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Subsurface Databases in GeoEnvironmental Engineering

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Stricter geotechnical and geoenvironmental regulations, large projects and sustainable design initiatives that dictate an interdisciplinary approach in design and maintenance of geoenvironmental and civil engineering structures impose a large amount of data that must be collected, analyzed, processed, reported, coordinated and interchanged among various stakeholders. Experiences of geoenvironmental companies and their methods of managing subsurface data is discussed and evaluated. Based on these experiences, a database management approach is presented as a means to aid and advance traditional practices in geoenvironmental engineering and enable easier interoperability with other engineering disciplines. The presentation reveals how field and lab data, when properly managed in geoenvironmental database can be easily turned into information and supplied to engineers in various disciplines in a form they expect and they can easily interpret. Furthermore, a properly designed centralized subsurface database allows for what-if scenarios and supports interoperability with Computer-Aided Design (CAD) applications for 2D site maps and 3D subsurface modelling, Geographic Information System (GIS) applications, Geoenvironmental Analysis and Design applications, Road Design applications, and Hydrology and Hydraulics applications. The paper concludes with how subsurface database management fits into or complements the traditional procedures, and provides notable enhancements in understanding and interpreting Site Investigation and Testing data, both in geoenvironmental engineering and in civil engineering disciplines that depend on geoenvironmental data.

1. Introduction

All too often organizations in the geoenvironmental field struggle with quantity and quality of data collected on site or produced in laboratories. The projects are growing larger, environmental requirements and standards stricter and more comprehensive, and the imperative for a cross-disciplinary approach is ever-increasing. This paper discusses experiences of geoenvironmental companies and their methods of managing subsurface data, incremental improvements they implemented in their workflows and eventually levelling technology to minimize abandon silo effect in favour of collaboration with other disciplines during project lifecycle.

2. Traditional approach and legacy data

Most senior experts in the geoenvironmental field will remember that working on the eve of the 21st century was fairly less complex, especially in terms of acquiring skills, understanding and following standards, and the quantity of data to process. The great deal of data collected and processed was on paper and that was the way data and reports were exchanged. A lot has changed however in last

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couple of decades, including regulations that increased quantity of data to process, need for quality control and quality assurance, and the size and complexity of projects. A few things shrunk: budgets and deadlines. All of these factors have made the traditional methods too time consuming.

3. Transitional period

First step many organizations undertook to renovate their reporting and data management capacity was adopting common Microsoft applications such as Microsoft Office Excel and Microsoft Office Word. If nothing else this produced nicer looking reports (Figure 1). Nevertheless to this day, there is surprisingly large number of companies that still use pen and paper in many workflows, which are sporadically and slowly being replaced with spreadsheets. More often than not, it was the Information Technology (IT) expansion in the last decade that made organizations start implementing these tools to a greater extent. Because these types of technology and tools were too generic they were inadequate to tackle geoenvironmental and engineering problems and they introduced new set of problems, Caronna (2005).

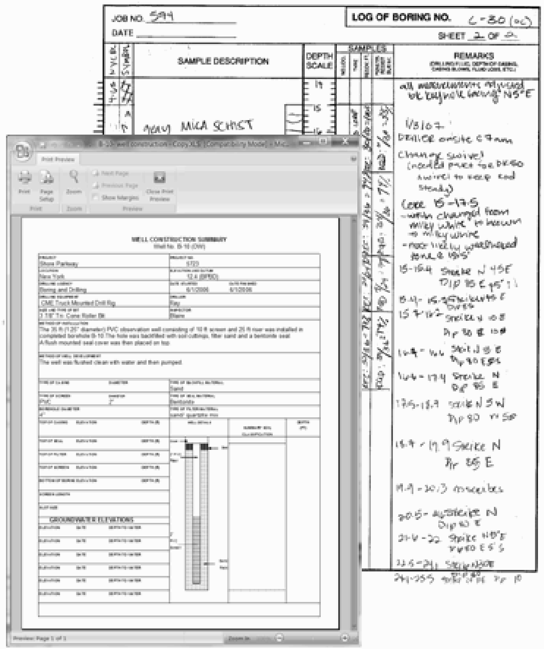

Figure 1: Data Management in transitional period

The two most notable problems of implementing inadequate technology and tools were the following. First, the technology was cumbersome to use, so stakeholders would struggle with using it. For that reason many veterans in the geoenvironmental field considered that the technology obscured the primary disciplines of geoenvironmental engineering and science, and takes too much time. This sometimes further delayed the application of technology tools. Second, data saved in these formats was difficult or impossible to reuse. It behaved, for most part, as electronic paper, and every time this data needed to be passed down the project workflow it needed to be retyped. This defeats the purpose of adopting new technology and tools. Because of the lack of technology and tools in this transitional period, some organizations developed their applications to include calculations, standards and quality assurance and control specific to their organization, locality or country.

One such tool, worth noting is the LA Contaminated Land gINT Tool, Leeke Associates (2004), which enables advanced data management, statistical analysis to CLR7, visualisation and reporting of soil and groundwater contamination data. The CLR 7 is a UK standard on Assessment of Risks to Human Health from Land Contamination: An Overview of the Development of Soil Guideline Values and Related Research, 2002. The tool identifies Soil Guideline Values (SGV) / trigger value exceedence and plots results graphically in plans, cross-sections, tables and histograms that highlight fails and outliers. The significance of this technology was in that it addressed three main points; it was based on a database, it was transparent or easy to use for geoenvironmental experts, and it offered a standard data exchange format, that is, easy reusability and passing data among different applications and different engineering disciplines.

In order for the next step to take place in widespread adoption of technology at many organizations, technology needs to become transparent for the stakeholders, letting them focus on their primary work and discipline, and it needs to offer data reusability, or an easy way to exchange data. These days, it is fairly easy to explain the transparency of technology, just by looking at Apple's iPhones and iPads that require no learning curve, thus being easily and quickly adopted by huge population and imitated by many vendors. The data reusability will be addressed in next section.

4. Data Reusability

Many geoenvironmental experts and organizations recognized that data reusability, which enables easy flow of data among disciplines, stakeholders and applications involved in the project, is essential for the iterative nature of projects, workflows, budgets, and deadlines.

4.1 Data Entered Once, Used Many Times

A properly designed database allows the entry of data just once, instead of reentry and reformatting for different purposes. However, the database is just the repository. To turn the data into information requires reporting, querying, and publishing tools to process and format the data to the required view and, in many cases, the ability to superimpose data from various sources or tests, field or lab, to obtain value insights into the context of the original data. For example, the database may hold the concentrations of some contaminate with depth in each of the boreholes and at different times. The data could be displayed as Table 1. This is valuable but merely mimics the data as it is stored in the database. Figure 2 shows other views of the data that would be more useful. To generate these results without a database and the appropriate reporting tools would require significant effort in manual manipulation and formatting of the data in various applications. Because of the iterative nature of projects, adding new data or updating existing updated would require significant effort without database.

4.2 Data Exchange Standards

A significant problem with data mobility is sharing the information between diverse programs and organizations, Kosnik (2007). For example, an analytical laboratory performs the tests and then must transmit the results to the consultant. The consultant must share the data between various analysis and design applications. The consultant must also provide the data to the owner/operator of the project. Each program and organization may have their own data format requirements. How can the data be exchanged without manual re-entry? A few organizations addressed or have been addressing the problem by establishing widely accepted data exchange standards or formats that enable easy data reusability. Some are listed below.

DIGGS. Data Interchange for Geotechnical and GeoEnvironmental Specialists (DIGGS) is a coalition of government agencies, universities and industry partners whose focus is on the creation and maintenance of an international data transfer standard for transportation related subsurface data. The coalition came into existence through coordination from the US Federal Highway Administration sponsoring meetings and eventually forming the pooled fund study project. The initial base schema consists of geotechnical data including Borehole, soil testing, site information and more. The first SIG is extending the schema to include Geo-Environmental testing. More SIGs and expanded membership are in the works. The draft DIGGS standard is available for review and comment.

AGS. The Association of Geotechnical and Geoenvironmental Specialists (AGS) is a non-profit trade association established to improve the profile and quality of geotechnical and geoenvironmental engineering. The membership comprises UK organisations and individuals having a common interest in the business of site investigation, geotechnics, geoenvironmental engineering, engineering geology, geochemistry, hydrogeology, and other related disciplines. The AGS data interchange format has been in use and revision since 1992.

LandXML.org, launched January 2000, is committed to providing a non-proprietary data standard (LandXML), driven by an industry consortium of partners. There is no direct cost to join LandXML.org, nor specific level of participation required.

Table 1: Table report produced by database.

Hole	Sample Depth (m)	Sample Reference	Sample Type	Sample Date and Time	Specimen Depth (m)	Specimen Reference	Specimen Description	Testing Laboratory	Test Date	Determinan d	Specimen Preparation	Result	Unit	Test Type	Test Method
Pot 1	1.15	1	J	01/01/2004 101500	1.15	1-1	Sandy CLAY with some gravel (SAMP)	CHM LAB	02/01 /2004	AS	AA	5000	mg /kg	SOLID _TOT	3.6
Pot 1	1.15	1	J	01/01/2004 101500	1.15	1-1	Sandy CLAY with some gravel (SAMP)			BENAP		5000	mg /kg	SOLID _TOT	0.6
Pot 1	1.15	1	J	01/01/2004 101500	1.15	1-1	Sandy CLAY with some gravel (SAMP)			CD		<0.07	mg /kg	SOLID _TOT	

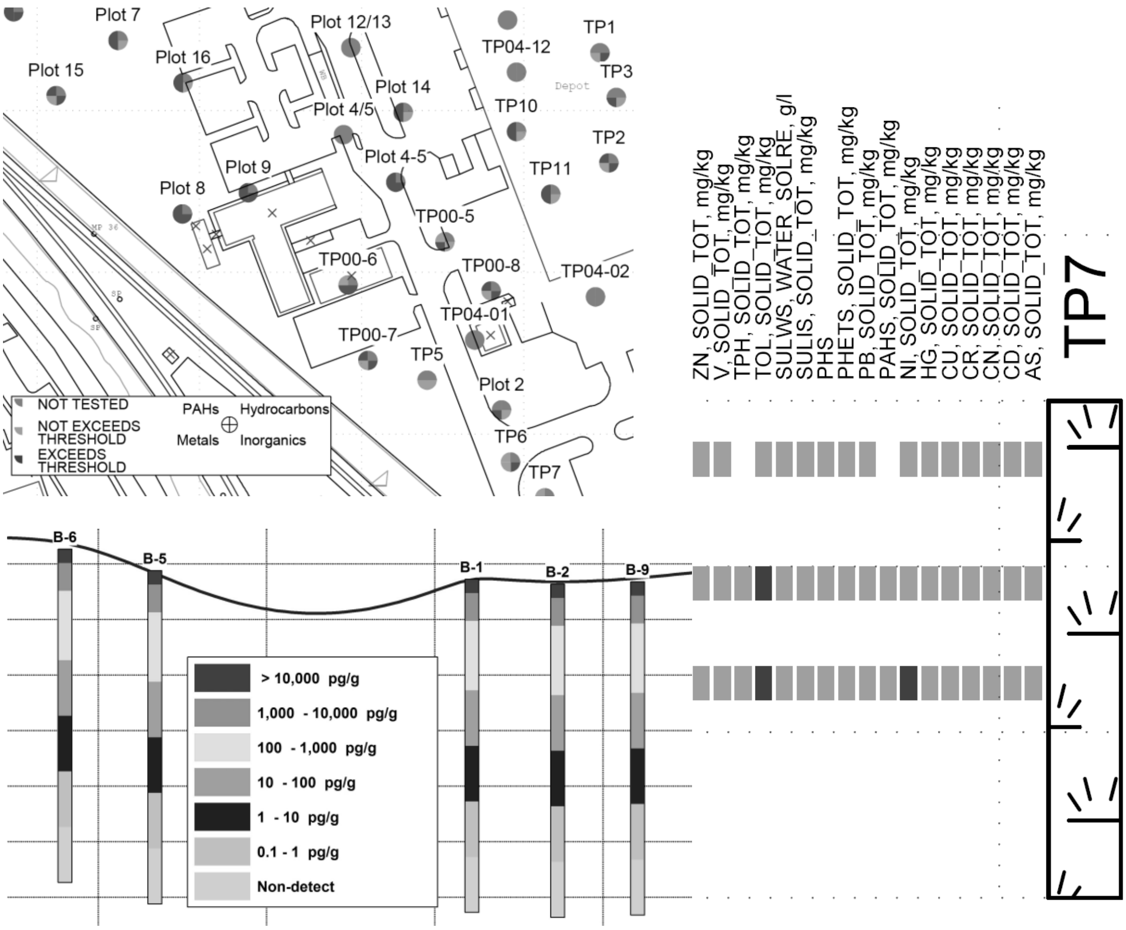

Figure 2: Example of various possible representations of same geoenvironmental data. The presence of determinants in figure, both on site map and profile is commonly shown in colour.

OGC. The Open Geospatial Consortium (OGC) is an international industry consortium of 445 companies, government agencies and universities participating in a consensus process to develop publicly available interface standards. OGC® Standards support interoperable solutions that "geo-enable" the Web, wireless and location-based services and mainstream IT. The standards empower technology developers to make complex spatial information and services accessible and useful with all kinds of applications. OGC standards are developed in a unique consensus process supported by the OGC's industry, government and academic members to enable geoprocessing technologies to interoperate, or "plug and play".

5. Collaborative approach

Figure 3, below shows collaborative approach with central geoenvironmental repository.

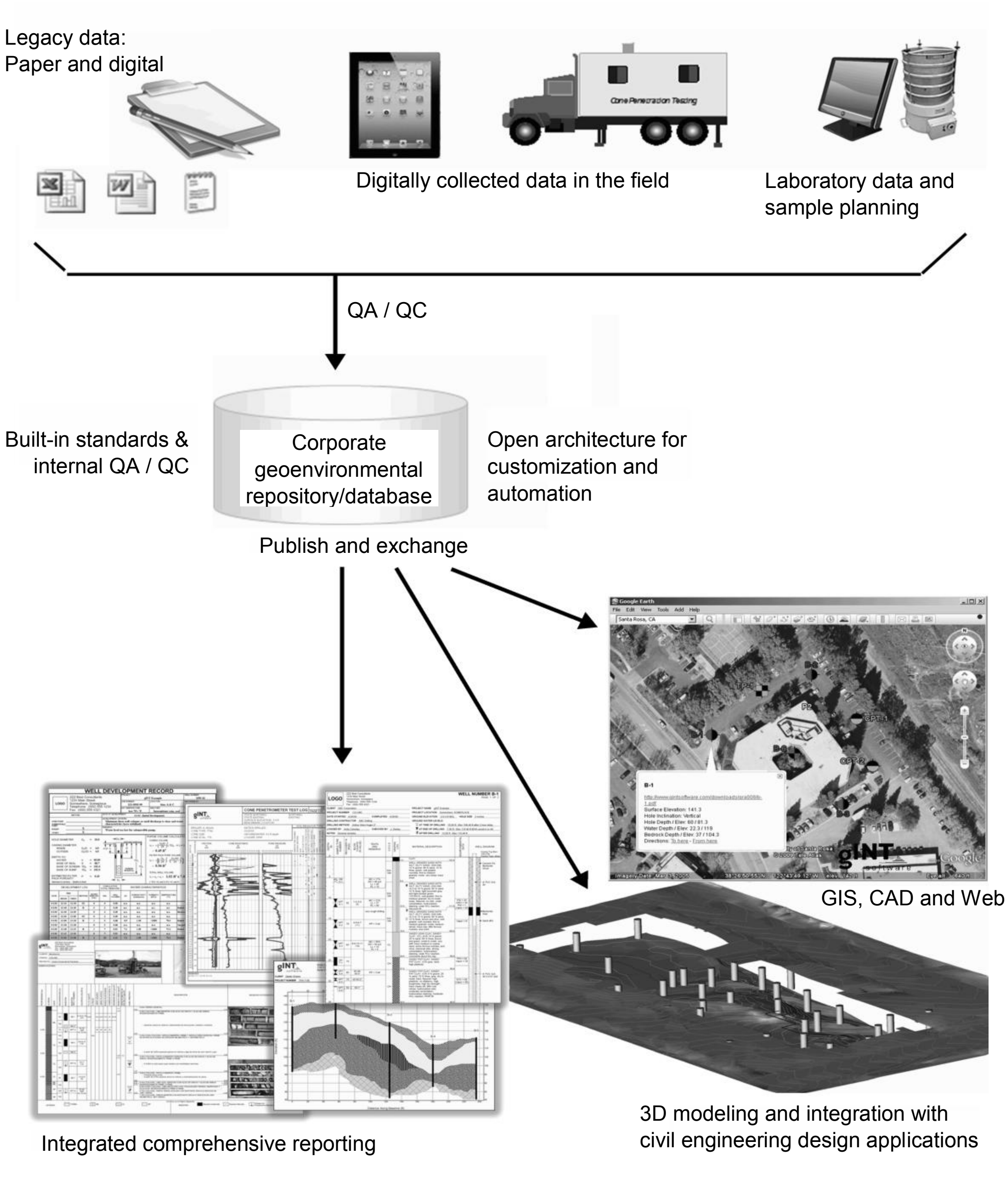

Figure 3: Geoenvironmental subsurface database with integrated reporting tool in the canter of collaborative approach.

After a decade of transitional period great many organizations that have been implementing technology in their workflows came to a common conclusion – a central geoenvironmental database with integrated reporting tools gives most flexible and transparent geoenvironmental data management. Properly administered geoenvironmental database allows for automated data import with integrated QA/QC, from variety of sources, Caronna (2005). It centralizes data to a single location, so searching for legacy data and all projects becomes easy and intuitive as opposed to searching for files in various locations on the networks or archives. Most databases have capability of internal QA/QC when data is being processed, and some of the databases have capabilities of implementing various geoenvironmental standards which is important for global companies who work in different localities. Further, the practice has shown that the optimized databases have integrated reporting engines to produce all required reports and submittals. Finally, the good geoenvironmental database also allows for, or has integrated means of easy publishing data in common GIS environments, and CAD environments, both 2D vector data and 3D data, that may be utilized in civil engineering applications such as road design, land development and so on, as shown in Figure 3. The most advanced databases also expose so called Application Programming Interface (API), which allows ultimate flexibility for organizations to automate any step of the workflow otherwise performed manually and develop or migrate calculations they commonly used outside of the database.

6. Conclusion

The implementation of central subsurface databases in geoenvironmental engineering addresses many challenges imposed to geoenvironmental discipline. The most acute problems are short deadlines, reduced budges, large quantity of data, assurance of data quality, capability of implementing variety of geoenvironmental standards, and clients demanding presentable reports, reusable data and data visualization, that is, capability of publishing data in GIS and CAD environments.

With a properly implemented geoenvironmental database, all subsurface data is centralized and consolidated so searching and querying data becomes intuitive and transparent, as well as reporting and publishing.

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