

## 1.0 INTRODUCTION

Carey Geoenvironmental Engineering (CGE) has completed a geotechnical investigation at the site of the proposed seven (7) Wind Turbine installations in Lingan near New Waterford, Nova Scotia. The assignment was completed for Cape Breton Power Ltd. Glace Bay, N.S.

The purpose of the geotechnical investigation was to assess the general subsurface conditions at the Wind Turbine development site and to provide engineering recommendations for use in design of the turbine project. In particular the assessment focused on Abandoned mine workings in this area and potential adverse impact on the turbine foundations.

The scope of the subsurface investigation included the following components:

1. Reconnaissance visit to the development site to view all Turbine locations. Subsurface investigations were completed at Site # 1 and Site # 7 in 2005.
2. Preliminary review of NSDNR geologic mapping and Dominion Coal Company mapping of the Glace Bay region.
3. Detailed review of coal mining records presently maintained by the N.S. Department of Natural Resources. Information included mapping of underground mining and drill hole logs.
4. Overlay of property and topographic information on mining mapping.
5. Meetings and conversations with NSDNR staff.

## 2.0 SITE DESCRIPTION

The general site location with respect to Cape Breton Island is shown on Figure 1. The site is located along the coastline between David Head and North Head near Lingan. Survey information was obtained from the Land Registration Office in Sydney.

The overall site covers an area of approximately 150 acres bordered by property of the Cape Breton Development Corporation (CBDC) to the West and the Nova Scotia Power Inc. to the East. The development includes 7 parcels of land varying in size from 1 to 60 acres.

The property is relatively level and has a thin (sparse) grass cover. The southeast portion of the property includes a relatively thick tree cover. There is an abandoned CBDC Phalen Colliery Fan Building beyond the west end of the site. The site is bounded by a steep cliff face to the North and East.

The following sections provide additional detail with respect to the site description.

### 2.1 Geology

Previous investigation have shown that the geologic strata is capable of supporting large structures if not affected by coal mining

#### 2.1.1 Surficial Geology

The site is located in the Sydney Coalfield geologic region, which is typically covered with a glacial till layers of approximately 3 to 5m with scattered thicker accumulations. The surficial geological unit is described as Silty SAND with some gravel (glacial till), with occasional cobbles and boulders derived from the underlying bedrock.

#### 2.1.2 Bedrock Geology

Sedimentary rock types of the upper Morien Formation underlie the project site. Reference to previous geologic studies in the area confirms the presence of thinly bedded, medium to coarse-grained sandstone and fine-grained siltstone. Coal seams are also found in this formation. Commercial coal mining occurred under the Town of New Waterford and in the Lingan area. Outcrop (Bootleg) mining occurred extensively in the Harbour Coal seam to the north of the development. Groundwater seepage generally occurs near the bedrock contact.

### 3.0 SUMMARY OF INVESTIGATION

#### 3.1 Background Reference

The following is a listing of Background references:

1. Topographic Map Sheet 10 46 2000 60 00. Scale 1: 10000. UTM 77(NAD 83)
2. Property Identification Mapping for subject area (7 parcels of land).
3. Geologic Mapping of Sydney Coal Basin. Map 86-1; Scale 1:50,000. Bohner and Giles, NSDNR;
4. Dominion Coal Company mapping on coal mining in Sydney Coalfield. Circa 1930. Scale 1 in. = ½ mile.
5. Mine Plan for Old Lingan Mine and No. 15 Colliery. NSDNR archival Document
6. Aerial photograph of 1953 View of the Subject Area.
7. Recent Aerial Photographs.
8. Carey Engineering reports on Foundation for Turbines # 1 and # 7.

The project site is located along the coastline between David Head and North Head near Lingan. The proposed project site is relatively level with slight differences in elevation. There is a ridge near the Lingan Highway at Elevation 36 metres (Geodetic Datum). There is a slight grade in the northeasterly direction toward the Atlantic Ocean. The Top of cliff above the Atlantic Ocean varies from 15 to 25 metres (Geodetic Datum).

Figure #2 shows the approximate location of the Phalen Seam and the other surrounding coal seams underlying the proposed Wind Turbine Development. The Figure also shows the approximate location of Drill Holes C-13, -14, -15 and -89 relative to the Wind Turbine project development.

The Project site is underlain by abandoned coal mining activity associated with the Dominion Coal Mining Corporation. Specifically, the Old Lingan Mine in the Phalen Seam is located beneath the majority of the project site. Figure #2 shows the outline of the Old Lingan Mine works in the Phalen Seam. A copy of the mapping is included in Appendix A. Colliery # 15 is located to the west of the project site. The main decline for the recently abandoned Lingan-Phalen mine also passes approximately 200 metres from the West boundary.

Information obtained from NSDNR records indicated that the Old Lingan Mine workings of the Phalen Seam are directly below the proposed locations for Turbines # 3 to # 6. Turbines # 1 and # 2 are immediately to the west and #7 to the east. The coal seams in this portion of the Sydney Basin dip at a much steeper grade than is the normal case. In the Lingan area the seams dip at 20 to 25%, whereas the norm is 4 to 6 % in other areas of the Sydney Coalfield.

The abandoned Old Lingan Mine workings vary from less than 100 feet to over 600 feet below sea level, (a datum which would be +/- 2 to 3 feet of Geodetic Datum.) These elevations are approximate and based on information obtained from NSDNR and from Dominion Coal Company records. Drill Hole logs were used to confirm the mining record information. Figure #2 shows the approximate location of drill holes C13 - C15 and C-89 relative to the project site. Copies of the Drill Hole logs are presented in Appendix B.

The Old Lingan Mine workings were mined by the room and pillar method. In this method, mining engineers calculated the required "support area" for pillars to maintain safe working conditions for underground miners. Historical information shows that this system worked extremely well and the engineers were diligent in their calculations as were the miners in their execution of the mine plans.

As the mine workings reached their economic limits, the company implemented the Retreat Mining Method. In this method, the support pillars would be "mined" as the company closed particular sections of the colliery. The practise of pillar mining or "robbing" significantly reduced the available support for the overlying strata. The result was extensive caving of the bedrock above the roof of the mine opening (Room). Consequently, mining engineers treated assessment of Retreat Room and Pillar Mining similar to Longwall mining.

The research on ground settlement due to coal mining is well documented for both room and pillar and for Longwall mining. The experts agree that precise prediction of room and pillar mining is extremely difficult, if not impossible (Peng 1992). Longwall predictions are difficult as well, but more predictable based on the total collapse of support in the coal seam.

The empirical relationship of low risk versus depth of intact bedrock suggests that 100 feet is a safe barrier for Room and Pillar mining. However collapsed pillars reduces the factor of safety.

Based on the Dominion Coal Company mapping, a portion of the Old Lingan Mine may have been mined using the Retreat Method or the pillars may have simply crushed due to geological factors. In particular, the area of "crushed pillars" occurred mainly to the west of the coastline at North Head. The mining workings identified with "pillar crushing" range from approximately 150 to 450 metres in length and from 20 to 70 metres in width near the proposed project site. Turbine # 5 and # 6 locations are near this area of abandoned mine workings.

After reviewing the Dominion Coal Company mapping it was determined that the proposed Turbine # 6 is located over a portion of the mining workings affected by the Pillar crushing. Figure # 3 shows the approximate location of Turbine #6 over the crushed pillar mining workings and Turbine # 5 site near the interface with the intact mine pillars. These workings are located approximately 300 metres west of the North Head coastline. The depth of Bedrock stratum over these workings is approximately 210 to 230 ft. It can be assumed that extensive caving occurred in this area after mine closure (late 1990's).

Lingan Site  
Cape Breton Wind Power

The Old Lingan Mine workings were terminated immediately west of proposed Turbine #7 location as shown on Figure #2 and #3. Turbines #1 and #2 are approximately 200 m northwest of the nearest Old Lingan Mine workings. The coal seam would be "in tact" beneath these locations and therefore are considered to be in a stable condition.

The mine workings in Old Lingan Mine are flooded to an estimated level near elevation 3 metres (Geodetic Datum). The hydrostatic upward pressure on the mine roof created by the flood conditions is significant. The flooded condition would tend to support the roof and maintain a stable condition throughout the Lingan Mine area above the Phalen seam.

The following is brief synopsis of geologic conditions at each Wind Turbine site:

**Wind Turbine #1:** Turbine situated between the boundary of underground workings in the Phalen Seam and Surface mining in the Harbour Seam. Geotechnical investigation completed near the Turbine foundation. Shallow soil and bedrock strata are in stable conditions.

**Wind Turbine #2:** Turbine situated between the boundary of underground workings in the Phalen Seam and Surface mining in the Harbour Seam. Test pits to be excavated nearby to confirm subsurface conditions

**Wind Turbine #3:** Turbine should be situated in area where there approximately 400 feet over underground workings in the Phalen Seam. Mining pillars reported to be stable in this location.

**Wind Turbine #4:** Turbine should be situated in area where there is approximately 225 to 250 feet over underground workings in the Phalen Seam. Mining pillars reported to be stable in this location.

**Wind Turbine #5:** Turbine should be situated in area where there approximately 200 to 230 feet over underground workings in the Phalen Seam. Turbine very near an area of crushed coal pillars

**Wind Turbine #6:** Turbine should be situated in area where there approximately 180 to 200 feet over underground workings in the Phalen Seam. Turbine location is over an area of crushed coal pillars

**Wind Turbine #7:** Turbine should be situated in area where there approximately 210 to 230 feet over the Phalen Seam. Turbine location immediately beyond Old Lingan Mine workings, therefore mining void anticipated in this area.

The Boutilier and Backpit seams also pass beneath the surface in the development area. These seams are relatively thin and had a low commercial potential in this area. Consequentially, there was not underground mining activity.

### **3.2 Surface (Outcrop) Mining**

Visual observations and illegal (bootleg) mining of the Harbour Seam was conducted in the area west of Davy's Head. According to drill hole log C-89 and NSDNR records; the Harbour Seam is approximately 45 to 55ft. below ground surface near Davy's Head. Figure #4 shows the approximate location of the bootlegged working in the Harbour Seam.

The surface mining in the Harbour is evident in the 1953 aerial photography on the development site. These illegal outcrop pits appear to be relatively extensive and may have reached 30 to 50 feet below original surface in some locations.

Previous test pit excavations for Turbine site # 1 did not encounter any coal seams. There was evidence of claystone or mudstone in one test pit. These seams are a typical indication of nearby coal occurrence.

Outcrop mining in the Boutlier Backpit seams apparently did not occur due to the limited thickness and poorer quality coal. Outcrop mining was apparently undertaken further west of the development site in the Boutlier seam.

Excavation at the Turbine # 7 site did encounter a thin coal seam. This was likely the Boutlier site or remnants of Boutlier seam. The excavations did not expose any evidence of surface coalmining in the area.

In summary, it appears that surface mining occurred to the north and west of the development site. Although the mining was extensive, it will not impact on the development. The Boutlier and Backpit seams do outcrop within the Development boundaries, however there is no evidence of mining activity in these 2 seams.

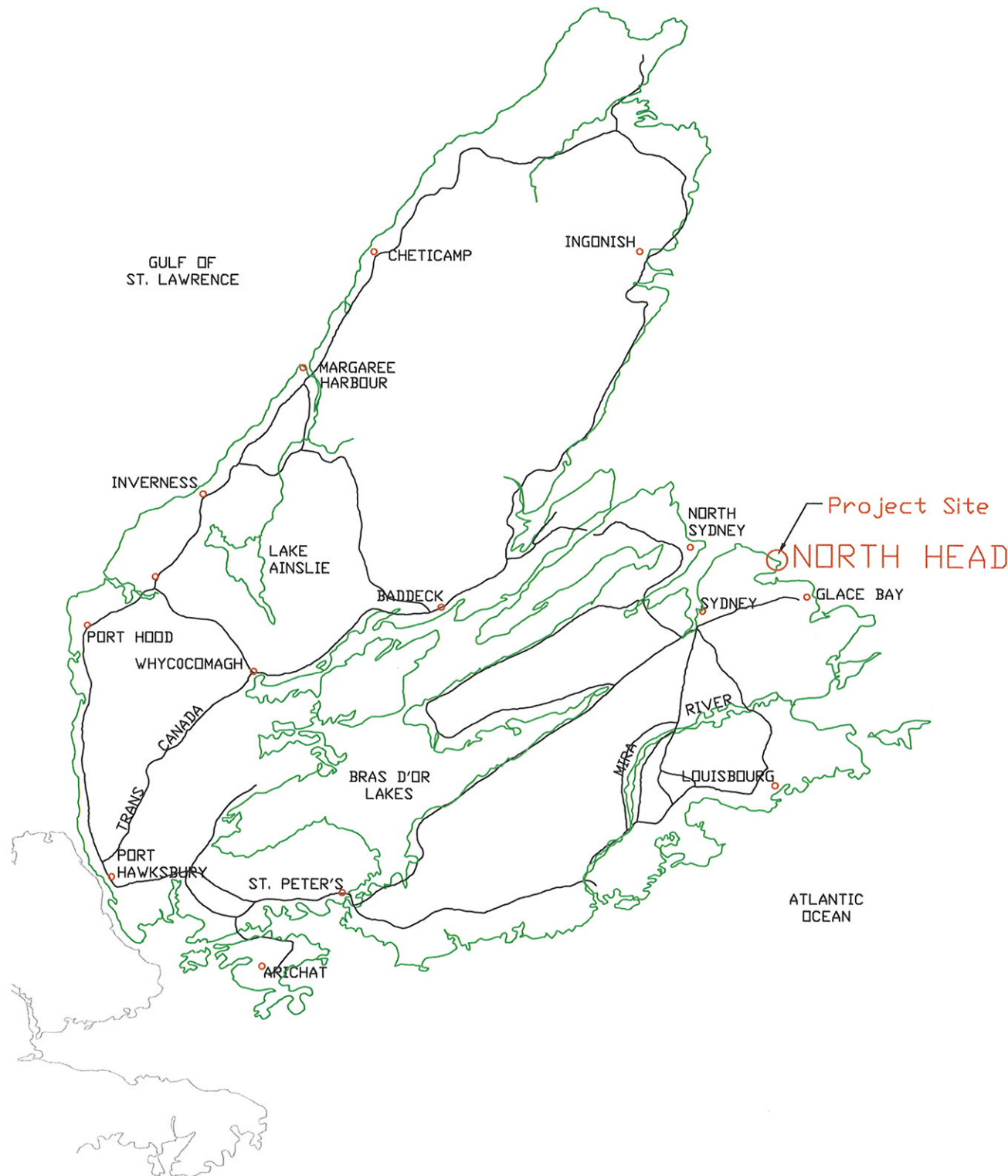
## 4.0 SUMMARY

1. There is no method to absolutely predict that an area underlain by “room & pillar” coal mining activity is “free” of risk for settlement. The long-term stability is based on the shear strength with the individual coal pillars. The flooded conditions and the length of time since the completion of mining are two positive factors with respect to low risk potential at Langan. The steep angle of projection of the coal seams at 20 to 25% and the indications of previously crushed pillars in the mine are negative factors with respect to risk.
2. Extensive underground and surface mining has occurred near the proposed Wind Turbine Development site. The geotechnical engineering investigation identified the most serious concerns with respect to settlement related issues are at Turbine # 5 and # 6 locations. These turbines are located in an area of “crushed pillars” in the abandoned Coal Old Langan Mine.
3. Relocating Turbine # 5 approximately 100 metres to the northwest should improve conditions with respect to potential deep subsidence problems. Relocating Turbine # 6 in either an easterly direction toward Turbine # 7 or northwesterly toward # 5 would improve the risk of mining related damage.
4. The depth of intact bedrock over a mine opening should be a minimum of 100 feet. This is an empirical measure based on mining records. At the Langan site, the 100 feet of intact bedrock should be available at all selected Turbine locations based on the information available. Deep Drill holes would be needed to confirm bedrock quality.
5. There is a concern that the turbines could be located near Outcrop (illegal) pits. Based on the review and test pitting at Turbine # 1 site, it appears the major illegal mining occurred to the north and west in the Harbour Seam. This will be confirmed in the field.
6. There is a potential for reclamation of the Outcrop Pits on PID # 15579105 parcel. Based on our observations, the reclamation should occur over 100 metres from turbines # 1 and # 2 and would not affect the structures. It is assumed excavation by explosives would not be required in the reclamation.

## 5.0 REFERENCES

1. Map 86-1 Geological Map of the Sydney coal Basin, Boehner and Gilles, 1986. N.S. Department of Mines and Energy
2. Plan of Dominion Coal Company Workings for Old Lingan Mine. Scale 1:2000. Drawing undated
3. Plan of dominion Coal Company Workings for colliery No. 15, Phalen Seam.
4. Plan of Dominion Coal Company Collieries and Workings. Undated
5. Surface Subsidence Engineering. S.S. Peng. 1992. Society for Mining, Metallurgy and Exploration Colorado
6. Prediction of Ground Movements caused by Mining. Karmis, M.A. and Aqioutantis, Z. 1992. 3<sup>rd</sup> Workshop on Surface Subsidence, Morgantown, W.V.





Dwg: **FIGURE #1**  
**PROPOSED SITE LOCATION**  
**LINGAN WIND TURBINE PROJECT**  
**CAPE BRETON POWER Ltd.**

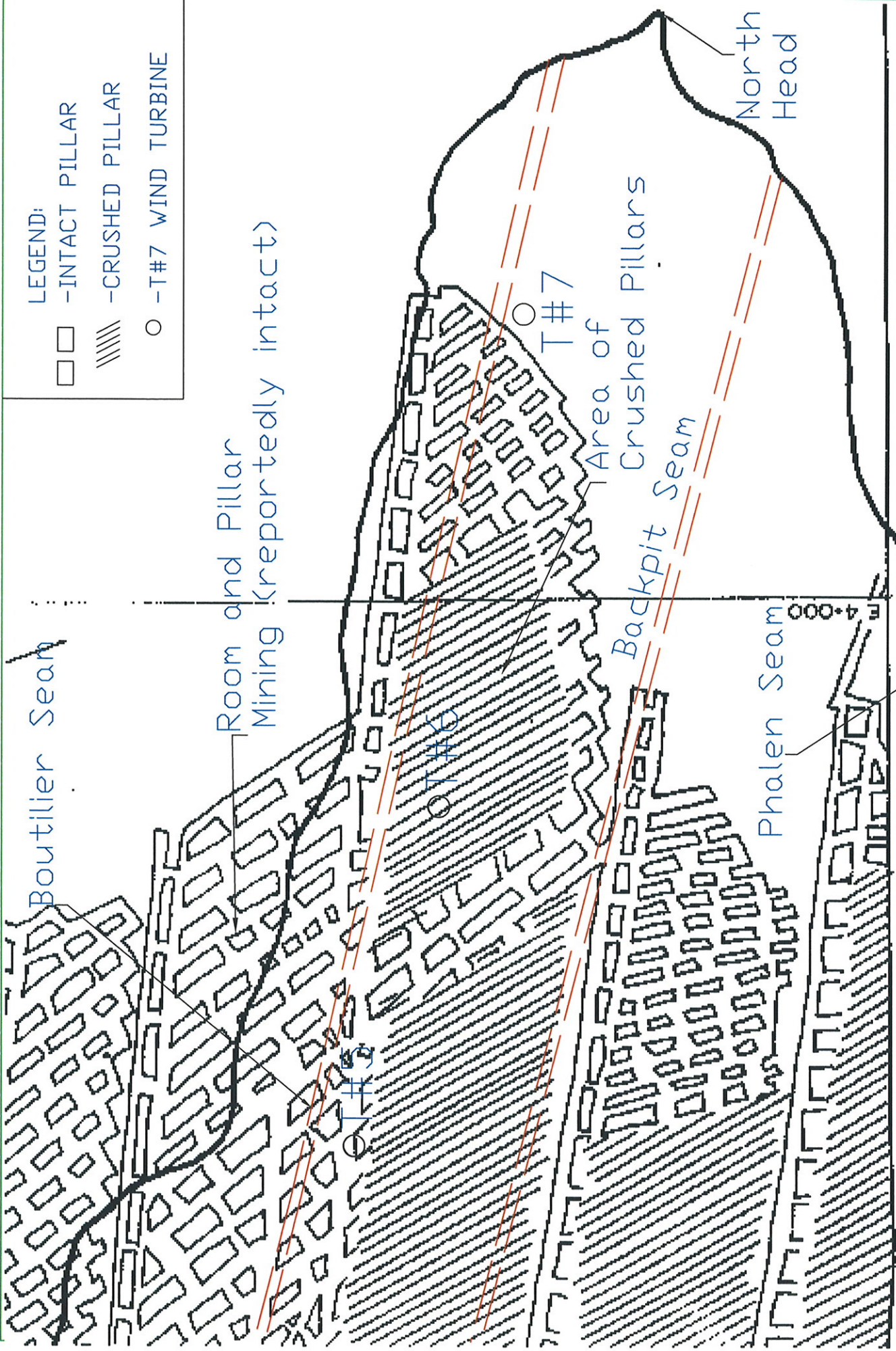
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Chkd By:	EC	Fig. No.:	FIG 1
Date:	FEB/06	Rev No.:	0
Scale:	NTS		



Drawn By	RC	Job No.	C-300-02
Checked By	EC	Fig. No.	FIG2
Date	FEB/06		
Scale	1:10000		
		Rev No.	0

FIGURE 2  
 COAL MINING INFORMATION  
 LINGAN WIND TURBINE PROJECT  
 CAPE BRETON POWER LTD.





LEGEND:  
 □ -INTACT PILLAR  
 ▨ -CRUSHED PILLAR  
 ○ -T#7 WIND TURBINE

Drawn By	RC	Job No.	C-300-02
Checked By	EC	Fig. No.1	FIG3
Date	FEB/06	Scale	NTS
Rev. No.1	0		

FIGURE 3  
 OLD LINGAN MINE LAYOUT  
 LINGAN WIND TURBINE PROJECT  
 CAPE BRETON POWER LTD.

Carey Geoenvironmental  
 Engineering  
 Bealdeck, NS



Emergency Seam

Harbour Seam

Evidence of Bootleg Mining

C89

C14

C15

T#3

Boutillier Seam

OT#4

Phalen Seam

Backpit Seam

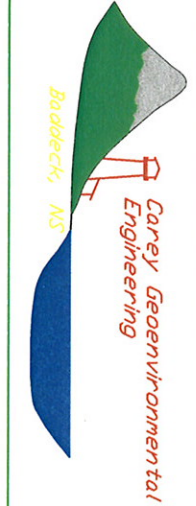
T#5

T#6

T#7

OT#1

OT#2



DWG#

FIGURE 4

LOCATION OF HARBOUR SEAM  
LINGAN WIND TURBINE PROJECT  
CAPE BRETON POWER LTD.

Drawn By	RC	Job No. 1	C-300-02
Chkd By	EC	Fig. No. 1	FIG4
Date	FEB/06	Rev. No. 1	0
Scale	NTS		