SITE INVESTIGATION WITHIN THE DEVELOPMENT PROCESS

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1. INTRODUCTION

A knowledge of the ground which forms a site is essential to its safe and economic development. This has been highlighted by numerous authorities over many years and will have been further emphasised by authors of papers presented at the Symposium on Investment, Insurance and Investigation (June 1997). It is vital that the process of acquisition of this knowledge ensures that it is gained competently, in a timely manner and to a degree which is adequate and appropriate to each stage of design and development. In this way risk and liability are minimised and the potential for economic and safe design maximised. Hence, the likelihood of project completion on time and within budget is dramatically increased.

This paper considers the nature of the Site Investigation process and highlights the ways in which it should be implemented within the site development process to best advantage.

2. THE NATURE OF SITE INVESTIGATION

In constructing a building, the materials of which it is to be made have generally been produced or selected under carefully controlled recent processes to meet precise specifications for content and performance. If they fail to meet these specifications they will be rejected. In contrast, however, the soils or rocks which are present at a site have resulted from the processes of nature over thousands of millions of years and have been subjected to an enormous range of influences including tectonic movements, volcanic activity, deposition, erosion, glaciation and

weathering. They have not been produced by any artifically controlled process to any specification and have to be accepted on the site, at least initially. In the very recent past, human activity has also had an influence and is another geomorphological process. Yet these materials are in a very real sense the most fundamental part of a site and play a major role in the construction process, in subsequent behaviour and hence in the success of a project.

There is therefore a vital compensating need to match the knowledge of a site's characteristics with the specifications for the construction materials if the reasonable aspirations of those who wish to develop, invest in, insure or use the facility to be constructed are to be met. Regrettably this need has neither been appreciated nor fulfilled in many if not most developments.

The nature of the investigation process is totally different from the construction process since it seeks to understand and measure the characteristics and distribution of the materials present rather than to specify them. The product is data, not a physical feature. The quality depends on those obtaining them, the value on those specifying and interpreting them. It is necessary to consider how the materials will respond to the proposed development in order to subject them to an appropriate scale and depth of study and to specify the form and nature of any insitu and laboratory testing which would be required.

Thus the process is one of Research and Development:- Research of the materials present so that Development can take place. Those undertaking this work must therefore understand this approach and be aware of geological, investigation, testing and interpretation processes.

3. STRUCTURE OF INVESTIGATION

3.1 Key Elements

The most important elements of the process of successful Site Investigation are:-

- Client Commitment.
- Competent Geotechnical Advice - at all stages.
- Competence of the Ground Investigation Specialist.
- Adequate funding and time allocation linked to-
- Phased investigation.

3.2 Client Commitment

An understanding by Clients of the importance of a knowledge of the ground to successful site development, and hence to the means of adequately investigating and interpreting it, is vital. It may be that the developer needs guidance in this

respect from his Principal Technical Advisers but a commitment to the process is vital. This Symposium should have at least stimulated that understanding. It may be that the primary motivation of individuals or groups will vary. Perhaps the dominant motivation with one developer may be the limitation of liability, in another the saving of construction cost, in a third for the need to complete projects to a well defined time schedule, in a fourth perhaps the certainty of cost is the key motivation or the minimisation of impact on the area or community. Whatever the motivation, adequate investigation will impact on all these areas. Public bodies such as the Highways Agency have for many years appreciated the importance of these aspects and have set up strategies to address them. Even with Clients such as this, however, it can be difficult to extend the message through all its departments.

Examples of success of the process of investigation, as well as examples of problems arising from the lack of it presented to this Symposium, together with much published data, should serve as justification for a commitment to adequate and good quality investigation. If things go wrong the Client suffers and insurance will never cover the whole cost of failure or claw back wasted time or opportunity. With Client commitment, all the components of the structure can be put in place.

3.3 Competent Advice and Implementation

In virtually all publications dealing with Site Investigation the common element of importance is seen to be the need for competent geotechnical advice at all stages from inception to construction and beyond. Increasingly, environmental concerns are seen as being of considerable importance and parallel those of geotechnical aspects. Both of these components are ground-related and the required experience may reside in the same individual or team.

3.3.1 Relevance

Why is it important that a geotechnical specialist is involved from the outset? They should bring with them the knowledge of geology to allow a three dimensional picture to be formulated from available data. In the context of initial proposals for development, the impact upon it of the perceived ground conditions and associated properties can be assessed and a strategy for investigation to delineate those properties formulated. This requires a knowledge of the techniques available to obtain these properties, their advantages and limitations, as well as the associated costs and time scales for determining them.

As data is obtained, so further understanding is required, not only of the investigation techniques but also of methods of testing, interpretation and available means of solving the problems which the ground conditions may give rise to. Where conventional foundations prove unsuitable, solutions may include specialist ground treatment or piling or may indicate that more sophisticated

analysis would be justified and an associated further focused investigation and testing programme developed.

3.3.2 Definitions

How then is the senior development team member to be defined and selected? In "Planning, procurement and quality management" (1) produced by the Site Investigation Steering Group (SISG) the characteristics, qualifications and experience of Geotechnical Advisers and Geotechnical Specialists are identified (Figure 1).

Consumer	Questionnaire replies: mean % spent	Calculated: % spent
Clients		
Government authorities	2.21	0.29
Manufacturing/commerce	0.76	0.22
Civil engineering contractors	0.85	0.23
Developers/builders	0.72	0.11
Consultants		
Architects	0.29	0.14
Multidiscipline consultants	0.92	0.23
Civil engineers	1.94	0.29
Structural engineers	0.23	0.16
Average	0.99	0.21

Figure 1 - Routes to becoming a Geotechnical Adviser (SISG 1993)

The emphasis is on both qualifications and experience. The infinite variety of ground conditions and of the demands which construction makes on them is such as to render experience of particular importance. Rarely do the conditions or requirements of schemes fall into simple text book cases. They are truly four dimensional. Simple models are useful but in essence form a type of "identikit" on which to base assumptions in design. In a memorable presentation to the Seventh European Conference on Soil Mechanics and Foundation Engineering in 1979, Dr Bassett drew the analogy between ground model selection and the Miss World Competition. Selection on the basis of the most detailed criteria still requires experience and does not guarantee behaviour under stress but may be

satisfactory for most, though not all purposes.

3.3.3 Selection of a Geotechnical Adviser

In "Planning, procurement and quality management" (1) guidance on the procurement of a Geotechnical Adviser is given. It indicates that the names or organisation of suitable candidates can be found in the British Geotechnical Society's Geotechnical Directory (2) or from the Membership Directory of the Association of Geotechnical and Geoenvironmental Specialists (AGS) (3). The latter group has drawn up a Code of Conduct for its members to follow and hence re-assure clients. From this initial step a short-list can be prepared and detailed CV's obtained together with the profile of the firm of which they are a part, if not an individual practice. The SISG document goes on to outline aspects such as responsibilities and the basis for remuneration.

From this appointment should flow the remaining requirements for adequate and appropriate investigation through the structure and form of investigation, interpretation, evaluation, construction monitoring and post-construction performance. These stages are dealt with later in this paper.

3.3.4 Selection of Ground Investigation Specialist

The Geotechnical Adviser, be it an individual or company, will either have within his own team the competence to undertake the physical investigation work or be aware of the companies which can supply the required service. It is equally important that these companies have the necessary expertise and capacity to produce results to the required standard at reasonable cost. It is important to recognise that the most competent are not necessarily the cheapest. If the exercise were merely to drill a hole and fill it in again perhaps that is one of a range of appropriate criteria, but even here the technical competence to drill in particular ground conditions to the necessary standard and depth, with the consequent disturbance and affects on programme, is equally important.

Technical capability in producing borehole records which accurately describe ground conditions is important, as is the ability to test soils to nationally recognised standards, where appropriate. British Drilling Association (BDA) accreditation of drillers goes some way to deal with the former problem whilst NAMAS (now UKAS) accreditation relates to the latter.

Various techniques for procurement are dealt with in the second SISG document (1) and in Uff and Clayton (4). Procurement on the basis of lowest price alone is not supported except with the commitment of a select list of perhaps three or four specialists. This process can take time and on major projects may be justified. However, when the scale of this work is judged in the context of the project costs

as a whole, and the constraints on time which the implementation of Liquidated Damages imply, perhaps it is time to reflect on this process.

It is clearly important to control costs but when it is realised that for a typical project, the costs of investigation average 0.21% of capital costs (see Figure 3) and the differential between costs of competing specialists may be some 10%, sometimes less, the allocation of this vital part of the process would be based on a potential saving of 0.021%. This seems out of proportion to the benefits which can accrue from careful selection and appointment of a competent specialist at rates which can be shown to be competitive, with the saving of time and increased commitment which can result. Many Clients are already taking this course of action.

3.3.5 Adequate Funding

Commitment to a project will increase with time as selection of a site is made and development proposals evolve. This is recognised in the phased structure of the investigation process. Commitment of funds to investigation can similarly be structured in the light of the foregoing and following considerations.

4. PHASES OF INVESTIGATION

4.1 Desk Study

One of the most valuable and cost-effective elements of a scheme is the Desk Study where the site is visually appraised and a search instigated for any information concerning the site such as its geology, any previous investigations, former uses, any history of performance and any features in the area which may have influenced the site or which the proposed development may influence. Several sites can be evaluated in this way at minimal cost, particularly bearing in mind that the consequences of a wrong choice are so significant.

We are fortunate in the U.K. that the archive held in public hands by the British Geological Survey is readily available and is being rendered increasingly so by Information Technology. Investigations throughout the country result in a continuous update of their records. Other developed countries have a similar archive. My personal experience of Hong Kong is that the data held by the Geotechnical Engineering office (GEO) is of enormous value.

Such a Desk Study should form an important part of the Health and Safety file of any site as required under C.D.M. regulations.

On the basis of this data a site can be selected, in conjunction with the Client's other criteria, and a physical site investigation planned.

4.2 Physical Investigation

Investigations are preferably done in stages where preliminary work is used to verify or clarify the desk study data and characterise the thicknesses, distribution and properties of the strata present. This data can then be used to form the basis for further testing to study particular problems or solutions which the preliminary work has highlighted. Other phases may well follow where further refinement is necessary.

It is important to recognise the iterative nature of this process as development proposals evolve. There is no such thing as the comprehensive "Site Investigation". The investigation will have been directed to a particular purpose and if used for another development, the data will need to be re-evaluated and further physical investigation may be necessary.

4.3 Construction Monitoring

An important phase in investigation is the construction period. It is necessary to continually update the model of the ground as more is revealed by excavation, piling or monitoring for example, so that confidence is increased or adjustments made to render construction or the final installation more efficient, in terms of cost, time or safety. In many projects the "Observational Method" is now being used as part of the design. This approach recognises the limits on ability to predict precise performance and incorporates a strategy for responding to various identified patterns of movement, for example, to maximise use of financial and time resources. The monitoring will form an essential part of the health check on a site and can give the basis for more confident predictions of future behaviour than can be justified by those based on limited laboratory testing and theoretical behaviour.

4.4 Post-Construction Monitoring

Post-construction monitoring is of value in providing both confidence and the basis for demonstrating performance so that it can be input into future schemes at other sites or even re-development of the same site. For example, how often has it been said that "this building hasn’t moved, so how can your predictions of movement in the adjacent building be correct?" All buildings move when subjected to increases or decreases in load but predictions are made typically on the basis of assumed maximum rather than an actual loading changes. Monitoring in construction may be seen as analogous to the monitoring which a surgeon undertakes prior to, during and after an operation. It is recognised that complex interactions take place in the human body during operations and this is no less true of the ground. A surgeon failing to monitor would be regarded as irresponsible, perhaps this could be said of the construction industry.

4.5 Benefits

These phased approaches to investigation need the continuity which comes from the involvement of a Geotechnical Adviser throughout a scheme. They allow investigation costs to match financial commitment. Desk studies and preliminary investigations can be used as a basis for both site selection and adjustment of building location within a site, often the single most important impact on cost of the whole scheme.

5. VALUE

The dominance of early stages of investigation on cost is illustrated in Figure 4 of the SISG document (1) and is reproduced below:

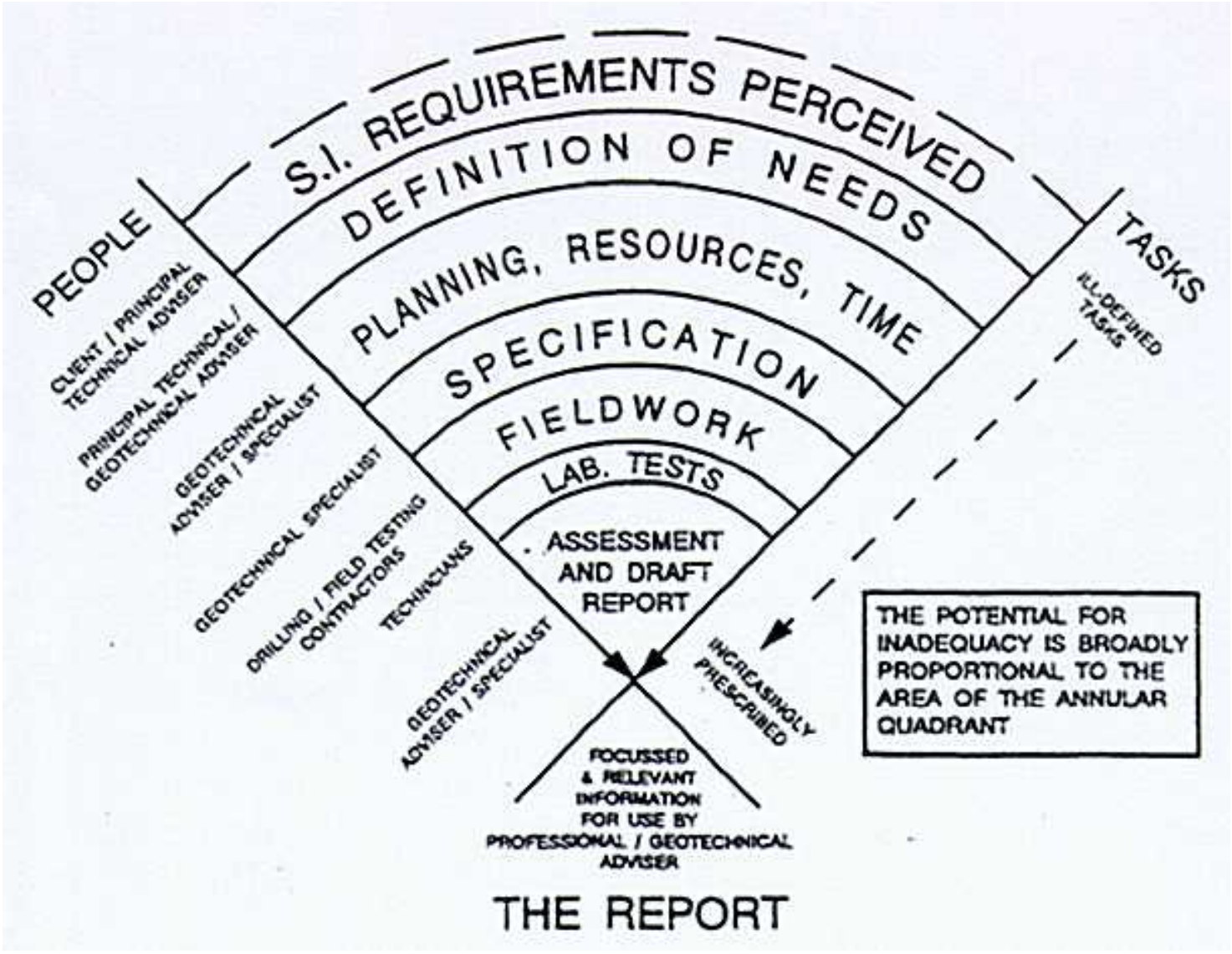

Figure 2 : Influence on quality of site investgation and dominance of early stages

(SISG - 1993)

This should not be taken to mean that extensive site investigation work is not necessary or of poor value. It is only of poor value if it is not well directed to respond to the various demands made by the development or highlighted by the desk study phase.

$$\textbf{Value} = \frac{\textbf{Function}}{\textbf{Cost}}$$

Too often value is seen as minimising cost rather than increasing function. In the Department of the Environment's consultation document "Constructing Quality" (5) the Quality Liaison Group recognise that cheapest initial cost is rarely the same as best value for money.

A table published by in 1972 and re-produced in Clayton, Matthews and Simons' book entitled "Site Investigation"(6), even though somewhat dated, illustrates the typical costs of site investigation as a proportion of capital works and of earthworks and foundation costs. For buildings, the costs are between 0.05 and 0.22% of capital cost of the works and 0.5 to 2.0% of earthworks and foundation costs. Similar costs were recorded in "Inadequate site investigation" (7) and reproduced in Figure 3.

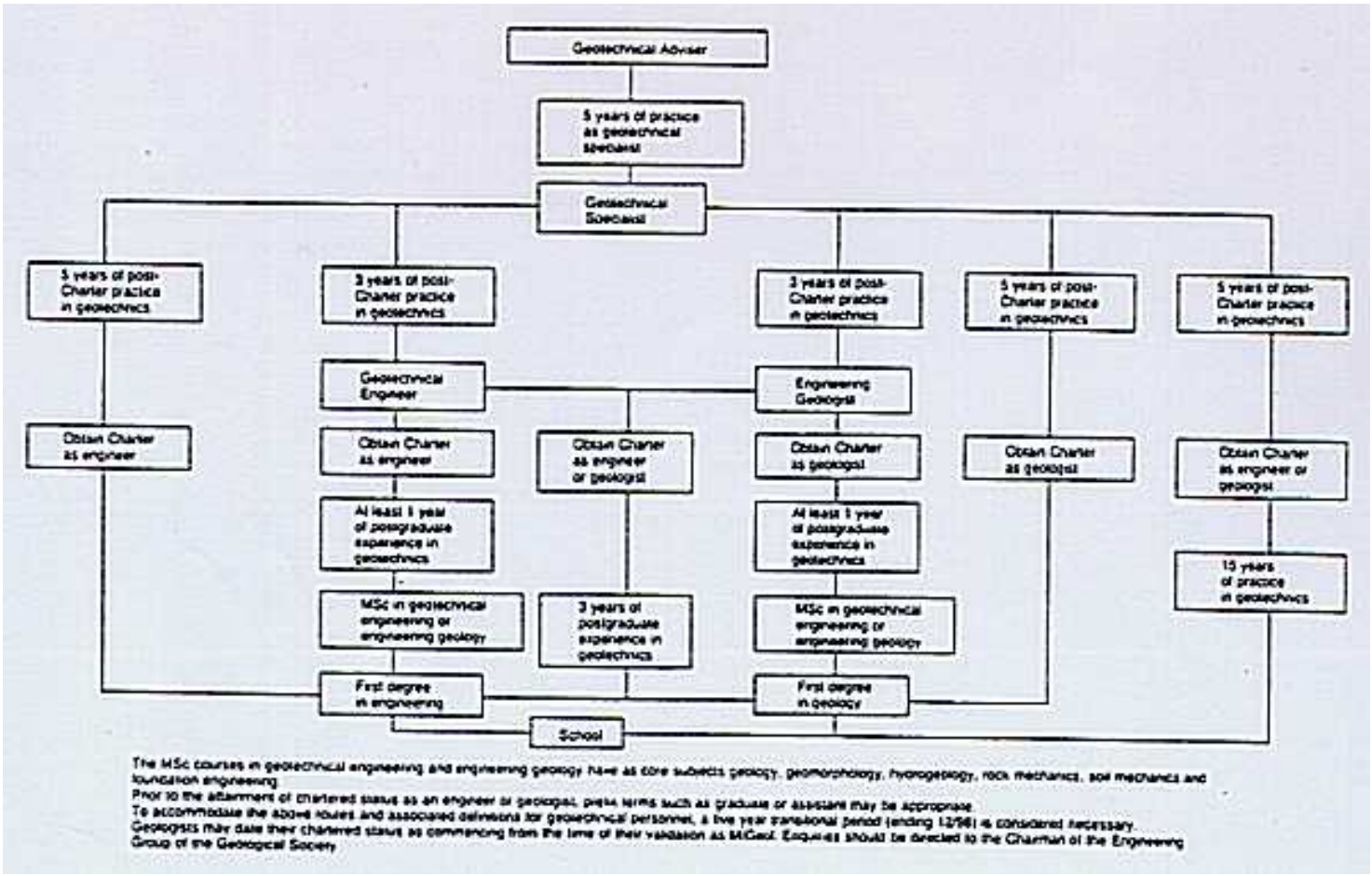

Figure 3 - Funding of site investigation projects as a percentage of total project costs
(Inadequate site investigation - 1991)

These costs can be seen to be small in relation to other costs and as stated by Littlejohn (7) "*you pay for a site investigation whether you have one or not*". In my belief you pay much more if your investigation is inadequate. Work in America indicates that up to 3% of project cost can be worthwhile. Hence, there is considerable scope for substantial increases in expenditure on Site Investigation in order to achieve the target of reducing construction costs by some 30% which is embodied in the Latham Report (8).

It is recognised that the cost of Site Investigation may be high in proportion to the cost of initial phases of procurement and design, however, and this may be the reason why many developers are reluctant to allocate sufficient resources to this. The main cost of a scheme is in the construction and the investment in adequate investigation of suitable quality should more than pay for itself on the project.

In developing the strategy for site investigation it is important that not only are sufficient funds allocated to the process but adequate time is allowed. By perceiving the site investigation as a single stage, problems can arise. If it is seen

to run in parallel with the other activities, however, the constraints on time are reduced and the benefits of a better targeted design and study will result. An understanding of the stages and scale of investigation is therefore important.

If the risks are less, the likelihood of insurance claims is less and the prospects for a successful project are enhanced. It is surely better to ensure a good project than insure an inferior one.

REFERENCES

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7) "Inadequate site investigation", The Institution of Civil Engineers, Thomas Telford, 1991.
8) "Constructing the Team", Sir Michael Latham, HMSO, July 1994.

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