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Enabling Access to Geological Information in Support of GMES

D7.1.25Geohazard Description for Cork

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EXECUTIVE SUMMARY

Cork City (Fig 2.1) is located on Ireland's Southern Atlantic coastal margin. Cork is Ireland's second city and the county town of Co. Cork, Ireland's largest county. Its picturesque undulations are home to a population of *c*. 120,000 souls. The city straddles the lower reaches and tidal section of the River Lee. The city's coat of arms, bearing the motto *Statio Bene Fide Carinis* – a safe Harbour for ships, underlines Cork's longstanding status as a major port city. Cork City Council's administrative boundary, which corresponds to the area of analysis of this project, covers an area of almost 40 km².

Ground instabilities affect parts of Cork City and the Geological Survey of Ireland has developed a map, and this report which shows and describes areas of potential or observed ground instabilities as part of the FP7 PanGeo project. Geological Survey of Ireland datasets along with Ordnance Survey of Ireland mapping, PSI datasets and limited field validation were used to develop this interpretation.

The PanGeo interpretation has led to the delineation of 5 polygons (areas) within which potential or observed ground instabilities have been identified. The main observed instabilities are associated with compressible ground. The largest area of potential instability is associated with the pure limestones which have the potential to give rise to instabilities associated with ground dissolution. In total 25.31 km² of the area (40 km²) is adjudged to have potential or observed ground instabilities.

The Geological Survey of Ireland, founded in 1845, is the National Earth Science Agency. It is responsible for providing geological advice and information, and for the acquisition of data for this purpose. The Geological Survey of Ireland produces a range of products including maps, reports and databases and acts as a knowledge centre and project partner in all aspects of Irish geology. It is a division of the Department of Communications, Energy & Natural Resources.

This map and report are broadly indicative of areas of terrain instability which have been produced using a wide variety of data sources at different scales and different levels of reliability. These data should never be used for site specific purposes. The Geological Survey of Ireland does not accept liability for any inaccuracies in this information. The entire dataset is designed for general information and strategic planning usage. The Geological Survey of Ireland makes no warranties on its fitness for any other purpose. The burden for determining fitness for other uses lies with the user. Information supplied is based on the material available to the Geological Survey of Ireland at the time of production and should not be regarded as complete data on the elements or areas being considered.

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2 INTRODUCTION

Cork City (Fig 2.1) is located on Ireland's Southern Atlantic coastal margin. Cork is Ireland's second city and the county town of Co. Cork, Ireland's largest county. Its picturesque undulations are home to a population of *c*. 120,000 souls. The city straddles the lower reaches and tidal section of the River Lee and the city's coat of arms, bearing the motto *Statio Bene Fide Carinis* – a safe Harbour for ships, underlines Cork's longstanding status as a major port city.

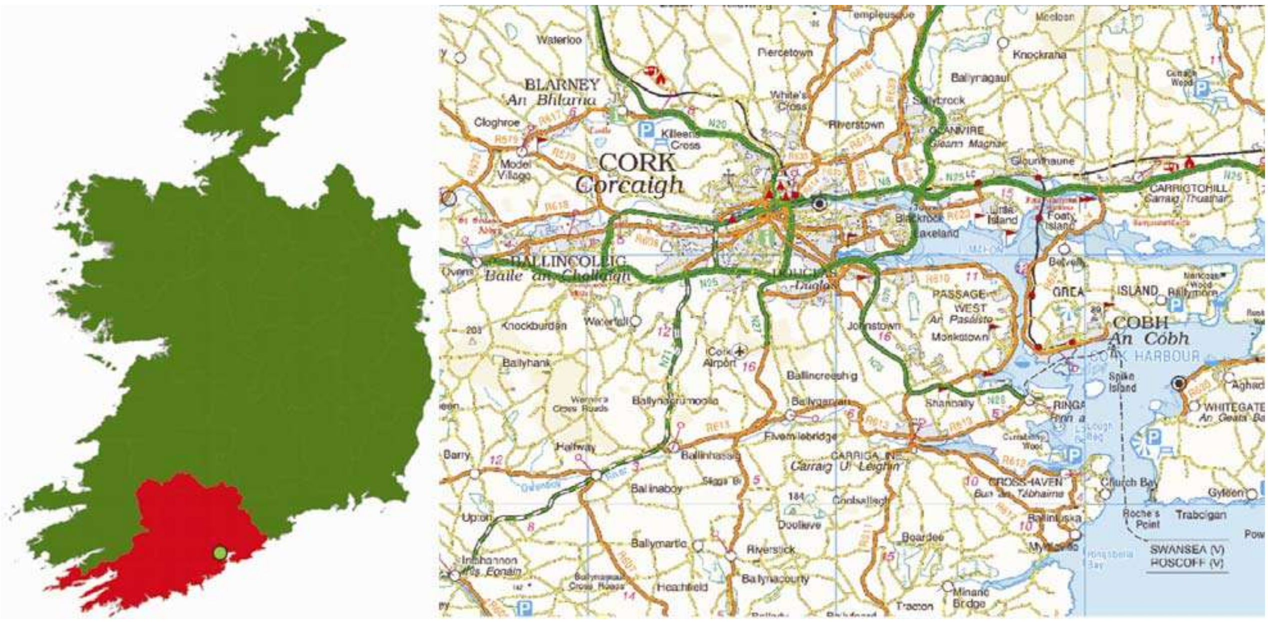

Fig 2.1 Location of Cork City relative to County Cork and the Republic of Ireland

The local governance of the city and its environs is administered by Cork City Council. The council's remit includes environment, recreation and sport, strategic planning and economic development, roads and transportation, housing and community, planning and development and culture and amenity. The City

Council's administrative boundary, which corresponds to the area of analysis of this project, is shown below in Fig 2.2. The City Council's administrative area covers almost 40 km².

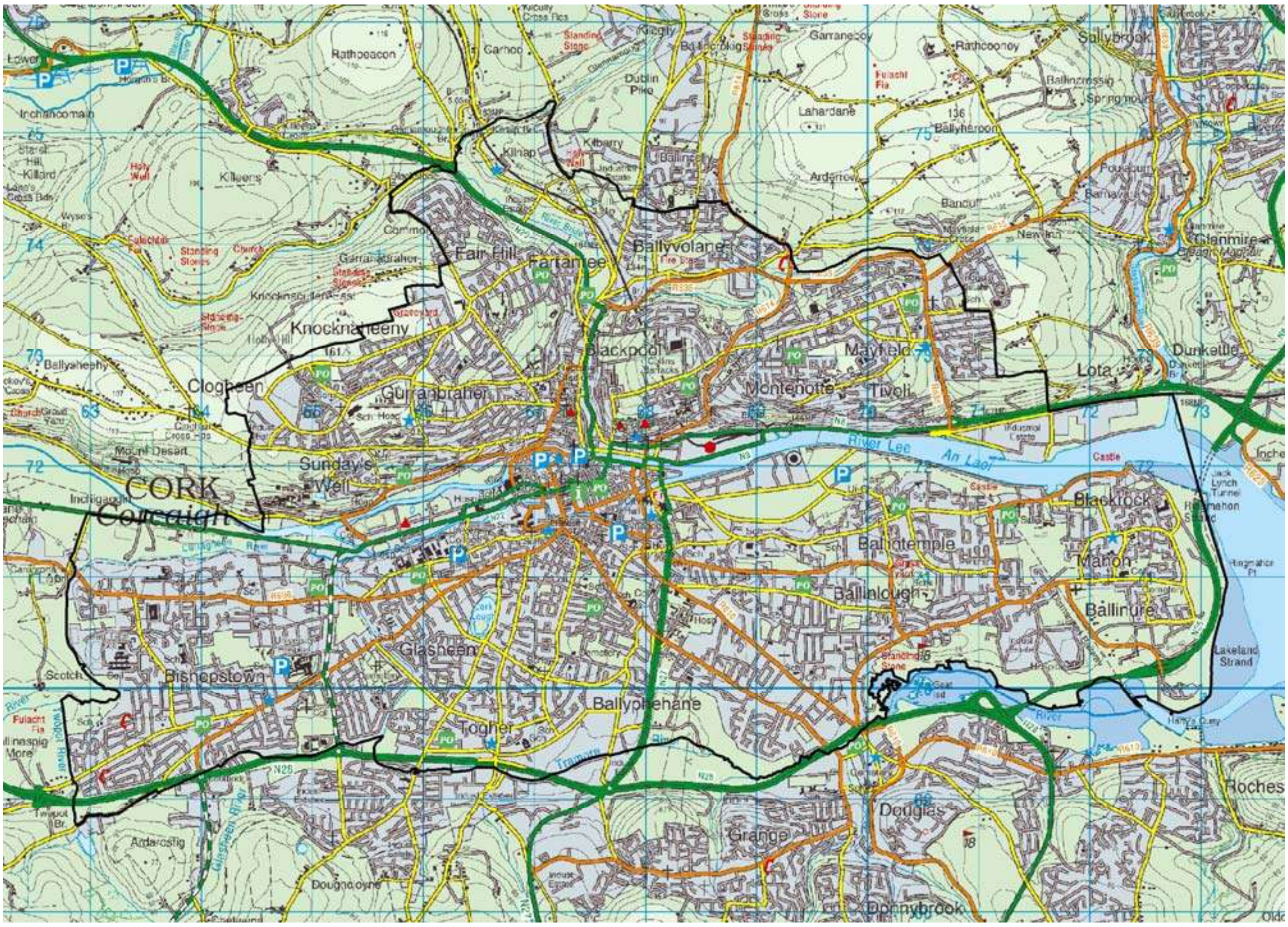

Fig 2.2 Boundary of PanGeo interpretation area.

Cork city is underlain by sedimentary rocks from the Devonian (415 - 360 million years ago) and Carboniferous (360 - 300 million years ago) geological Periods. The distribution of these different types of bedrock is governed by the palaeoenvironmental conditions and the sequence of deposition of the sediments that formed the rocks and their subsequent deformation and erosion over millions of years.

The rocks deposited during the Devonian Period in the Cork city area are known as the Old Red Sandstones (ORS). The ORS are thick sequences of red or purple coloured sandstones and mudstones. At this time Cork was an arid desert environment with large rivers depositing these sand and mud sediments over an alluvial plain.

The Carboniferous rocks in the area are the remnants of sediments deposited in a tropical shallow marine environment during the early Carboniferous. These Carboniferous rocks are mainly pure limestones and as such are susceptible to karstification, and formation of caves, sink holes and other karst landforms which can be a hazard to industrial and infrastructural projects such as factories, pipelines and roads if not considered and investigated in the planning and design stages of development.

These Devonian and Carboniferous rocks were deformed during an episode of tectonic activity, known as the Variscan Orogeny (mountain building period) spanning the end of the Carboniferous Period and the beginning of the Permian Period (300 million years ago). The ridge and valley topography of Cork is the result of Variscan mountain building. In Cork the rocks were folded into broad open anticlines and synclines with a wavelength of several kilometres. The anticlines are now, for the most part, the ridges, formed by the ORS. The synclines are now the valleys, which are floored by rocks of Carboniferous limestones (Fig 2.3).

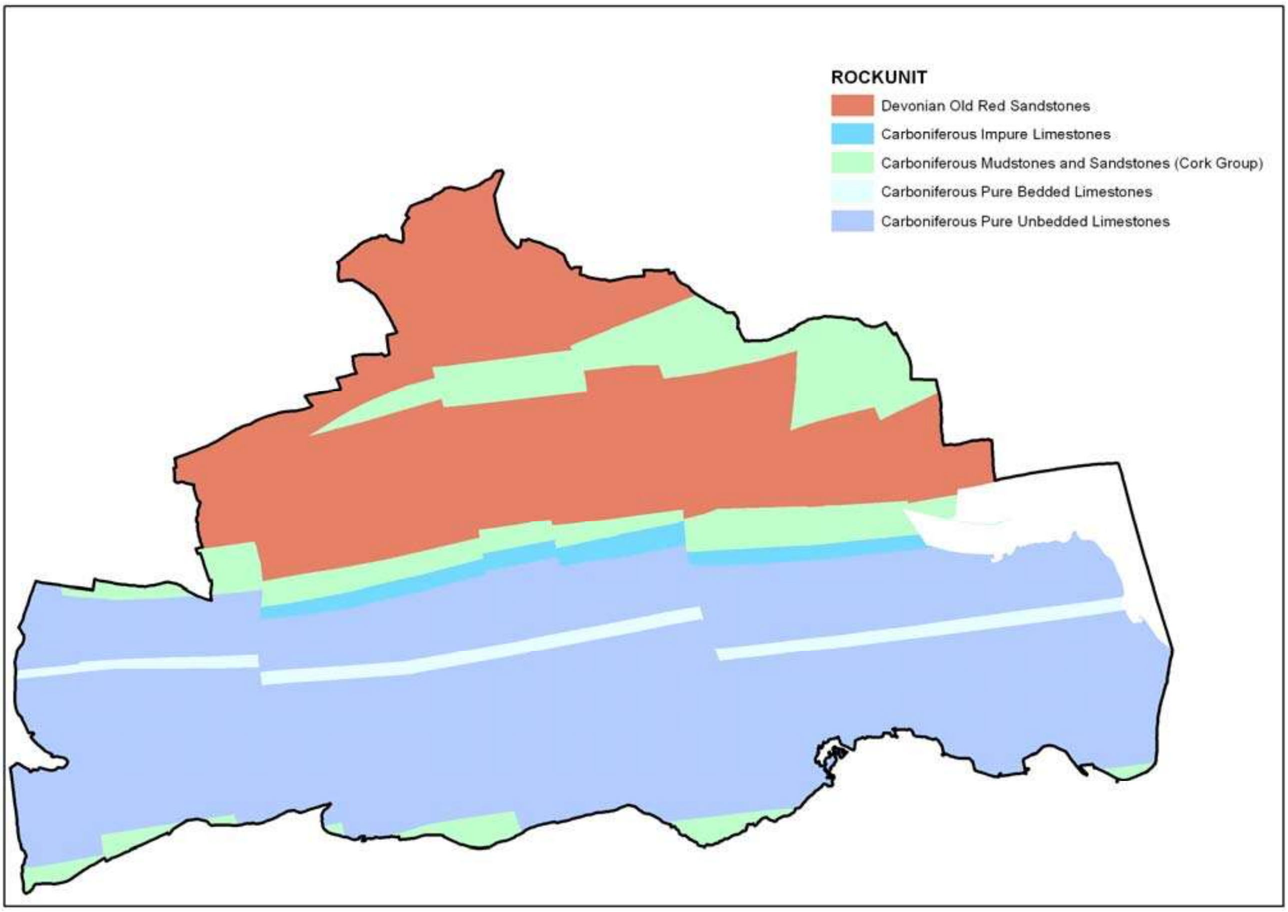

Fig 2.3 Simplified bedrock geology of the PanGeo interpretation area.

The shaping forces of the Variscan Orogeny and subsequent emergence and erosion of the land surface under a variety of palaeoenvironmental conditions underpins the broad trends in the landscape. The current expression of the natural landscape is the cumulative effect of these very ancient processes and the more recent sculpting and shaping influence of glaciations during the Quaternary Period (2.6 million years ago until the present day). These glaciations ended *c*. 10,000 years ago and the effects on the landscape include both an erosive and depositional legacy of glacier ice advancing and retreating over the area and concomitant fluctuations in relative sea level. Following the deglaciation of the area, compressible Holocence Epoch (10,000 years ago until the present day) sediments were naturally deposited by rivers and in lakes and also created with human intervention. These sediments include alluvial deposits in the river channels, estuarine silts and clays and reclaimed land.

These Holocene sediments and the location of the city at the nexus of land, river and sea are reflected in the name Cork which is derived from the Gaelic word *corach* meaning swamp or marsh. A map showing the distribution of the Quaternary sediment cover is shown in Fig 2.4.

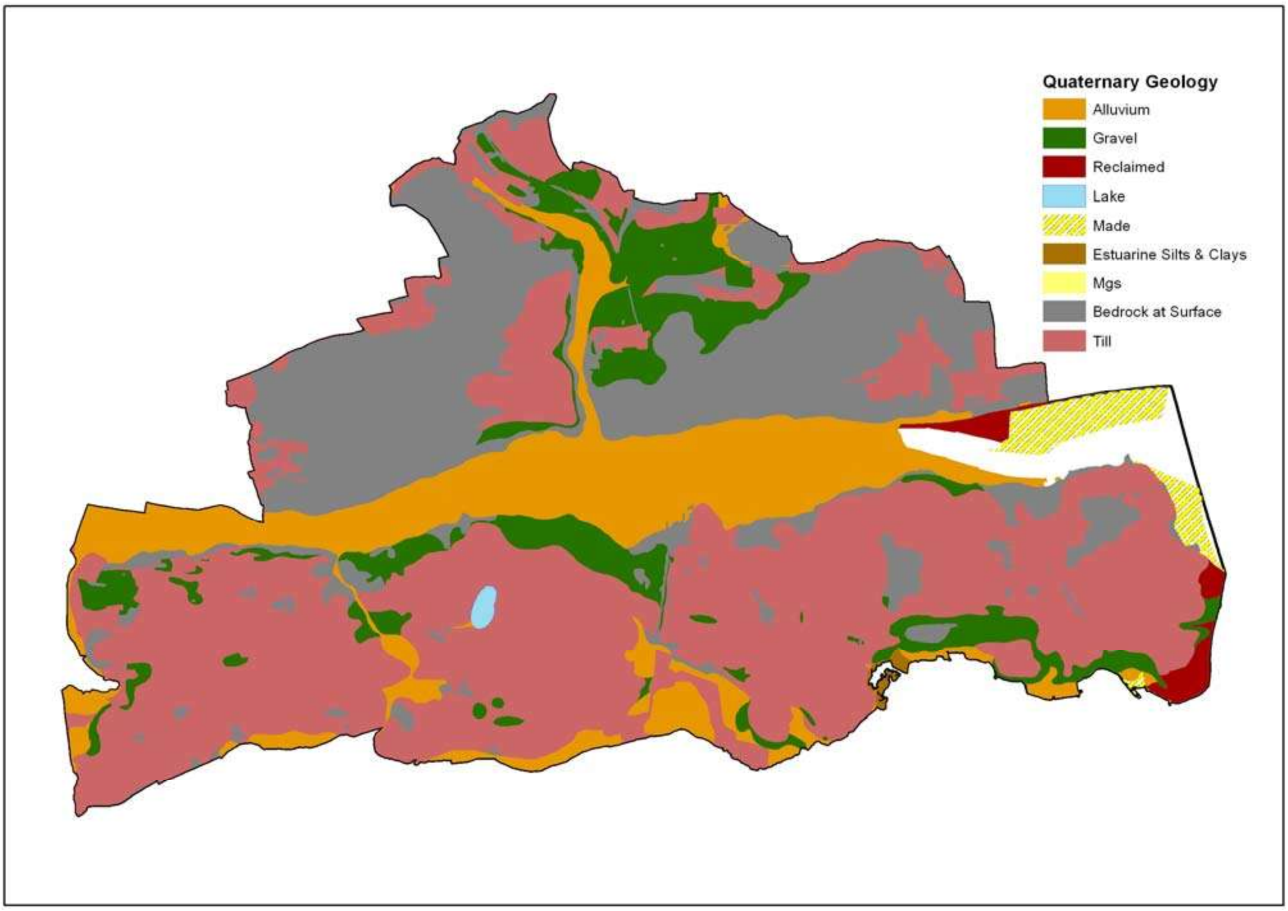

Fig 2.4 Quaternary geology of the PanGeo interpretation area.

The PanGeo interpretation has led to the delineation of 5 polygons (areas) within which potential or observed ground instabilities are identified. The main observed instabilities are associated with compressible ground. The largest area of potential instability is associated with the pure limestones which have the potential to give rise to instabilities associated with ground dissolution. A map showing the distribution of the potential and observed instabilities derived from the PanGeo interpretation is shown in Fig 2.5. Some polygons in Fig 2.5 may be obscured by others overlying them. In total 25.31 km² of the area (40 km²) is adjudged to have potential or observed ground instabilities.

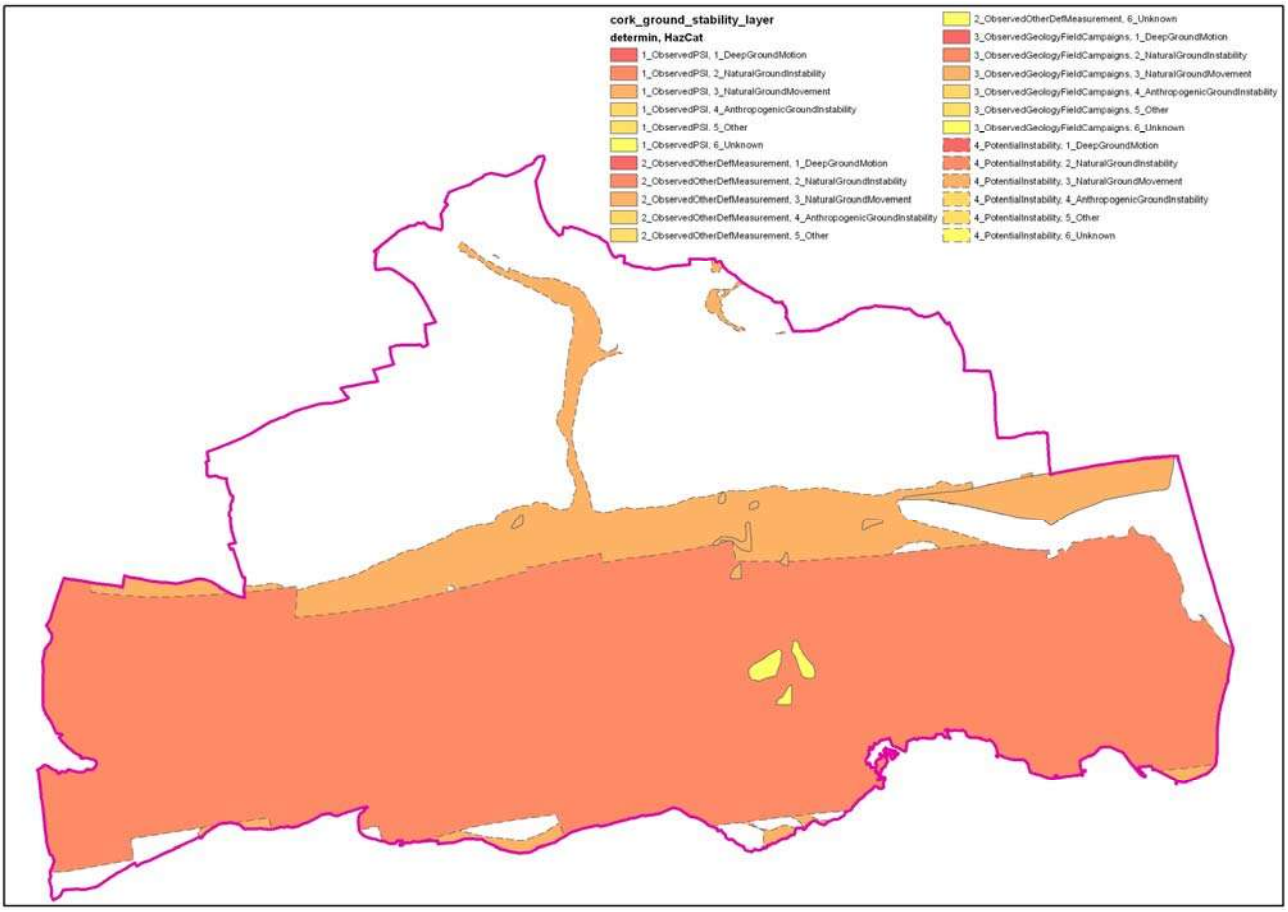

Fig 2.5 Potential and observed instabilities derived from the PanGeo interpretation.

The datasets used to derive this interpretation are listed here and described below:

- ☐ Geological Survey of Ireland 1:100,000 Bedrock Geological mapping
- ☐ Geological Survey of Ireland 1:50,000 Quaternary Geological mapping
- ☐ Geological Survey of Ireland Karst Features Database (point data)
- ☐ Geological Survey of Ireland Geotechnical Database (point data)
- ☐ Geological Survey of Ireland Landslides Database
- ☐ Ordnance Survey Ireland Historic 6 inch mapping
- ☐ Ordnance Survey Ireland 2004 & 2000 Aerial imagery
- ☐ Cork Terrafirma PSI data

Geological Survey of Ireland 1:100,000 Bedrock Geological mapping (point, line and plolygon data)

These maps show the distribution of rock units interpreted to lie beneath the superficial cover of soil and glacial deposits. This dataset is freely available for download, viewing or WMS connection on http://www.gsi.ie/Mapping.htm.

Geological Survey of Ireland 1:50,000 Quaternary Geological mapping (point, line and plolygon data)

These maps show the distribution of the superficial cover of Holocene and glacial deposits. The map distinguishes between the following broad categories of deposits: till (boulder clay), sand/gravel, peat, alluvium, lake silt and clay, marl and made ground. This Quaternary geology map shows the dominant sediment type within 1 metre of the surface. This dataset is freely available for download and viewing on http://www.gsi.ie/Mapping.htm.

Geological Survey of Ireland Karst Features Database (point data)

A database of karst features, showing the location and relevant characteristics of individual karst features across Ireland. This dataset is freely available for download on http://www.gsi.ie/Mapping.htm.

Geological Survey of Ireland Geotechnical Database (point data)

This database contains the reports of site investigation work undertaken to determine the ground conditions at the location of proposed development projects. The reports typically contain a text report and borehole, trial pit and probe logs, as well as field tests and laboratory sample analyses. The data is also critical for the modelling of the subsurface geology and in geological mapping of the overburden (Quaternary sediments) and the bedrock. This dataset is freely available for download and viewing on http://www.gsi.ie/Mapping.htm.

Geological Survey of Ireland Landslides Database (point & plolygon data)

A database of past slope failure events with data, where available, on location, landslide type, materials, causes, and impacts. This dataset is freely available for download and viewing on http://www.gsi.ie/Mapping.htm.

Ordanance Survey Ireland Historic 6 inch (1: 10,560) mapping (raster data)

These data were captured between 1829 and 1842 when Ordnance Survey Ireland completed the first ever large-scale survey of an entire country. Several editions of these maps were produced. In the context of the PanGeo project these data provide valuable insights into Irish historic land-use patterns. These data are commercial products and are used by Geological Survey of Ireland under the terms of Ordnance Survey Ireland Licence No. EN 0047212.

Ordnance Survey Ireland 2004 & 2000 Aerial imagery (raster data)

Ortho rectified photographs corrected to allow for slopes and other distortions so that it corresponds exactly to large scale mapping. In the context of the PanGeo project these data provide valuable insights into present day land-use patterns. These data are commercial products and are used by Geological Survey of Ireland under the terms of Ordnance Survey Ireland Licence No. EN 0047212.

Cork PSI data was produced by NPA Fugro Ltd. for use by the Geological Survey of Ireland in the GMES Terrafirma project. ERS-1, ERS-2 and Envisat satellite data were used to derive the PSI product for an area somewhat larger than the site under investigation for the PanGeo interpretation as can be seen in Fig 2.6. The description that follows refers to the GMES Terrafirma project dataset:

- ☐ ERS-1, ERS-2 and Envisat data
- ☐ 23/05/1992 to 06/09/2005
- ☐ 56 scenes
- ☐ ~800 km², 30735 PS points
- ☐ Average motion -0.669mm per year
- ☐ Maximum heave 20.90mm per year

- Maximum subsidence -19.9mm per year

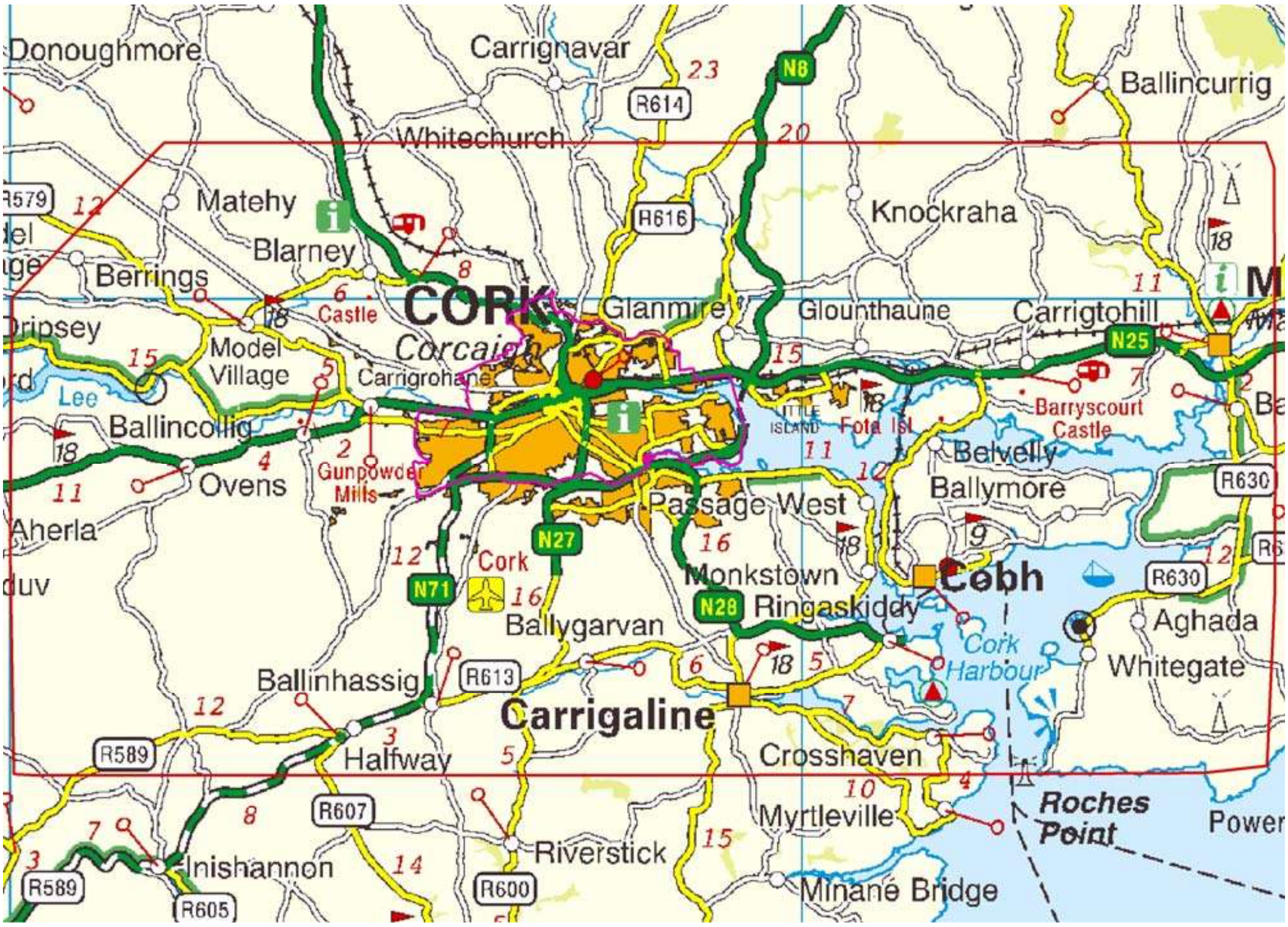

Fig 2.6 Area covered by GMES Terrafirma data in red outline, PanGeo interpretation area in pink outline

The following comments were made by Fugro NPA Ltd on the quality and reliability of the data:

“Complex processing site. Majority of AOI outside urban areas and characterised by low PS density. Region of downward motion in North West of result (loss of point coverage possibly due to motion rate outside of PSI limits). A number of individual points across AOI exhibit downward and upward motion trend. Downward motion trend in East Cork dock area. Note that there is a temporal separation of ~3 ¾ years between the last ERS-2 SAR (20000530) scene and the first ENVISAT ASAR (20040120) scene. It is not possible to predict motion phenomena during this data ‘gap’.”

“Difficult atmospheric conditions, possible non-linear deformation signal within atmospherics.”

3 *PGGH_CORK_001*

3.1 GENERAL PROPERTIES OF THE MOTION AREA

This polygon is distributed across Lee Valley (Fig PGGH_Cork_001.1) with its parts resting on Carboniferous and Devonian bedrock units (Fig PGGH_Cork_001.2) and alluvial deposits (Fig PGGH_Cork_001.3).

The typical landuse type for this polygon is continuous urban fabric and port areas along with Páirc Uí Chaoimh, a sports stadium. Pre-development geotechnical site investigation can mitigate or avoid the unfavourable effect of this geohazard. This polygon extends over c. 0.06 km².

Fig PGGH_Cork_001.1 Distribution of subsiding polygon (blue outline) overlying aerial imagery (Licence No. EN 0047212).

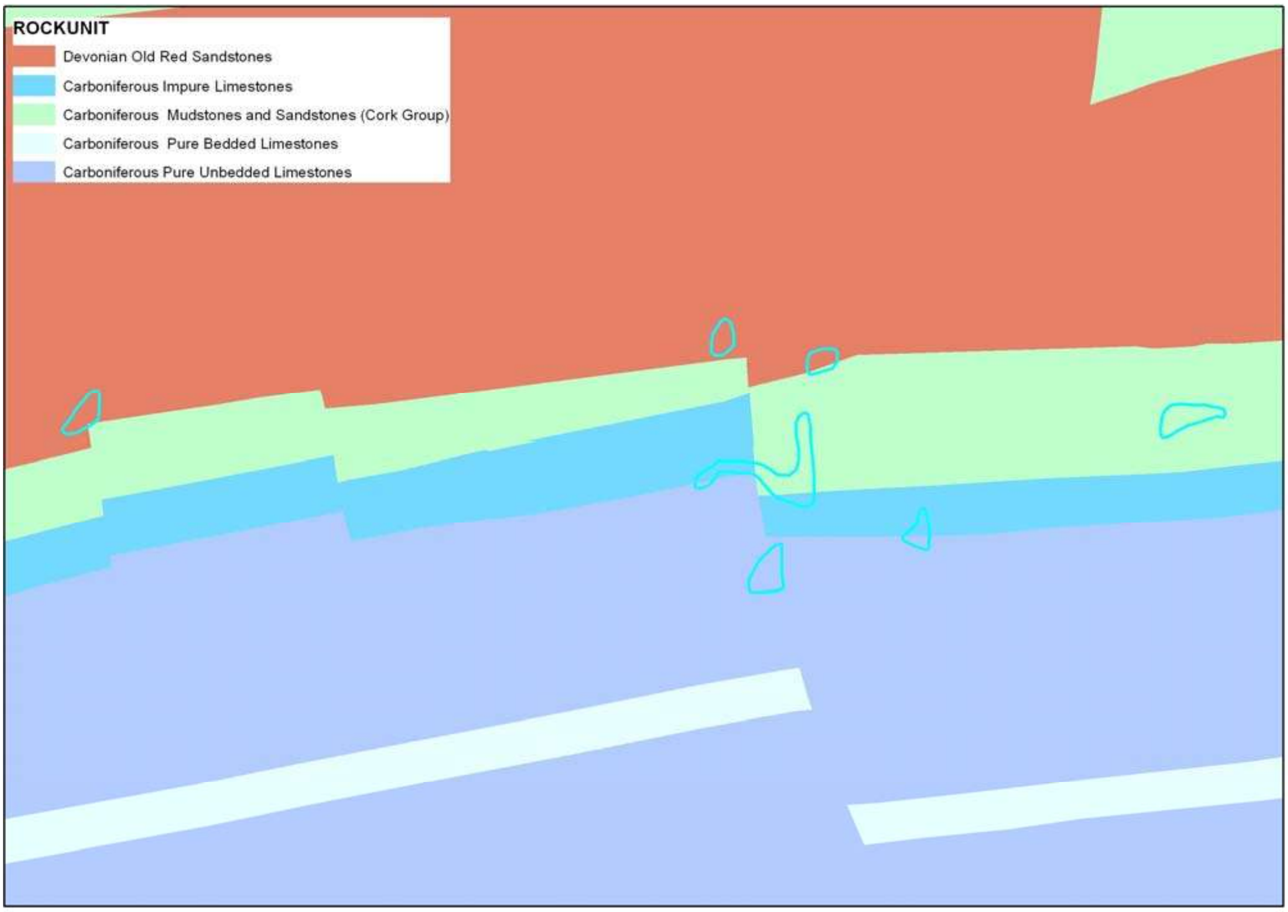

Fig PGGH_Cork_001.2 Distribution of subsiding polygon (blue outline) and bedrock geology units

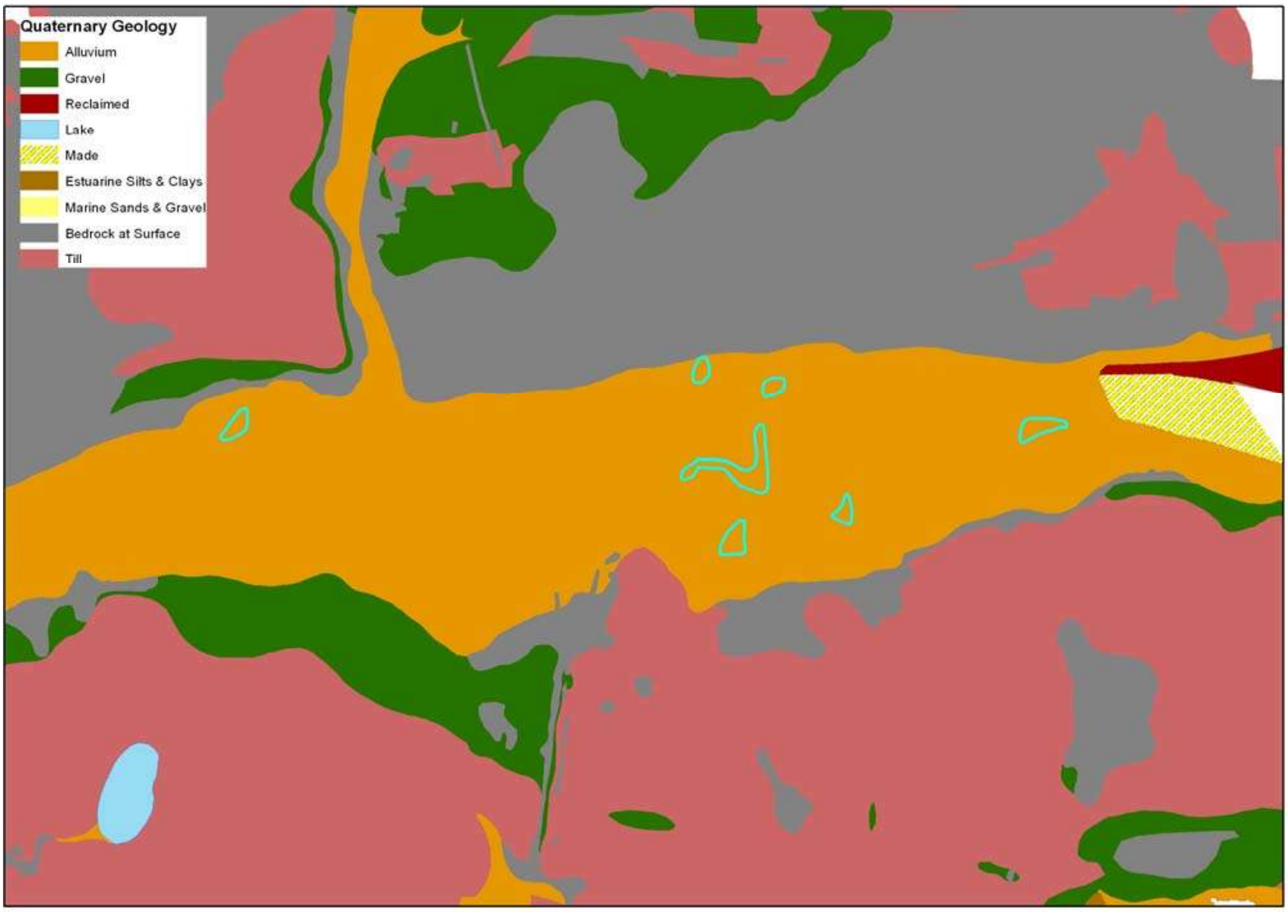

Fig PGGH_Cork_001.3 Distribution of subsiding polygon (blue outline) and Quaternary geology units

3.2 SPECIFIC GEOHAZARD TYPE

Natural Ground Movement: Compressible Ground

3.3 TYPE OF MOTION

Subsidence

3.4 THE DETERMINATION METHOD

Observed in PSI data.

3.5 CONFIDENCE IN THE INTERPRETATION

This polygon has a "Low" interpretation confidence. The polygon was delineated on the basis of PSI data and Geological Survey of Ireland Quaternary geology mapping.

Geological Survey of Ireland Quaternary geology mapping show the distribution of the superficial cover of Holocene and glacial deposits and also where bedrock outcrops or lies within 1 meter of the surface. The uppermost deposit that achieves a thickness of >1m is the deposit that appears on the map. A more detailed 3D model of the deposits, which is in development for Cork City, will allow a more comprehensive analysis of the lateral and vertical distribution of these deposits.

Geological Survey of Ireland Quaternary geology mapping distinguishes between the following broad categories of deposits: till (boulder clay), sand/gravel, peat, alluvium, lake silt and clay, marl and made ground. Sand/gravel and boulder clay are further divided to show the dominant stone type contained. The data collected during fieldwork based on the analysis of exposures available and the identification and description of morphological features is supported by the acquisition of geophysical or borehole data where sediment type was unknown or uncertain. The Quaternary geology map shows the dominant sediment type within 1 metre of the surface. This dataset is freely available for download and viewing on http://www.gsi.ie/Mapping.htm.

3.6 GEOLOGICAL INTERPRETATION OF THE MOTION

The alluvial deposits on which this polygon rests are composed of soft compressible sediments. Applying a loading to these deposits can compress the deposits and result in the lowering of the land surface. The alluvial deposits overly deeper glaciofluvial gravels and land scarcity in urban areas can result in the dewatering of these deposits when developing basement structures, which in turn can lead to the destabilisation of nearby structures.

3.7 EVIDENCE FOR THE INSTABILITY

Images below (and their captions) give an indication of the nature of the instability in this polygon.

Fig PGGH_Cork_001.4 Cracks in building (highlighted)

Fig PGGH_Cork_001.5 Somewhat repaired crack in a 3m high wall


Fig PGGH_Cork_001.6 Cracks in building (highlighted)

Fig PGGH_Cork_001.3 Cracks in building and slight tilting

4 *PGGH_CORK_002*

4.1 GENERAL PROPERTIES OF THE MOTION AREA

This polygon is distributed in the Balinlough area of Cork City (Fig PGGH_Cork_002.1) with its parts resting on Carboniferous bedrock units (Fig PGGH_Cork_002.2) and till or bedrock within 1 meter of the surface (Fig PGGH_Cork_002.3).

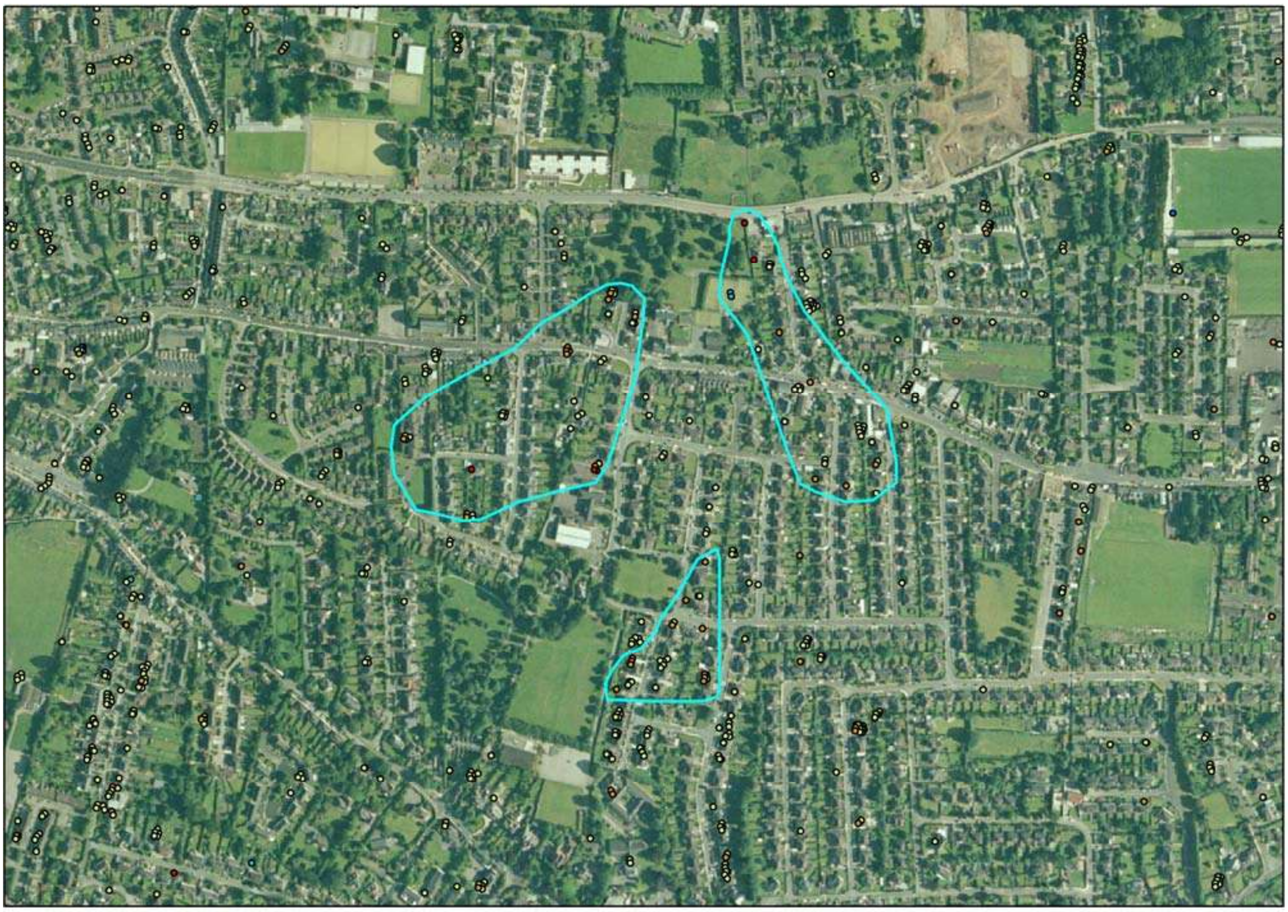

Fig PGGH_Cork_002.1 Distribution of subsiding polygon (blue outline) and PSI data (red & orange indicate movement away from the satellite) overlying aerial imagery (Licence No. EN 0047212).

Fig PGGH_Cork_002.2 Distribution of subsiding polygon (blue outline) and bedrock geology units

Fig PGGH_Cork_002.3 Distribution of subsiding polygon (blue outline) and Quaternary geology units

The typical landuse type for this polygon is continuous urban fabric which is mainly residential developments with occasional retail units. This polygon extends over c. 0.09 km².

4.2 SPECIFIC GEOHAZARD TYPE

Unknown

4.3 TYPE OF MOTION

Subsidence

4.4 THE DETERMINATION METHOD

Observed in PSI data.

4.5 CONFIDENCE IN THE INTERPRETATION

This polygon was delineated exclusively on the basis of the PSI data and has a “Low” interpretation confidence. Terrain instability was observed within the polygon but it is suspected that terrain instabilities are more extensive throughout this area and therefore the polygon boundaries only reflect a subset of the instability.

4.6 GEOLOGICAL INTERPRETATION OF THE MOTION

Unknown

4.7 EVIDENCE FOR THE INSTABILITY

Anecdotal and visual evidence was collected during field-validation work. Images below (and their captions) give an indication of the nature of the instability in this polygon.

Fig PGGH_Cork_002.4 Cracking in building

Fig PGGH_Cork_002.5 Typical newly underpinned and re-plastered house

Fig PGGH_Cork_002.6 Cracking and displacement in walls

Fig PGGH_Cork_002.8 Reinforcement against movement at the side of house (highlighted)

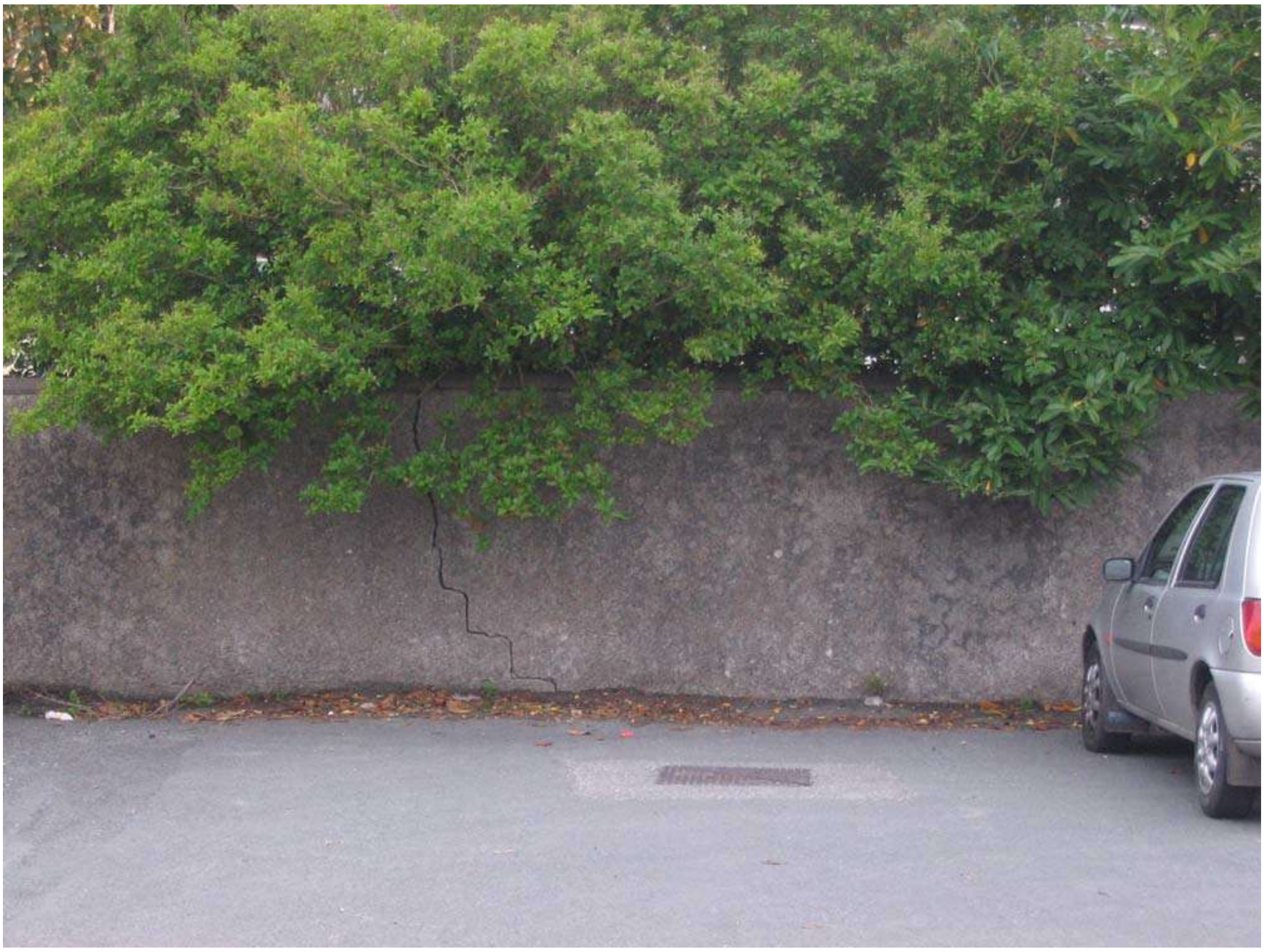

Fig PGGH_Cork_002.9 Cracking and displacement in walls

5 *PGGH_CORK_003*

5.1 GENERAL PROPERTIES OF THE MOTION AREA

This site is located in the port area of Cork City (Fig PGGH_Cork_003.1). It rests on Carboniferous bedrock units and reclaimed land overlain by a layer of made ground in the eastern part of the polygon (Fig PGGH_Cork_003.2). Pre-development geotechnical site investigation may mitigate or avoid the unfavourable effect of this geohazard. This polygon extends over c. 0.62 km².

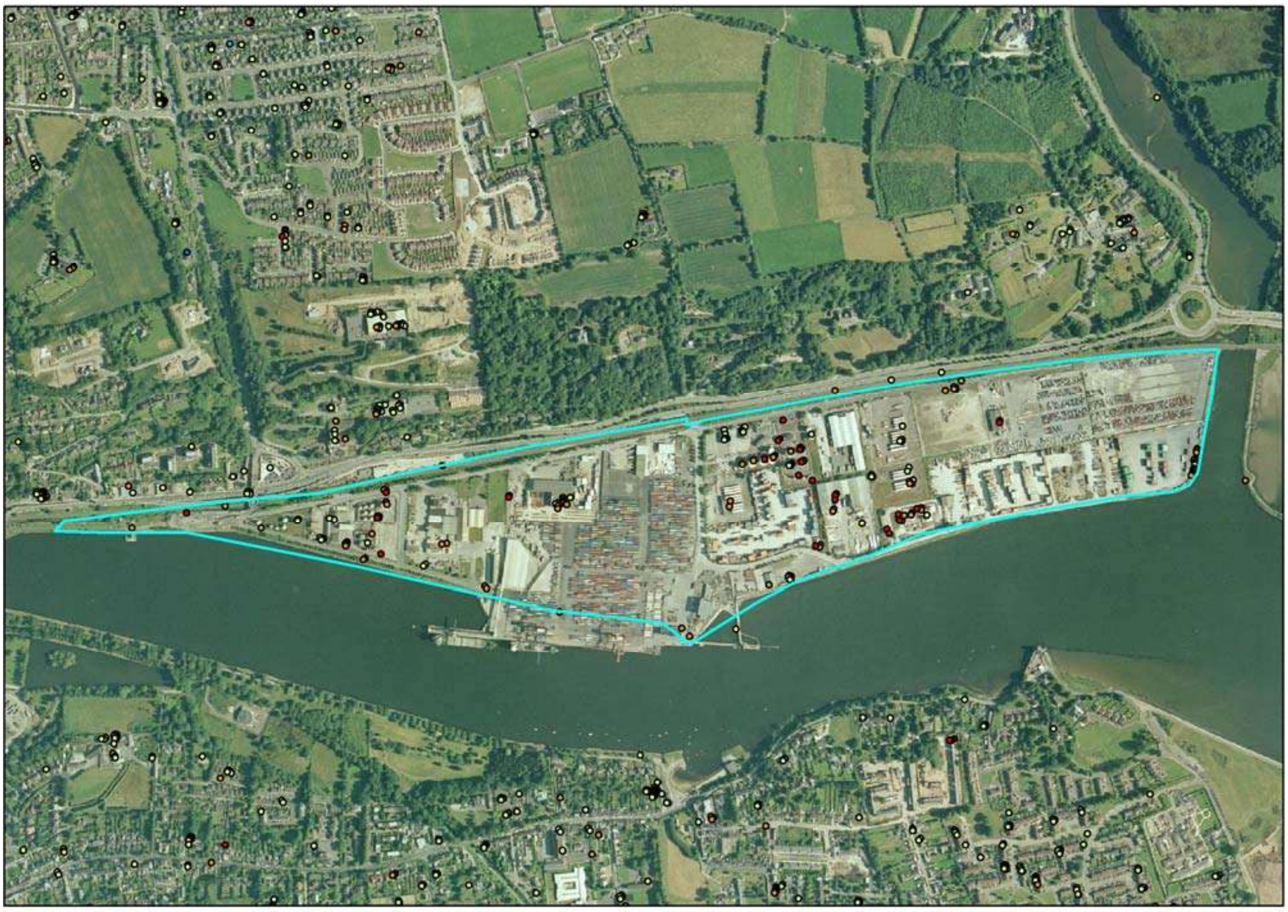

Fig PGGH_Cork_003.1 Distribution of subsiding polygon (blue outline) and PSI data (red & orange indicate movement away from the satellite) overlying aerial imagery (Licence No. EN 0047212).

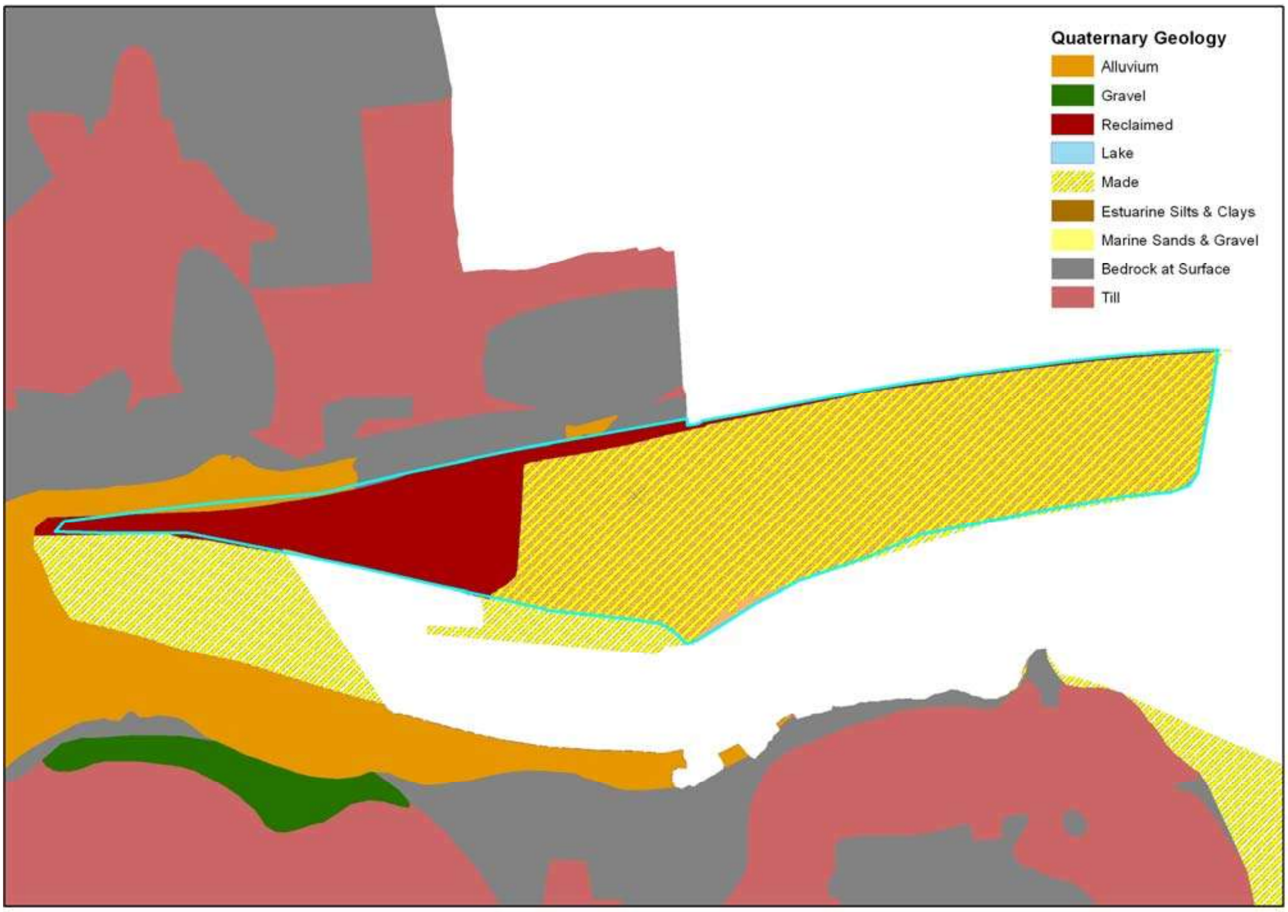

Fig PGGH_Cork_003.2 Distribution of subsiding polygon (blue outline) and Quaternary geology units

5.2 SPECIFIC GEOHAZARD TYPE

Natural Ground Movement: Compressible Ground

5.3 TYPE OF MOTION

Subsidence

5.4 THE DETERMINATION METHOD

Observed in PSI data.

5.5 CONFIDENCE IN THE INTERPRETATION

This polygon has a "Medium" interpretation confidence. The polygon was delineated on the basis of PSI data and Geological Survey of Ireland Quaternary geology mapping with reference to the Geological Survey of Ireland Geotechnical Database.

Geological Survey of Ireland Quaternary geology mapping show the distribution of the superficial cover of Holocene and glacial deposits and also where bedrock outcrops or lies within 1 meter of the surface. The uppermost deposit that achieves a thickness of >1m is the deposit that appears on the map. A more detailed 3D model of the deposits, which is in development for Cork City, will allow a more comprehensive analysis of the lateral and vertical distribution of these deposits.

Geological Survey of Ireland Quaternary geology mapping distinguishes between the following broad categories of deposits: till (boulder clay), sand/gravel, peat, alluvium, lake silt and clay, marl and made ground. Sand/gravel and boulder clay are further divided to show the dominant stone type contained. The data collected during fieldwork based on the analysis of exposures available and the identification and description of morphological features is supported by the acquisition of geophysical or borehole data where sediment type was unknown or uncertain. The Quaternary geology map shows the dominant sediment type within 1 metre of the surface. This dataset is freely available for download and viewing on http://www.gsi.ie/Mapping.htm.

The Geological Survey of Ireland Geotechnical Database contains the reports of site investigation work undertaken to determine the ground conditions at the location of proposed development projects. The reports typically contain a text report and borehole, trial pit and probe logs, as well as field tests and laboratory sample analyses. The data is also critical for the modelling of the subsurface geology and in geological mapping of the overburden (Quaternary sediments) and the bedrock. This dataset is freely available for download and viewing on http://www.gsi.ie/Mapping.htm.

5.6 GEOLOGICAL INTERPRETATION OF THE MOTION

The reclaimed lands on which this polygon rests are composed of soft compressible sediments. Applying a loading to these deposits can compress the deposits and result in the lowering of the land surface. These sediments are loaded by made ground in parts and by buildings, roads and goods. In the past, at this site, lines of willow trees were planted, and breakwaters built, to delineate the river channel. In addition this resulted in a slowing the flow of water and sedimentation on the lee side of these objects (Fig PGGH_Cork_003.3 and Fig PGGH_Cork_003.4). By this action, estuarine deposits quickly reached a level where they could be reclaimed and turned to other uses.

Fig PGGH_Cork_003.3 Early edition of Ordanance Survey Ireland Historic 6 inch (1: 10,560) mapping (Licence No. EN 0047212) with Geological Survey of Ireland annotations showing how the site appeared at some point during the 19th Century.

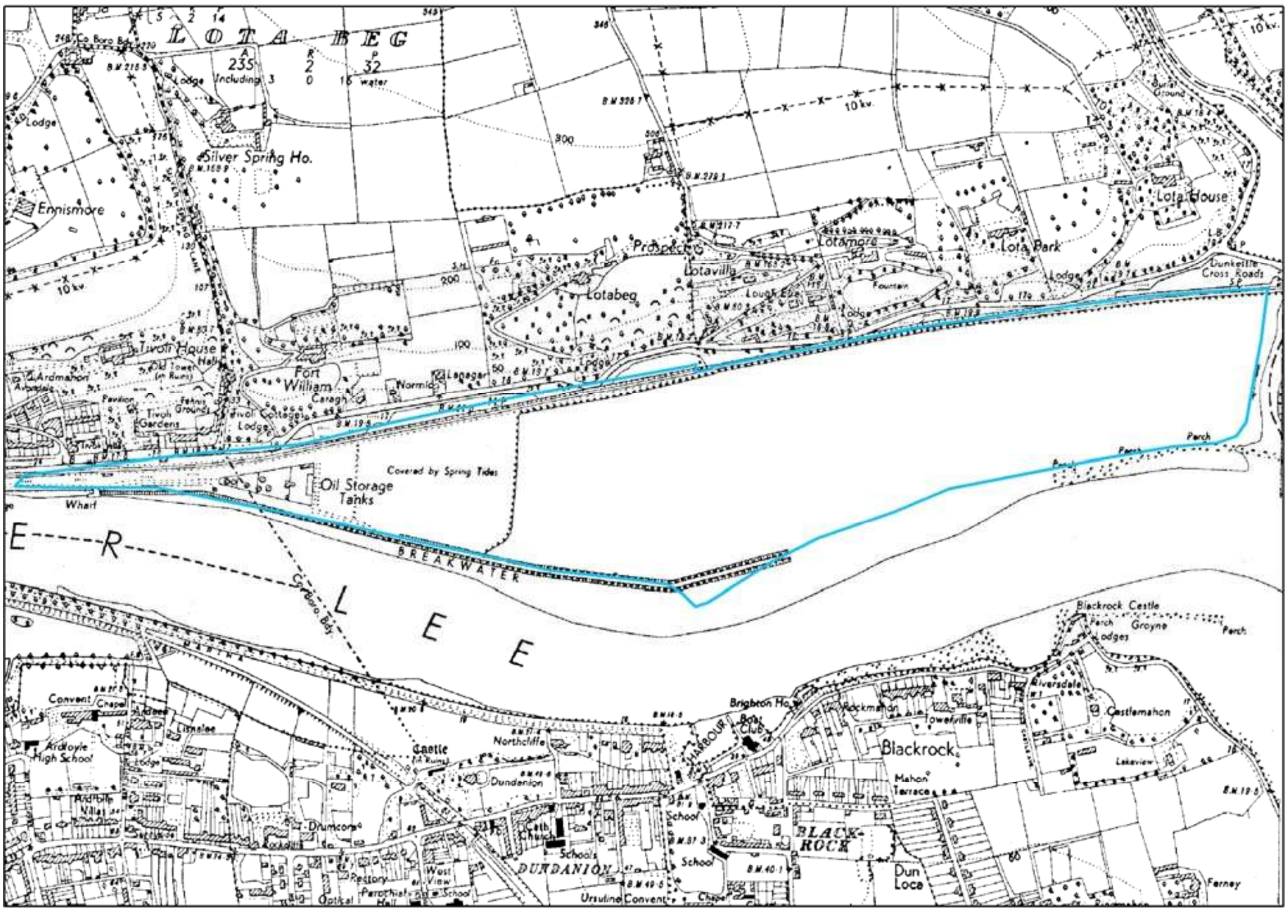

Fig PGGH_Cork_003.4 Later edition of Ordanance Survey Ireland Historic 6 inch (1: 10,560) mapping (Licence No. EN 0047212) showing how the site appeared at some subsequent point.

5.7 EVIDENCE FOR THE INSTABILITY

Some of the Cork Port areas, this polygon included, have insurmountable access restrictions.

The image below (and its caption) gives an indication of the nature of the instability in this polygon.

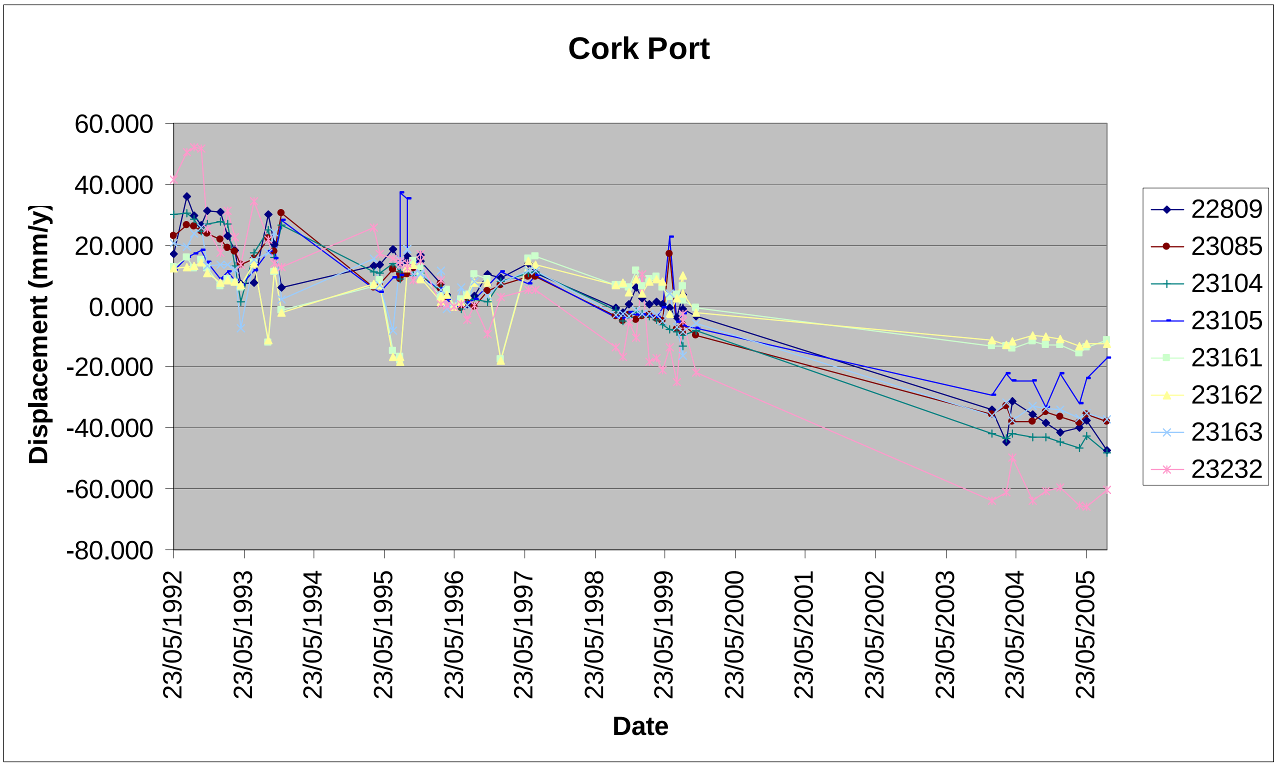

Fig PGGH_Cork_003.4 A selection of points from the polygon showing the time series of motion

Large 'jumps' in the curves indicate significant non-linear motion that cannot be captured by the PSI technique in this instance.

6 *PGGH_CORK_004*

6.1 GENERAL PROPERTIES OF THE MOTION AREA

This polygon is distributed across Cork City (Fig PGGH_Cork_004.1) with its parts resting on Carboniferous and Devonian bedrock units (Fig PGGH_Cork_004.2) and potentially compressible Quaternary deposits (Fig PGGH_Cork_004.3).

The most common landuse type for this polygon is continuous urban fabric but the port areas are also represented along with natural and agricultural areas. Pre-development geotechnical site investigation can mitigate or avoid the unfavourable effect of this geohazard. This polygon extends over c. 7.36 km².

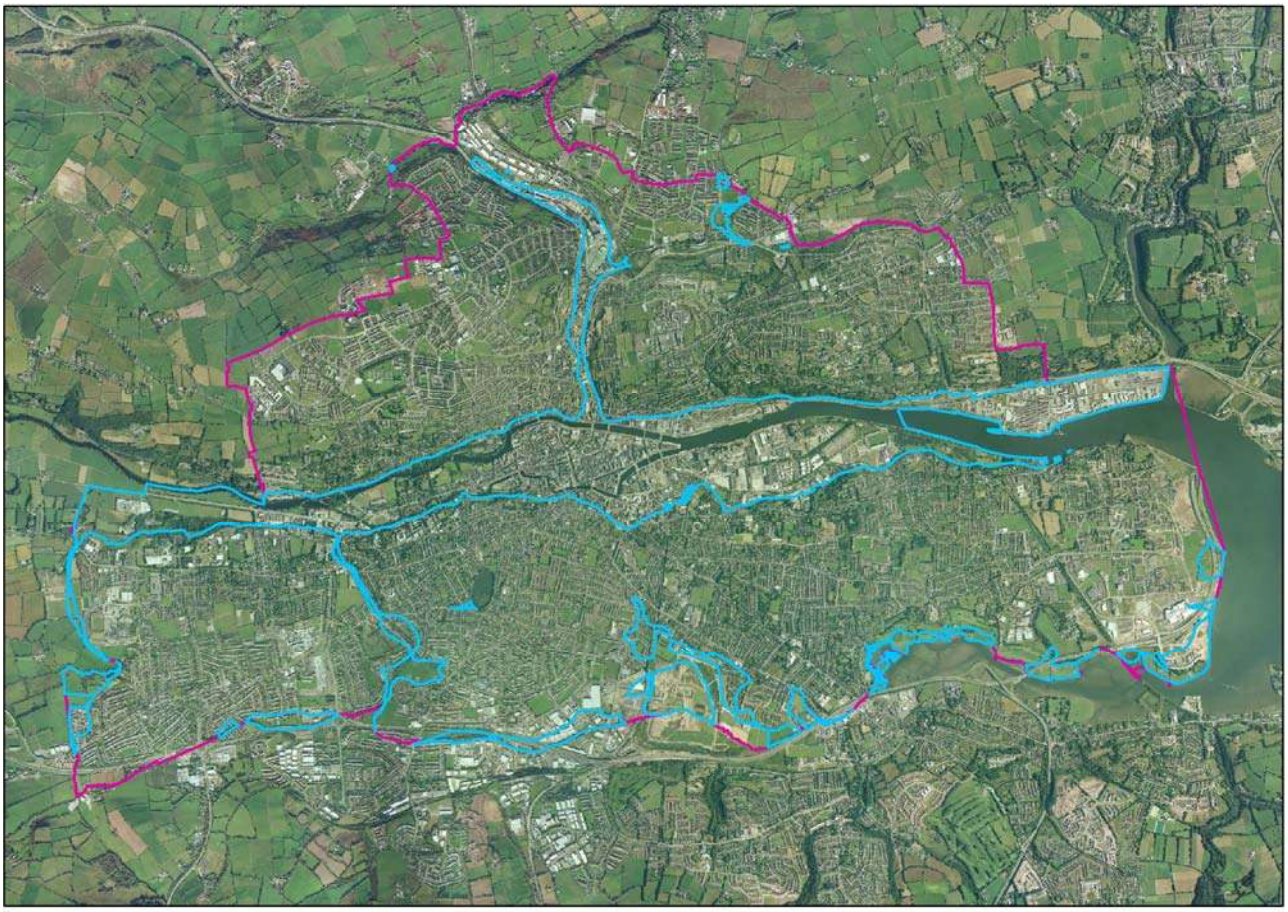

Fig PGGH_Cork_004.1 Distribution of potential compressible ground polygon (blue outline) over aerial imagery (Licence No. EN 0047212).

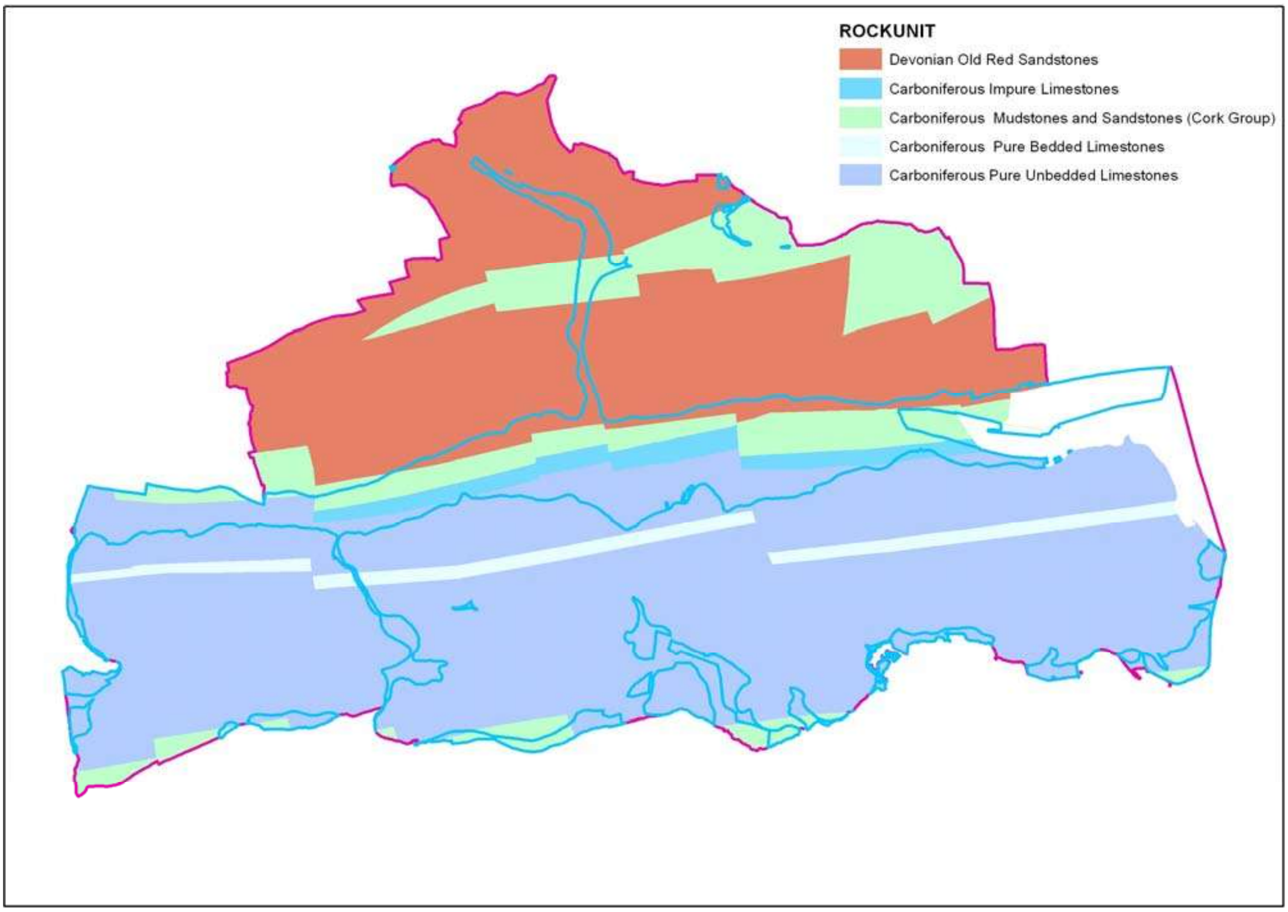

Fig PGGH_Cork_004.2 Distribution of potential compressible ground polygon (blue outline) and bedrock geology units

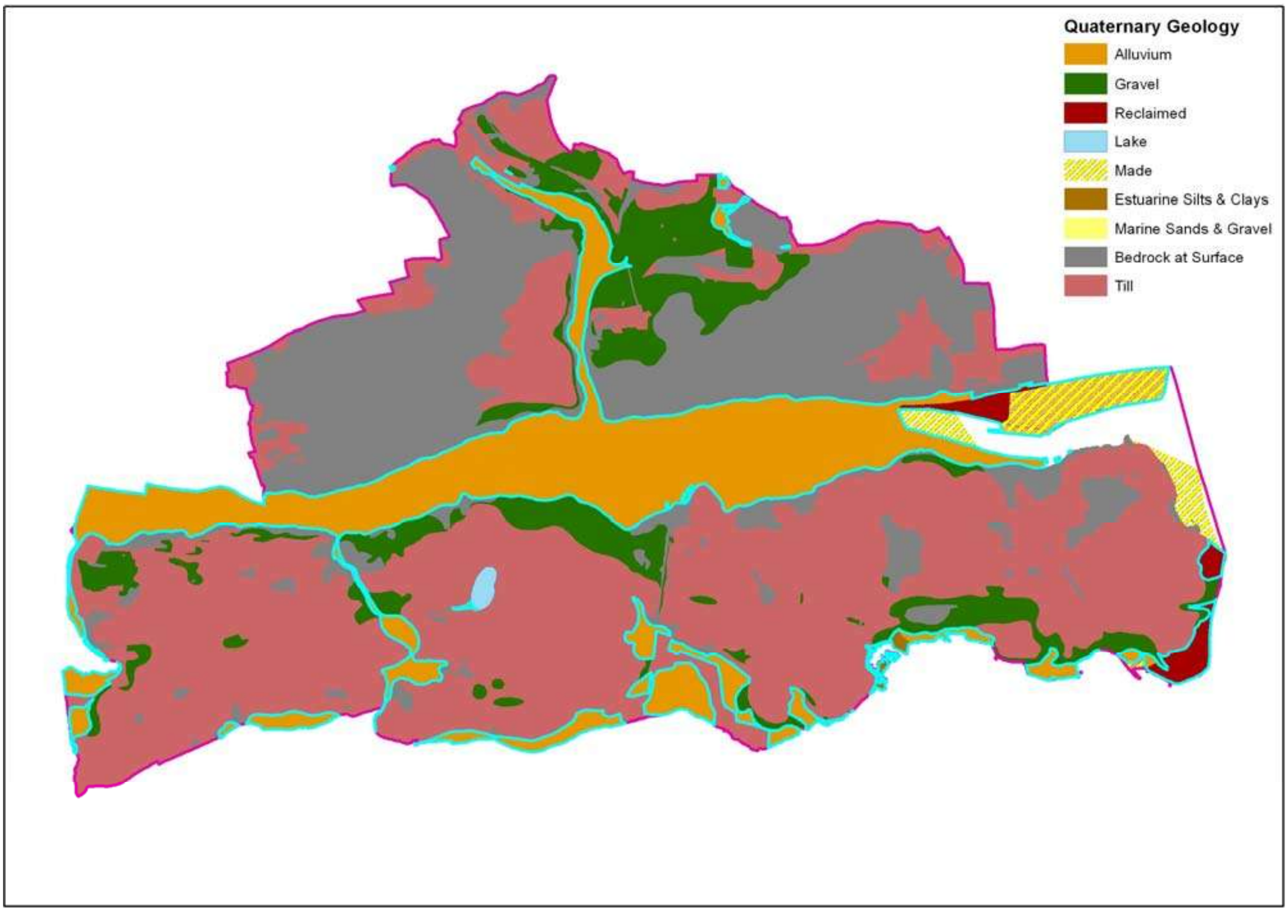

Fig PGGH_Cork_004.3 Distribution of potential compressible ground polygon (blue outline) and Quaternary geology units

6.2 SPECIFIC GEOHAZARD TYPE

Natural Ground Movement: Compressible Ground

6.3 TYPE OF MOTION

Subsidence

6.4 THE DETERMINATION METHOD

Potential Motion

6.5 CONFIDENCE IN THE INTERPRETATION

Medium confidence is assigned to this polygon which is derived from deposits show on the Geological Survey of Ireland Quaternary geology mapping.

Instability in these deposits has the potential to occur where they are intersected by development. Geological Survey of Ireland Quaternary geology mapping is primarily conducted using aerial imagery and DEM interpretation combined with geological drilling and geophysical survey techniques. These techniques are difficult to use in urban areas where the natural deposits are obscured by buildings, infrastructure and the landscaping of, and sometimes limited access to, open areas. Cork City has played host to settlements on these deposits for several hundred years and some of these sediments will already be compressed to the point that, in and of themselves, they no longer pose any risk to development.

Geological Survey of Ireland Quaternary geology mapping show the distribution of the superficial cover of Holocene and glacial deposits and also where bedrock outcrops or lies within 1 meter of the surface. The uppermost deposit that achieves a thickness of >1m is the deposit that appears on the map. A more detailed 3D model of the deposits, which is in development for Cork City, will allow a more comprehensive analysis of the lateral and vertical distribution (and potential for compression) in these deposits.

The map distinguishes between the following broad categories of deposits: till (boulder clay), sand/gravel, peat, alluvium, lake silt and clay, marl and made ground. Sand/gravel and boulder clay are further divided to show the dominant stone type contained. The data collected during fieldwork based on the analysis of exposures available and the identification and description of morphological features is supported by the acquisition of geophysical or borehole data where sediment type was unknown or uncertain. The Quaternary geology map shows the dominant sediment type within 1 metre of the surface. This dataset is freely available for download and viewing on http://www.gsi.ie/Mapping.htm.

6.6 GEOLOGICAL INTERPRETATION OF THE MOTION

The alluvial, estuarine and reclaimed deposits on which this polygon rests are composed of soft compressible sediments. Applying a loading to these deposits can compress the deposits and result in the lowering of the land surface. These deposits overly deeper glaciofluvial gravels and land scarcity in urban areas can result in the dewatering of these deposits when developing basement structures, which in turn can lead to the destabilisation nearby structures.

6.7 EVIDENCE FOR THE INSTABILITY

Abundant and widespread anecdotal and visual evidence was collected during field-validation work. Evidence for these instabilities is repeatedly documented in publications. Images below (and their captions) give an indication of the nature of the instability in this polygon.

Fig PGGH_Cork_004.4 Tilt in buildings

Fig PGGH_Cork_004.5 Repaired cracks in buildings

Fig PGGH_Cork_004.6 Repaired walls


Fig PGGH_Cork_004.7 Collapsed walls

Fig PGGH_Cork_004.8 Recently underpinned buildings

Fig PGGH_Cork_004.9 Subsidence of paved areas and tilting of structures

Fig PGGH_Cork_004.10 Recent underpinning and cracked walls

7 *PGGH_CORK_005*

7.1 GENERAL PROPERTIES OF THE MOTION AREA

This polygon located across the southern half of Cork City (Fig PGGH_Cork_005.1) with its parts resting on Carboniferous bedrock units (Fig PGGH_Cork_005.2) which are believed to have potential for ground dissolution. The polygon extends across a variety of Quaternary deposits (Fig PGGH_Cork_005.3).

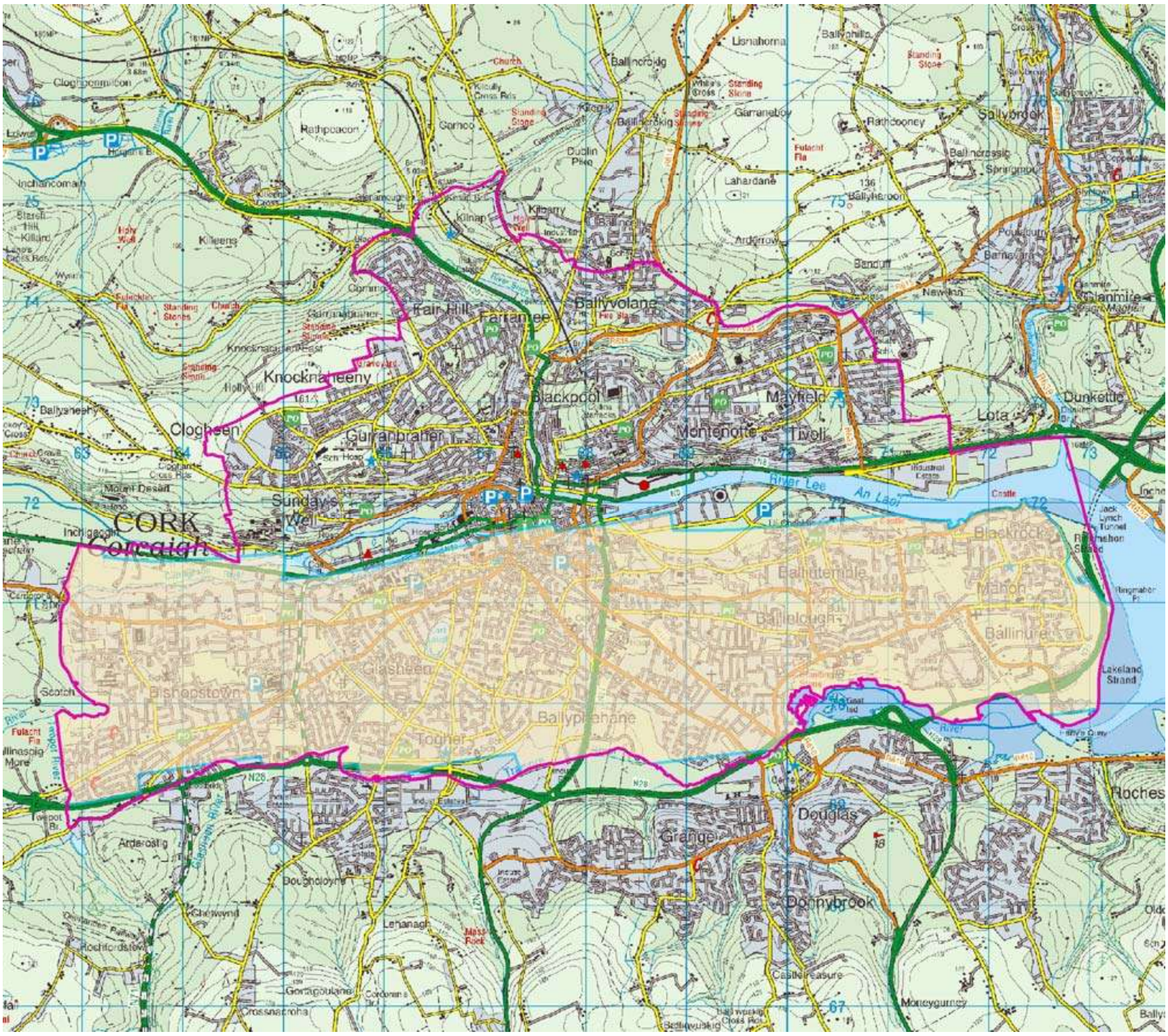

Fig PGGH_Cork_005.1 Location of potential ground dissolution polygon (mauve) over Ordnance Survey Ireland base mapping (Licence No. EN 0047212).

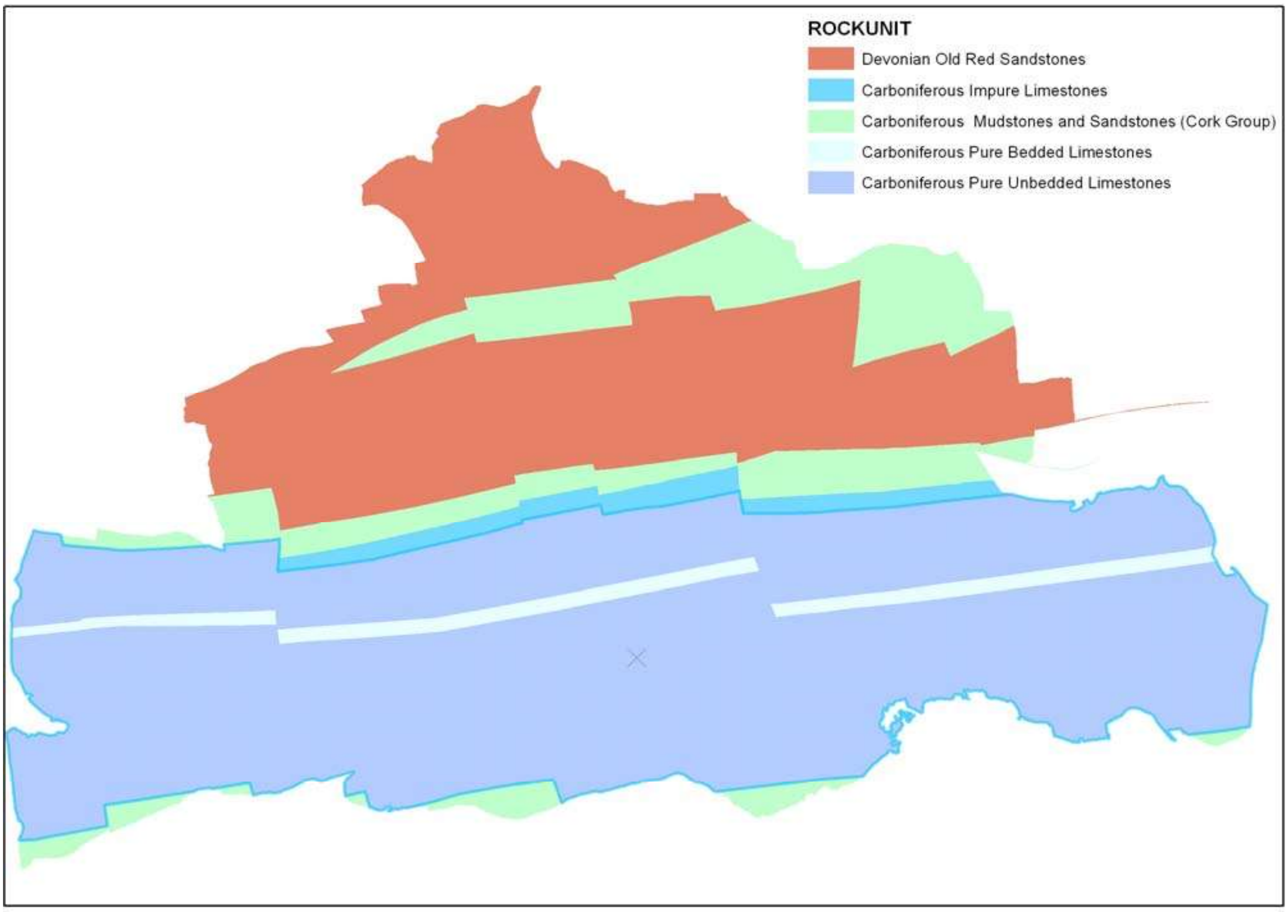

Fig PGGH_Cork_005.2 Location of potential ground dissolution polygon (blue outline) and bedrock geology units.

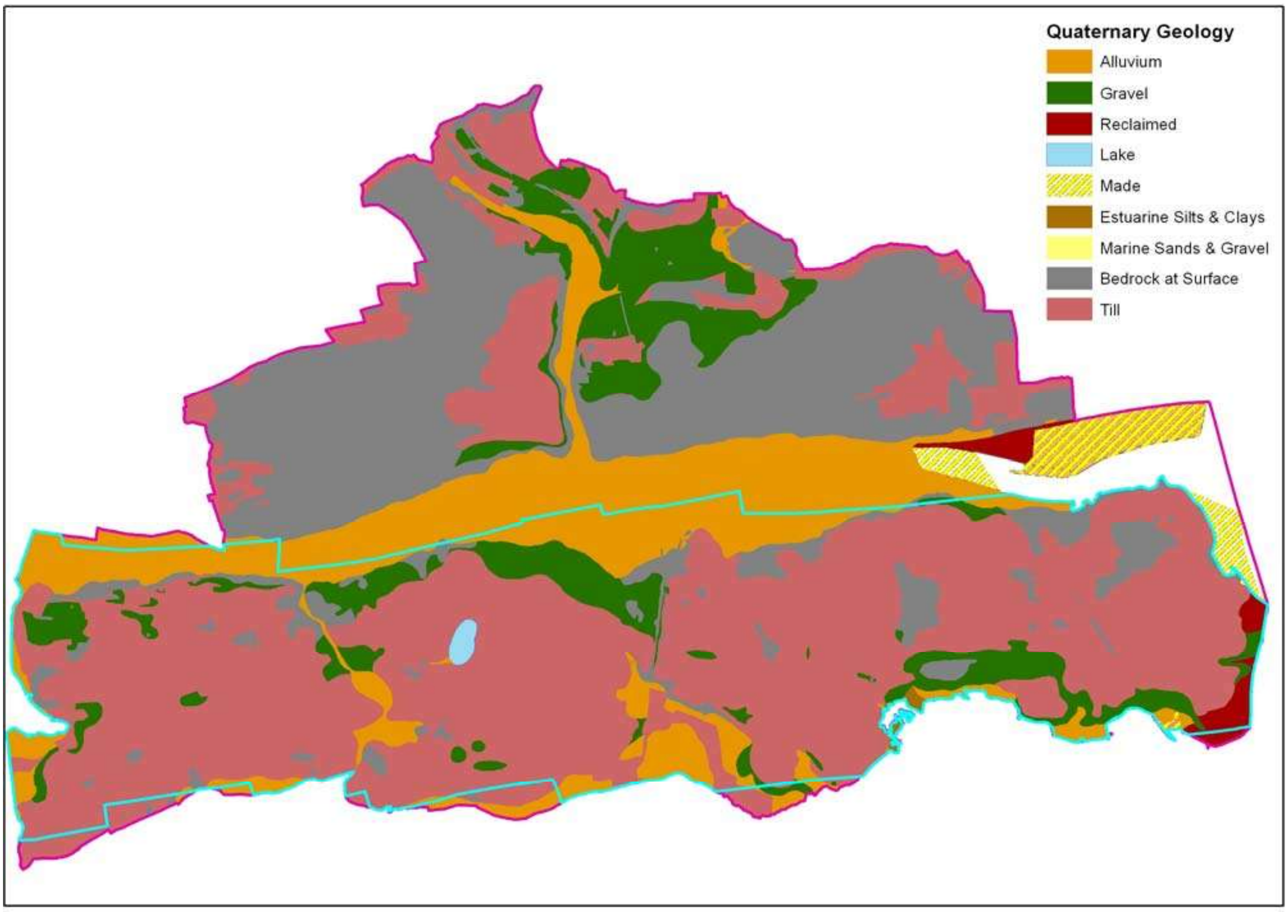

Fig PGGH_Cork_005.3 Location of potential ground dissolution polygon (blue outline) and Quaternary geology units.

The most common landuse type for this polygon is continuous urban fabric along with natural and agricultural areas. Pre-development geotechnical and geophysical site investigation coupled with karst hazard potential mapping can mitigate or avoid the unfavourable effect of this geohazard. This polygon extends over c. 21.18 km².

7.2 SPECIFIC GEOHAZARD TYPE

Natural Ground Instability: Ground Dissolution

7.3 TYPE OF MOTION

Subsidence

7.4 THE DETERMINATION METHOD

Potential Motion.

7.5 CONFIDENCE IN THE INTERPRETATION

A value of “Low” is assigned to the confidence of this polygon which is derived from the Geological Survey of Ireland 1:100,000 Bedrock Geological mapping and Geological Survey of Ireland Karst Features Database.

Geological Survey of Ireland 1:100,000 Bedrock Geological mapping shows the distribution of rock units interpreted to lie beneath the superficial cover of soil and glacial deposits. This dataset is freely available for download, viewing or WMS connection on http://www.gsi.ie/Mapping.htm.

The Geological Survey of Ireland Karst Features Database is a database of karst features, showing the location and relevant characteristics of individual karst features across Ireland. This dataset is freely available for download on http://www.gsi.ie/Mapping.htm.

7.6 GEOLOGICAL INTERPRETATION OF THE MOTION

Karst is a term used to describe landforms that develop on or in rock types that are readily dissolved by water. These features can undermine the surface and lead to subsidence or collapse.

Karst features in this polygon are commonly the result of historic weathering of the limestone bedrock. The tropical conditions that obtained c. 35 million years ago and a relative sea level c. 60m lower than the present day are considered to have led to the formation of these features.

The presence of karst features in this location is considered to imbue this area with the potential for karst features to develop or reactivate in the future. Due to its particular characteristics, including an irregular bedrock surface, the presence of large voids and rapid underground drainage, karst limestone presents special problems for engineering projects such as roads, bridges, tunnels, sewerage pipelines and mining. Careful preparatory investigations are therefore required with special design measures and provision for unforeseen problems.

The understanding and control of drainage is of critical importance in karst areas. Inadequately controlled drainage can trigger previously dormant karst activity. Good drainage design in karst areas should include redirection of natural drainage away from the structure, sealing of all drains and surface areas, and avoidance of soak-pits and distribution systems.

7.7 EVIDENCE FOR THE INSTABILITY

Evidence for these instabilities is repeatedly documented in publications. Images below (and their captions) give an indication of the nature of the potential instability in this polygon.

Fig PGGH_Cork_005.4 Ordanance Survey Ireland Historic 6 inch (1: 10,560) mapping (Licence No. EN 0047212) with Geological Survey of Ireland annotations detailing the presence of fissures and caverns typical of the area.

Fig PGGH_Cork_005.5 Area within the polygon known as Beaumont Caves with large visible fissures

Fig PGGH_Cork_005.6 Ordanance Survey Ireland Historic 6 inch (1: 10,560) mapping (Licence No. EN 0047212) with Geological Survey of Ireland annotations describing the cliff face as "very cavernous and fissured."

PANGEO GEOHAZARD GLOSSARY

Hazard
Something with the potential to cause harm.

Natural Hazard
A natural hazard is a natural process or phenomenon that may cause loss of life, injury or other impacts, property damage, lost livelihoods and services, social and economic disruption, or environmental damage. (Council of the European Union – Commission Staff Working Paper – Risk Assessment and Mapping Guidelines for Disaster Management).

Geohazard (Geological hazard)
A geological process with the potential to cause harm.

Risk
The likelihood that the harm from a particular hazard will be realised.

Types of Geohazard

1. Deep Ground Motions

Ground motion can occur at different scales and depths. This section contains the geohazards that are caused by processes in the deep subsurface.

1.1. Earthquake (seismic hazard)

Earthquakes are the observable effects of vibrations (known as seismic waves) within the Earth's crust arising from relatively rapid stress release, typically along a fault zone.

Damage to buildings and other infrastructure can be caused as the ground shakes during the passage of seismic waves. Other effects include liquefaction of water-saturated soft ground, potentially leading to a loss in ground strength and the extrusion of water-saturated sediments as 'mud volcanoes' and the like. Ground shaking can also trigger secondary events such as landslides and tsunami. Secondary effects such as these should be mapped into the other relevant PanGeo geohazard classes. Some earthquakes are associated with significant permanent vertical or lateral ground movement. Changes to drainage systems can cause flooding. There is potential for injury and loss of life during earthquakes.

Seismic hazard can be assessed by reference to the size and frequency of recorded earthquakes, although individual earthquakes are essentially unpredictable. Individual events occur on time-scales of seconds or minutes. Modern infrastructure should be designed to withstand probable local seismic events.

1.2. *Tectonic Movements*

Tectonic movements are large scale processes that affect the earth's crust. These processes can lead to areas of the crust rising or falling. Importantly it is the neotectonic movements that are still active and may therefore produce a ground motion that can be measured by PSI. Neotectonic movements are typically due to the stresses introduced through movements of the earth's plates. These types of motion are likely to be on a broad scale and so it may not be possible to measure them using the SAR scene relative measurements of PSI.

1.3. Salt Tectonics

Localised motions can be associated with the movement of evaporate deposits, these are termed salt tectonics and can produce both uplift and subsidence depending on the exact mechanisms at play.

1.4. Volcanic Inflation/Deflation

Volcanic activity can lead to the creation of lava flows, ash flows, debris and ash falls, and debris flows of various kinds. It might be accompanied by release of poisonous or suffocating gases, in some instances with explosive violence, or by significant seismic activity or ground movement. Secondary effects can include landslide and flooding. For PanGeo we are interested in hazards associated with ground instability. Ground instability associated with volcanoes tends to relate to inflation and deflation of the ground surface as magma volumes change. Secondary effects such as landslides should be mapped into the other relevant PanGeo geohazard classes.

2. Natural Ground Instability

The propensity for upward, lateral or downward movement of the ground can be caused by a number of natural geological processes. Some movements associated with particular hazards may be gradual or occur suddenly and also may vary from millimetre to metre or tens of metres scale. Note that anthropogenic deposits can be affected by natural ground instability.

Significant natural ground instability has the potential to cause damage to buildings and structures, and weaker structures are most likely to be affected. It should be noted, however, that many buildings, particularly more modern ones, are built to such a standard that they can remain unaffected in areas of even significant ground movement. The susceptibility of built structures to damage from geohazards might also depend on local factors such as the type of nearby vegetation, or the nature of the landforms in the area.

The effects of natural ground instability often occur over a local area as opposed to the effects of natural ground movements which occur over larger areas.

2.1. Land Slide

A landslide is a relatively rapid outward and downward movement of a mass of rock or soil on a slope, due to the force of gravity. The stability of a slope can be reduced by removing ground at the base of the slope, increasing the water content of the materials forming the slope or by placing material on the slope, especially at the top. Property damage by landslide can occur through the removal of supporting ground from under the property or by the movement of material onto the property. Large landslides in coastal areas can cause tsunami.

The assessment of landslide hazard refers to the stability of the present land surface, including existing anthropogenically-modified slopes as expressed in local topographic maps or digital terrain models. It does not encompass a consideration of the stability of new excavations.

Land prone to landslide will normally remain stable unless the topography is altered by erosion or excavation, the land is loaded or pore water pressure increases. Landslide might also be initiated by seismic shock, frost action, or change in atmospheric pressure.

This hazard is significant in surface deposits but may extend to more than 10 m depth. The common consequences are damage to properties, including transportation routes and other kinds of infrastructure, and underground services. Some landslides can be stabilised by engineering.

2.2. Soil Creep

Soil creep is a very slow movement of soil and rock particles down slope and is a result of expansion and contraction of the soil through cycles of freezing and thawing or wetting and drying.

2.3. Ground Dissolution

Some rocks and minerals are soluble in water and can be progressively removed by the flow of water through the ground. This process tends to create cavities, potentially leading to the collapse of overlying materials and possibly subsidence at the surface.

The common types of soluble rocks and minerals are limestones, gypsum and halite.

Cavities can become unstable following flooding, including flooding caused by broken service pipes. Changes in the nature of surface runoff, excavating or loading the ground, groundwater abstraction, and inappropriate installation of soakaways can also trigger subsidence in otherwise stable areas.

2.4. Collapsible Ground

Collapsible ground comprises materials with large spaces between solid particles. They can collapse when they become saturated by water and a building (or other structure) places too great a load on it. If the material below a building collapses it may cause the building to sink. If the collapsible ground is variable in thickness or distribution, different parts of the building may sink by different amounts, possibly causing tilting, cracking or distortion. Collapse will occur only following saturation by water and/or loading beyond criticality. This hazard can be significant in surface deposits and possibly also in buried superficial deposits.

2.5. Running Sand/ Liquefaction

Running sand occurs when loosely-packed sand, saturated with water, flows into an excavation, borehole or other type of void. The pressure of the water filling the spaces between the sand grains reduces the contact between the grains and they are carried along by the flow. This can lead to subsidence of the surrounding ground.

If sand below a building runs it may remove support and the building may sink. Different parts of the building may sink by different amounts, possibly causing tilting, cracking or distortion. The common consequences are damage to properties or underground services. This hazard tends to be self-limited by decrease in head of water.

Liquefaction of water-saturated soft ground often results as an effect of earthquake activity but can also be triggered by manmade vibrations due to construction works. It can potentially lead to a loss in ground strength and the extrusion of water-saturated sediments as 'mud volcanoes' and the like. Soils vulnerable to liquefaction represent areas of potential ground instability.

3. Natural Ground Movement

The effects of natural ground movement often occur over a larger area as opposed to the effects of natural ground instability, which occur over local areas.

3.1. *Shrink-Swell Clays*

A shrinking and swelling clay changes volume significantly according to how much water it contains. All clay deposits change volume as their water content varies, typically swelling in winter and shrinking in summer, but some do so to a greater extent than others. Most foundations are designed and built to withstand seasonal changes. However, in some circumstances, buildings constructed on clay that is particularly prone to swelling and shrinking behaviour may experience problems. Contributory circumstances could include drought, leaking service pipes, tree roots drying-out of the ground, or changes to local drainage such as the creation of soakaways. Shrinkage may remove support from the foundations of a building, whereas clay expansion may lead to uplift (heave) or lateral stress on part or all of a structure; any such movements may cause cracking and distortion.

The existence of this hazard depends on a change in soil moisture and on differential ground movement. Uniform ground movement may not of itself present a hazard. This hazard is generally significant only in the top five metres of ground.

3.2. Compressible Ground

Many ground materials contain water-filled pores (the spaces between solid particles). Ground is compressible if a load can cause the water in the pore space to be squeezed out, causing the ground to decrease in thickness. If ground is extremely compressible the building may sink. If the ground is not uniformly compressible, different parts of the building may sink by different amounts, possibly causing tilting, cracking or distortion.

This hazard commonly depends on differential compaction, as uniform compaction may not of itself present a hazard. Differential compaction requires that some structure that might be susceptible to subsidence damage has been built on non-uniform ground. The common consequences are damage to existing properties that were not built to a sufficient standard, and possible damage to underground services.

4. Man Made (Anthropogenic) Ground Instability

Anthropogenic instability covers a local area which has been brought about by the activity of man. Subsidence (downward movement) of the ground can result from a number of different types of anthropogenic activity, namely mining (for a variety of commodities), or tunnelling (for transport, underground service conduits, or underground living or storage space).

Subsidence over a regional area can result from fluid extraction (for water, brine, or hydrocarbons). Uplift or heave of the ground can occur when fluid is allowed to move back into an area from where it was previously extracted and groundwater recharge occurs. This fluid recovery may include injection of water or gas.

4.1. Ground Water Management - Shallow Compaction

7.7.1.1 Ground water management may be applied for example to ensure the exploitability of existing agricultural land in lowland coastal areas. Groundwater management can lead to higher or lower water levels of phreatic groundwater and of deeper aquifers in the shallow subsurface. Groundwater occupies pore and interstitial spaces and fractures within sediments and rocks and therefore exerts a pressure. When the water is drained the pore pressure or effective stress is reduced. This leads to consolidation of especially soft sediments, such as clay and peat. This change in the sediment volume leads to subsidence. Similarly when groundwater levels are allowed to recover, uplift may be a result of increasing pore pressure.

4.2. Ground Water Management - Peat Oxidation

7.7.1.2 Ground water management may be applied for example to ensure the exploitability of existing agricultural land in lowland coastal areas. Groundwater management can lead to higher or lower water levels of phreatic groundwater and of deeper aquifers in the shallow subsurface. Peat oxidation is the chemical reaction where peat starts decomposing and will waste away with time. This loss of soil volume leads to subsidence. It occurs when layers of peat in the subsurface are exposed to oxygen. As long as peat is located in saturated ground layers this process does not take place. However peat oxidation does occur in unsaturated soils, for instance in areas where ground water management lowers ground water levels.

4.3. Groundwater Abstraction

Groundwater also occupies pore and interstitial spaces and fractures within sediments and rocks in the deeper subsurface. When this water is removed, for instance through pumping for drinking water or lowering of water levels in mines, the pore pressure or effective stress is reduced and consolidation of the sediments and rocks causes a change in the sediment and rock volume. This leads to subsidence. Similarly when aquifer levels are allowed to recover, uplift may be a result of increasing pore pressure. Deep geothermal energy systems should not lead to ground movement. They involve closed systems where water, which was extracted from a deep aquifer, will be pumped back into that same aquifer. However, geothermal heat pumps are used at shallower depths. Although these are also closed systems, ground movement might occur temporarily (e.g. seasonally) or even permanently.

4.4. Mining

Mining is the removal of material from the ground, in the context of PanGeo we consider mining to relate to the removal of solid minerals. The ground surface may experience motion due to readjustments in the overburden if underground mine workings fail.

4.5. Underground Construction

In PanGeo we are interested in underground construction that might bring about ground instability. An example of this would be underground tunnelling; the removal of subsurface material can alter the support for the overlying material therefore leading to ground motions.

4.6. Made Ground

Made ground comprises of anthropogenic deposits of all kinds such as land reclamation, site and pad preparation by sand infill, road and rail embankments, levees and landfills for waste disposal. Examples of land reclamation are artificial islands, beach restoration and artificial harbours. Reclaimed land as well as embankments and levees are generally made up of sand, which is not prone to compaction as are clay and peat. However, two ground instability processes will occur: consolidation of this artificial ground and compaction of the ground below due to the load of the artificial ground and the structure it supports, e.g. a building. Depending on its composition and mode of deposition, landfill can also be a compressible deposit.

4.7. Oil and Gas Production

Similar to abstraction of groundwater the production of oil and gas decreases the pore pressure of the reservoir rocks and therefore can cause consolidation and subsidence of the surface. Storage of material in the depleted reservoir (such as natural gas or CO^2) can lead to surface uplift.

5. Other

These are areas of instability for which the geological explanation does not fit into any of the categories above.

6. Unknown

These are areas of identified motion for which a geological interpretation cannot be found.

Geohazard Groupings to be used in PanGeo

1. Deep Seated Motions
   a. Earthquake (seismic hazard)
   b. Tectonic Movements
   c. Salt Tectonics
   d. Volcanic Inflation/Deflation

2. Natural Ground Instability
   a. Land Slide
   b. Soil Creep
   c. Ground Dissolution
   d. Collapsible Ground
   e. Running Sand/Liquefaction

3. Natural Ground Movement
   a. Shrink-Swell Clays
   b. Compressible Ground

4. Man Made (Anthropogenic) Ground Instability
   a. Ground Water Management - Shallow Compaction
   b. Ground Water Management - Peat Oxidation
   c. Groundwater Abstraction
   d. Mining
   e. Underground Construction
   f. Made Ground
   g. Oil and Gas Production

5. Other

6. Unknown