determination of the Railway Order, amendments to the reference design may be made (either as a result of negotiation and agreement between RPA and interested parties or as a result of requirements by An Bord Pleanála as part of its determination of the application). Such changes could give rise to significant differences between the Reference Design and the Final Design but would, of course, be subject to environmental assessment and public consultation and scrutiny.

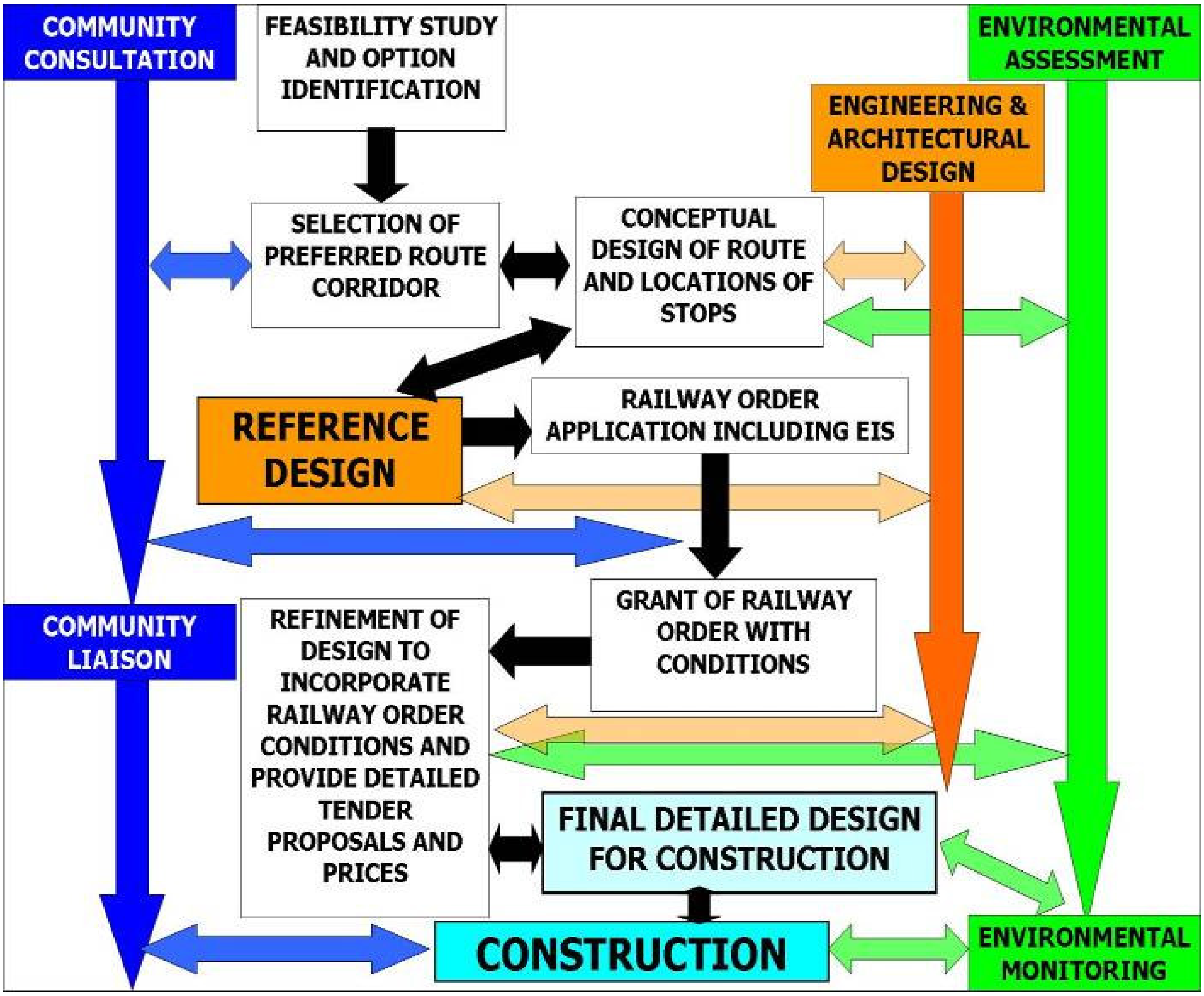

Figure 2: Evolution of the final design for construction and its relationship to the Railway Order process, environmental assessment and community consultation and liaison

Ground conditions (geology)

3.1.5 The design of engineering work on, in and with the ground starts with the application of broad principles that are known to govern work of this kind, *e.g.* the excavation of holes for stations, the formation of foundations for structures, the excavation of tunnels and shafts, the disposal of spoil and control of ground water. To start the process, all these are assumed to behave as they "normally do", where knowledge of this expected behaviour comes from a considerable body of experience gained in practice from such work around the world. It is available to all engineers through the technical publications they can access and conferences and meetings they attend. Case histories underpin our knowledge of the ground and how it works; if the theories do not agree with case history it is the theory that changes over time as the knowledge gained from case histories is incorporated into engineering practice.

3.1.6 The next stage checks that what exists at this site can be described by the conditions expected from this body of knowledge, *i.e.* that the soils are like those in the case histories and that the water and rock are like those encountered elsewhere, for example in Dublin Port Tunnel. The Dublin Port Tunnel case history is very important for the design of the bored tunnels for Metro North because it involved creating tunnels in similar geological strata, not very far away. In order to check whether what exists at the site is 'as expected' and to identify site specific details, the ground must be investigated. Records are consulted, (*e.g.* those produced by the Irish Geological Survey), and archives visited, (*e.g.* for archaeological and other historical uses of the ground). Shortcomings in this knowledge are rectified by drilling holes into the ground where necessary and taking samples for testing. All this builds up a body of knowledge that is based on experience and calibrated against local on-site conditions, so as to allow a Reference Design, and ultimately a Final Design to be completed.

3.1.7 As far as the ground is concerned, neither the Reference Design nor the Final Design presumes to know what is under every piece of ground – that is something a ground engineer only knows once it has been excavated. Excavation under these circumstances is made possible by (i) the ability of contracts to accommodate changing and unexpected conditions (which by this time are expected to be small and local changes of conditions from those expected), and (ii) the ability of the construction process to respond to the changing ground conditions so that conditions in the ground (and the effects at the surface to which they give rise) can be controlled.

3.1.8 The gathering, testing and incorporation of information on ground conditions is an essential and integral part of the design process described in Figure 2. It is generally phased so that, as the design evolves and requires more reliable information, investigations can be targeted appropriately. An effective ground investigation at the reference design stage aims to provide sufficient knowledge for construction to be priced and detailed construction processes to be defined. It also aims to be sufficiently detailed for the risks that actual conditions are different from those assumed to be identified and evaluated. If risks arising from uncertainty with respect to ground conditions are considered to be too high (or significant departures from the Reference Design are being contemplated), then further ground investigation may be indicated, even at a late stage in the detailed design process, or sometimes during the course of construction.

3.1.9 The Dublin Metro North scheme has now reached the stage where contractors who are able to take on such projects have been invited to bid for the work. They have been given access to all the data acquired so far about the ground by the team working on the Reference Design, the Reference Design itself, and details of the restrictions that will be imposed for environmental and other reasons. It is the contractors who will decide what particular machines and methods they will use to satisfy these requirements and they who will make assessments of ground related risk and build into their costings and work plans requirements for further data collection either before or during the construction work. This is the way such projects are commonly done around the world; the contractors considered for this sort of contract will have international experience. It is the successful contractor who will produce the Detailed Design; in other words, much of the work that has been done by the RPA will be done again by the contractor but this time with knowledge of the machinery, and men, and processes that they plan to deploy to achieve the work, as well as with the benefit of the EIS and the work that underlies it.

3.1.10 The relationship between the ground investigation and the Reference Design is described in more detail in paragraphs 3.2.1 and 3.2.2 below.

Limits of deviation

3.1.11 The Reference Design will be refined as described above in the light of further information about the ground, the engineering solutions proposed by the contractor, and to comply with conditions imposed in the Railway Order when granted. However, the Reference Design is also the design that has been submitted with the Railway Order which, when granted, will amount to a detailed planning permission. If the Reference Design is absolutely prescriptive in every detail, planning permission will be granted for a scheme that must be constructed exactly as described and therefore gives no scope to a contractor to propose an alternative solution that meets the client's objective whilst reducing engineering risks and project costs. Similarly, a prescriptive scheme at this stage would not allow for sensible adjustments to be made in the light of additional ground investigation information or more detailed analysis of that which has already been assembled. To give the contractor room to innovate and improve the scheme, and also to adjust appropriately to the ground conditions actually encountered (because ground conditions can never be perfectly known in advance, as described above), 'limits of deviation' are set for a project such as this. The following excerpts from the Draft Railway Order, Part 2, Article 6 describe the limits of deviation proposed for the Dublin Metro North Reference Design:

6 Deviation

In executing any of the authorised works the Agency may —

(a) where those works are situated in a public road —

- (i) deviate laterally by any distance not exceeding 2.5 metres from the lines or situations shown on the plan,
- (ii) deviate vertically by any distance not exceeding 1 metre upwards from the levels shown on the plan,
- (iii) deviate vertically by any distance not exceeding 1 metre downwards from the levels shown on the plan,
- (iv) deviate longitudinally by any distance not exceeding 20 metres,

(b) where those works form part of an underground stop other than such parts as are situated in a public road, amend the internal layout of the stop provided that such amendments do not reduce the accessibility or amenity of the publicly accessible areas within the stop;

(c) where those works form part of an underground tunnel or stop —

- (i) deviate laterally by any distance not exceeding 10 metres from the lines or situations shown on the plan,
- (ii) deviate vertically by any distance not exceeding 5 metres upwards from the levels shown on the plan,
- (iii) deviate vertically by any distance not exceeding 10 metres downwards from the levels shown on the plan,
- (iv) deviate longitudinally by any distance not exceeding 20 metres,

(d) in respect of all other works —

- (i) deviate laterally by any distance not exceeding 5 metres from the lines or situations shown on the plan,
- (ii) deviate vertically by any distance not exceeding 2 metres upwards from the levels shown on the plan,
- (iii) deviate vertically by any distance not exceeding 2 metres downwards from the levels shown on the plan,
- (iv) deviate longitudinally by any distance not exceeding 20 metres.

3.1.12 There are certain locations where the amounts of allowable deviation (particularly in relation to the minimum depths of bored tunnels beneath properties and the proximity of surface structures to residential properties) set out in Article 6 have been reduced; there are no circumstances where they have been increased. Rather than setting these out on a complex schedule, the Railway Order Drawings show the limit of surface and sub-surface lands to be acquired in order to construct the scheme. It will be a legal and contractual requirement for the contractor to remain within the limits of land that has been acquired and therefore these limits coincide with the allowable deviation at any point.

3.1.13 In Appendix 2, we provide a schedule of the proposed depths to the track level in the bored tunnel beneath every road that crosses it between St Stephen's Green and Albert College Park (also referred to in the application as 'Hampstead Park'). In Appendix 2, we also provide an estimated depth to the top of the Reference Design tunnels (based on the expected diameter of the tunnels) and the minimum depth to the tunnel if the contractor were to construct it at the upper limit of the subsurface lands to be acquired.

Instrumentation and monitoring

3.1.14 As indicated in paragraph 3.1.7 above, a ground investigation cannot provide perfect knowledge of the ground conditions that will actually be encountered or of the behaviour of the ground when disturbed. It is therefore essential, during the work, for contractors to have "ears" and "eyes" in the ground that can detect changes which are significant for managing ground response to ground engineering and managing the (related) environmental impacts caused by the work. These "eyes" and "ears" are provided by the installation of instrumentation and the results of ongoing monitoring of the instruments are used to identify the need to adjust details of the working methods and to establish whether those changes have had the desired effect. The following example scenarios demonstrate how this works in practice:

- Monitoring of vibration caused by the progress of the tunnel boring machine at a sensitive surface location as the tunnel approaches demonstrates that the amount of vibration is close to the maximum value allowed, and is expected to increase as the tunnel advances closer to that location. The results of monitoring at this and other comparable locations are used to re-calibrate the predictive model for the propagation of vibration through the ground and the rate of progress of the tunnel boring machine is revised and/or adjustments made to the set up of the machine to reduce the vibrations experienced. Further monitoring of the instruments as the tunnel approaches, passes beneath and moves away from the subject location demonstrates that the adjustments have had the desired effect and/or provide the contractor with the information needed to make further adjustments.
- Noise monitoring (and complaints) demonstrate that contractors working at one of the surface sites have exceeded noise limits required in the contract and the Railway Order at the subject properties. The work is reviewed to establish the scope for: re-programming of noisy activities to reduce cumulative effects; replacing some items of plant with less noisy alternatives; and introducing additional screening. The effect of remedial action taken is monitored and any necessary further adjustments or controls implemented.

3.1.15 This method of working is seen by engineers as a normal part of the efficient and sensitive excavation and construction of ground works. It provides a constructive framework for public liaison and feedback, and ensures that the impacts of the scheme are monitored and appropriate actions taken to reduce them to a minimum.

3.1.16 Instrumentation and monitoring are so important to this scheme that the contractor may be instructed by the RPA to pass responsibility for it to an independent body. The task for such an independent body would be to ensure that the instrumentation system is functioning and monitored as required, that the output from the monitoring is stored and interpreted, and that this information is available to all who need it in appropriate formats as feedback for: verifying design assumptions; monitoring compliance with environmental conditions and making any necessary reports to regulatory authorities; regulating construction progress; and informing residents and other stakeholders affected by the ground works (see below).

Public consultation and liaison

3.1.17 In Figure 2, we make a distinction between 'public consultation' and 'public liaison'. Public consultation and public liaison are essential elements of the design evolution process.

3.1.18 ***Public consultation*** in this context is interaction with the public that influences the design process (*e.g.* the consultation exercises that took place for Metro North during the route selection phase and public input to the Railway Order process that is underway now). As the design becomes more detailed and the range of options more limited (culminating in a Railway Order and final design for implementation), the extent to which public consultation can influence the outcome decreases.

3.1.19 ***Public liaison*** involves exchange of information between the public, the contractor and the RPA about the project during its implementation that, through a process of negotiation or mediation, may bring about improvements in performance or changes in methods (*e.g.* if complaints and/or monitoring indicate that a particular aspect of the project is causing an unacceptable impact on members of the public, through a process of negotiation, a change can be agreed to the way the job is done to mitigate the effects – see paragraph 3.1.14 above).

3.1.20 Figure 2 shows 'consultation' occurring up to the granting of the Railway Order and 'liaison' continuing throughout the final detailed design and construction phases. These activities advance in stages from general acceptance of the need and benefits of such a scheme up to the details of where, when and how the proposal is to come to reality and how its effects are to be limited during the implementation phase. In fact, there is no clean break between 'consultation' and 'liaison', rather a transition from one to the other.

3.1.21 In some respects planning and deciding what to do in a project of this size have similarities to planning and deciding an important family event; perhaps a wedding, an anniversary, or a holiday. For such an event, the plans evolve over time, accommodating opinions and sensitivities of a range of people involved, as well as financial constraints *etc*, through a process of consultation. Inevitably, some decisions can only be made "on the day" as events unfold; a degree of flexibility is always necessary and this requires liaison between key individuals to make sure the right decisions are made.

3.2 How tunnels and underground stations are constructed

Bored Running Tunnels

3.2.1 The bored running tunnels for the sections of the Dublin Metro North scheme between St Stephen's Green and Albert Park and beneath Dublin Airport will comprise twin circular tunnels with an excavated diameter of approximately 6.4 metres, with the tunnel crown approximately 4.8m above track level[4]. These will be constructed by mechanised excavation using Tunnel Boring Machines (TBMs). The TBMs which are envisaged to be used on the project are, in effect, mobile linear production lines where excavation of the ground, erection of the lining support and stabilisation of the excavated surfaces take place simultaneously. Tunnel engineers will always seek to match the excavation and support capabilities of their TBMs to the ground conditions which are anticipated to be excavated along the tunnel route. To achieve this, ground investigations comprising borehole surveys are undertaken (as described above). These surveys include *in situ* and laboratory testing to determine soil and rock mass characteristics and also testing to establish the groundwater regime of the soils and rocks through which the tunnels will be driven.

3.2.2 The engineers who have developed the Reference Design of the project have undertaken a significant ground investigation which includes specific borehole surveys along the route and study of relevant ground investigation data from other projects (as described above). Comprehensive review of all of the factual data obtained has enabled the engineers to establish the types of ground which will be encountered by the TBMs during construction (this will include sediments (sand, clay, silt and gravel) deposited by glaciers that covered the area during the Ice Ages as well as the Carboniferous Limestone bedrock upon which these were laid). This review has also allowed the engineers to infer the likely depth to the interface between rock and sediment interface (a boundary known as "rockhead"). Tunnellers need to know which lengths of tunnel are expected to be in rock (*i.e.* below rockhead) and which will be above rockhead in sediment (which is referred to by engineers in a short-hand way as "soil"), and along which lengths the tunnel may pass from one to the other or straddle the boundary. As is described in paragraph 4.6.4 below, there is likely to be a transitional zone where broken limestone is mixed with soil materials at rockhead; in areas such as North Dublin that have been glaciated in the geological past and where the bedrock is soluble, rockhead is rarely a single, clearly defined, surface. The ground investigation will have collected relevant information with which to establish the character of the rockhead (particularly the nature of the materials in the transitional zone and the width of that zone between intact rock and overlying sediments). This information is available to the tenderers now and will be available to the appointed contractor (supplemented if necessary by additional information that they may collect in further ground investigations). Using the ground investigation information, contractors will make their own assessment of the ground conditions at and around the rock/sediment interface, where that is relevant to the tunnel alignment that is proposed in the final design (*i.e.* where the tunnels pass through, straddle or run close to this zone). At the Reference Design stage, it is important to know, with reasonable confidence, where the rockhead is so that alternative vertical alignments for the tunnels can be evaluated in relation to the engineering challenges that they are likely to present and their practical and economic advantages and disadvantages. On the summary geological drawings that

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4 Taken from a draft drawing provided by RPA: "*Typical running tunnel cross section showing equipment arrangement*", Drawing No. TU-0201-B01

we have seen[5], the inferred rockhead surface is depicted as a single surface with question marks along it to indicate that it is inferred at this stage; this is what we would expect to see at this stage of the design/ground investigation process. It is the depth to this surface as shown on the RPA's geological profile drawings which is given in Appendix 2.

3.2.3 It is known that the strata at the tunnel horizon will, for the most part, comprise limestone bedrock overlain by glacial till (mixtures of gravels, sands, silts and clays). In strata that is predominantly stiff clay, the ground conditions are considered to be stable and there is little likelihood of surface settlement caused by consolidation of the clay overlying rockhead, due to drawdown of groundwater into the tunnels.

3.2.4 In the schedule at Appendix 2 (Volume III), we have measured from the RPA's summary ground investigation drawings the depth to the inferred rockhead horizon beneath every road that crosses the bored tunnel between St Stephen's Green and Albert College Park and provided an estimate of the thickness of limestone between the top of the tunnel and rockhead. These measurements may change as further information becomes available from the ground investigation. Even so, it is evident that the vertical alignment of the Reference Design will pass through two zones along the route where the tunnels are likely to be constructed on the rock/ sediment interface or entirely in sediment, which is identified as comprising glacial sands and gravels. Glacial sands and gravels are saturated strata which have limited ability to bind their particles together and where, without special provisions on the TBMs, ground movement and groundwater ingress at the tunnel face will create surface settlement (see Section 4.6 below).

3.2.5 The first such location is at or close to the TBM launch site in Albert College Park (also referred to in the documents as Hampstead Park). The geological long section produced for the Reference Design shows glacial sands and gravels within the glacial till at this location. The boundaries of the sand and gravel deposits are not defined and it is anticipated that further site investigation will be required, as their presence would impact negatively on the TBM launch activity. It is probable that improvement of the ground by way of consolidation grouting will be necessary to ensure successful launch of the TBMs. Consolidation grouting injects a milky suspension of either clay or clay and cement or lime, to permeate the pores of the ground so providing the ground with strength, because it now has fewer voids and its particles are bound together by the grout between them. It also reduces the ability of the ground to transmit groundwater because its voids have been either filled or blocked. The use of the term "consolidation" in relation to grouting means strengthening and solidifying – it is not the "consolidation" that is associated with settlement and referred to in Section 4.6 of this report. In any event, if surface movement does occur in this location there will be no impact upon the residences adjacent to the working site in Hampstead Park, because the tunnels will be entirely below rockhead by the time they cross Hampstead Avenue. The inferred geological long section shows that, after launch, where the tunnels cross Hampstead Avenue at approximate chainage 13740 metres, the tunnel face will comprise limestone bedrock overlain by boulder clay with rock cover to the TBMs increasing rapidly as the tunnels are driven south towards the Griffith Avenue stop (see Appendix 2).

3.2.6 The second location where the bored running tunnels are likely to be excavated either on the bedrock/sediment interface or entirely in deposits comprising sands and gravels,

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5 Jacobs Drawings: *"Exploratory hole location plan and inferred geological section (incl. MGI data) (sheets 10-14 of 14)"* Contract No. B0307000, Drawing No. B-MN-0000-GE-230-234 (rev A01)

extends over a length of approximately 1000 metres and encompasses both the Mater and Parnell Square stops. It is understood that the primary driver for the tunnel level shown on the Railway Order drawings along this length is the architectural design of the stations. In particular, the architects' key objective has been to limit to a minimum the depth of underground stations to ensure maximum accessibility for the travelling public. This is the reason why the Reference Design shows the tunnel horizon in this position, which is highly unfavourable from the point of view of tunnelling. Special engineering measures will therefore be required to ensure that the tunnelling process (that is excavation and the installation of concrete lining to support the excavated surfaces) does not cause ground movements and settlements which will damage property or cause disruption at the surface. In the light of the inevitable uncertainty at this stage regarding the precise level of the top of the intact limestone and the characteristics of the mixed ground immediately above it (as described in paragraph 4.6.4 below), design and implementation of these special engineering measures will have to be associated with further site investigation aimed at providing adequate information about the ground conditions. An alternative approach would be to re-design the tunnel alignment at a lower level so as to avoid the engineering challenges associated with tunnelling with a mixed face at rockhead. It remains to be seen whether tenderers for the construction contract will propose this during the detailed design phase.

3.2.7 The project designers have recognised that tunnelling on the rock/sediment interface or wholly in the sands and gravels is not without the potential for problems and sensibly they have stated that closed face TBMs will be required. The EIS in Volume 2, Chapter 9 (Soils and Geology), paragraph 9.4.2 (Mitigation Measures) states:

"The running tunnels will be constructed using a TBM with the capability to pressurise and support the tunnel face to minimise ground loss. Probing ahead of the tunnel face to determine problematic ground conditions in advance, such as water bearing sand lenses in the glacial till, rockhead profile uncertainty and mixed face conditions will be undertaken as necessary".

3.2.8 The designers are therefore setting down the requirement for TBMs used on the project to be either Earth Pressure Balance Machines (EPBMs) or Slurry Shields. Both types serve the same purpose of balancing the earth/groundwater pressure at the tunnel face by pressurising the excavated material to control the stability of the tunnel face (EPBM) or by mixing pressurised bentonite slurry with excavated material to achieve the same result (slurry shield). In both cases the excavated material is pressurised and mixed in the cutterhead chamber in front of a pressure bulkhead, thereby creating a balance with the earth/groundwater pressure in the non-cohesive saturated soils through which the tunnels are being driven. The significant difference between EPBMs and slurry shields is the mechanism by which the pressurised excavated material is removed from the cutterhead chamber, safely reduced to atmospheric pressure within the TBM and transported from the tunnel.

3.2.9 These tunnelling machines are sophisticated, and despite being rugged, heavy civil engineering plant, they are capable of a high degree of control. Properly used they are effective in minimising ground movements which lead to surface settlements. There is much precedent experience of the successful use of such TBMs in extremely adverse conditions. There are of course pluses and minuses for each type of TBM, dependent upon the ground conditions which are anticipated to be encountered. Selection of the right machine will be a function of the skill and experience of the tunnelling contractor engaged to undertake the Works as well as his assessment of the ground conditions. That said, informed observers will be aware that collapses and major settlements at surface level have occurred on tunnelling projects. Ongoing monitoring and instrumentation schemes, when properly designed and implemented, will ensure 'early warning' and positive feedback as described in Section 3.1 above, so avoiding such troubles.

Single Shield TBMs are a suitable choice for brittle or soft rock. In shield tunnelling the tunnel is lined with concrete segments. To tunnel forward, the hydraulic thrust cylinders of the Single Shield TBM push against the last installed lining ring.

Mined Crossover Tunnel and Cross Passages

3.2.10 It is proposed to construct a crossover tunnel and numerous cross passages between the running tunnels. The crossover tunnel is located underneath the school sports ground (St Patrick's College) adjacent to Ferguson Road and the cross passages are proposed at maximum 250 metre spacing along the tunnel route. The crossover tunnel is required to provide the facility to switch trains from one running tunnel to the other and the cross passages are required for safe access/egress during operation and maintenance of the tunnels, and especially for use during emergencies. These are normal facilities, to be found on metro systems worldwide.

3.2.11 The geological sections summarising the interpretation of ground investigation data used for the reference design[6] shows that the crossover tunnel will be constructed at about 35 metres below ground level with around 20 metres of limestone bedrock cover overlain by boulder clay and some lenses of sand and gravel. The designers have indicated that the tunnel will be excavated by mechanical means and/or drill and blast. Mechanical excavation will be dependent upon the rock mass characteristics *i.e.* strength, fracture spacing *etc* and the availability of suitable road header tunnelling machines to undertake this work. If drill and blast methods are used, the use of explosives will be carefully controlled, commencing with trial blasts using small charges to provide the basis for the design of production blasts that will comply with conditions attached to the Railway Order

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6 Jacobs Drawing: *"Exploratory hole location plan and inferred geological section (incl. MGI data) (sheet 11 of 14)"* Contract No. B0307000, Drawing No. B-MN-0000-GE-231 (rev A01)

in relation to blast vibrations and ground-borne noise. Main blasts during construction of the tunnel will be monitored on adjacent surface properties to ensure that vibration limits are not exceeded and to provide further information to feed back into the design of subsequent blasts (to reduce vibration to a minimum and ensure efficient use of explosives). There is precedent experience of blasting in the limestone bedrock and boulder clay of Dublin to create new tunnel systems (Grand Canal Drainage Tunnel, 5km x 4 metres diameter, circa 1973 – 1975), where no significant adverse effects at ground level were suffered.

3.2.12 The cross passages are short tunnels set at right angles to the main running tunnels and making direct connections between them. These are located for the most part in the limestone bedrock or the boulder clay and the construction methodology will be similar to that of the crossover tunnel. Where cross passages are located in areas of sands and gravels or soft ground, or where significant water ingress is present, localised ground treatment, by way of consolidation grouting and/or fissure grouting will be required. In both the crossover tunnel and the cross passages, the tunnel advance will be staged to allow immediate installation of primary support to excavated surfaces. Support of the excavated faces will be provided using a combination of sprayed concrete, lattice arch girders and rock bolts, dependent upon the specific requirement at each tunnel face.

Shaft and Station Box Construction

3.2.13 The Reference Design for underground stations and shafts allows for robust and internationally proven construction methods to ensure that no significant movement occurs in the sediments overlying rockhead. The residents and other interested parties with whom we have been working to date, are affected by shaft and station box construction between Ballymun and Parnell Square Stops. The design engineers have scheduled applicable excavation and support techniques for this length of line as detailed below:

Ballymun and DCU Stops	The stop structures will be constructed using cut and cover method of construction using diaphragm[7] walls as primary support.
St Patrick's Shaft	Secant[8] piles will provide support to upper soft ground strata. Rock excavation will be by mechanical methods and or drill and blast.
Griffith Avenue Stop	Stop structure will be construction using cut and cover form of construction. Contiguous pile walls in the glacial till (boulder clay) to rockhead.
Drumcondra Stop	Stop structure will be constructed using cut and over with contiguous pile walls in the glacial till to rockhead.
Mater Stop	Stop structure will be constructed using rigid diaphragm walls to formation level.
Parnell Square Stop	Stop structure will be constructed using rigid diaphragm walls to formation level.

7 **A diaphragm wall** is a wall that is constructed in the ground prior to excavation so that it supports the sides of the excavation once the material inside the wall is excavated. The wall is constructed by excavating down in narrow slots, to form panels that join to create the wall required, replacing the *in situ* material removed as excavation is undertaken with bentonite (clay) slurry to support the slot and then replacing the bentonite slurry with reinforced concrete.

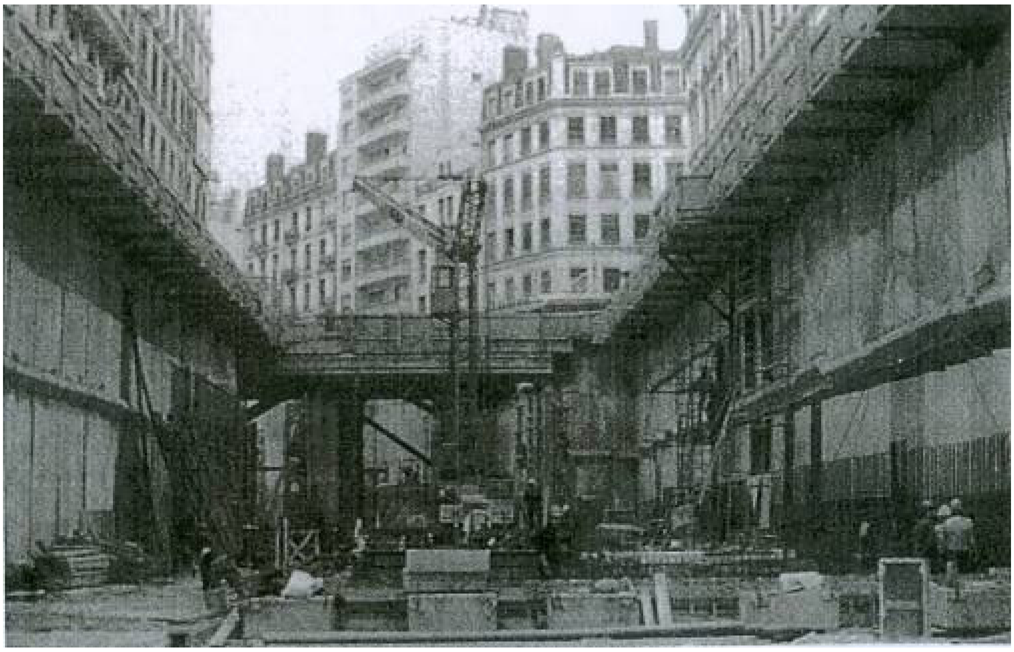
8 **Creating a secant wall** is similar to forming a diaphragm wall but is achieved through drilling a line of partially intersecting large diameter boreholes within which the replacement of *in situ* ground with reinforced concrete takes place.

3.2.14 All of the foregoing methods scheduled by the designers are considered appropriate methodology to provide support to the sediments overlying rock and to prevent ground movement. There are several case histories for deep basement construction in Dublin, similar to those proposed for station construction, which have been successfully completed without incidence of ground movement.

3.2.15 The most significant issue will be disruption and nuisance caused by the construction process which will necessarily affect the lives of those people who live and work in the community around these structures. Experience of similar construction processes in London has shown that much can be done to reduce or even eradicate such disruption and nuisance. The erection of acoustic barriers and canopies can reduce noise from construction sites to less than normal background levels and implementation of a strict regime of cleaning, wheel washing *etc* can ensure that the necessarily dirty excavation and construction processes are not carried outside the worksite compound. Such measures are now commonplace on major construction sites, and their implementation on the Dublin Metro North project should be a foregone conclusion.

3.2.16 Cut and cover tunnel construction is undertaken in a similar manner to station box construction and uses the same range of techniques (especially construction of diaphragm and secant walls).

3.2.17 Further information on tunnelling and related topics can be found in Appendix 4, in which a number of specific questions referred to us by the group Residents for Realignment have been addressed.



Lyon Metro, Saxe-Gambetta station: completed station excavation showing precast diaphragm walls