FEHILY TIMONEY & COMPANY

CONSULTANTS IN ENGINEERING & ENVIRONMENTAL SCIENCES

Our Ref: 2004/133/01/let001/FOR

Mr. Iain Douglas
Planning Section
Mayo County Council
Áras an Chontae
The Mall
Castlebar
Co. Mayo

24 February 2004

RE: Geotechnical Note on EIS for proposed Bellanaboy Bridge Gas Terminal

Dear Mr. Douglas

Please find enclosed a copy of our Geotechnical Note on the EIS for the proposed Bellanaboy Bridge Gas Terminal, Co. Mayo, as faxed to you earlier today.

If you have any queries on this matter, please do not hesitate to contact me.

Yours sincerely

03/3343

Gerry O'Sullivan
for and on behalf of **Fehily Timoney & Company**

Encl.

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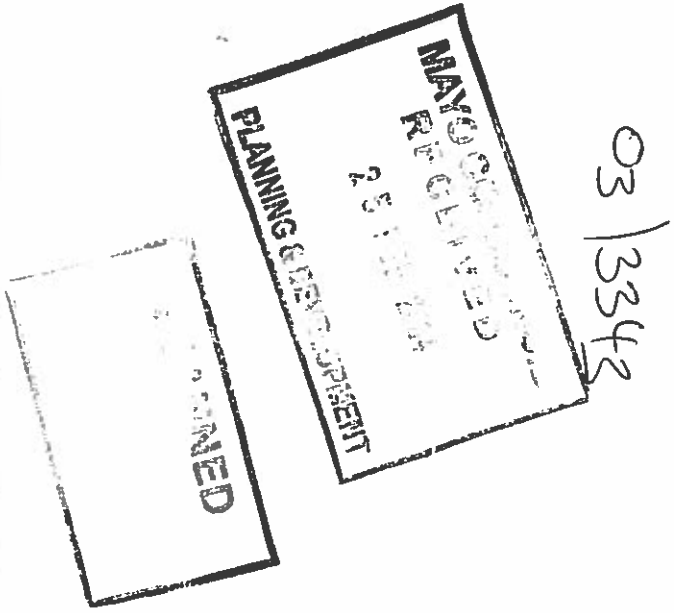

03/3342

Proposed Bellanaboy Bridge Gas Terminal, Bellanaboy Bridge, Bellagelly South, Co. Mayo

Geotechnical Note on Environmental Impact Statement

Prepared for

Mayo County Council
Áras an Chontae
Castlebar
Co. Mayo

Prepared by

Fehily Timoney & Co.
Core House
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February 2004

FEHILY TIMONEY & COMPANY

Proposed Bellanaboy Bridge Gas Terminal, Bellanaboy Bridge, Bellagelly South, Co. Mayo

Geotechnical Note on Environmental Impact Statement

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1. INTRODUCTION

This geotechnical note has been prepared by Fehily Timoney & Company (FTC), further to a request from Mayo County Council (MCC) to provide an independent commentary on geotechnical aspects of an environmental impact statement (EIS), relating to the proposed Bellanaboy Bridge Gas Terminal, at Bellanaboy Bridge, Bellagelly South, Co. Mayo, with particular reference to issues relating to the influence of the proposed works on the general stability of the extensive peat deposits, which are known to exist in the immediate vicinity of the works.

To facilitate the preparation of this geotechnical note, MCC has supplied FTC with a copy of the EIS, comprising:

- Volume 1, which relates to the proposed gas terminal at Bellanaboy Bridge and contains four books, the main EIS in one book and Technical Appendices 1, 2 & 3 in three separate books
- Volume 2, which relates to the proposed Srahmore Peat Deposition Site, at Bangor Erris, Co Mayo

As the request to FTC from MCC was to provide geotechnical comment on issues relating to the influence of the proposed works on the general stability of the extensive peat deposits in the vicinity, this note is based on a detailed reading of only a limited part of Volume 1 of the EIS, namely:

(a) the Non-Technical Summary, in order to obtain an overview of the project
(b) Chapter 5: Construction, Parts 5.1 to 5.6
(c) Chapter 8: Soils, Geology & Hydrogeology, all parts
(d) Technical Appendix 1: Geology, Hydrogeology & Global Stability, all parts
(e) Technical Appendix 2: Earthworks, all parts

Geotechnical commentary on Volume 2, which relates to the Srathmore Peat Deposition Site, is based on a detailed reading of Chapters 1 to 3 and Chapter 8 of Volume 2.

2. BELLANABOY BRIDGE GAS TERMINAL SITE

The soil and ground water conditions at the proposed gas terminal site have been summarized briefly in Chapter 8 of the EIS. This summary is based on Technical Appendix 1, which comprises a detailed analysis of the site investigation data, the development of a suitable soil and ground water model for the site and consideration of the implications of this model for the proposed terminal development activities on the site, with particular emphasis on the implications for stability of the peat in the general vicinity of the site. Technical Appendix 2 considers in some detail the design and construction of all geotechnical structures associated with the proposed terminal, including the presentation of detailed design calculations, together with a detailed summary of the proposed sequencing of construction activities.

3. BELLANABOY BRIDGE GAS TERMINAL SITE – TECHNICAL APPENDIX 1

The site investigation fieldwork was quite extensive and appears to have been sufficient to provide a comprehensive picture of the soil and ground water conditions on the site. It revealed a soil profile comprising 1m to 5m of very soft or soft peat, overlying not more than 3m of mineral soil, overlying head and weathered schist bedrock, overlying intact schist bedrock.

A considerable quantity of field data was acquired on both the permeability of the different strata and the level of the groundwater table. The interpretation of ground water conditions on the site is particularly significant in the light of the proposed development. While the ground water table in the peat was found to be generally close to the existing ground surface, numerous ground water table observations within the rock provided strong evidence that the ground water table in the bedrock was generally significantly below the ground surface over much of the site, that it was consistently at a level below the proposed level of the terminal platform and that it came close to the water table in the peat only in the vicinity of the southern extremity of the terminal platform footprint. The field permeability measurements indicated that the permeability was uniformly low within the head and highly weathered bedrock at the higher levels and within the unweathered bedrock at lower levels. Within the moderately weathered, highly fractured bedrock (core recovery in the range 75% to 90%), the measured permeability was consistently about an order of magnitude greater than at the higher and lower levels. On the basis of this interpretation, it is expected that any significant flows of ground water within the bedrock will occur in the moderately weathered zone.

Global stability of the peat has been considered in Chapter 10. On the basis of a historical review of mass movement of Irish bogs, it has been concluded that the prevailing slope angles in the vicinity of the site are such that natural failures would not be expected to occur. However, it was acknowledged that there was historical evidence that uncontrolled interference by man has led to bog failures on sites, where the slope angles were only 2°, which is only marginally greater than the very modest slope angles prevailing on the present site. On the basis of a morphological study of a 20 km^2 study area surrounding the site, it was concluded that there was no evidence of slope instability, except due to river erosion of peat slopes in the floodplain of the river. Sliding wedge stability analyses were carried out on a number of cross-sections through the site.

Very cautious estimates of the undrained shear strength of the peat, corresponding to the very lowest values measured in field tests, were used in these analyses, which yielded calculated factors of safety of 2.3 or greater.

4. BELLANABOY BRIDGE GAS TERMINAL SITE – TECHNICAL APPENDIX 2

Technical Appendix 2 considers in some detail the design and construction of all geotechnical structures associated with the proposed terminal, including the presentation of detailed design calculations, together with a detailed summary of the proposed sequencing of construction activities.

The basic construction strategy for the terminal platform is to remove all peat from the footprint of the terminal platform, to reduce its moisture content by windrowing on site and to transport it to a peat deposition site at Srahmore. Elsewhere on the site, it is proposed to leave the peat in place and to improve its geotechnical properties using dry deep mixing technology.

It is proposed to leave the peat in place and to improve it using dry deep mixing along all access roads, within the footprint of the administration building and warehouse car park, within the footprint of the temporary construction facility and around the perimeter of the settlement ponds. While dry deep mixing using a cement binder to improve the geotechnical properties of soft soils is a well-established technology in Japan and the U.S.A., and to a lesser extent in Europe, particularly in Scandinavia, it is new to Ireland. While an outline proposal for the execution of the deep mixing has been included in the Earthworks Report (Technical Appendix 2), it has been acknowledged that field trials will be required to finalise the design. Such field trials would be normal on any large contract, even where the technology is well established. A more detailed note on dry deep mixing of peat is included below. It is proposed, probably as a precaution against local failure near the edges of the improved peat, to install steel sheet piling along the perimeter of all improved peat. The use of steel sheet piles in addition to deep mixing is indicative of a cautious approach to site development. In the case of the perimeter road around and between the settlement ponds, the improved peat will be contained on either side by a steel sheet piled wall, to form a cofferdam around the settlement ponds, which will be created by excavating peat to an appropriate depth.

The terminal platform is proposed to be 9m below existing ground level at its north-western corner and 3m above existing ground level at its south-western extremity. The peat is between 1.5m and 3.6m thick under the footprint of the terminal platform, increasing in thickness generally from north-east to south-west. It is proposed to remove all of the peat from this area. Most of the perimeter of the terminal platform will be in cut. It is proposed to retain the peat along this cut perimeter using gabion walls, founded at a depth of 0.9m below the top of the mineral soil. The design calculations for these gabion walls (in Chapter 4) indicate that a cautious approach has been taken in estimating the lateral loading from the retained peat. It is proposed that the gabion walls be installed in advance of mass excavation of the peat and that only a short face of peat be exposed as the gabion wall construction advances. It is also proposed that the peat immediately uphill of the gabion wall be strengthened by deep mixing and/or supported by a temporary steel sheet piled retaining wall to ensure that the peat is temporarily retained during construction of the gabion wall. Again, this is indicative of a cautious approach to the construction.

At the southern part of the terminal platform, where the proposed levels are above existing ground levels, it is proposed to strengthen the peat using deep mixing and to install a steel sheet piled wall to retain the peat outside of the excavation area. In order to minimize the impact of groundwater flow from the mineral soil and the underlying bedrock into the excavation through the peat, it is proposed to install two rows of deep wells well in advance of the peat excavation works and to use vacuum assisted pumping to draw down the bedrock water level. In addition to drawing down the bedrock water table, it is hoped that this will also induce under-drainage of the peat with a possible beneficial effect of reducing its water content in advance of mass excavation. When the peat has been removed right up to the sheet piled wall, it is proposed to bring the fill up to existing ground level using a vertically faced geotextile reinforced soil embankment, to ensure that the fill will be self-supporting and not exert any lateral pressures on the peat when the temporary sheet piled wall is removed at the end of construction.

The strategy of windrowing the peat on site before transporting it to the peat deposition site at Srahmore is predicated on being able to remove the peat from the north-eastern corner of the terminal platform and transporting it directly to Srahmore without windrowing, so as to create an initial platform for the windrowing activities. It is stated in the report that it is the advice of Bord na Mona that the thinner peat stratum in this part of the site will be sufficiently dry and fibrous to facilitate its transport immediately upon excavation to Srahmore.

While there is no explicit reference in the EIS to the installation within the boundaries of the site of the supply gas pipeline from the Corrib gas field to the gas terminal, a methodology for the installation of a 900mm diameter piped drain from the terminal area to the settlement ponds has been described at the end of Chapter 6 of Technical Appendix 2. It is proposed to improve the peat by deep mixing along the route of this pipe, to facilitate the construction of a temporary haul road, and to install the pipe in a sheet pile supported trench. It is proposed to use ground anchors to tie down the polyethylene pipe so as to resist uplift buoyancy forces on an empty pipe. The proposed approach is stated to be based on experience of installing gas pipelines in peat elsewhere in Ireland. The strategy should serve to minimize the impact of the construction works on the peat and constitutes a cautious approach to the work.

In Technical Appendix 2, there is a consistent design strategy of improving the peat in places where it is to be retained and of minimizing the impact of the construction of the terminal platform on the surrounding peat. Detailed consideration has been given to the management of surface and ground water flows, both in the short term and in the long term. The outline of the sequencing of construction activities in Chapter 11 indicates that detailed consideration has been given at this stage to the orderly execution of the works.

5. SRAHMORE PEAT DEPOSITION SITE

The deposition works at Srahmore comprise the partial re-filling of cutover peatland using the windrowed peat from the gas terminal site. It is proposed that all of the peat deposition work will be undertaken by and supervised by Bord na Mona personnel, who have considerable expertise in handling peat and detailed local knowledge of working the Srahmore site. This should ensure that the transport, deposition and spreading of the imported peat within the cutover peatland will be carried out effectively.

A new main access road to the Srahmore site is proposed from the R313. Probing of the peat has indicated that the peat along the proposed route of this access road varies in thickness from about 6m at the R313 to about 0.6m in the peat reception area. There appears to be no quantitative site investigation data in the area of the site access road where the peat is thickest, close to the R313. It is proposed to construct a geogrid reinforced road pavement directly on the peat. If further site investigation were to indicate that the peat were too soft and compressible to sustain the proposed road pavement in a serviceable condition over the duration of the deposition project, the peat could be improved using the deep mixing technology proposed for the gas terminal site.

As the remaining peat cover in the proposed peat reception area appears to be relatively thin, the proposed reinforced concrete slab in this area should prove serviceable for the duration of the project.

6. IMPROVEMENT OF PEAT BY DRY DEEP MIXING

While dry deep mixing using a cement binder to improve the geotechnical properties of soft soils is a well-established technology in Japan and the U.S.A., and to a lesser extent in Europe, particularly in Scandinavia, it is new to Ireland. Even where the technology is well established in the treatment of organic soils, there is very limited experience of treating peaty soils, which are almost 100% organic. There are two publications of particular significance in the context of the proposed works at Bellanaboy. An international collaborative research project, EuroSoilStab, funded by the European Union, on the development of design and construction methods to stabilise soft organic soils, led to the publication of the very informative "Design Guide: Soft Soil Stabilisation" in 2000. The research work on Irish peat, which was undertaken at Trinity College Dublin as part of the EuroSoilStab project, has been presented in some detail in a recent paper, "Some experiences on the stabilization of Irish peats", in the Canadian Geotechnical Journal (Hebib, S. & Farrell, E.R., 2003).

The proposed dry deep mixing of the peat at Bellanaboy should be designed and executed in accordance with the design guide and should be informed in particular by the findings of Hebib and Farrell (2003) on Irish peat. While different combinations of cement, gypsum, blast furnace slag, pulverised fuel ash and lime have proved to be effective in soft soils with organic contents up to 30%, the design guide advises that only cement alone, cement + gypsum, or cement + blast furnace slag should be considered for peat. The laboratory-based study by Hebib & Farrell (2003) on two Irish peats showed that, while a combination of blast furnace slag and gypsum was very effective when applied to one Irish peat, it was entirely ineffective in improving the geotechnical properties of the other one. A cement binder was shown to be effective in both cases. The study also showed that it was extremely important to place a surcharge load on the stabilized peat as soon as possible following deep mixing.

The design guide recommends that, particularly where local experience of deep mixing is lacking, an initial laboratory study should be undertaken to evaluate the effects of deep mixing on the soil under ideal laboratory conditions. On the basis of experience, it is estimated that the shear strength capacity developed under mixing conditions in the field is typically only 20% to 50% of the shear strength of comparable laboratory mixed soil. When the laboratory study has been completed successfully, it is imperative that field trials be conducted in advance of the main project and that these trials be guided by what has been learned in the laboratory.

In the case of the Bellanaboy site, it would be reasonable to expect that a laboratory study of the effectiveness of dry deep mixing on the peat from the site be carried out in advance of any field trials and that field trials be executed in advance of any other site work on the project to demonstrate the effectiveness of potentially suitable dry deep mixing field strategies.

Euro Soil Stab: Design Guide: Soft Soil Stabilization. European Union, CT97-0351, Project No. BE 96-3177

Hebib, S. & Farrell, E.R. (2003) Some experiences on the stabilisation of Irish peats. Can. Geotech. J. 40: 107-120.

7. CONCLUSIONS

The site investigation fieldwork, described in the EIS, was quite extensive and appears to have been sufficient to provide a comprehensive picture of the soil and ground water conditions on the site.

In developing a construction strategy for the complete removal of peat from the footprint of the terminal platform, consideration has been given to minimizing the impact of the construction on the peat at levels both above and below the terminal area.

In all other parts of the site where any construction work is envisaged, it is proposed to stabilize the peat using dry deep mixing using a cement binder. In addition, it is proposed to construct sheet pile retaining walls around the perimeter of the improved peat, to minimize the impact of any site activities on the in situ peat outside of the stabilized areas. Here again, consideration has been given to minimizing the impact of the works on in situ peat immediately adjacent to the works.

While field trials are proposed to enable the development of an appropriate dry deep mixing strategy, it would be reasonable to expect that such field trials be preceded by a detailed laboratory study on the effectiveness of dry deep mixing on the peat from the site, particularly in the absence of experience in the application of dry deep mixing technology to Irish peat sites. On the basis of recent laboratory studies on peat from other Irish sites, there is good reason to be optimistic that the proposed dry deep mixing strategy will prove to be effective.

The proposal to use the expertise of Bord na Mona to enable the removal of excavated peat from the site and its controlled deposition at Srahmore appears to be sound. It appears to be recognized in the EIS that the need to dry the peat at Bellanaboy before it can be transported to Srahmore will have a controlling effect on the rate of development of the Bellanaboy site.

Consideration has been given in the EIS to the need to control all water flows on the site and to direct them to the settlement ponds in such a way as to avoid any possible adverse impact on the in situ peat surrounding the works.

In summary, from a geotechnical viewpoint, reasonable care has been taken in assessing the geotechnical characteristics of the site and in proposing a workable strategy for construction, which will minimize any impact on the in situ peat surrounding the site.