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Guidelines for the development and application of engineering geological models on projects

專案計畫工程地質模型(EGM)之建構及應用指引

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專案計畫工程地質模型(EGM)建構及應用指引

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Guidelines for the development and application of engineering geological models on projects

專案計畫工程地質模型(EGM)建構及應用指引

INTRODUCTION

簡介

The purpose of these Guidelines is to provide succinct, practical, accessible and authoritative advice on the effective use of Engineering Geological Models in a wide range of applications including civil engineering, mining, geohazard studies, offshore studies, land-use planning and environmental assessments. The Guidelines are broad ranging, intended for use or reference by stakeholders in projects of all scales that interact with or require an understanding of the ground. They are intended to have worldwide application.

本『工程地質模型建構及應用指引』旨在提供簡潔、實用、易於理解和具專業水準的建議，期能應用在廣泛的領域(包括土木工程、採礦、地質災害研究、離岸研究、土地利用規劃和環境評估），以強調工程地質模型的重要性。本指引所涵蓋的應用範圍廣泛，可在不同規模的專案計畫中，提供相關人員有關地盤或與地盤互制作用的資訊，期望本指引能於全世界廣泛應用。

An Engineering Geological Model (EGM) is a comprehensive knowledge framework that supports the interpretation and assessment of the engineering geological conditions and allows the interaction of these conditions with the proposed project to be evaluated, so that appropriate engineering decisions can be made throughout the life cycle of the project from inception to decommissioning. In adopting this definition, the intention is to move beyond the concept that a 'model' is a simplified and static three-dimensional representation of the ground conditions and recognise that the formation and development of the EGM is an on-going process of knowledge accumulation that provides direction and control to the ground engineering throughout a project.

工程地質模型 (Engineering Geological Model, 以下簡稱 EGM) 是一個綜合、完整的條件認知框架，用以協助各項工程地質狀況的解釋和分析，並整體評估工程地質狀況與專案計畫之間的相互關係，以從計畫開始到結束的全生命週期中，都能做出最適當的決策。採用上述定義，是為了要打破“模型”只是一種簡化，且屬於靜態的三維地盤條件之概念，並希望能強化 EGM 的建置和精進，這是一種資訊持續積累的滾動進展過程，此過程能夠持續提供專案計畫的相關工程，自始至終之方向指引和工程地質條件掌控。

The Guidelines have been developed to provide guidance to practitioners on the 'EGM approach', including 3D digital modelling techniques, and to inform consultants, clients, owners, government bodies and regulators about the use of Engineering Geological Models on projects.

本指引提供相關從業人員有關"EGM 方法"(包括 3D 數位建模技術)的原則，並讓顧問公司、客戶、業主、政府機關業務主管人員等，了解如何在專案計畫中應用工程地質模型。

The Guidelines were developed by members of the IAEG C25 – Commission for the Use of Engineering Geological Models – and represent the consensus views of the contributors.

本指引由 IAEG 委員會 C25(工程地質模型應用委員會)的成員訂定，所有內容代表參與撰稿者們的共識。

It is intended that these Guidelines will be translated into other languages for dissemination internationally within the ground engineering community. The Guidelines will be reviewed and revised after one year in response to feedback from their use in different parts of the world.

EGM 指引會被翻譯成其他語言，以便廣泛應用在國際上與大地工程有關之團體。本指引將根據在世界上不同地區使用者的回饋意見，在一年後重新審視並修訂。

The Guidelines comprise three parts:

EGM 指引包含以下三部分：

1. Advisory Clauses for the development of EGMs (Part 1). Advisory Clauses indicate how an appropriate EGM should be developed for any project that interacts with the ground.

1. 建置 EGM(第一部分)：建議條款的內容，主要係指出應如何在地盤與專案計畫間建置適當的 EGM。

2. Commentary on the Advisory Clauses (Part 2). The Commentary provides additional supporting information, where necessary, for each Advisory Clause and is structured with the same paragraph numbering to allow ease of referencing; hypertext links are provided where relevant.

2. EGM 建議條款的解說(第二部分)：對於每一項建議條款，在必要時，提供較詳細的輔助資訊，會與建議條款採用相同的段落編碼，以便於參考；相關的電子資訊將提供超連結鏈接。

3. Examples of EGM applications (Part 3). The Examples provide overviews of the application of EGMs to a variety of project types.

3. EGM 應用範例(第三部分)：範例提供 EGM 於各種型式專案計畫的應用概述。

Notes:

註解：

1. The purpose of these Guidelines is to provide information and assist decision making; the Guidelines are not intended to define a standard of work.

1. 本指引目的，是在提供相關資訊與做為輔助決策的依據，而不是當做一種工作的標準。

2. The Guidelines should not be interpreted as prescribing a course of action or procedure on model building as there may be variations in approach and method to account for specific engineering geological and project needs.

2. 本指引不應被解釋為生硬的建模行動方針或是步驟，因為對於特定的工程地質及專案計畫需求，處理途徑和採用方法可能會有所不同。

Background

背景

The use of 'models' in engineering geology was discussed by Zaruba and Mencl (1954 in Czech) and Morgenstern and Cruden (1977), although the first time a cross section through the ground was created to illustrate the geological conditions for an engineering project was, arguably, the first engineering geological model. An example is the work of William Smith and the development of geological maps and sections associated with canal construction in the UK in the 18th century. Fookes (1997) brought the idea of models in engineering geology to a wider audience but referred to the models simply as geological models. Fookes et al. (2000) refined the approach to include the concept of the 'total geological history,' that is, that the engineering characteristics of the ground result from the entire geological and geomorphological history of the area. Knill (2003) suggested that a 'geological model' is inadequate on its own for engineering purposes because it does not sufficiently define the engineering conditions within the natural ground or help deliver a design. He proposed that it was more useful to think of geological models, ground models and geotechnical models, with the type of model being related to the progression of the project. Bock et al. (2004) provided a perspective on the relationship between the disciplines of engineering geology, soil mechanics and rock mechanics, the areas of interest of the associated international learned societies and the nature of geological models and ground models.

有關於"模型"在工程地質學中的應用這一議題，我們可以追溯到 1954 年捷克工程地質學者 Zaruba & Mencl (1954)以及 1977 年 Morgenstern 和 Cruden (1977) 兩篇論文之相關討論，雖然有人會認為只要能呈現出地質狀況之地質剖面，即應可以被視為工程地質模型於專案計畫之應用，

因此十八世紀英國的 William Smith 在運河建設計畫中，所完成的地質圖及相關地質剖面成果，應該可以算是先例。Fookes (1997)將模型的概念帶進工程地質並影響更多的讀者，但是該論文只單純的將模型稱為地質模型。Fookes et al. (2000) 納入" 地質總史"的概念，即地盤的工程特性均係來自於該地區完整的地質和地貌歷史過程。Knill (2003)認為"地質模型"本身並不足以直接應用於工程目的，因為它沒有充分定義出自然地盤內的工程條件，因此無助於工程設計。Knill 更進一步建議應整合地質模型、地盤模型和地工模型等三種模型，如果能進一步結合與計畫進展有關的各種模型會更為有用。Bock et al. (2004)則是提出將工程地質學、土壤力學與岩石力學等三個領域的特性及其相關性加以整合，並加入與此三領域相關的國際學/協會所關心的課題，一併討論地質模型與地盤模型的主體架構。

IAEG Commission C25 published an interim report (Parry et al., 2014) that defined a model as "an approximation of reality created for the purpose of solving a problem", outlined a methodology for developing engineering geological models, differentiated the conceptual and the observational component of that process and provided examples. This approach has been adopted in recent guidelines (for example, The Geological Society, London, Engineering Geology Special Publication, 28, for glacial and periglacial terrains, Giles et al., 2017). However, the C25 approach has not yet been incorporated in National and International Standards.
IAEG C25 委員會過去出版的初步報告(Parry et al., 2014)，將地質模型定義為"為了解決實際問題而創造的現況近似體"，概述了建構 EGM 的方法學，區分了 EGM 建模過程中概念成分與觀察成分之不同，並提供了範例。這報告已在最近的一些指引中有被採用，包括：倫敦地質學會的工程地質特刊第 28 號，將其應用於冰川和冰緣地區(Giles et al, 2017)。然而，C25 出版的初步報告，還未被納為國家或是國際的標準。

Baynes et al. (2021) expanded on the C25 interim report and emphasised that the EGM is a knowledge framework that can be used to understand and communicate everything that is known about the geological and associated engineering information at any stage of a project.
Baynes et al. (2021)增加了 C25 初步報告的篇幅，並強調 EGM 是一種認知框架，可以在計畫的各階段，了解與互補已知的地質與工程相關資訊。

These current Guidelines were developed by members of the IAEG C25 - Commission for the Use of Engineering Geological Models - following the IAEG 12th Asian Regional Conference in 2019 at Jeju, South Korea. A first draft of the Guidelines was presented at the IAEG 3rd European Regional Conference in Athens in October 2021. The Guidelines were subsequently revised following comments received at and after the Athens meeting, including a contribution from IAEG C28 - Commission for Reliability Quantification of the Geological Model in Large Civil Engineering Projects.
目前的指引是由 IAEG C25(工程地質模型應用委員會)的成員，在 2019 年韓國濟州島舉行的 IAEG 第 12 屆亞洲區域會議之後所制訂。本指引的初稿於 2021 年 10 月在雅典舉行的 IAEG 第三

屆歐洲區域會議上提出，根據雅典會議期間以及其後收到的回饋意見，隨後進行了本指引的修訂(其中包括 IAEG C28 -大型土木工程計畫中地質模型可靠度量化委員會的建議)。

Contributors to the Guidelines and their countries of origin are listed in Appendix A.
附錄 A 列出 EGM 指引的撰稿者與其所屬國籍。

Guidelines for the development and application of engineering geological models on projects

專案計畫工程地質模型(EGM)建構及應用指引

1. ADVISORY CLAUSES

1. 建議條文

1.1 EGM DEVELOPMENT PRINCIPLES

1.1 EGM 工程地質模型建構及應用指引

1.1.1 Definitions

1.1.1 定義

Important terms that are used throughout these Guidelines are defined here; other terms are defined where they appear in the text.
此節定義本指引中使用的重要專業術語；其它未於此處定義者將在文中出現時定義。

- Model – an approximation of reality created for the purpose of solving a problem.
- 模型 – 為解決問題而建置之現況近似體。
- Engineering geology – The application of geological, geomorphological and hydrogeological knowledge to engineering.
- 工程地質學 – 將地質學、地形學和水文地質學知識應用於工程問題之學理。
- Engineering Geological Model (EGM) – a comprehensive knowledge framework that allows for the logical evaluation and interpretation of the geological, geomorphological and hydrogeological conditions that could impact a project and their engineering characteristics. The EGM comprises both conceptual and observational components and may consist of a number of interrelated models and approaches. The Geological Model, the Geotechnical Model and a Geohazard Assessment are outputs from the EGM knowledge framework.
- 工程地質模型（EGM） – EGM 為一個綜合、完整的認知框架，特別針對可能影響工程計畫及其工程特性的地質、地形和水文地質狀況等，進行邏輯評估和解析。EGM 包括概念和觀測兩成分，並可能由若干相互關聯的模型和方法組合而成。地質模型、地工模型和地質災害評估等，均是由 EGM 認知體系所產出。
- Conceptual Model – a model based mainly on engineering geological concepts and interpretations and the knowledge that certain engineering geological conditions and processes are likely to have certain engineering characteristics.
- 概念模型 – 主要基於工程地質概念、知識和解析等訊息，用以建立特定工程特性之地質狀況和作用之相關模型。
- Observational Model – a model based mainly on engineering and geological observations and measurements that are constrained in space by 3D data (xyz) or in space and time by 4D data (xyz plus time). Increasingly, the observational model is developed within a digital environment.

- 觀測模型 – 主要係基於工程上和地質上所觀測和量測到的結果所建構之模型，模型屬於空間的三維資料（xyz）或在加上時序後，成為包括時空的四維資料。此外，目前有越來越多的觀測模型是在數位環境下建置的。

- Engineering geological units – volumes of the ground with a similar geological history and similar engineering characteristics that are established in the context of the project engineering.

- 工程地質單元 – 在工程專案計畫中，具有相似地質歷史和工程特性的地盤區域範圍。

- Engineering geological mapping – the preparation of a map depicting the distribution and surface boundaries of engineering geological units, geological structures, geomorphology and hydrogeological conditions that are of significance to the project using appropriate symbology carried out at a scale and level of detail determined by the purpose of the mapping, that might range from regional resource assessment to confirmation of foundation conditions.

- 工程地質製圖 – 使用適當的符號系統，描繪對工程計畫具有重要意義的工程地質單元、地質構造、地形特徵與水文地質狀況等之空間分布情形，圖上表現出其在地表的邊界，剖面則表現空間延展之情形。範圍可涵蓋從區域資源評估到結構物基礎條件的確認，其尺度和精細程度則依據製圖目的而定。

- Geological Model – an output from the EGM knowledge framework that represents the distribution in 3D space of the engineering geological units, hydrogeological conditions and geological and geomorphological processes.

- 地質模型 – EGM 知識框架的產出之一，用以描述工程地質單元於三維空間之分佈情形、水文地質狀況，以及地質和地形作用。

- Geotechnical Model – an output from the EGM knowledge framework that provides the engineering characteristics and/or geotechnical parameters of relevant aspects of the Geological Model.

- 地工模型 – EGM 認知框架的產出之一，提供與地質模型相關之工程特性和(或)地工參數。

- Analytical Model – a simplification of the Geotechnical Model developed for the purpose of engineering assessment, analysis or design.

- 解析模型 – 由地工模型簡化後的結果，此模型用於工程評估、分析或設計。

- Digital Model – collation and presentation of data within a software environment to allow visualisation, interpretation and aid in communication of parts of the EGM, increasingly developed in 3D.

- 數位模型 – 在數位軟體環境中整理和呈現數據，再輔以視覺化、解說，協助說明 EGM 的部分內容，已有越來越多的數位模型均以三維形式建置。

- Digital visualisation – the output of a digital model, usually a graphic display in 2D or 3D of selected parts of the data.

- 數位視覺化 – 數位模型的產出方式，通常屬於特定資料的二維或三維圖形展示。

- Ground Model – type of model, often specified as a deliverable in contracts or required by Standards, that provides a summary of the understanding of the ground and groundwater conditions at a site at a specific point in time. This may include geotechnical parameters for the various units contained within it. The meaning of this term varies in different codes and standards.

- 地盤模型 – 提供於某特定點在特定時間點，對工址中地盤和地下水條件的明瞭概要，應包含各工程地質單元的可能地工參數，通常是合約或規範所要求提交之成果。然此專業術語於不同的法規和作業標準中可能會有不同之意涵。

- Geohazards – geological and geomorphological processes or phenomena that can adversely impact a project, for example, karst development, landslides, underground mining, ground gas, seismic activity etc.

- 地質災害 – 可能會對工程計畫產生不利影響的地質與地形作用或現象，例如喀斯特地形、山崩、地下採礦、地下氣體、地震活動等。

- Project – the purpose for which the EGM is being developed. EGMs are commonly used to assess the ground response to an engineering project but they are also used for broader application such as the assessment of natural resources, regional geohazard assessments etc.

- 專案工程計畫 – 建置 EGM 之目的。大部分的 EGM 通常用於評估一個工程計畫的地盤反應，但也可做更廣泛的應用，例如自然資源的評估、區域地質災害評估等。

1.1.2 Fundamental principles

1.1.2 基本原理

1.1.2.1 The EGM evaluates interactions between the project and the ground

1.1.2.1 EGM 用於評估專案計畫與地盤間的互制作用

The purpose of the EGM is to evaluate the ground response to change and usually involves consideration of the possible interactions between the project and the ground. An effective EGM should anticipate what might be in the ground and how the ground might respond to the project.

考慮到專案工程計畫與地盤間可能產生的互制作用，因此建立 EGM 之目的為評估地盤反應變化。完整之 EGM 需要能夠預估地盤的特性，以及地盤在工程開發後將產生甚麼改變。

1.1.2.2 The EGM knowledge framework

1.1.2.2 EGM 認知框架

The EGM knowledge framework represents an understanding of the geological conditions that are of engineering significance to the project and that can be used to solve engineering problems, (Figure 1-1). The EGM is not one 'model' but multiple dynamic models, as well as being the repository of the underlying data (if that is not held within the models themselves), the supporting documentation (for example, the site investigation reports) and the knowledge framework that holds these components together. To the extent that is practical, the EGM should be based on all available and relevant knowledge, should be logically constructed following the principles established in these Guidelines, should be focused on the relevant geological conditions and engineering characteristics of significance to the project and should be clearly communicated.

EGM 認知框架表現對專案計畫重要地質狀況的理解，並且可以用來解決相關的工程問題(EGM 於專案計畫全生命週期之建置詳圖 1-1)；EGM 並非僅僅為"一個模型"，EGM 是"多重"且屬於"動態"的模型， EGM 亦是資料儲存庫(但模型並非僅有資料)，同時也包含建置模型用到的所有相關輔助文件(如工址調查報告)，以及囊括上述各要件所需要之知識。務實來看，EGM 應根據所有可及的、相關的知訊，按照本指引所建立的原則，以具有邏輯性的方式建構，並且應聚焦在與工程計畫相關之地質狀況上，更應與 EGM 使用者進行非常清楚以及有效的溝通。

Three key outputs from the EGM for a project are the Geological Model, the Geotechnical Model and a Geohazard Assessment.

對一個專案計畫而言， EGM 三個最重要的產出為地質模型、地工模型以及地質災害評估。

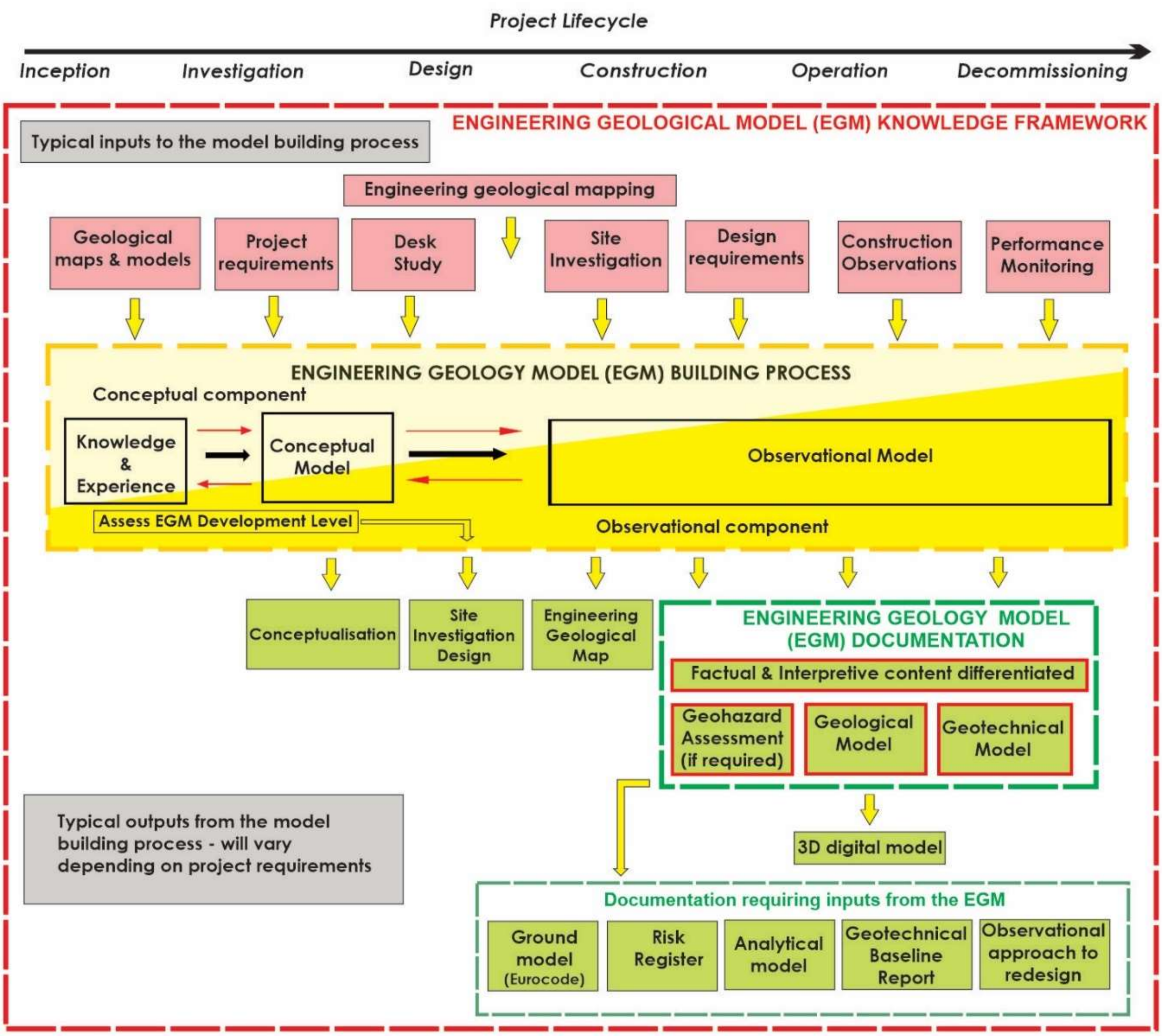

Figure 1-1 A schematic visualisation of the EGM development through the project lifecycle.

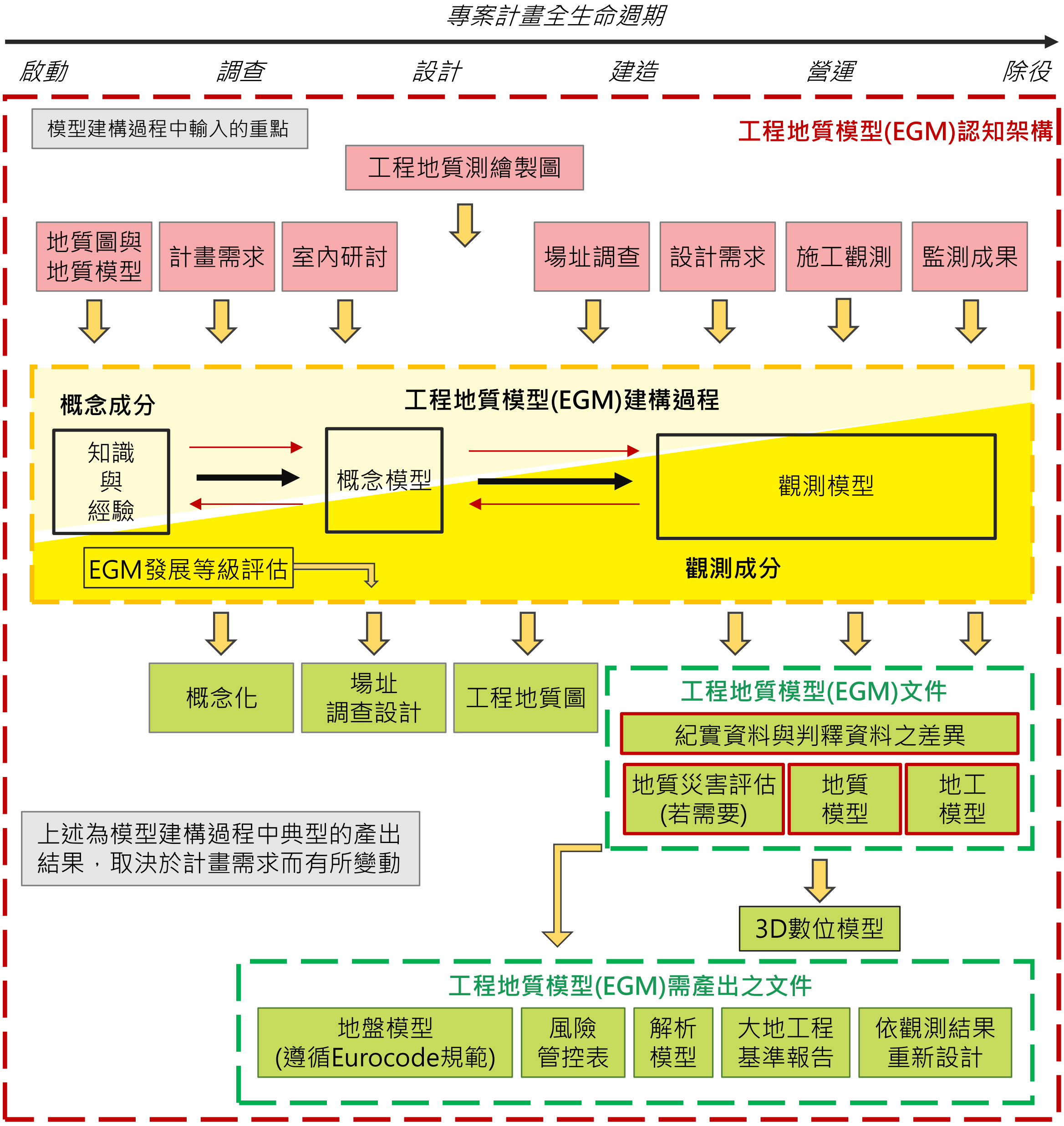

圖 1-1　EGM 於專案計畫全生命週期之發展歷程

1.1.2.3 EGMs comprise conceptual ideas and observational data

1.1.2.3 EGM 模型概念與調查資料整合

The balance of conceptual ideas and observational data within an EGM will vary depending on the project type, its scale, the geotechnical complexity of the site and the stage of the project (Figure 1-1). Evaluation of the ground at the start of a project is primarily conceptual in that it is based mainly on knowledge, experience and reference to other published examples of similar geological and geomorphological conditions. As the project progresses and increasing amounts of observational data become available the EGM evolves but the conceptual model remains as the framework for assessing the interpretation of those data.

在 EGM 的建置上，概念想法與調查觀測資料之間的平衡點，很大程度地取決於工程計畫類型、規模、工址的地工複雜性以及工程計畫進展的階段(詳圖 1-1)。在工程計畫起始階段，針對地盤的評估主要是概念式的，其奠基於工程人員的背景知識、實務經驗，以及類似地質/地形狀況下、已公開發表之案例。隨著工程計畫的進展，調查觀測資料量會逐漸增加，EGM 亦應逐步精進，然而概念模型仍然是持續做為“解析” 調查觀測資料之核心架構。

The techniques involved in developing conceptual models and observational models are different. The first involves the act of conceptualisation and the second involves the act of evaluating data and assembling information. However, their use in the development of EGMs is so profoundly interlinked that, in reality, they form two different but essential and complementary tools that must be combined at all stages of the project to generate an appropriate EGM.

建置概念模型與觀測模型的技術及方法是有差異的，前者涉及概念化的作為，後者則為評估資料並彙集有用訊息。然而在建置 EGM 的實際運用上，兩者是密切連結的，它們塑造出兩種不同、卻又都屬於必要且互補的工具，在工程計畫的任何階段都需要結合兩者，以產生適合的 EGM。

At any stage of the project engineering analysis should proceed cautiously until conceptual ideas and observational data have been reconciled and any residual discrepancies can be managed as project risks accepted by all relevant parties (Figure 1-2).

在工程計畫的任一階段，工程分析都必須謹慎地進行，直到概念想法與調查觀測資料一致，或是兩者雖有所出入，但其差異對於工程計畫的風險在可控制的範圍，且可為各方所接受。工程計畫相互關係的概念與觀測模型詳圖 1-2。

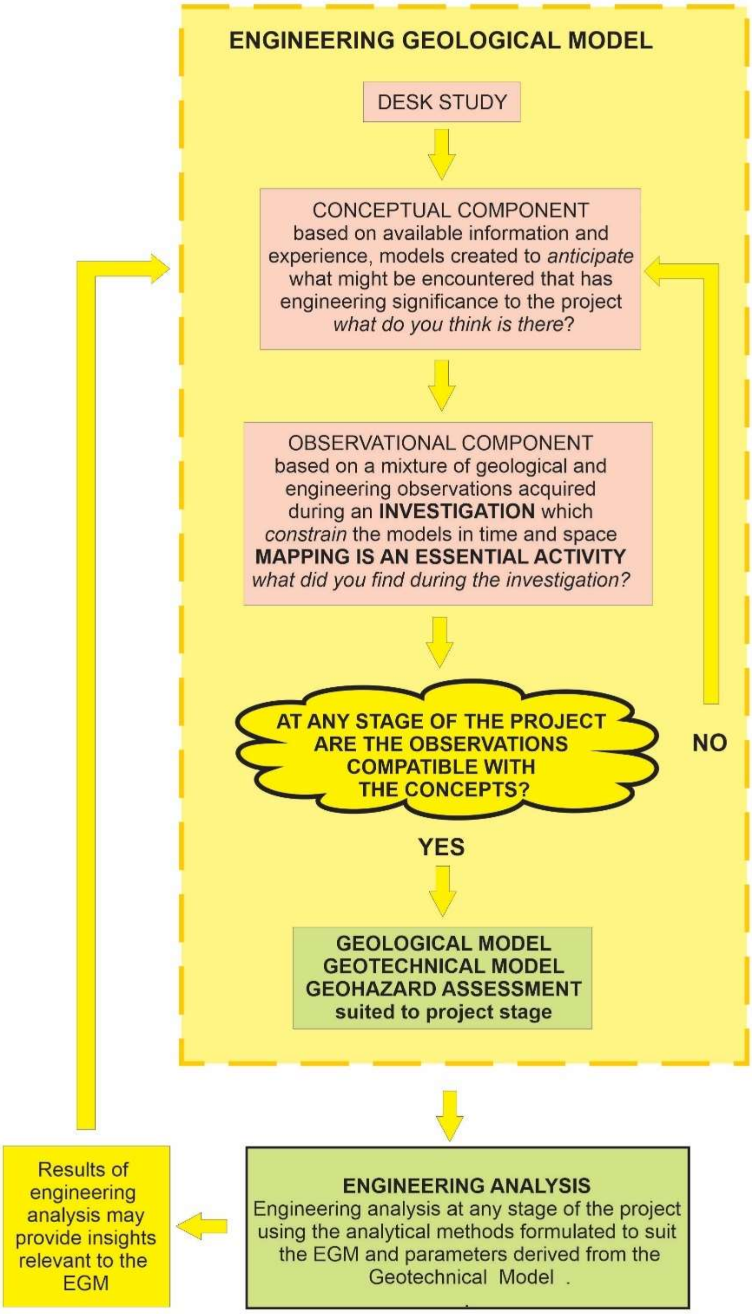

Figure 1-2 Engineering analysis should proceed when observations are compatible with concepts.

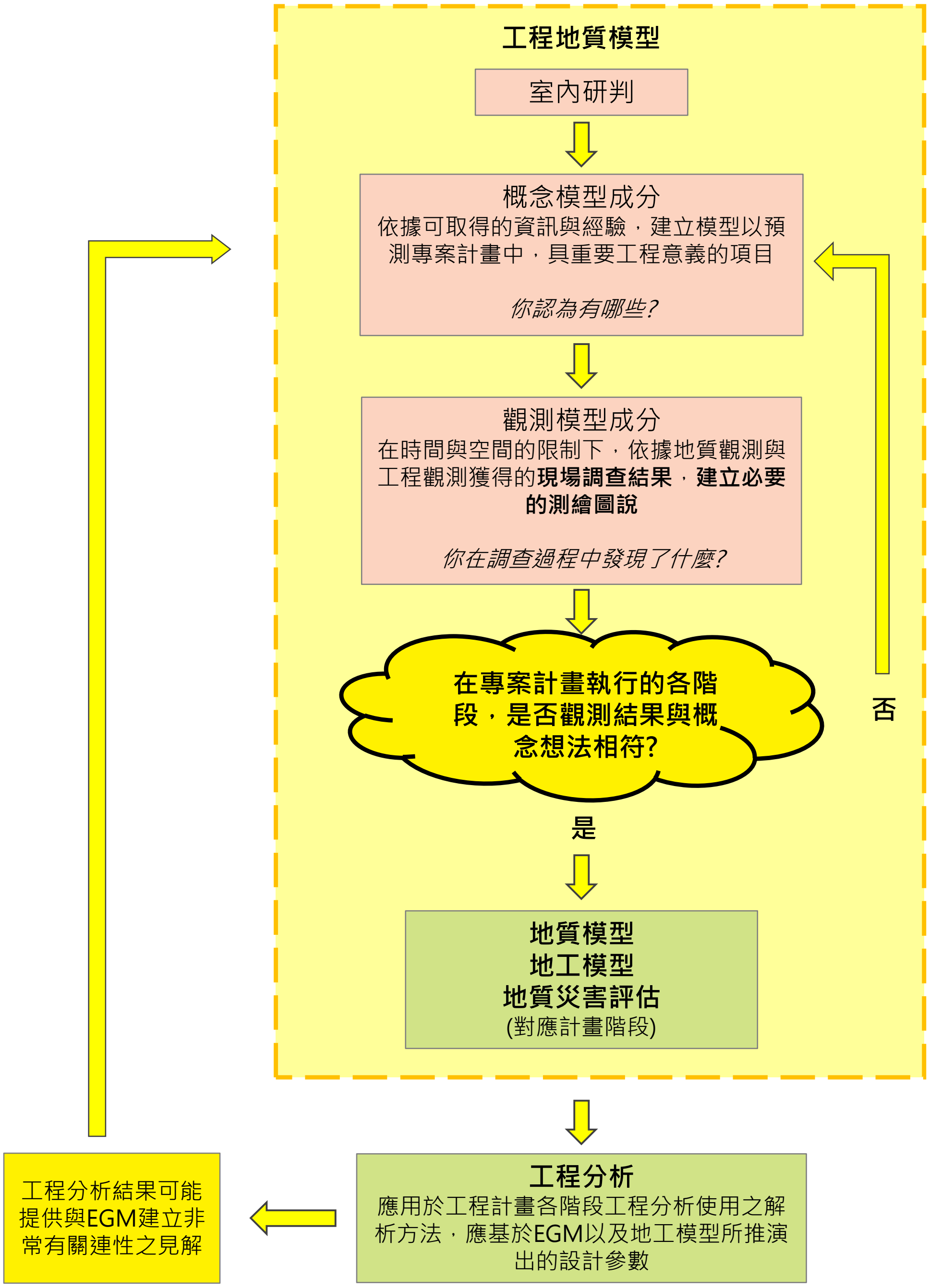

圖 1-2　當調查觀測資料與概念想法相符時，方可進行工程分析

1.1.2.4 An EGM should be developed for all projects

1.1.2.4 任何工程計畫皆應建置 EGM

An EGM should be developed for all projects that interact with the ground and is equally applicable for very large and very small projects and over a variety of geographical scales. Note that for very small, simple projects, the EGM can be presented in a single short interpretive report.
不論佔地面積或工程規模大小，所有會與地盤產生互制影響之工程計畫均應建置一套 EGM。如果是屬於規模小、性質單純的工程計畫，EGM 只需要是一本簡要的地質解釋性報告。

1.1.2.5 The EGM is relevant throughout the project life cycle

1.1.2.5 貫穿整個工程計畫的生命週期都需要 EGM

The EGM development should commence at the project inception stage and be revised throughout the life cycle of the project, potentially passing between multiple owners and consultants, and provides a transparent and logical framework for developing ground related project deliverables (Figure 1-1). The EGM knowledge framework should also be an integral part of the project management system because the EGM documents what is known about the ground and, therefore, should form part of the contract documentation (depending upon the contract delivery mechanism) and the basis of design.
對於與地盤工程計畫有關的 EGM，應自工程計畫之始即應著手建構，並於整個工程計畫生命週期中持續做修正，以完成一個有用、透明且合乎邏輯的認知框架(詳圖 1-1)，在建構期間可能會有數個不同的業主與顧問公司參與。由於 EGM 涵括了已知地盤的相關特性，因此應將 EGM 整合於工程計畫管理系統中，同時也應該做為合約文件的一部分(取決於合約提交機制)，並納入設計基準中。

1.1.2.6 Knowledge of geology and engineering is required to develop an EGM

1.1.2.6 建置 EGM 需要地質學及工程背景知識

Knowledge and experience of both geology and engineering is required to develop an effective EGM but the emphasis should be on geology. This knowledge should be based on education, ideally involving at least a first degree in geology or a degree with geology as a major component and, ideally, postgraduate training in engineering geology or geological engineering, or a significant period of mentoring under the supervision of an experienced engineering geologist. In some circumstances and on simple projects, a competent geotechnical engineer with significant geological knowledge and/or with valid practical experience in the geological setting of the project should be able to build a reliable EGM.
建構理想的 EGM，同時需要地質以及工程的背景知識暨經驗，但關鍵仍偏重於地質學。合理的說，這些背景知識應該奠基於教育，包括地質學或課程以地質學為主的學士學位，再經過攻

讀工程地質或地質工程碩士期間的訓練、或是學士能夠由經驗豐富的工程地質師指導過一段時間。在某些特定情況、且工程計畫相對單純時，如果大地工程師具備良好的地質學背景，或曾參與類似工程地質條件之工程計畫，累積了豐富的實務經驗，亦能勝任建構可靠的 EGM 工作。

1.2 EGM DEVELOPMENT PROCESS

1.2 EGM 建置程序

1.2.1 Overview of development process

1.2.1 EGM 建置程序概述

1.2.1.1 Initial steps

1.2.1.1 初始步驟

The following key questions should be asked at the beginning of the project:
為了建置 EGM，於工程計畫起始時，應先條列出下列關鍵課題：

- Where is the project located (geography/geology/geomorphology/environment)?
- 工程計畫的位置 ? (地理/地質/地貌/環境)
- What is the type and scale of the project, how will it interact with the ground, what are the key dimensions and design requirements, including the design life, and what are the key geotechnical constraints, concerns or consequences of failure for a project of this type?
- 工程計畫的類型及規模? 與地盤之互制關係? 關鍵尺寸與設計需求(包括設計年限)? 此類工程計畫之關鍵大地工程限制、關注點或工程失效的後果為何?
- What existing information with respect to the possible ground conditions is available?
- 關於工程計畫可能遭遇到之類似地盤條件的參考文獻?
- What is the geological/geomorphological/anthropogenic history of the region/site that might be of engineering significance to the project?
- 對於工程計畫的區域或工址，具有重大工程影響之地質、地貌或人為開發歷史?
- What geohazards may be present?
- 可能發生之地質災害為何?
- What are the groundwater and surface water conditions and how could they impact the project?
- 地表水及地下水的條件，及其對工程計畫之影響?
- What is the current status of the project, for example is it on hold, seeking financial backing, under construction etc?

- 工程計畫目前的狀態為何? 例如：目前是否擱置暫停、尋求財務支援或正在施工中等。

Answering these key questions remains relevant throughout the project life.
在工程計畫的全生命週期期間，所建置的 EGM，應持續滾動檢討這些關鍵問題。

1.2.1.2 The development process

1.2.1.2 EGM 建置程序

The EGM development process involves the following essential steps, usually with repeated iterations of most steps:
EGM 建置程序包括下列各項必要的步驟，大部分的步驟經常需要重複交叉執行：

- Assemble team, define scope and purpose.
- 組建團隊，定義計畫範疇及目的。
- Assemble relevant engineering and engineering geological information of significance to the project in a desk study.
- 於室內研判時，應彙整(不僅只於蒐集)對於計畫具有重要意義之工程及工程地質資訊。
- Undertake an initial reconnaissance mapping by a competent engineering geologist.
- 由具有專業能力與經驗之工程地質師，執行初步的調查與製圖工作。
- Conceptualise the likely engineering geological conditions based on the knowledge and experience and the desk study at the beginning of the project but re-evaluate using other information as it becomes available at later stages of the project.
- 於計畫初始階段，依據專業知識、經驗及室內研判的結果，概念化可能的工程地質狀況。於計畫後續階段，應匯入其它的資訊，重新評析此一概念模型。
- Identify and document key uncertainties in a risk register. This register is used throughout the project's life cycle and needs to be updated on a regular basis.
- 辨識關鍵的不確定性，並將其記錄於風險管控表(Risk Register)中，此風險管控表將於工程計畫的全生命週期期間，延續使用並且定期更新。
- Acquire observations through investigations (these may include, but will not be limited to, remote sensing, mapping, geophysics, exploratory holes, sampling and testing); the importance of engineering geological mapping in investigations cannot be over emphasised.

- 透過地質調查獲取相關的資料(至少包括遙測、測繪、地球物理探測、鑽探、取樣及試驗等)，地質調查完成的工程地質圖，其重要性是不言可喻的。
- Combine the observations and the concepts to develop an interpretation of the site conditions; if necessary, re-evaluate the conceptual model.
- 整併調查資料與概念模型，對於工址的相關條件，建構出完整的的闡釋說明。如果必要，應重新再調整概念模型。
- Define engineering geological units, interpret their distribution and generate a Geological Model.
- 清楚定義各工程地質單元，說明其在空間的分布，並進而建立一個地質模型。
- Characterize the engineering geological units, the hydrogeological conditions and the geological processes using geotechnical parameters developed from the desk study, investigations and experience and generate a Geotechnical Model.
- 綜合室內研判、調查作業及經驗所獲致之大地工程參數，描繪出工程地質單元、水文地質狀況及地質作用的特性，以建立一個大地工程模型。
- Identify significant uncertainties, gaps and discrepancies in the knowledge framework; these are potential risks to the project and should be added to the risk register.
- 在認知框架中，設法辨識出顯著不確定性、資訊落差及條件不一致之處，這些都屬於工程計畫的潛在風險，並且應清楚記錄於風險管控表中。
- Evaluate the risks and, if necessary, undertake additional investigations to improve the knowledge framework, minimise unknowns and reduce risks.
- 評估計畫潛在風險高低，可增加額外的調查工作，以精進認知框架，使不清楚的部分減到最少，以降低風險。

The EGM development process is illustrated in Figure 1-3 and detailed below.

EGM 建置程序詳圖 1-3，並說明如下。

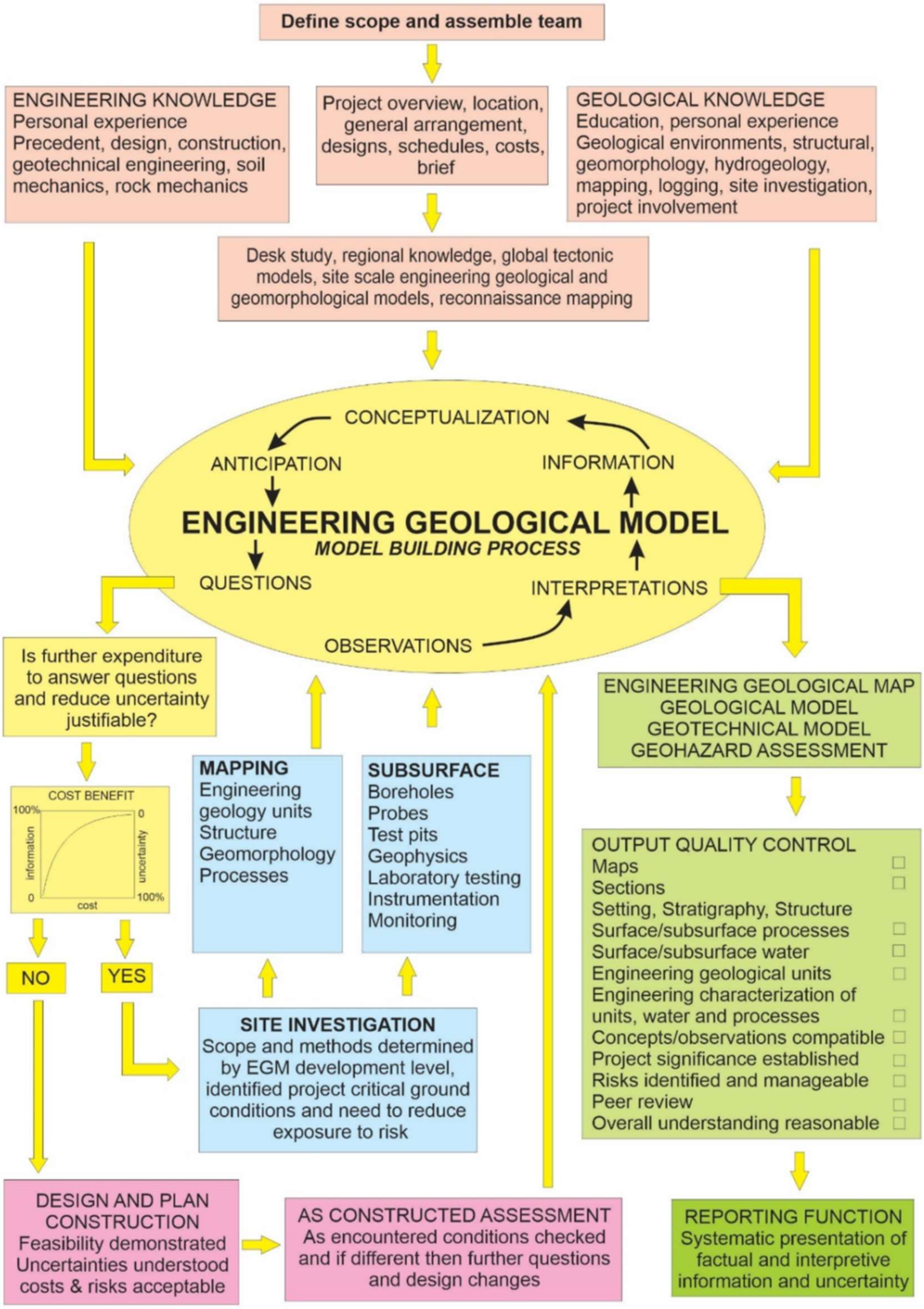

Figure 1-3 The EGM development process.

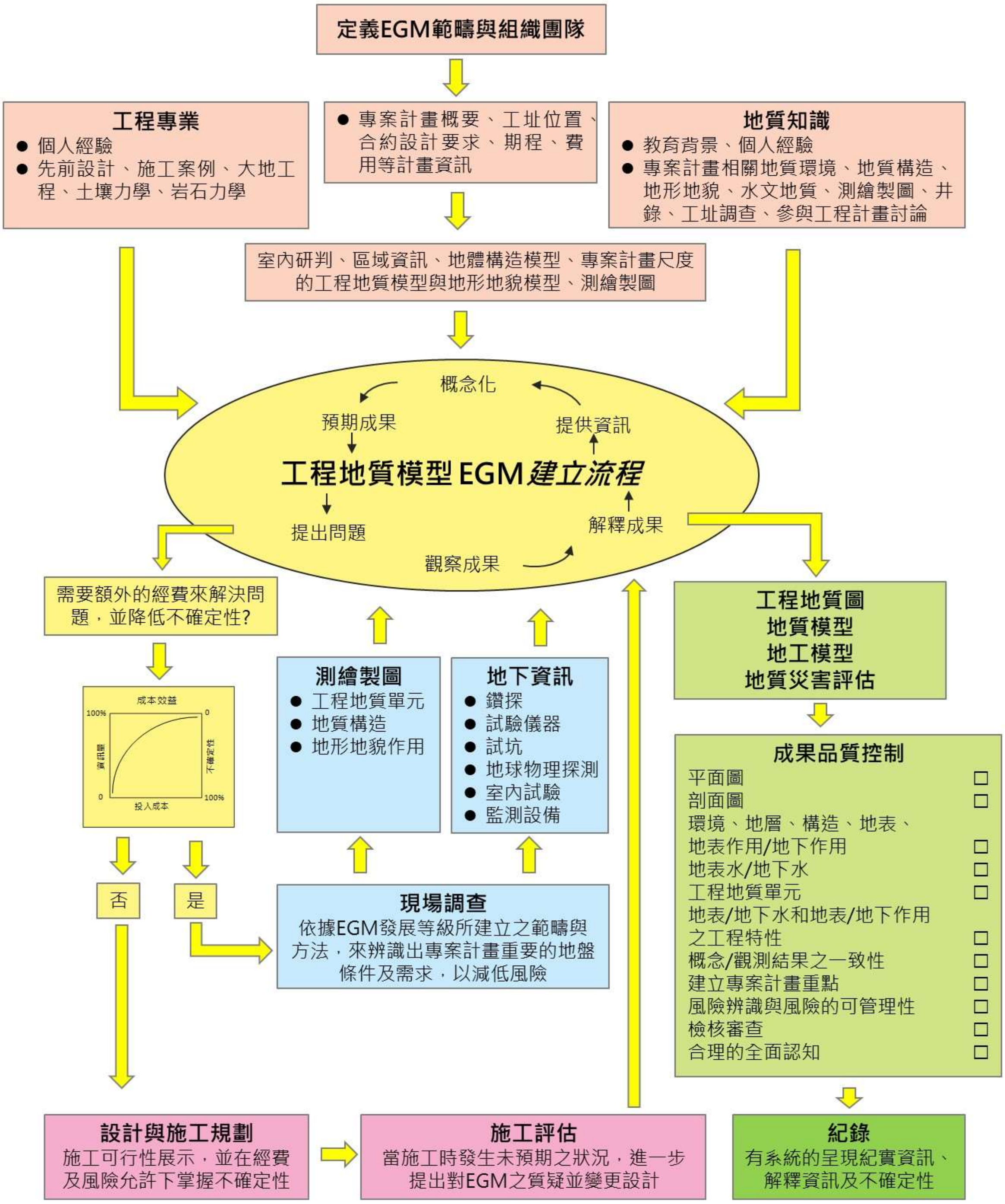

圖 1-3　工程地質模型發展程序

1.2.2 Choice of development level of EGM

1.2.2 EGM 建模等級選擇

The level of development of the EGM that should be adopted is a function of the geotechnical complexity considered in the context of the project complexity and the consequences of failure; guidance on the choice of the level of development is provided in Tables 1-1 and 1-2. The development level should be revised if the investigation indicates that the geotechnical complexity is higher than anticipated.

建置 EGM 的等級，係依據大地工程的複雜程度，以及其相依於計畫的複雜程度和失效可能的後果而定。等級選擇的指引如表 1-1 和表 1-2 所示。當調查結果顯示大地工程的複雜程度高於預期時，建模的等級則必須重新修訂。

Table 1-1 EGM development levels related to project and geotechnical complexity. **

表 1-1 EGM 建模等級依計畫及大地工程複雜度而定**

	Geotechnical complexity of the ground that could influence the project - as indicated by the conceptual model developed in accordance with these Guidelines 可能影響工程計畫的地盤地工複雜度 – 源自概念模型(依本指引所建立)		
Project Complexity## 計畫複雜度	SIMPLE/UNIFORM: 單一的/均質的： Gently dipping or horizontal strata, uniform soils, no geohazards, few geotechnical constraints 和緩傾斜或水平的岩層、均質的土壤、無地質災害、很少大地工程限制條件	MODERATE/VARIABLE: 中等複雜的/具變異性的： Variable folding and/or faulting, variable soils, unconformities, few geohazards, some potential geotechnical constraints 岩層具變化性的褶皺和/或斷層、多樣性土壤、不整合岩層、有地質災害、具少數潛在的大地工程限制	COMPLEX/HAZARDOUS: 複雜的/具危險性的： Highly variable folding and/or faulting, deep irregular soils, unconformities, considerable geotechnical complexity, significant geohazards such as major landslide complexes, active faults, karst or the potential for geohazards magnitude and/or frequency to be increased by the project 岩層具複雜變化的褶皺和/或斷層、層厚且不均質土壤、不整合岩層、明顯複雜的大地工程性質、活動性顯著的地質災害(例如大型邊坡滑動複合體、活動斷層、喀斯特地形)，或地質災害規模及/或發生頻率因專案計畫開

			發而增加。
Minor engineering development, small footprint, low consequence of failure 小型工程開發、佔地面積小、工程失效代價低	Level 1	Level 1	Level 2
Medium sized engineering development, with medium consequence of failure 中型工程開發、工程失效代價中度	Level 2	Level 2	Level 3
Major infrastructure, large linear projects, regional studies, high consequences of failure 重大基礎設施、大型線狀計畫、區域研究、工程失效代價高	Level 3	Level 3	Level 3

** When assessing the appropriate EGM development level, advice should be sought from a competent engineering geologist.

** 必須參考具專業能力與經驗的工程地質師提供的建議，以評估工程地質模型建模的等級。

Project complexity is subjective; low and medium consequence of failure would typically be limited to financial impacts; high consequence of failure would typically be associated with loss of life; failure is when the project does not perform in accordance with the design/specified performance.

工程計畫的複雜程度是屬於主觀認定的結果。低度或中度工程失效代價一般僅限於財產的損失；高度工程失效的代價則涉及人的命傷亡；工程失效是指專案計畫未按照設計或規範要求執行。

Table 1-2 Guidance on scope requirements for EGM development levels

表 1-2 EGM 建模等級的範疇要求指引

	Level 1	Level 2	Level 3
Specialist studies 專業研究	None 無	None 無	Commission separate geohazard studies (where applicable) Possibility of specialized geological studies Possibility of ground / structure interaction studies 委託單獨的地質災害研究(可行時) 可選擇進行專業地質研究 可選擇進行地盤/結構互制研究
Mapping 工程地質圖測繪	Minimum of site visit, reconnaissance mapping, engineering geological sketch map/cross section of site 少量現勘、勘查測繪製圖，現場工程地質素描/剖面圖	Engineering geological mapping including cross sections of site and surrounds 工程地質圖與剖面圖測繪，包括工址及週遭	Engineering geological mapping including cross sections of project site and surrounds, at a variety of scales 各種比例之工程地質圖與剖面圖測繪，包括工程計畫工址及週遭
Subsurface investigations 地下調查	Single stage minor subsurface investigations for example, trial pits, boreholes as appropriate 單一階段小規模地下調查，例如：試坑，若真的需要可以考慮鑽探調查	Subsurface investigations as appropriate using boreholes, cone penetrometer tests, geophysics etc. Instrumentation 若適當，可採用鑽探、圓錐貫入試驗(CPT)、地球物理探測等方式調查，或設置監測儀器	Multistage subsurface investigations using methods such as boreholes, in situ testing, geophysics etc., instrumentation and long-term monitoring as appropriate. Base line data collection 多階段地下調查，採用鑽探、現地試驗、地球物理探測等方式，若適當，可考慮設置監測儀器及長時間監測，基準資料蒐集
Laboratory testing 實驗室試驗	Limited or no laboratory testing 無或有限數量的實驗室試驗	Laboratory testing as appropriate 若適當，進行實驗室試驗	Extensive and possibly specialised laboratory testing as appropriate 若適當，進行大量且專業的廣泛及特定種類實驗室試驗
Documentation 紀錄文件	Documentation of the EGM in a simple combined factual and interpretive report EGM 紀錄文件為單一	Documentation of the EGM in factual and interpretive reports EGM 紀錄文件為各自獨立的紀實及分析報	Documentation of the EGM in factual and interpretive reports. Consideration of 3D digital visualization

	合併的紀實、分析報告	告	EGM 紀錄文件為各自獨立的紀實及分析報告 考量使用三維數位視覺化呈現
Team 團隊	Possibly a single individual responsible for the works 可能由單一人負責此作業	Small team of engineering geologists and geotechnical engineers responsible for the works 由工程地質師及大地工程師組成的小型團隊負責此作業	Large multi-disciplinary group responsible for the works 由大規模、跨領域的專家群負責此作業
Review 審查	Internal Review++ 內部審查++	Internal/External Peer Review++ 內部/外部同儕審查++	External Review/Panel of Experts++ 外部同儕審查/專家小組++

++ Company specific review requirements may exist.

++ 可能存在各公司特定的審查要求

1.2.3 Details of the development process

1.2.3 EGM 建模程序細節

1.2.3.1 Assemble team, define scope and purpose

1.2.3.1 組織團隊、定義範疇及目標

The composition of the team will depend on the likely complexity of both the project and the ground. This could range from an individual with the necessary geological and engineering knowledge for a small project to a multi-disciplinary group and a review panel for a major project. Roles and responsibilities of the team, the reviewer(s) and the approvers should be documented. The team should start off by defining the scope and purpose of the EGM and should take account of any planned changes to the ownership of the EGM, for example where the EGM is developed by a government agency then transferred to the winning bidder for the contract. Where the team joins the project at a later stage, or the project is transferred between contractually separate parties, then the existing project documentation should be reviewed to identify any gaps or inadequacies.

團隊的組成取決於專案計畫本身及地盤的複雜性，團隊規模可小至由具有必要的地質及工程專業的個人負責之小型計畫，大至需要跨領域團隊及審查小組的大型計畫。執行團隊、審查人員、批准人員各自的角色及職責均應記錄在案。團隊開始執行計畫時應釐清 EGM 的範疇及目標，並且應考慮到預期內的 EGM 所有權移轉，例如 EGM 由政府機關負責建立後，可能會轉移給得標的承包團隊。如果執行團隊是在計畫後期階段才加入，或者參與計畫是自合約中的不同單位之間移轉，則應覆核既有專案計畫文件，以釐清任何有落差或不充分的資訊。

1.2.3.2 Assemble relevant engineering and geological information in a desk study

1.2.3.2 在室內研判階段彙整有意義的工程及地質資訊

A desk study is an information gathering exercise to assemble relevant material so that the maximum value can be derived from existing available sources prior to spending time and money collecting new information. Primary information will likely be geological maps and memoirs, topographic maps, any existing site investigation data such as boreholes, remote sensing data, geohazard information etc. Historical data should not be disregarded as a consequence of being superseded by more recent datasets or being recorded in a style not in line with current standards.

室內研判是一個以提取出有意義資訊為目標，而進行資料彙整的過程，因此在花錢、花時間調查產生新資料之前，室內研判可以從既有文獻資料彙整取得最大效益。主要的文獻資料可能是地質圖、地質紀錄、地形圖或任何現有的工址調查資料：如鑽探、遙測資料、地質災害資訊等。歷史資料不能因為有新的數據可以取代，或紀錄不符現今標準而理所當然的被忽視。

As part of the desk study reconnaissance mapping should be undertaken where practical. This allows the evaluation of the desk study data and assists conceptualisation.

如果可行，應進行實地勘查測繪並作為室內研判的一部分，這有助於評估室內資料並幫助概念化。

1.2.3.3 Conceptualise the EGM

1.2.3.3 概念化 EGM

Conceptualisation is the process whereby all the available information is considered and an understanding is developed of what the ground conditions at the site are likely to be and how they developed over time. This should take place initially after the desk study but then should be carried out periodically as additional information is acquired. Conceptualisation allows an assessment of what conditions and what variations may be present and the geological and geomorphological processes that have produced them and that could be of engineering significance to the project.

概念化是一個過程，在這個過程中，將所有可用資訊考慮進去，透過此一過程可理解現場地盤條件可能是如何形成，以及如何隨時間發展至今。概念化應在初始階段室內研判後進行，但隨著後續新增資訊的取得，需定期的進行概念化更新。概念化可以評估形成至今可能具有工程意義的條件與變化、以及造成這些條件或變化之地質與地形作用。

During conceptualisation the following aspects of the site should be considered:

在概念化的過程中，需要考慮工址的下列幾個方面：

1.2.3.3.1 Project Setting

1.2.3.3.1 工程計畫設定

This should be based on an appreciation of:

這應該基於以下認識：

- The overall tectonic setting and regional geology of the project location.
- 工程專案計畫所在工址的整體地質構造背景和區域地質。
- The current, past and potential future climatic settings of the project location.
- 工程計畫所在工址的現在、過去以及未來可能的氣候條件。
- The requirement to look beyond the immediate site area, for example the evaluation of landslide hazards originating from outside the site area.

- 需要考量到目前的工址區域以外的範圍，例如評估來自於工址範圍外的山崩危害。

1.2.3.3.2 Stratigraphy – rock and soil types and relationships

1.2.3.3.2 地層-岩石及土壤種類以及相互關聯

This requires an understanding of rock-forming and rock-modifying processes as well as the processes of soil origin and transportation and deposition that produced the rock and soil types in the project area. This allows consideration of rock mass and rock and soil material properties, the likely characteristics of engineering geological units, including the boundary conditions of the units, plus their likely geometry, distribution and relationships - both with each other and with the project.

需要了解專案計畫範圍岩石形成與變化的過程，以及土壤自母岩風化、搬運、沉積至形成岩石的過程以及土壤種類。這考慮到岩體、岩石、和土壤材料性質、工程地質單元的可能特徵，包含工程地質單元的邊界條件、衍生至單元可能的幾何形貌、分布、相互關係-包含這些特徵的相互關聯，以及這些特徵與計畫間的關聯。

The stratigraphical age of the materials and the identification of the sequence of geological events that the materials have been subject to since their formation should be understood. This supports the application of the total geological model approach in which all of the engineering characteristics of the ground are interpreted as resulting from the entire geological and geomorphological history of the area.

應該了解地層的年代，及識別地層形成後所經歷的地質事件順序，這可以協助應用 “全地質歷史”方法解釋。地盤的所有工程特性都受該區整個地質和地貌影響。

1.2.3.3.3 Geological Structure

1.2.3.3.3 地質構造

An understanding of geological structures should be developed, including the presence of tectonic features at all scales and the nature of the boundaries of engineering geological units and the discontinuities within them, their origin, geometry, spacing, extent, characteristic features and their engineering significance. This understanding should also include the timing and sequence of rock and soil forming events, deformation phases, landform development and stress relief effects.

應建立對於工址地質構造之認知，包含不同尺度的現有構造特徵、工程地質單元的邊界、以及其中之不連續面，其生成、幾何形貌、間距、延伸性、特性以及對工程之重要性。此認知也應該包含土壤與岩石形成時間、以及形成事件順序、變形階段、地貌發育、應力解壓影響。

1.2.3.3.4 Surface and subsurface processes

1.2.3.3.4 地表及地下變化過程

Identification of possible active or potentially reactivated geohazards and an initial evaluation of their likely variations in magnitude and frequency over time is required. The surface and subsurface water conditions and how they might change over time should also be evaluated.

識別出可能發生或有再發生潛勢的地質災害，並對這些地質災害隨時間而發生的可能規模及頻率變化進行初步評估，還需評估地表及地下水文條件如何地隨時間變化。

1.2.3.3.5 Initial engineering geological characterisation

1.2.3.3.5 初始工程地質特性特徵化

It may be possible to attribute geotechnical parameters to parts of the conceptual model, based on existing data or knowledge, insofar as is reasonable given the data available, for example, soil and rock strength, stiffness, permeability, geomorphological process rates, etc. Evaluation of potential geotechnical risks (and possible project opportunities) can be used to populate an initial risk register.

基於既有資料或知識，以及現階段可及資料，可以將大地工程參數(例如土壤及岩石強度、勁度、透水性、地貌變遷速率)等納入成為概念模型的一部分。潛在大地工程風險(和可能的專案計畫機會) 的評估，可以納入初始的風險管控表中。

1.2.3.3.6 Initial Geological Model

1.2.3.3.6 初始地質模型

Conceptualisation will generate an initial Geological Model that can be used to plan the site investigation. The Geological Model is then refined by acquiring observational data from the site investigations.

概念化生成之初始地質模型，可用於規劃工址調查計畫，而後工址調查所取得觀測資料可以用來更新並完善該地質模型。

1.2.3.4 Acquire observations of the project area through investigations

1.2.3.4 經由調查獲得專案計畫地區的觀測結果

Information acquired during the desk study is the starting point for developing both conceptual and observational models. However, most observations are acquired during the site investigation stage(s) of the project. Further observations should be added during construction and operation.

概念模型和觀測模型的建置，都應該是以室內研判期間獲得的資訊作為起始點。然而，大多數觀測結果是在專案計畫工址調查階段才獲得的。施工和營運階段中也應該增加進一步的調查觀測作業。

Site investigations that consist solely of observations and interpretations without the use of a conceptual framework are likely to be fundamentally flawed and should not be accepted.

工址調查單純僅納入調查觀測結果以及解釋，而未導入工程地質概念模式架構，極可能導致成果存在根本性的缺陷，且不應被接受。

Following conceptualisation there should be a broad understanding of the possible characteristics and distribution of engineering geological units at the site, the nature of any geohazards and any suspected gaps in the knowledge framework. This understanding should then be focussed on the ground characteristics that are critical for design and used to identify investigation targets and plan investigations that will improve the understanding and reduce uncertainty in those critical areas.

跟隨著工程地質概念化之後，應開始嘗試廣泛了解與認知工址中的工程地質單元特性與分布、地質災害特性，以及在工程地質知識架構中疑似存在的缺漏或落差。此了解與認知應聚焦於對設計至關重要的地盤特性，並用來確立工址調查關鍵區域、調查目標及調查規劃以完善前述之了解與認知，並減少不確定性。

The importance of mapping that includes observations and interpretations in investigating any project is emphasised. All projects should have an engineering geological map compiled and 'owned' by the team responsible for carrying out the investigations. Essentially, such maps must be developed out in the field, although increasingly the field component involves ground truthing of maps prepared in the office by combining observations derived from various data sets within a 2D or 3D digital environment or from interpretation of remote sensing imagery.

再次強調，任何專案計畫在調查階段之測繪製圖(包括觀測資料與解釋)是非常重要的。所有計畫執行調查工作的團隊都應該編修及擁有"屬於自己"的工程地質圖。雖然已經有越來越多的工址真實調查觀測資料，是在室內利用 2D 或 3D 數位環境結合不同調查觀測資料集建置而成、或由遙測影像判釋而取得，但是基本上，專案計畫工程地質圖還是必須產出自現地調查觀測。

For larger projects or more complex sites or critical structures, the site investigation is usually multi-staged with the acquired observational data being compared to the conceptual model to see which areas of uncertainty and which risks remain to be explored in successive stages of the investigation.

對於大型計畫、更加複雜的工址或重要結構物，工址調查通常都是多階段的，各階段均應將獲得的調查觀測資料與概念模型比較，以了解工址還有哪些不確定性、哪些風險尚待後續階段之工址調查將之釐清。

The investigations will acquire observational data that typically includes:

現地調查所獲得之觀察資料通常包括：

- Topographic survey, and increasingly using LiDAR (Light detection and ranging) generated DEMs (Digital Elevation Models).
- 地形測量結果，以及越來越多地使用光達(LiDAR, Light detection and ranging) 所生成的數值高程模型（DEM）。
- Engineering geological mapping at various scales ranging from regional studies, project area studies, geotechnical component studies and individual foundation studies. All mapping should be seamlessly integrated into the one data set that can be viewed at a variety of scales.
- 各種尺度的工程地質圖，包括從區域調查、專案計畫工址調查、大地工程相關元素調查、到個別結構物基礎調查，同一個資料集應能彙集所有圖面所需資料，並能在不同比例尺下檢視。
- Information from intrusive investigation techniques such as boreholes, test pits, shafts, adits etc.
- 侵入性調查的資訊，例如鑽探、試坑、豎井、橫坑等。
- Downhole data such as borehole imaging, geophysics and other tools.
- 井測數據，例如孔內攝影、地球物理井測和其他工具。
- Installed instrumentation and the results of monitoring.
- 已安裝的監測儀器和監測結果。
- Laboratory and field test results.
- 實驗室和現地試驗結果。
- Groundwater and surface water measurements.
- 地下水和地表水測量資料。
- Geophysical survey results.

- 地球物理探查成果。
- Descriptions and classifications (for example, rock types, rock strength classes using recognised systems and terminology).
- 描述和分類成果（例如，岩石類型、透過經認可的岩石強度分級系統之強度分級結果）。
- Measurements such as intersection depths of engineering geological units in a borehole, strikes and dips on strata and discontinuities.
- 各種量測成果，例如鑽探中工程地質單元分界深度、層面以及其它不連續面之走向和傾角。
- Remote sensing techniques such as InSAR (interferometric synthetic aperture radar).
- 遙測技術應用成果，例如應用干涉合成孔徑雷達 (InSAR)獲取之資料。
- Other observational data including temporal observational models (for example, time series of seismicity, rainfall, landsides etc) that are critical for predicting the frequency of future geohazards.
- 其他調查觀測資料，包括對預測未來地質災害頻率至關重要的時間域觀測模型（例如，地震、降雨、山崩等的時間序列）。

Mapping should commence following the development of the conceptual model and can initially be based on remote sensing; where practical, this can be evaluated during field reconnaissance. Detailed mapping can be undertaken using a variety of techniques ranging from simple tape measure surveys from control points to locating the observations on a high-resolution DEM (where available) or orthophotos.

測繪工程地質圖應在概念模型完成後開始，最初可由遙測影像下手。在實務上，這可以透過現地勘查予以評估進行。詳細的工程地質圖可以從控制點之間的簡單的皮尺測量，到利用高解析數值地形模型（如果可以取得）或正射影像上進行觀測結果之定位等各種不同技術進行測繪。

It is essential that any engineering geological mapping also captures geological patterns (for example, lineaments, structural patterns, discontinuity types and contact traces etc.) as well as the geomorphology.

重要的是，所有工程地質圖還應能掌握地質特徵（例如，線形、構造模樣、不連續面類型和接觸跡等）以及地貌。

1.2.3.4.1 Input data verification

1.2.3.4.1 輸入資料的驗證

Before any interpretation of the observational data there should be a data review and collation step where the key questions of accuracy, usefulness and representativeness should be tested for each dataset. Any concerns about accuracy and representativeness of the dataset should be documented with possible explanations discussed.

在對調查觀測資料進行解釋之前，應對每組資料進行檢查和核對，資料檢查和核對重點問題包括資料之準確度、可用性、代表性等。任何對於資料的準確性和代表性有疑慮處，都應記錄下來，並討論可能的解釋。

1.2.3.5 Combining conceptual ideas and observational data together in the EGM

1.2.3.5 將概念想法和調查觀測資料結合在 EGM 中

Combining the conceptual and observational components involves interpretation.

模型結合概念和調查觀測兩成分之過程中需要進行"解釋"

Interpretation has traditionally involved the creation of paper-based maps, sections, sketches and text but is now increasingly carried out in a digital model environment. This involves 'surface interpretation' during the development of a 3D digital model in which engineering geological maps, geomorphological maps, LiDAR, topography, field mapping and observations etc. are collated and used to interpret the ground conditions. It is essential that such surface interpretation should be ground truthed in the field.

在傳統上，繪製紙本地質圖、剖面圖、素描及文字描述都包含了"解釋"的成分在內，但現在越來越多"解釋"被包含在數位模型環境。3D 數位模型建立過程，涉及"(工程地質單元)界面解釋"，這些數位建模所需之地盤條件解釋乃經由整合校核工程地質圖、地貌圖、光達、地形資料、野外測繪和觀測成果來達成。3D 數位模型建置過程中採用之 "界面" 均須經過野外現地資料予以確認。

This iterative process of combining the conceptual and observational components of the EGM in an interpretation should be traceable, documented and structured. Subjective judgments by those responsible for developing the EGM should be avoided and replaced with objective and assessable sources (for example, models and case histories from literature, mapping, geotechnical investigation, geotechnical monitoring, etc.) together with the reasoning behind their adoption in the interpretation.

進行地質解釋時，結合 EGM 概念成分和調查觀測成分的迭代過程，必須是可追溯、記錄和結構化的。建置 EGM 時應避免負責建模人員之主觀判斷，資料解釋應基於客觀且可受公評的資訊來源(例如，衍生自文獻、地質圖資、大地工程調查監測等之模型或案例研究)及其所採用地質解釋背後之邏輯。

Field-based engineering geological and geomorphological mapping is rarely undertaken as a matter of course on projects, yet it is a technique that requires both field-based observation and conceptual interpretation to be carried out concurrently and, in doing so, generates the quintessential 2D visualisation of the EGM in the form of the map. Some form of engineering geological and geomorphological mapping should be an essential part of every project.

基於現地的工程地質及地貌測繪在專案計畫中很少被當作一回事，但它卻是最後能以圖面形式產生典範的二維可視化 EGM 所必要之技術。同時，此一技術亦必須基於現地調查觀測及概念化解釋兩者之結合。工程地質和地貌測繪成果(不論以何種形式呈現)應該是每個專案計畫的必要成分。

1.2.3.6 Defining and characterizing engineering geological units

1.2.3.6 定義及特徵化工程地質單元

A key product of any EGM is the definition of engineering geological units that are based on an understanding of their engineering geological characteristics/geotechnical behavior and are appropriate for the project engineering. The definition of engineering geological units supports the development of the Geological Model.

EGM 的重要產出之一為定義工程地質單元，此一工作乃是基於對其工程地質特性與大地工程力學行為之了解，以及確認單元劃分對各該工程專案計畫是恰當的，定義工程地質單元為建構地質模型之基礎。

A common approach is to adopt engineering geological units based on the distinctive litho-stratigraphical divisions identified on the site (that is, the units of soil and rock that can be differentiated) that are usually subdivisions of the chronostratigraphical units (age based units) provided on the geological map. However, lithostratigraphical units may not correspond to the most useful engineering geological units (that is, they may not take into account distinctive geomorphological processes, geotechnical behavior, hydrogeological characteristics etc.) Furthermore, the resolution of stratigraphical units may not suit the purpose of the model.

常見區分工程地質單元的方法，是於現地調查後依據岩性地層進行劃分（由此即可區分土壤單元和岩石單元），此方法通常是參考地質圖上所提供的年代地層單元（以地質年代區分的單

元）。然而，岩性地層單元可能並非最適用的工程地質單元（如岩性地層單元可能未考慮地形作用與演化過程、大地工程力學行為、水文地質特徵等）。此外，岩性地層單元劃分的解析度亦可能不適合於建置工程地質模型之目的。

Nevertheless, engineering geological units should not cross published lithostratigraphical boundaries, such as boundaries shown on geological maps. The lithostratigraphical unit contains a distinct geological history and different geological histories should not be combined in a single engineering geological unit, even if the geotechnical characteristics are similar. The exceptions to this are fault zones that may need to be considered separately and that, by definition, cross the litho-stratigraphical boundaries. Note that these boundaries will be scale dependent – the boundaries for a regional model may be different from the boundaries for a site scale model.

儘管如此，工程地質單元不應跨越已發表的岩性地層界線，例如地質圖上顯示的地層界線。岩性地層單元包含了特定的地質歷史，即使大地工程特性相似，具不同的地質歷史的地層不應合併為一個工程地質單元。然而斷層帶例外，根據定義，斷層帶會分隔岩性地層邊界，但這情況可以另外考慮。須注意這些工程地質單元邊界將取決於製圖比例尺，大範圍、區域性規模的工程地質單元邊界可能與小範圍、工程工址規模的工程地質單元邊界不同。

The engineering geological units chosen should reflect those conditions that are of significance to the project and may include geological controls such as weathering, alteration and faulting. Figure 1-4 outlines the operations involved in establishing engineering geological units and thus developing the Geological Model.

工程地質單元的選擇應能反映對工程專案計畫具有重要意義的條件，比如風化、蝕變和斷層作用。圖 1-4 概述了如何建立工程地質單元和進一步建置地質模型。

As with other aspects of the EGM, the resolution and scale of the engineering geological units should be clearly linked to the EGM scope and purpose. The engineering geological units adopted should be reviewed as additional data become available.

與 EGM 的其它面向一致，工程地質單元劃分之解析度和尺度應與 EGM 的範疇及目的明確聯結。當獲得更多資料時，應再回頭檢視所採用的工程地質單元劃分是否合理。

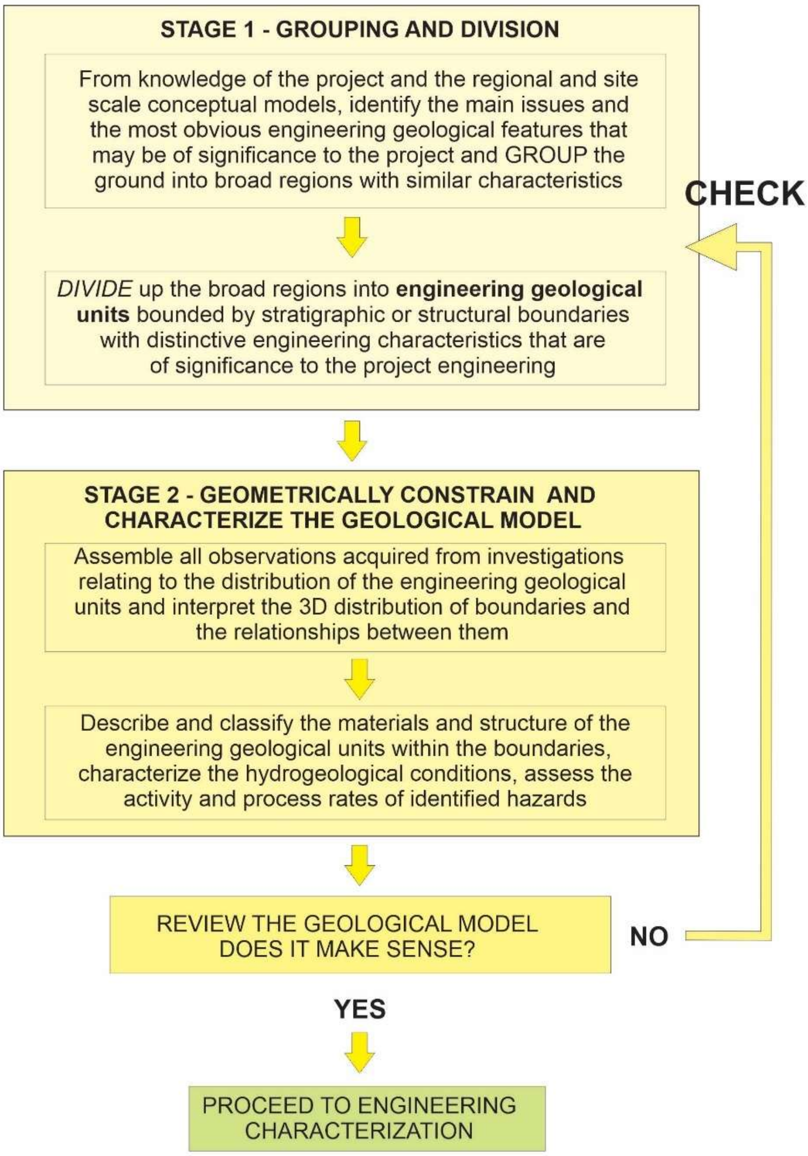

Figure 1-4 Establishing engineering geological units and the basis of the Geological Model.

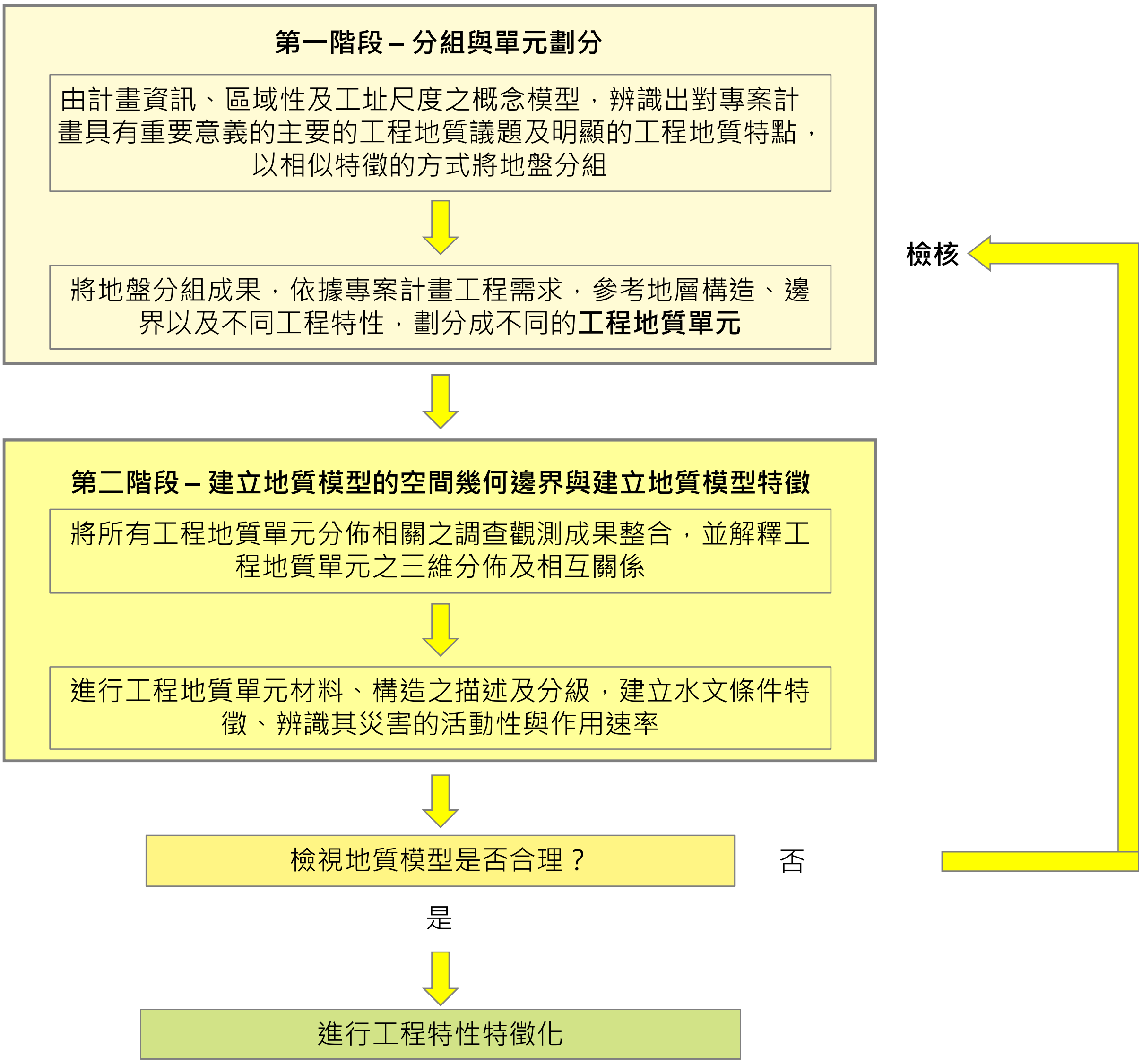

圖 1-4　建立工程地質單元及其作為地質模型之基礎

1.2.3.6.1 Geotechnical complexity

1.2.3.6.1 大地工程複雜性

In geotechnically complex areas, geotechnical properties may vary rapidly, potentially across a wide range, within the project site. Geotechnical complexity should, where possible, be reflected in the Geological Model in the form of sufficient engineering geological units with appropriate distributions and interrelationships. Where this is not possible, simplification may be necessary and the EGM documentation should describe the geological processes and geological history that produced the geotechnical complexity, the nature of any simplifying assumptions used in generating the engineering geological units and illustrate the potential complexity using a visualisation of the conceptual model.

在大地工程條件複雜的區域，地工特性可能會在涵蓋範圍寬廣之專案計畫工址內觀察到很快速的變化。地工複雜性應盡可能的反映在地質模型中，並以工程地質單元分佈和相互關係的方式適當呈現地工複雜性。如果無法將地工複雜性完整反映在地質模型中，則可能需要進行簡化，並於 EGM 文件中描述導致地工複雜性的地質作用與地質歷史、記錄產生工程地質單元過程中任何簡化的假設，以及使用視覺化概念模型描述潛在複雜性。

1.2.3.7 Engineering characterisation

1.2.3.7 工程特徵化

Engineering characterisation involves evaluating and assigning geotechnical parameters relevant to the project engineering to each engineering geological unit in the Geological Model, that then evolves into a Geotechnical Model.

工程特徵化包含評估與給定與計畫相關之大地工程參數至地質模型中每一個工程地質單元，經特徵化過程後可演變成為大地工程模型。

The process commences during conceptualisation although any parameters assigned at this stage will probably be associated with considerable uncertainty. The site investigation involves in situ and laboratory testing to assist with the evaluation of the relevant geotechnical parameters that will vary depending on both the ground conditions and the type of project. The results of the investigations will improve the characterisation of the engineering geological units and reduce uncertainty but may differ from what was envisaged in the conceptual model.

工程特性特徵化啟始自概念化階段，雖然此一階段所給定參數可能有相當大的不確定性。工址調查包含現場和實驗室試驗，用以評估相關的工程參數，這些參數的需求視地盤條件和計畫種類而定。工址調查結果將改進工程地質單元的特徵化並減少不確定性，但可能會與概念模型中的設想有所不同。

The Geotechnical Model might involve a simplification of the details contained within the Geological Model, for example, with respect to a complex fault zone, this might reduce to the bounding surfaces and some simplifying assumptions on the strength, stiffness and permeability of the entire fault zone. However, any simplification should not remove key engineering geological units that need to be considered separately due to their geotechnical behaviour.

地工模型可能涉及簡化地質模型中所包含的細節，以複雜的斷層帶簡化為例，大地工程模型可能只呈現出斷層帶的邊界，並對斷層帶的強度、勁度和滲透率提出簡化假設。然而，任何簡化都不應刪除因其地工行為特殊而需要單獨考慮的關鍵工程地質單元。

The following approach should be adopted:

工程特性特徵化應採用以下方法：

- The focus should be on engineering characteristics that are relevant to the project.
- 重點應放在與專案工程計畫相關的工程特徵上。
- Group the laboratory and in situ test results for each engineering geological unit identified.
- 應針對各別工程地質單元進行實驗室試驗和現場試驗結果資料的分組。
- Material properties and geotechnical parameters should be assigned primarily from the site-specific investigations. However, these may be supplemented with values derived from experience, theory, correlation or empiricism provided that the method of determination is explained, justified and referenced.
- 材料性質和地工參數給定主要應依據現場工址調查結果。然而，這些亦可透過經驗、理論、相關性或經驗法則加以補充，前提是判定的方法必須先進行說明、論證和引用。
- Consider bias resulting from sampling and testing difficulties and the number of tests for each unit and decide the range of representative values for the engineering geological unit. Averaging of material properties that masks the presence of significant weaker zones should not be undertaken, and the full range of results must be assessed to identify the probability of values being higher and/or lower than the representative values.
- 考量取樣及試驗困難以及每個工程地質單元試驗數量造成的偏差，訂定各工程地質單元參數值的代表性範圍。此外，不應對於含有明顯弱帶的材料特性進行平均，而必須評估全部試驗結果之範圍，以確認試驗值高於或低於代表值的可能性。
- Compare the representative values with experience and published values for similar units.

- 將試驗後決定之代表值，與類似工程地質單元之經驗值及已發表之代表值進行比較。
- Consider and explain any anomalous or extreme results. These may indicate that the engineering geological units may need refining.
- 考慮並解釋任何異常或極端之結果。這些可能代表此工程地質單元可能需要調整改進。
- Highlight any limitations in the data or the analysis.
- 指出資料或分析中的限制。

Note that the choice of engineering parameters for use in analysis by the designer should be based on the above information, ideally presented graphically, coupled with considerations of project engineering objectives, risk and possibly code requirements.

請注意，設計者選擇用於分析的工程參數應基於上述特徵化資訊，這些特徵化資訊應配合圖表呈現，同時工程參數選擇應考慮工程目標、風險和可能的規範要求。

1.2.3.7.1 Zoning

1.2.3.7.1 分區

Once the engineering geological units have been defined and the geotechnical characteristics assessed it may be useful to define zones or domains with the same geotechnical characteristics. The zones may be defined by geomechanical behaviour, seismic velocity, rock mass classification etc. but may also be based on any attribute of engineering significance to the project, for example acid sulphate potential, landslide susceptibility, or groundwater geochemistry, so that the EGM can be used for a variety of engineering analyses, risk assessment, constructability assessment etc. The decision on appropriate zoning should be made in conjunction with designers and the broader engineering team.

一旦定義了工程地質單元並評估了地工特性，即可進一步定義具有相同地工特性區域或範圍。這些分區可以通過地質力學行為、地震波速、岩體分類等來定義，也可基於對計畫具有工程意義的任何屬性來定義，例如硫酸鹽潛勢、山崩潛感性或地下水地化學性質，使 EGM 可用於各種工程分析、風險評估、施工性評估等，適當之分區應由設計者和工程團隊共同決定。

The scale at which zoning is undertaken should reflect the nature of the data and how the outputs are to be used. Zoning should neither be more detailed nor less detailed than the data allow.

分區的尺度應反映資料的本質以及如何供後續使用，且分區應依資料的詳實度如實應用，不應比資料詳細，也不應比資料粗略。

A common mistake is to zone the ground at, say, borehole scale, then try to 'join the dots' between boreholes. It is almost impossible to factor in the broader geological setting and total geological history using this method. For the EGM to effectively contribute to engineering analysis and design, the sensitivity of the analyses to certain critical zones defined by the model should inform the resolution and scale of the zoning.

例如一個常見的錯誤是按鑽探尺度對地盤進行分區，並採用鑽孔間任意加以連接。此方法幾乎不可能將廣泛的地質背景與地質歷史納入考慮。為了使 EGM 有效應用在工程分析和設計，模型中定義的關鍵分區對分析結果之敏感性，應能顯示其解析度和比例尺之影響。

1.2.3.8 Uncertainty, gaps and discrepancies in the EGM

1.2.3.8 EGM 的不確定性、資訊落差與不一致

During the development of the EGM there should be periodic assessments of the degree of agreement between the evolving conceptual ideas and the progressively acquired observational data. These assessments will typically take place at agreed project reporting stages.

在建置 EGM 的過程中，應該定期評估概念想法與逐漸獲得的調查觀測資料之間的相符程度，而這些評估通常會在計畫核定階段進行。

If there is a disconnect between what is anticipated to be present and what has been found during investigations, the reasons for this need to be identified and the EGM improved. If during design the EGM does not allow a realistic prediction of how the ground will respond to the project with the required level of certainty, then more information is needed to improve the EGM. Improvements to the EGM to mitigate identified risks may take the form of further investigations or design strategies such as increased conservatism or the adoption of the observational method during construction.

如果預期情況與調查之實際情況間存在差異，需釐清造成差異的原因並改進 EGM。如果在設計期間 EGM 對於因專案計畫開發可能造成之地盤反應，無法提供滿足特定把握程度之預測，則需補充更多資訊來改善 EGM。透過更多的調查、採較保守設計或在施工期間採取觀察法(觀測施工反應以回饋設計)等方式，可以改善 EGM 並降低所辨識到的風險。

As a project moves into the construction phase, the exposed ground conditions should be evaluated against the conditions anticipated by the EGM. Then an assessment must be made as to whether or not these variations could potentially impact on the design or construction methodology and whether or not these methodologies need to be changed or if the risk register requires updating.

當計畫進入施工階段，應將 EGM 預估的地盤條件與現場已確認地盤條件進行比較，評估二者差異是否對設計或施工方法產生潛在影響，以及是否需要更改施工方法或更新風險管控表。

Throughout the development of the EGM uncertainty, gaps and discrepancies may be manifested as risks. Where potential risks to the project are judged to be significant, these should be recorded in the risk register. Management of those risks should be based on an understanding of the level of risk that is acceptable to the client, the general public and as determined by any legislation. The risk appetite/risk tolerance of the client should be based on an informed understanding of the known ground conditions that should be communicated using the EGM.

在 EGM 的整個建置過程中，不確定性、資訊落差及不一致可視為風險。如果專案工程計畫中判斷有重大潛在風險存在，應標註在風險管控表中。風險管理應基於對業主與一般民眾對於風險理解與可接受度，並符合相對應法規。業主對於風險偏好與風險承受力應該是基於利用 EGM 溝通對地盤條件理解後而建立的。

1.2.4 EGM and Eurocode

1.2.4 工程地質模型及歐盟規範

The approach described in this section is an overarching process suited to developing an EGM knowledge framework for engineering decision making on any type of project at any stage of the project lifecycle. The Eurocode approach has a more restricted application to select stages of certain types of projects and there are terminological differences notably with respect to the components of a 'ground model', whilst the concept of an Engineering Geological Model developed throughout the project lifecycle is not mentioned.

本節描述之方法，包含多樣性、適用於建立 EGM 的知識框架的程序，以利提供各類型工程、於計畫生命週期的各階段進行工程決策時參考。歐盟規範所訂定之方法，於某些特定計畫的選擇階段有更多應用限制，特別是關於“地盤模型”的構成成分存在用辭上的差異，且應於於專案計畫全生命週期的各階段建立工程地質模型這一想法，並未於歐盟規範中被提及。

Refer to Commentary Section 2.2 EGM DEVELOPMENT PROCESS for further information

相關資訊請參考註釋章節第 2.2 節：EGM 建置程序

1.3 ASSEMBLY AND COMMUNICATION OF THE EGM

1.3 EGM 組成與溝通

1.3.1 Introduction

1.3.1 簡介

The EGM should be documented in a format that can be used to communicate the various components of the EGM, principally to consultants and contractors, but also to other audiences.

EGM應以可向顧問公司、承包商及其他受眾溝通之形式予以記錄，溝通內容應包括EGM各組成成分。

The documentation should include text, maps and sections as a minimum but more often will consist of detailed text and accompanying diagrams, tables, logs, photographs, maps, sections, data sets, processed data and digital models that should each be essentially transparent, self-explanatory, self-contained and be able to be clearly and easily understood.

這份紀錄文件應至少包括文本、平面圖和剖面圖，但更常包括詳細的文本和隨附的圖、表、岩心紀錄、照片、平面圖和剖面圖、資料集、處理過的資料，及數值模型。前述資料文檔需資訊透明、不言自明、詳細且能夠清晰易懂。

All encoded EGM data should be processed/preserved within a centralised, standardised and integrated data management and presentation system. The data can range from hand-drawn maps and sections to 3D (spatial) models including, sometimes, sophisticated software-generated models and 4D (spatial and temporal) models that describe process rates.

所有編碼後的EGM資料都應處理及保存在集中、標準化和整合的資料管理展示系統中。這些資料可能是手繪平面圖和剖面圖到3D（空間）模型，有時甚至可能是精細的軟體所生成模型或是描述地質作用速率的4D（空間和時間）模型。

1.3.2 Brief for documentation of EGM components

1.3.2 EGM 組成成分之紀錄文件簡介

Table 1-3 is an example brief for consultants to follow when documenting the various components of an EGM. For small projects many of these items could be described in single paragraphs and the entire documentation presented in one brief report.

表1-3是提供顧問公司在記錄EGM的各個組成成分之簡要的範例。對於小型計畫，其中許多項目可以用單個段落描述，整個EGM紀錄文件可以是一份簡短報告。

In some circumstances, a site investigation may be designed using an EGM but upon completion of the investigation the contractual requirement may the production of a Factual Report only. The result will be that documentation of the EGM will be incomplete because it is lacking an interpretive content and this should be acknowledged and documented by all parties to the contract.

在某些情況下，EGM規劃了工址調查，但在調查完成後，合約可能僅要求提供紀實報告。此情形可能導致EGM的紀錄文件不夠完整，因它缺乏解釋性內容。合約各方都應認知和記錄這情形。

For large projects there may be several volumes of different reports in which the EGM components are included.

對於大型計畫，可能會有好幾冊攸關EGM各組成成分之報告。

When tendering for geotechnical services for large projects the provision of all of the components of an EGM should ideally be a separate scope item alongside and related to the provision of Factual and Interpretive Reports. In those circumstances, the Request for Tender documents should specifically describe the EGM development expectations, whilst the Tender evaluation process should consider the proponent's EGM capabilities and appropriate budget allowances should be made at project inception.

在與地工相關之大型專案計畫招標時，EGM的所有組成內容，理想上應將紀實報告和解釋報告獨立出來。在這種情況下，招標文件應具體描述EGM建置的預期成果，而招標評選估過程應考慮競標者對建置EGM的能力，並在專案計畫中編列適當預算執行。

1.3.3 Project procurement implications

1.3.3 專案計畫採購之應用

Documentation of the EGM components prepared in accordance with these Guidelines should ideally be included or referenced within the project documentation. Depending on the Client's project procurement strategy, there should be identifiable preservation points within the project schedule when the documentation of the EGM components should be completed and preserved as a record of what was known at that time. As the project progresses, the documentation of the EGM components can then be revised to reflect the changing knowledge. The following are typical preservation points:

根據指引所建立的EGM組成成分之紀錄文件，最好涵蓋在專案計畫文件中或於計畫文件引述。依據業主的計畫採購策略，在計畫時程表中應制訂EGM建立查核點，以利瞭解EGM完成時間與查核紀錄。隨著計畫的進展，可根據知識之累積滾動式修正EGM。以下是典型的查核點建議：

- For small projects there will be a single preservation point, usually at the completion of the site investigation.
- 對於小型計畫，通常在工址調查完成後會有一個單獨的查核點。
- For larger projects some, or all, of the following preservation points may apply:
    - At the completion of the Desk Study.
    - At the completion of each stage of the Investigation.
    - At completion of each stage of Design.
    - At finalisation of the contract for the Main Works.
    - At the agreement of Baseline Conditions, if applicable.
    - At agreed milestones during construction related to the completion of various project elements, for example, dam foundations, tunnels etc.
- 對於大型計畫，以下部分或全部的查核點可能適用：
    - 在室內研判完成時。
    - 在調查的每個階段結束時。
    - 在工程設計的每個階段完成時。
    - 在合約主要工作項目的定稿階段。
    - 在基準條件(Baseline Conditions)報告（如有）核定後。
    - 在施工期間各計畫項目所協定的里程碑完成時，例如大壩基礎、隧道等。

When tendering for the main works the contract documentation should ensure that the EGM is transferred to tenderers, where contractual arrangements allow.

在對主要工程進行招標時，合約文件內容應確保 EGM 可在合約同意下轉讓給投標者使用。

Table 1-3 Brief for documentation of EGM components

表 1-3 EGM 組成成分之紀錄文件簡介

1.	Documentation of the EGM components should follow the IAEG Guidelines for the development and application of engineering geological models on projects.

EGM 組成成分之紀錄文件應遵循 IAEG 指引，包括開發工程地質模型和於工程專案計畫之應用。

2. The EGM Development Level agreed with the client (the scope of the study) should be indicated.

   應說明與業主協定（研究範疇）的 EGM 開發等級。

3. A Factual Report should be presented that provides the results of all investigations, observations and laboratory testing including information from all previous studies.

   紀實報告應提供所有調查、觀測和室內試驗的結果，並包括先前研究的所有資訊。

4. An Interpretive Report should be presented (possibly as separate reports) that includes:

   解釋報告（可能作為單獨的報告）應包括：

   (i) The findings of the Desk Study.

   室內研判的發現。

   (ii) The Conceptual Model and the initial key risks identified.

   概念模型與所辨識之初始關鍵風險。

   (iii) The rationale for the site investigation design taking into account the conceptual model and the key ground risks.

   考慮概念模型和關鍵地盤風險所規劃的現場調查設計之邏輯。

   (iv) The identified Engineering Geological Units - volumes of the ground with a similar geological history and a similar geotechnical behaviour in the context of the project engineering.

   工程地質單元劃分結果 - 在專案工程計畫的背景考量下，具有相似地質歷史和相似的地工特性的地盤區域範圍。

   (v) A Geological Model that presents the distribution in 3D space of the engineering geological units, hydrogeological conditions and geological processes and how those might change in time.

   建立能展現工程地質單元、水文地質狀況和地質過程之 3D 空間分布以及隨時間變化地質作用的地質模型。

   (vi) A Geotechnical Model that presents the engineering characteristics and relevant geotechnical parameters of every aspect of the Geological Model. For every engineering geological unit identified an engineering description and geotechnical parameters should be provided.

   建立能代表地質模型中各單元工程特性和相關地工參數的大地工程模型，並提供每個工程地質單元所判釋的工程描述與地工參數。

   (vii) Maps, plans and sections at appropriate scales should be provided to illustrate the interpreted Geological and Geotechnical Models and to inform the engineering assessment of all geotechnical elements of the project. The combination of geological, geotechnical and project engineering information in the one drawing or set of drawings is often useful.

   提供適當比例尺的平面圖和剖面圖，以闡述經解釋後之地質模型和大地工程模型，以提供該專案計畫的所有地工參數之工程評估所需。提供一張或一組整合地質、地工及工程專案計畫資訊的圖說，通常很有用。

   (viii) A Geohazard Assessment if needed

進行必要的地質災害評估

(ix) If a 3D digital model forms part of the documentation a 3D Digital Model Report should be provided.

如果 3D 數值模型為 EGM 紀錄文件之一部分，應提供 3D 數值模型報告。

1.3.4 Reporting the EGM

1.3.4 EGM 報告

The reporting should be clearly differentiated into:

報告應明確區分為：

- Factual information and observations.
- 實際資訊與調查觀測
- Interpretations, including conceptualisations.
- 解釋描述，包括概念化
- Opinions.
- 觀點

The recommended reporting requirements for the following report types are described below.

以下介紹不同報告類型的需求建議。

1.3.4.1 Factual Report

1.3.4.1 紀實報告

A Factual Report should include, but may not be limited to, the following information:

紀實報告應包括，但不限於以下資訊：

- Objectives and agreed scope.
- 目的和協定的工作範疇。
- Location and description of the project site.
- 專案計畫工址的位置與工址描述。
- Description of the regional and local geology and any anthropogenic modifications to the project site based on pre-existing data.

- 根據既有資料，說明專案計畫工址之區域地質、現地地質，以及人為活動所造成的工址改變。
- Details of any previous investigations at the site or in close proximity.
- 過去工址或鄰近相似區域之任何詳細的調查資訊。
- A plan showing existing and current investigation locations.
- 既有和目前調查位置之平面圖。
- Investigation methods employed.
- 採用的調查方法。
- Results of investigations and information acquired.
- 調查成果及獲得的資訊。
- Laboratory and *in situ* testing carried out and a summary of the results.
- 採用的室內試驗和現地試驗，以及其試驗結果總結。

Any interpretation undertaken as part of the factual report, for example, the assigning of lithological or stratigraphical units, or geophysical interpretation, should be clearly recorded as such and the uncertainty associated with it, including alternative interpretations, documented. A 'limitation statement' relating to any interpretive aspects of what is primarily the factual content of the report may be included.

紀實報告中任何經解釋的內容，例如：岩性或地層單位的劃分，或地球物理探測結果的解釋，都應明確地記錄其不確定性及可替代的解釋。有關紀實報告書內容的任何解釋，應包括其限制聲明。

1.3.4.2 Interpretive Report

1.3.4.2 解釋報告

The Interpretive Report should include, but may not be limited to, the following components:
解釋報告應包括但不限於以下要項：

- Reference to the data upon which the interpretation is based (the factual or data report).
- 各項解釋說明所參考的資料（紀實或資料報告）。
- The findings of the desk study.
- 室內研判的成果。

- The conceptual model and the initial key risks identified.
- 概念模型與所辨識的初期關鍵風險。
- The rationale for the site investigation design taking into account the conceptual model and the key risks and uncertainties.
- 考慮概念模型、工址關鍵風險及不確定性，所規劃的現場調查作業之邏輯。
- Based on the findings of the investigation, sufficiently detailed and documented information relating to the following aspects of the project is required:
- 根據調查結果，需要下列與計畫有關、足夠詳細和有據可查的資料：
    - Stratigraphy, lithology, age, weathering and alteration.
    - 地層、岩性、年代、風化和侵蝕。
    - Structural setting, defect or discontinuity characteristics.
    - 構造、缺陷或不連續面的特徵。
    - Geomorphology and relevant surface and subsurface processes.
    - 地貌和與地貌相關之地表和地表下作用。
    - Surface and groundwater conditions.
    - 地表水和地下水條件。
    - Total Geological History relevant to the likely ground conditions.
    - 與地盤條件相關的“全地質歷史”。
    - Details of any anthropogenic modification to the project site.
    - 專案計畫工址中任何人為活動所造成改變的詳細資訊。
- The identified Engineering Geological Units and the basis for their adoption.
- 判釋的工程地質單元及其劃分採用的依據。
- A Geological Model that presents the distribution in 3D space of the engineering geological units, hydrogeological conditions and geological processes and how those might change in time, their controls and boundary conditions and groundwater, geomorphological processes and geohazards that have been observed or interpreted to occur on and around the site. The Geological Model should characterise units of the ground with similar engineering properties

and describe boundaries where changes in conditions may occur. The regional context of the Geological Model should be discussed. Uncertainty in the Geological Model should be characterised. Depending upon project and reporting requirements, the Geological Model that is presented may have a specific project-related focus and may be better described as, for example, a hydrogeological model or a rock mass model.

- 能呈現工程地質單元、水文地質狀況和地質作用的 3D 空間分佈以及它們如何隨時間變化之地質模型、其控制因素和邊界條件、地下水、地貌作用和工址以及周圍已觀察到或認為會發生的地質災害。地質模型應表徵具有相似工程特性的單元，並描述發生特性變化的邊界。地質模型的區域地質特性應予以討論，並闡述(特徵化)地質模型的不確定性。根據專案計畫報告要求，所提出的地質模型應與計畫關心特定重點相關，例如專案計畫關心重點為水文地質模型或岩體模型。

- A Geotechnical Model that presents the engineering characteristics and geotechnical parameters of every relevant aspect of the Geological Model, considering the project to be procured. For every engineering geological unit identified an engineering description and geotechnical parameters should be provided. The range of material properties should be described and the typical range of parameters provided. Uncertainty in the Geotechnical Model should be characterised. The choice of engineering parameters for use in analysis should be based on the above information.

- 能展示專案計畫地質模型各單元其工程特性及相關之地工參數的地工模型。對每個劃分的工程地質單元，應當提供工程特性描述和地工參數，並應描述材料特性的範圍和提供的典型參數範圍，而地工模型的不確定性也需闡述(特徵化)。分析使用的工程參數應基於上述資訊加以選擇。

- Any zoning that has been used or domains that have been defined and the basis for their adoption.

- 任何已使用的分區或已定義的區域，以及說明劃分的根據。

- A Geohazard Assessment where needed.

- 地質災害評估(若有必要時)。

- An engineering interpretation of the implications of the ground conditions for the project.

- 地盤條件可能影響專案計畫的相關工程解釋。

- Maps and sections at appropriate scales covering the site and surrounds should be provided to illustrate the interpreted Geological and Geotechnical Models and to inform the engineering assessment of all geotechnical elements of the project. Depending upon the project, the combination of information relating to the Geological Model and the Geotechnical Model in the one drawing can be useful as the basis for providing presentations to clients, shareholders, insurers, or the general public.

- 應提供涵蓋工址和周圍地區的適當比例尺之平面圖和剖面圖，以說明所解釋的地質模型和地工模型，並為計畫所有地工要項的工程評估提供資訊。視專案計畫的特性，利用整合地質模型和地工模型的圖資，有利於向業主、雇主、保險公司或公眾提供說明。
- If a 3D digital model forms part of the documentation a 3D Digital Model Report should be provided that communicates digital model uncertainty and reliability. All relevant database files that include interpreted data and the 3D data files (for example, the mesh files for the engineering geological boundary surfaces) should be included.
- 如果 3D 數值模型為紀錄文件之一部分，應提供 3D 數值模型報告以說明模型的不確定性和可靠度。包括解釋資料和 3D 資料檔（例如，工程地質邊界表面的網格資料）在內的所有相關資料庫檔案均應提供。
- Recommendations for further work, if relevant or necessary.
- 如果相關或必要，應提出工程地質模型建模後續工作的建議。
- Uncertainties remaining.
- 說明仍存在的不確定性。
- A 'limitations statement' relating to any aspects of the report, where this is deemed necessary.
- 如果認為有必要，需提出報告的有關的"限制聲明"。

1.3.4.3 Geotechnical Baseline Report

1.3.4.3 大地工程基準報告

In some larger projects, particularly underground works, the Owner and their engineers may opt to prepare a Geotechnical Baseline Report (GBR) to allocate the risks associated with the ground between the employer and the contractor.
在一些較大的計畫中，特別是地下工程，業主及其工程師可以選擇準備大地工程基準報告 (Geotechnical Baseline Report, GBR)，來定調業主和承包商之間與地盤相關的風險。

1.3.4.4 Engineering Geological Maps and Sections

1.3.4.4 工程地質圖與剖面圖

Engineering Geological maps and sections are a fundamental part of the EGM knowledge framework and should be prepared in accordance with these Guidelines.
工程地質圖和剖面圖是 EGM 知識框架的基本組成部分，應按照本指引編製。

1.3.5 Creating and visualising a 3D digital model

1.3.5 建立以及視覺化 3D 數位模型

There has been a recent but fundamental shift to using software to create 3D digital models, typically for medium to large scale projects or where complex geology is encountered. This, in turn, has led to a step change improvement in the interoperability of the EGM knowledge framework with other disciplines. A typical 3D digital model development process is shown in Figure 1-5 below.

近期使用軟體建立 3D 數位模型漸趨增多，特別是在中大型專案或複雜的地質情況。亦使 EGM 知識框架與其他專業領域的互通性逐漸精進。典型的 3D 數位模型建立流程如圖 1-5 所示。

1.3.5.1 Modelling Software

1.3.5.1 建模軟體

There is a wide range of software packages that can be used to produce 3D and 2D digital models.

現有已經有多種套裝軟體可以用於產出 3D 及 2D 的數位模型。

1.3.5.2 Data Sources and Management

1.3.5.2 資料來源與管理

Clear, retrievable records of how datasets are created/modified/interpreted/stored, as well as of verification and other stages of the development process should be retained. To assist in the check/review/verification/approval process it is important to retain clear, retrievable records (metadata) of how datasets are created/modified/interpreted/stored. The linkages between original datasets and the modified model datasets are useful to maintain consistency, accountability and to provide insight into model uncertainty.

應保留關於如何創建/修改/解釋/存儲數據集以及驗證和開發過程其他階段的清晰、可檢索的紀錄。為了協助檢查/審查/驗證/批准過程，保留關於如何創建/修改/解釋/存儲數據集的清晰、可檢索的紀錄（詮釋資料）非常重要。原始資料與修改後用於建模的模型資料之間應該保有一致性、可解釋(合宜)性，且能有助於洞察模型的不確定性。

1.3.5.3 3D digital model documentation

1.3.5.3 3D 數位模型紀錄文件

Each significant version of a 3D digital model should be accompanied by a 3D Digital Model Report.

每個重要的 3D 數位模型版本都應附有 3D 數位模型報告。

The 3D Digital Model Report should document:

3D 數位模型報告應記錄：

- The project, the purpose and the scope of the model.
- 專案計畫簡介，模型的目的和範疇。
- A summary of the site engineering geology.
- 工址之工程地質綜述。
- The geographical extent, scale and applicability of the model and the coordinate system used.
- 所使用之坐標系統，以及模型的地理空間範圍、比例尺和適用性。
- The inputs into the model, including subsurface data, map data, surface and subsurface point data and surfaces and meshes that have been used to formulate the digital model, an assessment of the quality and reliability of the different datasets and what manipulation/transformation has been undertaken for them to be incorporated into the model.
- 記錄模型的輸入資料，包括地下資料、地圖資料、地表和地下點資料以及用於建置數位模型的曲面和網格、對不同資料集的品質和可靠性的評估結果，以及將它們納入模型時進行了哪些操作/轉換。
- The units and bounding surfaces shown in the digital model, that may be geological, engineering geological, geomorphological, hydrogeological or geochemical, depending on the model purpose.
- 數位模型中顯示的工程地質單元和邊界曲面，可能是地質、工程地質、地貌、水文地質或地球化學特性單元，具體取決於建立模型之目的。
- The data that have not been used and why they have been omitted.
- 未使用的資料以及不使用這些資料的原因。
- The reliability and status of the model and an outline any other assumptions and uncertainties in the model, including model reliability and related risks.
- 模型的可靠度和狀態，並概述模型中的任何其它假設和不確定性，包括模型可靠度和相關風險。
- Evidence of verification.

- 有經過驗證之證據。
- A summary of outputs produced from the model, including any limitations.
- 綜述透過模型而產生之輸出成果，包括使用這些輸出成果之任何限制。
- The Model Decision Register and a listing of the data management/version development of the 3D digital model including:
    - Date of decision.
    - Detail of decision/change.
    - Justification for the decision/change.
    - Verification/review comments.
- 模型決策管制表和 3D 數位模型的資料管理/版本開發清單，包括：
    - 決策日期。
    - 決策/變更的詳細資訊。
    - 決定/更改的理由正確性評估。
    - 驗證/審查評論。

The 3D Digital Model Report should be updated each time the 3D digital model is re-issued. On larger projects where investigations are occurring on multiple fronts the model can be updated daily as the model can be linked directly to databases and new data are automatically incorporated. A competent engineering geologist should check new data when they are imported to confirm the appropriateness of the existing interpretation and to perform any manual editing required to incorporate the new dataset.

每次重新發佈 3D 數位模型時，都應更新 3D 數位模型報告。在多方調查的大型專案計畫，模型可以直接連結到資料庫並且會自動合併新資料，因此模型可以每天更新。在導入合併新資料時，應先由能勝任(具專業能力與經驗)、稱職的工程地質師對新資料進行檢查，以確認自動判釋結果的合理性，同時手動編輯所需調整的內容。

1.3.5.4 Review of 3D digital models

1.3.5.4 3D 數位模型審查

Review of 3D digital models should demonstrate their reliability with emphasis on the quality of the process involved in their construction, clarity of understanding and transparency with respect to uncertainties. Above all else, the review should demonstrate the agreement between the outputs of the digital model and the reality of the observed and interpreted engineering geological conditions.

3D 數位模型的審查應呈現其可靠度，重點是建置 3D 數位模型過程的品質及關於不確定性的理解清晰度和透明度。最重要的是審查應呈現出，數位模型輸出成果與經過調查觀測以及解釋過的真實的工程地質狀況，兩者之間的一致性程度。

Whenever 3D digital models are developed, it is recommended that illustrative 2D plans and sections should also be generated to ensure that linkage to the underlying EGM is transparent and can be explored by non-technical individuals without the use of proprietary viewing software. The development of illustrative plans and sections is also often a useful way of detecting engineering geological 'irregularities' in the model.

每當建置 3D 數位模型時，建議應一併製作說明清楚的 2D 平面圖和剖面圖，確保與 EGM 之間是透明連接的，並且非技術人員可在不使用專用軟體之情況下瞭解 EGM。平面圖和剖面圖通常也是檢測出模型中不正常處的有效方法。

The checklist in Table 1-4 below provides specific items for consideration during review and verification where a 3D digital model has been developed.

表 1-4 詳列 3D 數位模型審查和驗證所需要考慮的特定項目。

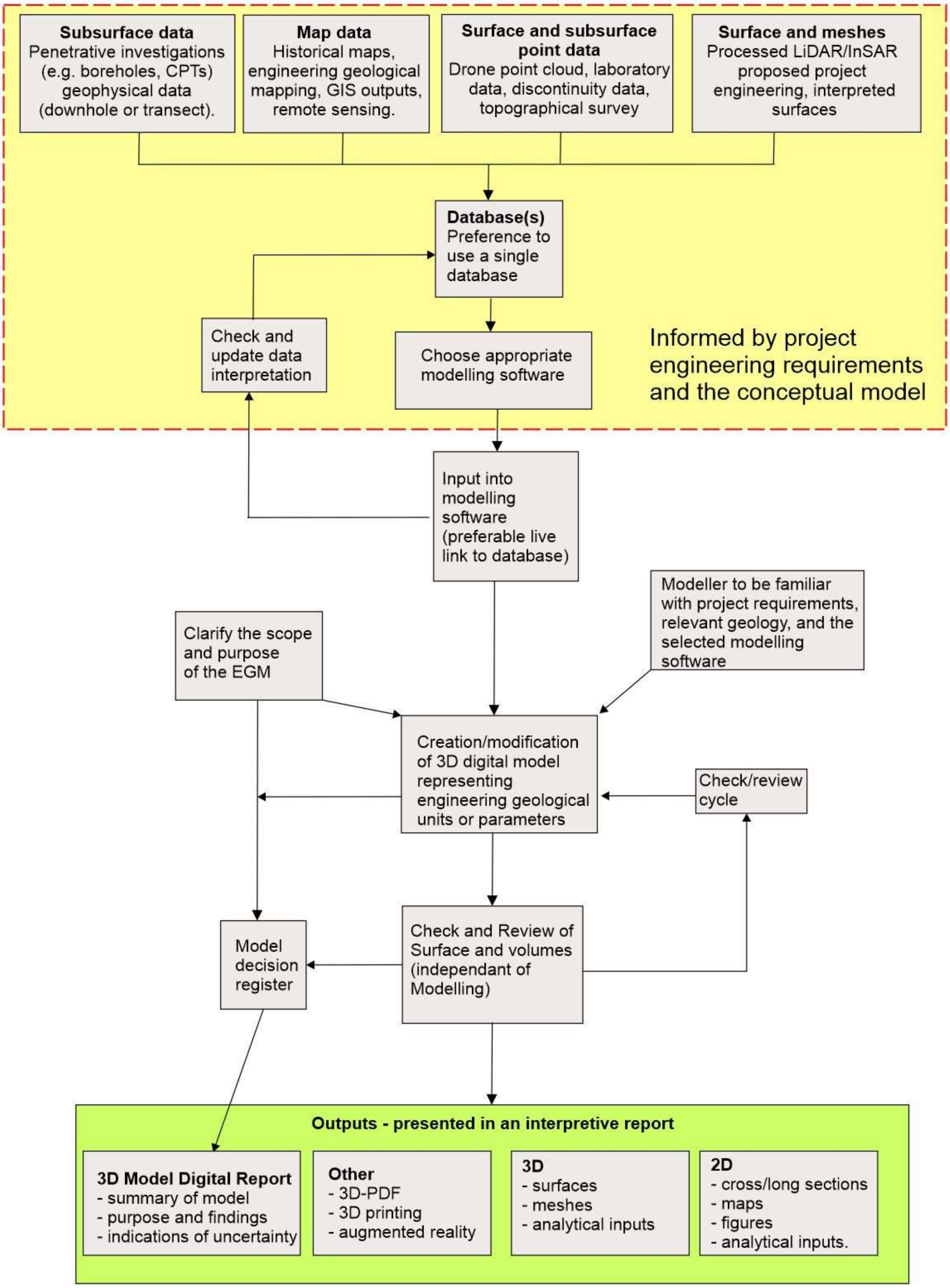

Figure 1-5 Typical digital 3D digital model development process.

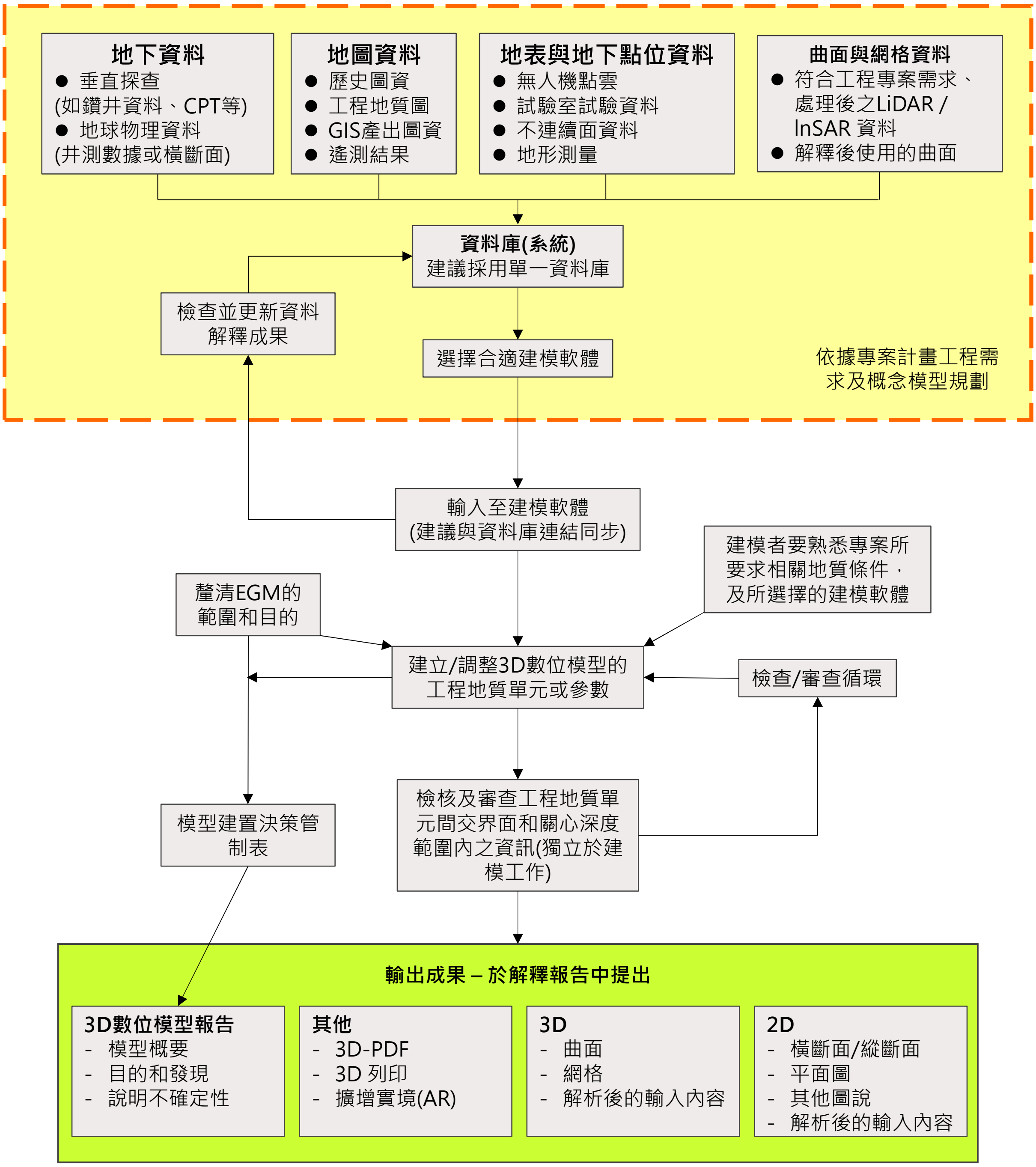

圖 1-5　典型的數位化 3D 數位模型建置過程

Table 1-4 Checklist for review of 3D digital models.

表 1-4 數位模型審查清單

Key activity 主要項目	Status 檢核結果
Has the purpose of the model been clearly defined? 是否明確定義了建立模型的目的？	
Does the model extent cover the area of interest to the project and the extent of possible effects of the project, if the model is to be used for assessments of effects? 如果模型使用於評估專案計畫影響性，模型範圍是否皆已涵蓋專案計畫所涉及和可能影響的範圍？	
Have the sources of data used to formulate the model been clearly identified? 使用於建立模型的資料是否有確認過來源？	
Is the quality of the data available sufficient for the purpose of the model? 使用的資料品質是否能夠滿足建立模型的目的？	
Do any other potentially useful data sources need to be incorporated into the model? 是否有其他可能有用的資料需整合到模型中？	
Are data that have been specifically omitted from the model reasonable to disregard and have reasons been given why these sources have not been considered applicable? 模型中被省略不用的資訊是否合理，是否說明為什麼這些資訊被視為不適用的理由？	
Are there an adequate number of data points and a reasonable distribution of points across the model area to make a reasonable representative interpretation? 模型區域內的資料點數量是否足夠，點的分佈是否足以做出合理的代表性解釋？	
Is the manipulation of the data that has been used applicable and geologically reasonable? 對已使用的資料處理方式是否適用，從地質角度來說使用資料是合理的？	
Has the model been reviewed in accordance with the EGM Development Level? 是否根據 EGM 開發等級對模型進行審查？	
Has the Reviewer been 'walked through' the model by the Modeller? 建模者是否有向檢核者實際操作並解釋模型？	
Have illustrative maps and cross sections been provided? 是否提供說明清楚的平面圖和剖面圖？	
Has a 3D Digital Model Report been prepared that includes a Model Decision Register, identified uncertainties and associated risks and recommendations to improve reliability? 是否備有 3D 數位模型報告，其中包括模型決策管制表、已識別的不確定性和相關風險以及提高可靠性的建議？	

1.3.5.5 Outputs of 3D digital models

1.3.5.5 3D 數位模型的輸出

Once the 3D digital model and the outputs have been checked and verified and are ready for issue the digital model itself and the specified outputs can be delivered. The nature of the outputs will influence how the information is presented. They might be 3D or 2D outputs (or both) depending on the project requirements but there may be no need for visualisation software if this is not the most effective method of communication – maps, charts, cartoons, presentations etc. may be more effective. The form in which the outputs are presented, and the level of detail included, should be tailored to the audience.

一旦 3D 數位模型及輸出檔經過檢查和驗證並準備好發佈，就可以提交數位模型本身和指定的輸出檔。3D 數位模型輸出的性質將影響訊息呈現的方式。根據專案計畫要求，它們可以是 3D 或 2D 輸出（或兩者皆有）。但如果這不是最有效的溝通方法，亦可能不需要可視化軟體，有時候地圖、圖表、示意圖、報告展示等可能更有效。最終，應該以適合受眾的方式呈現輸出的形式以及詳細程度。

Refer to Commentary Section 2.3 ASSEMBLY AND COMMUNICATION OF THE EGM for further information
相關資訊請參考註釋章節第 2.3 節：EGM 的組成與溝通

1.4 MANAGING EGM UNCERTAINTY

1.4 管理 EGM 的不確定性

1.4.1 Introduction

1.4.1 簡介

Uncertainty within the EGM has the potential to reduce the reliability of the project engineering and increase the potential for project risks. The uncertainty should be assessed and strategies developed to reduce the uncertainty and the associated project risks to agreed levels.

EGM 的不確定性有可能降低專案工程計畫的可靠度，並增加專案計畫風險。應對 EGM 的不確定性進行評估，並針對如何降低此不確定性與相關專案風險來制定策略，以降低至可容許的等級。

1.4.2 Sources of uncertainty

1.4.2 不確定性來源

The way that the knowledge is accumulated within the EGM reflects the dynamic relationship between the conceptual component and the observational component. These two fundamental components of the EGM are characterized by different sources of uncertainty: conceptual uncertainty and observational uncertainty.

EGM 知識積累的方式反映了概念成分和觀察成分之間的動態關係。這兩個 EGM 基本組成部分具有不同的不確定性來源：「概念不確定性」和「觀測不確定性」。

- Uncertainty occurring in the conceptualisation process is due to a lack of knowledge or bias. This is also known as epistemic uncertainty but for ease of reference these Guidelines have adopted the term conceptual uncertainty. Conceptual uncertainty primarily reflects the appropriateness of the concepts underlying the EGM that, in turn, are heavily dependent on the knowledge and experience of those involved.

- 發生在概念化過程中的不確定性，是由於缺乏知識或偏見，也稱為「知識不確定性」。為了便於參考，指引都採用「概念不確定性」此術語。概念不確定性主要反映了 EGM 所依據的概念的適當性，而這些概念又在很大程度上取決於建模相關人員的知識和經驗。

- Uncertainty in the data within the observational model is due to variability and randomness of the intrinsic properties of the ground and the measurement accuracy of the testing devices. This is known as aleatory uncertainty but for ease of reference these Guidelines have adopted the term observational uncertainty. Areas with fewer direct observations are likely to be more uncertain than areas with frequent direct observations. Note that any interpretation of the data within the observational model will be associated with conceptual uncertainty.

- 觀測模型中資料的不確定性，是由地盤內在特性的變異性和隨機性以及試驗設備的測量精度造成的。這被稱為「隨機不確定性」，但為了便於參考，本指引採用了「觀測不確定性」一詞。直接觀察數量較少的區域可能比較多直接觀察的區域更具有不確定。請注意，觀測模型中資料解釋都與概念不確定性相關聯。

1.4.3 Holistic assessment of EGM reliability by review

1.4.3 利用審查對 EGM 的可靠度進行整體評估

Review of the project should assess the reliability of the observational and conceptual components of the EGM holistically, rather than separating them. The Development Level of the project provides guidance as to the type of review (Section 1.2.2. – Tables 1-1 & 1-2).

在專案審查時，應針對 EGM 的調查觀測成分和概念成分的可靠度進行整體評估，而不是將它們分開評估。計畫的開發等級（編註：級別越高越複雜）決定了審查方式（第 1.2.2 節 – 表 1-1 和 1-2）。

- For Level 1 projects internal reviews will provide a basic check of EGM reliability. Another engineering geologist from the project team responsible for the EGM should undertake a check of the development and refinement of the model. The reliability of the conceptual component should be benchmarked against appropriate conceptual analogues derived from education, experience and the literature and the compatibility of the observational component with the conceptual component evaluated.

- 對於第 1 級的計畫， EGM 可靠度的基本檢查可依靠內部審查提供協助。可請求 EGM 計畫團隊的工程地質師，檢查模型的開發和精進要項。概念成分的可靠度應與得自教育、經驗和文獻中適當概念類比進行比較，另外，也應比較調查觀測成分與所評估的概念成分的相容性。

- For Level 2 projects the review will be as for Level 1 but undertaken by external reviewers. These may be external to the project team or external to the organisation itself.

- 對於第 2 級的計畫，審查將與 1 級相同，但是由外部審查委員進行。這些可能是計畫團隊外部的，也可能是組織本身外部的。

- For Level 3 projects an expert review panel consisting of acknowledged experts should ideally be used to assess the reliability of an EGM by independently reviewing and commenting on the content, completeness and reliability of the project documentation. These should be appointed by the client as independent specialists.

- 對於第 3 級的計畫，最好由知名專家組成的專家評審小組，通過獨立評審和評論專案計畫紀錄文件的內容、完整性和可靠度，以評估 EGM 的可靠度。這些專家應由客戶指派且為獨立專家。

1.4.4 Other methods of assessing the uncertainty and reliability of the EGM

1.4.4 其他評估工程地質模型不確定性和可靠度的方法

All the information that contributes to the EGM needs to be assessed to evaluate both uncertainty and reliability. For the observational component of the EGM, such checks are relatively straightforward and can be undertaken either quantitatively or qualitatively.

所有 EGM 的資訊都需要進行不確定性和可靠度評估。對於 EGM 的調查觀測成分，此類檢查相對簡單直接，可以定量或定性地進行。

However, quantitative methods cannot realistically assist in reducing reliability errors stemming from inaccuracies in conceptual understanding. Only by checking the veracity of the concepts through qualitative approaches can this component of the EGM be assessed and, thus, its level of reliability confirmed.

然而，因概念理解不精確而導致的可靠度問題，無法透過定量方法克服或降低錯誤。EGM 的概念成分可靠度水準，只能透過定性方法檢查概念的真實性，才能予以確認。

1.4.4.1 Assessing the reliability of the conceptual component

1.4.4.1 評估概念成分的可靠度

An approach to the assessment of the conceptual component of the EGM is illustrated in Figure 1-6. This approach should be adopted at all stages of the project by individuals, peer reviewers and expert panels.

圖 1-6 說明了評估 EGM 概念成分的方法。專案計畫的所有階段，不論是個人、同儕評審和專家小組的審查，均應採用這種方法。

The best means for assessing the reliability of the conceptual component is through expert panel or peer review. However, basic qualitative checks of the conceptual reliability of an EGM should also made as it is developed. Self-checking, as well as internal checking, should always be carried out, the results of which should be documented.

評估「概念成分可靠度」的最佳方法是通過專家小組或同儕評審。然而，在 EGM 開發過程中，應對 EGM 的「概念可靠度」進行基本的定性、質化檢查，同時也應進行內部自我檢查，並記錄檢核結果。

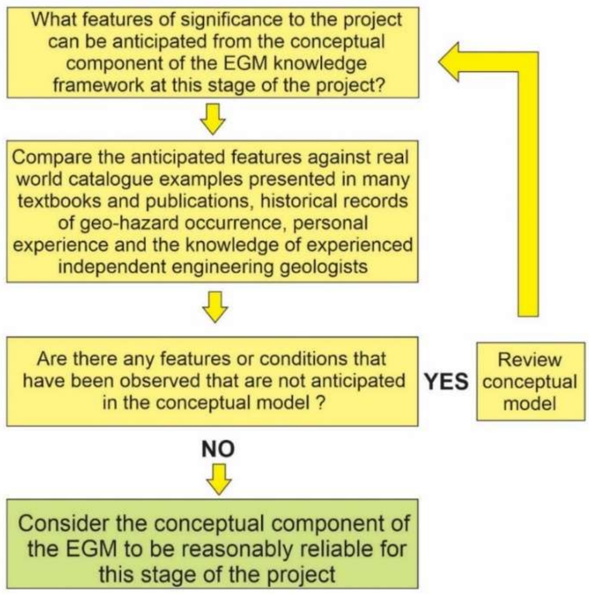

Figure 1-6 Approach for assessing the reliability of the conceptual component of the EGM.

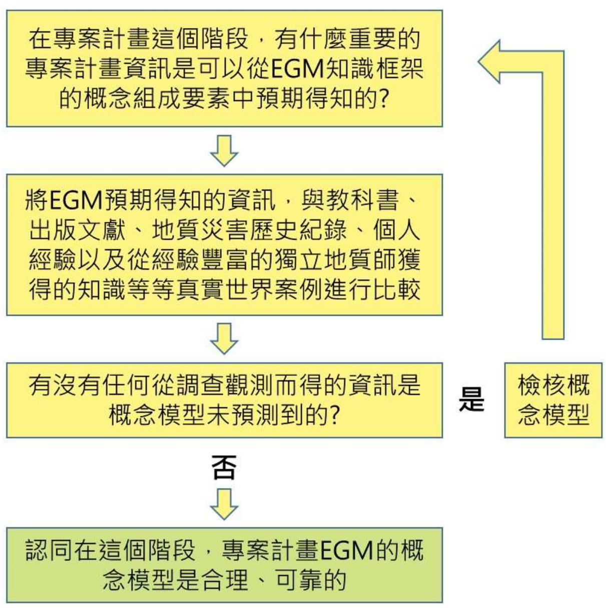

圖 1-6　評估 EGM 概念成分可靠度的方法

1.4.4.2 Assessing the reliability of observational component - qualitative approaches

1.4.4.2 評估調查觀測成分的可靠度 - 定性方法

The reliability of the observational component of the EGM can be communicated qualitatively using methods such as thematic maps and the classification of the reliability of datasets.

可以使用主題式平面、剖面圖和資料的可靠度定性分類方法，評估 EGM 調查觀測成分的可靠度。

1.4.4.3 Assessing the reliability of observational component - semi-quantitative approaches

1.4.4.3 評估調查觀測成分的可靠度 - 半定量方法

Various methods have been devised in which the components of the EGM are graded and the various scores combined to provide an ordinal numerical assessment of reliability.

目前已經有多種方法可針對 EGM 的調查觀測成分可靠度進行分級，並將各種分數組合起來，以量(數字)化可靠度。

1.4.4.4 Assessing the reliability of observational component - quantitative approaches

1.4.4.4 評估調查觀測成分的可靠度 - 定量方法

Quantitative assessments are limited to evaluating the observational components of the EGM, and three families of tools can be employed:

定量評估僅限應用於評估 EGM 的調查觀測成分，可以使用三種工具群：

- Random Field simulations and Random Finite Element Method (RFEM involves the use of random virtual ground combined with finite element analysis within a Monte Carlo simulation).
- 隨機場模擬和隨機有限元素法（RFEM 是以蒙地卡羅模擬中的隨機虛擬地盤做有限元素分析）。
- Geostatistical methods (both stationary and non-stationary, such as kriging methods).
- 地質統計方法（包括定常性與非定常性，例如 kriging 法）。
- Stochastic simulations.
- 隨機模擬。

Refer to Commentary Section 2.4 MANAGING EGM UNCERTAINTY for further information

相關資訊請參考註釋章節第 **2.4** 節“管理 **EGM** 的不確定性”

1.5 ENSURING EGM QUALITY

1.5 確保 EGM 品質

1.5.1 Checking the quality of the EGM development process

1.5.1 EGM 開發流程的品質檢核

An EGM of appropriate quality should be achieved if these Guidelines are implemented. A QA/QC (Quality Assurance/Quality Control) checklist for adherence to these Guidelines is set out in Table 1-5.

當落實 EGM 指引的建議時，我們可以得到一個良好品質的 EGM。表 1-5 是根據 EGM 指引所創立的品質保證/品質控制(QA/QC)檢核流程表。

Table 1-5 EGM QA/QC Process Checklist

表 1-5 EGM 品質保證/品質控制檢核流程表

Key activity 主要項目	Status 檢核結果
Has an effective, competent team, including a reviewer, been assembled? 是否組成了一個有效、稱職的團隊(包括審查者)?	
Has the scope and purpose of the EGM been clearly defined? 是否已明確定義 EGM 應用的範疇及目的?	
Is the EGM compliant with the tender documents/specifications? EGM 是否符合招標文件與規格?	
Has the relevant engineering and geological information of significance to the project been assembled in a desk study? 是否在室內研判階段即已納入專案計畫相關的工程與地質資訊?	
Has an appropriate geographical extent and scale been defined to present the EGM? 是否已適當定義 EGM 所需的範圍與比例尺?	
Have observations been acquired through investigations and documented as facts? 觀測結果是否依據現場調查而來，並予以詳實記錄?	
Are the sources of data used to formulate the EGM clearly identified? 是否清楚地確認過建立 EGM 所引用的資料來源?	
Is the quality of the data available sufficient to meet the purposes of the EGM? 所使用資料的品質是否滿足 EGM 建立的目的?	
Are there any other potentially useful data sources?	

是否還有其他可能有用的資料來源?	
Have data been specifically omitted from the EGM and is that reasonable? 是否有資料於建立模型時被忽略? 其是否合理?	
Have observations been related to the concepts and a range of engineering geological conditions been conceptualised and interpreted? 調查觀測結果是否能與工程地質條件概念結合?其中工程地質狀況是否被解釋及概念化?	
Have engineering geological units and their engineering characteristics been defined? 是否已定義工程地質單元及其工程特性?	
Has a Geological Model been presented? 是否提出地質模型?	
Has a Geotechnical Model been presented? 是否提出地工模型?	
Has a Geohazard Assessment been presented? 是否提出地質災害評估?	
Have significant risks, gaps and discrepancies in the knowledge framework been identified? 是否辨識出知識框架中值得注意的風險、資訊落差及不一致之處?	
Has information for use in engineering analysis been provided? 是否提供工程分析所需資訊?	
Has the entire EGM knowledge framework been documented? 是否記載完整 EGM 的知識框架?	
Have maps and sections been provided to illustrate the engineering geological conditions that are of significance to the project? 是否以平面圖和剖面圖來說明對計畫具有重要意義的工程地質狀況？	
Has further knowledge required to improve the EGM, reduce the risks, facilitate upgrade to the design or deal with claims been indicated? 是否提供足以改善工程地質模型、降低風險、提升設計品質或處理求償爭議的進一步資訊?	
If a 3D digital model has been developed has the checklist in Table 1-4 been completed? 如果建立了 3D 數位模型，是否已依表 1-4 完成檢核?	
Has the EGM been reviewed by a suitably qualified and experienced engineering geologist appropriate to the level of complexity of the geology and the project? EMG 是否經合格且經驗豐富工程地質師進行審查? 審查者應能匹配於此專案計畫涉及的地質與工程複雜程度。	

Refer to Commentary Section 2.5 ENSURING EGM QUALITY for further information

相關資訊請參考註釋章節第 **2.5** 節：確保 **EGM** 品質