

The Borehole Markup Language

BoreholeML

*A Comprehensive and Applicable
Borehole Information Exchange Format*

- Introduction -

State Geological Surveys of Germany
and
Federal Institute for Geosciences and Natural Resources

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1. Summary

Geological information in general is an important basis for a sustainable development of the subsistence of all citizens in Europe and all over the world. It covers many various challenges from ensuring accessibility to natural resources, investigation for building foundation, risks of land slides and flooding hazards up to environmental problems like identifying waste disposal sites and providing information on ground water pollution.

The legal responsibilities for storage and management of drilling data in Germany are with the federal state geological surveys. As the lack of a common exchange format for borehole data was a significant handicap in many cross-border projects, a special working group (PK-XML) was established to model an XML-based format. The working group began the modelling process in September 2003, parallel and accompanying the EU-project “eEarth” (electronic access to the Earth through boreholes). The result of this working group is a Markup Language for borehole data (BoreholeML, BML). It was developed continuously and meanwhile it has reached version 3 (BML3).

A nationwide project “Interoperable Borehole Data” started in 2009. Aims of the project are the compilation of the standardised borehole information exchange format BML3 and the nationwide comprehensive retrieval of the BML3 data within the Geo Data Infrastructure Germany (GDI-DE) by means of web services.

The interoperability of the borehole information exchange format BML3 leads to an easier and increased borehole data transfer especially in cross-border projects. Federal and regional authorities, universities and other research facilities can exchange their borehole data in a standardised way as well as planning agencies and consulting engineers will benefit from a standardised approach.

In contrast to the former BML1 and 2 schema, the BML3 data model is currently only available as concept model with referenced codelists in form of a dictionary. An BML3 application schema has still to be developed as feature types for the WFS. Within the Project “Interoperable Borehole Data” the model will be integrated into the INSPIRE modelling framework as far as possible to follow a standard-based approach in geodata modelling.

It is expected that the validated version of BML3 application schema will be available in September 2010. Subsequently the integration of geotechnical data (GeoValML) into BML4 will start.

2. Accept the challenge for a standardised borehole information exchange

2.1 *Necessity for a standardised borehole information exchange format*

Knowledge of borehole data is crucial, since the geological situation needs to be investigated and subsurface features viewed to resolve problems of accessibility to natural resources, investigation for building foundation, risks of land slides, flooding hazards etc. Public authorities, companies and finally all citizens have a vital interest in subsurface data. Geological features, like rock layers or groundwater aquifers, are naturally extended features which are not limited to any administrative units and therefore need to be handled with cross-border views.

However, subsurface data derived from drilling or mining activities are collected and stored in project files or repositories, which are managed by the geological survey organisations in their own country or state, mainly in proprietary formats. If geological features of a certain extent are concerned, a vast amount of distributed data has to be handled. First, there is the need to identify the necessary information in the area of investigation, e.g. viewing location maps. Second, a search in the header data of the borehole descriptions – so-called metadata – like drilling purpose or depth must be possible. Next, the necessary detail data is needed in a format which can be processed consistently and independently by special software. Therefore an urgent demand exists for a standardised exchange format with additional multilingual support.

2.2 Legal acts for information exchange between public authorities, companies and citizens

At present there are three legal acts for information exchange between public authorities, companies and citizens in Germany, one for data input (a) and two for data output (b, c) [1,2]. Similar regulations exist for other European countries because the information laws are introduced by the European Commission.

(a) Geoscientific information about subsurface features in Germany is based on a special law to prospect and protect natural resources (“Lagerstättengesetz”). This forces responsible companies and also private persons to hand over information of planned and conducted geophysical subsurface investigations and machine driven borings to the responsible governmental authorities (State Geological Surveys, SGD). In case a borehole is planned to go deeper than 100 metres, it is necessary to apply for a permit at the mining authority (“Landesbergbehörde”). When finished, all relevant geoscientific information from the prospecting activities is asked to be copied to the relevant State Geological Survey. This includes all layer and strata descriptions for input into the borehole database by default as well as seismic surveys, gravity, log measurements, core inspections, pump tests etc.

Due to this legal act, submitted geoscience and borehole data are managed by the State Geological Surveys and the databases are thus covering the area of the respective state. However, the legal basis on which geophysical and borehole data are collected is a federal law, valid for the whole community of Geological Survey Organisations in Germany. A somewhat special situation exists in the Exclusive Economic Zone in the German part of the North Sea as the federal authorities are responsible for this region. By virtue of this reason, data from offshore exploration activities are submitted to the Hydrocarbon Information and Data Exchange Centre (“Erdölgeologischer Austausch”) managed at the Landesamt für Bergbau, Energie und Geologie (LBEG, State Authority for Mining, Energy and Geology of Lower Saxony).

(b) Data access for citizens is mainly based on the Environmental Information Law (“Umweltinformationsgesetz”, UIG). The UIG gives rights to any person with accepted interest to access all geoscientific information relevant to the environment unless restricted by one or more of the following evidences:

- i. the data is still in use by an unfinished process (“laufende Verfahren”)
- ii. the data include personal data of private persons (“personenbezogene Daten”)
- iii. the data include secrets of company management (“Betriebs- und Geschäftsgeheimnisse”, BuG) indicated by the sender.

Restricted access according to UIG is only accepted for detailed data below the metadata

level. Information on databases (metadata of catalogue level) and header data of boreholes (borehole metadata) are not subject to restricted access.

(c) The Freedom of Information Act (“Informationsfreiheitsgesetz”, IFG) extends the rights of (b) for inspection of general decision processes for persons facing their authorities. The same restrictions stated for (b) apply here. Further, there are more restrictions if distinct public affairs have to be protected.

Additionally, the European and national regulations due to the INSPIRE directive aim at the public use of environmental data. Particularly, geological information like it is covered by the BML is explicitly listed in annex II and concretized in “Definition of Annex Themes and Scope”.

2.3 *Situation in Germany and in Europe for geological data*

Due to the federal organisation of the State Geological Surveys in Germany which are subordinated public authorities assigned to the ministries of economy or environment of the German federal states, there are as many borehole databases as states exist. Each survey of the respective state organises and runs a borehole database with its own structure, its own database management system and the necessary software for interpretation of the measurements. Moreover, the borehole information is described by about 5 different geological standards in the various states.

This splitted situation in Germany is similar to the European conditions in the large context. All over Europe we have to deal with many different standards and databases too, although normally only one central geological survey per European country exists.

Therefore suitable strategies must be developed to organise a borehole data exchange within Germany and the European countries as well. For example, projects on cross-border geological features need an agreement to common lists of geological and geotechnical terms to which the individual terms must be mapped.

3. Recent activities in Europe

Since some decades, the European Community is funding many joint scientific projects between the member states dealing especially with the compilation and the establishment of inventories of geological and geophysical data e.g. during the eContent and eContentplus research framework (GEIXS [3], GEOMIND [4], OneGeology-Europe [5], eEarth [6], eWater [7], Geo-Seas [8] etc.). The intention for the set-up and linkage of such catalogues is to expose the available information to the scientific community as well to public authorities and companies, enabling a subsequent data exchange or purchase.

The following considerations will be confined to the recent outcomes of projects related to geological data inventories both in Europe and particularly in Germany.

3.1 *Base projects*

The European project eEarth (“electronic access to the Earth through boreholes”) and the development of the Multilingual Thesaurus are of outstanding importance for the concept of the borehole data exchange since these activities laid the basis for a standardised multilingual borehole data structure. This structure consists of different parts describing the header and strata data as well the existence of additional information like supporting archive material or laboratorial details. The data format is already expressed by means of XML and especially GML for the location and the drilling path.

The repository of the geological terms has been extracted from the Multilingual Thesaurus (see below) and has been extended to other eEarth project languages like Polish which had not yet been included in the thesaurus. The repository allows the geological terms to be translated on-the-fly from the national to the user's language by changing the language in the client application.

3.1.1 Multilingual Thesaurus (MT)

A "thesaurus" in the field of information management is a list of terms or keywords used to describe the content of a document in bibliographic databases and to assist in the selection and retrieval of documents by subject.

The IUGS Commission on the Management and Application of Geoscience Information (CGI, previously CoGeoInfo) in collaboration with ICSTI (International Council for Scientific and Technical Information) has published the second edition of the Multilingual Thesaurus of Geosciences in 1995 (see [9]). The printed version contains six languages English (American), French, German, Russian, Spanish and Italian. The database also contains Czech and Finnish. The Multilingual Thesaurus (MT) contains 5823 key terms expressed as descriptors (preferred terms) or non-descriptors (non-preferred terms) in the language versions of the MT.

As the CoGeoInfo working group disbanded, CGI took the initiative to establish a new working group. The terms and categories have been revised about 5 years ago. Much of this work is done voluntarily.

3.1.2 EC project eEarth

The EC-funded project eEarth has created a framework for multilingual cross-border geodata exchange between six EU countries during the years from 2003 to 2005. The project consortium consists of the Netherlands Institute of Applied Geoscience (TNO-NITG, NL), British Geological Survey (BGS, UK), German Geological Survey (Bundesanstalt für Geowissenschaften und Rohstoffe, BGR), Lithuanian Geological Survey (LTG, LT), Polish Geological Institute (PGI, PL), Geofond (CZ), Geodan Mobile Solutions (NL), and Golder Associates (IT).

In total the eEarth system gives access to 2.7 million borehole records contained in the national databases.

The main outcomes from the eEarth project are a central web portal to the national geodatabase applications, a multilingual user interface to the national databases, "on-the-fly" translation facilities for standardised geoscientific terms, GIS functions for search and dissemination of the borehole information, access to geodata via mobile devices, online data ordering and payment.

3.2 German activities

3.2.1 Borehole Markup Language (BML)

The legal responsibilities for storage and management of drilling data in Germany are with the federal state geological surveys. As the lack of a common exchange format for borehole data was a significant handicap in many cross-border projects, a special working group (PK-XML) was established to model an XML-based format. The working group began the modelling process in September 2003, parallel to the EU-project "eEarth" (see above). The result of this working group is a Markup Language for borehole data (BoreholeML, BML). It was developed continuously and meanwhile it has reached version

3. The BoreholeML 3 is described in chapter 6.

3.2.2 Project Interoperable Borehole Data

In June 2009 BGR received money to conduct the project “Interoperable borehole data in the nationwide Geo Data Infrastructure” (“Interoperable Bohrdaten im bundesweiten Geodatenportal”) and to implement the results yielded by the working group PK-XML. Project partners are the State Geological Surveys in Germany extended by the Federal Waterways Engineering and Research Institute (Bundesanstalt für Wasserbau, BAW). The project started in August 2009 and will be finished by October 2011.

Aims of the project are the compilation of the standardised borehole information exchange format BML3 (see chapter 6) and the nationwide comprehensive retrieval of borehole data within the Geo Data Infrastructure Germany (GDI-DE) by means of web services. For this purpose the specific data formats of the federal states are exported into the exchange format, defined by the BML3-standard. The future user – companies, public authorities und interested individuals – will have access to these standardised data of the federal states via a public web client, which is an extended version of the eEarth-Client “borehole viewer Germany” (“Bohrpunktkarte-DE”).

At the beginning of the next year, the client component for data search and exchange – originally developed for the eEarth project – will be adapted to the needs for the geological surveys and the expanded BML.

4. Exchange formats

This chapter lists some data specifications created in the past for borehole data exchange between companies. However, these formats are either specific for a special purpose, e.g. the data transfer between hydrocarbon producing companies, or they don't use the contemporary Extensible Markup Language (XML). Nevertheless these data specifications are unsuitable to put the data exchange between diverse data producing institutions and a consumer into practise.

4.1.1 WITS-ML

The **W**ellsite **I**nformation **T**ransfer **S**tandard **M**arkup **L**anguage (WITSML) is a standard for sending well site information in an XML document format between business partners of the petroleum industry [10]. XML schemas are used to define the content of an XML document. The WITSML standard consists of two specifications which are versioned independently: Data Schema and Application Program Interface (API).

The WITSML standard was developed through cooperation between Energistics (a society of companies in the field of the energy market¹), the Ground Water Protection Council (GWPC) and the US Bureau of Land Management (BLM). The work was partly funded by a grant from the US Department of Energy (DOE). Its purpose was to create a batch data exchange standard to facilitate the reduction of the cost of information exchange between the petroleum and mining industries and regulatory agencies over the Internet.

WITSML is accompanied by PRODML for production data and RESQML for reservoir information.

¹ The predecessor of Energistics was formed in October 1990 by five founding sponsor oil companies: BP, Chevron, Elf (since merged into Total), Mobil (since merged into ExxonMobil), and Texaco (since merged into Chevron) under the name Petrotechnical Open Software Corporation (POSC).

4.1.2 LAS

Log **ASCII** Standard (LAS) is an older ASCII exchange format for logging data created by some oil producing and prospecting companies like Texaco and Schlumberger GeoQuest [11]. Version 3.0 is from June 2000. An open source data conversion utility for LAS to WITSML well log dataset conversion was developed and released by Energistics.

4.1.3 ATS

The hydrocarbon companies conducting well borings in Germany are affiliated in the consortium of oil and natural gas producing businesses ("Wirtschaftsverband Erdöl- und Erdgasgewinnung" – WEG). For their data transfer, lists of common stratigraphic terms were compiled. Due to the business field these terms concentrate on the geological description of the hydrocarbon deposits, the so-called ATS-keys. Moreover, because these lists contain chronostratigraphic data, they are considered as intellectual property of the consortium members. So the use of the ATS-keys is essentially restricted to the member firms of the WEG and the Hydrocarbon Information and Data Exchange Centre at the State Authority for Mining, Energy and Geology of Lower Saxony.

5. Use cases

5.1.1 Easier data exchange

The interoperability of the borehole information exchange format BML3 leads to an easier and increased borehole data transfer especially in cross-border projects.

At first, public institutions, e.g. federal and regional authorities, universities and other research facilities, can exchange their borehole data in a standardised way.

Second, BML3 allows an easier borehole data exchange between public institutions and private enterprises like consulting engineers and planning agencies. As a result tasks in various fields, e.g. structural and civil engineering, city and regional planning, land-use planning, soil conservation, water protection, agriculture and forestry, are performed more effectively.

Further, it is expected that planning agencies working in different countries or cross-border projects will gain time by analysing borehole data. This will be enforced when companies developing application software for borehole data will enhance their software to support the BML standard like it is intended in the actual project (s. chapter 3.2.2).

5.1.2 eEarth-Client

As mentioned in chapter 3.1.2 the eEarth web portal [12] leads the user to the national internet-clients for accessing borehole data. The German eEarth-Client is called "borehole viewer Germany" ("Bohrpunktkarte Deutschland") [13], which provides a full featured WebGIS-Interface usable with a common internet browser. This application is designed as a national access point with its own metadata database for descriptive information about the boreholes.

The recent client already fulfils four main purposes to present and offer borehole data (use cases):

1. The publication of borehole locations based on topographic maps in an interactive WebGIS-Client
2. A search engine to identify boreholes via geographical search or text search by

attribute

3. An opportunity for ordering additional data of the selected borehole location by e-mail contact (no direct view yet except for data from Lower Saxony)
4. Multilingual support

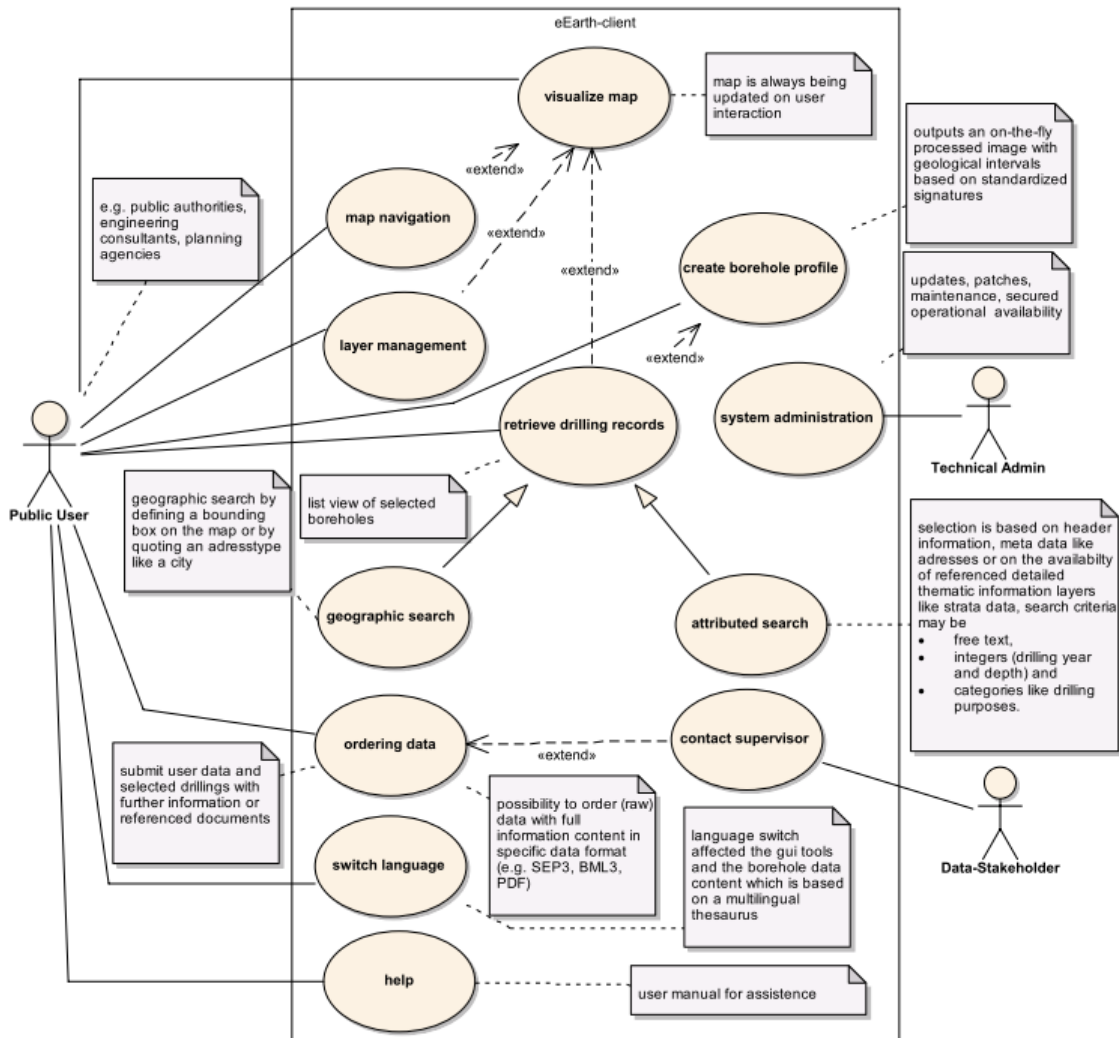


Figure 1: Use cases in the eEarth-client

Figure 1 gives a summarized overview on the user interaction possibilities with the actual client. The different search options are one of the major system components, enabling precise filtering of vast amount of data. All requests are done very shortly because of database tuning. It's easy to filter boreholes via header data and availability of strata and technical data.

In the future a direct delivery of BML3 borehole data via an OGC compliant Web Feature Service provided by the SGD is possible. Further, geo- and software engineering companies are closely involved in the project to realise and implement the technical part in existing and popular software products for borehole data management. So it is expected to establish an industry standard with BML3. As a result the modified eEarth-Client will be the first full featured prototype to demonstrate the functionality of BML3 and make borehole data easily accessible for the public domain.

The BML-model is designed to be flexible with the possibility to add further detailed information just by connecting them to the header class when needed for further development (see chapter 6.4). This also applies to the underlying codelists to determine the semantic content for the given attributes. These codelists are put together into a dictionary which is extensible without any structural modification of the model.

6. Development of the Borehole Markup Language

The modelling process of the Borehole Markup Language (BML) began after foundation of the PK-XML working group in September 2003. It was decided to proceed in three steps and start

- in step 1 with the borehole header information (BML1). The need for this was given in supporting the EU-project eEarth and the development of a borehole demonstrator for Germany, showing borehole locations on topographic maps in an Internet application.
- In step 2 the main focus was laid on the geological strata details (BML2). These data, mainly derived from sample and layer descriptions, are the core data in the various borehole databases in Germany and in many other European countries.
- Step 3 was intended to finalize the modelling process and add a number of technical data from the drilling process, installation and technical equipment. Currently BML version 3 is revised to include already modelled parts during the INSPIRE process. For example, the parts of contact addresses or coordinate systems will be replaced. A contractor will subsequently entrusted with the elaboration of a XSD schema from the revised model.
- In the near future BML3 will be enhanced by inclusion of laboratory data (see chapter 6.4). The Federal Waterways Engineering and Research Institute (BAW) of Germany has already developed a data model for geotechnical tests which will be merged with BML3 and result in the next version (presumably called BML4).

6.1 Header information (BML1)

Version 1 of the BML was modelled for exchange of borehole header information. It includes location and identification data, the detecting fields for drill method, drilling year, purpose, and last drilled horizon as well as a number of metadata, stating the availability of further information on detailed data (e.g. strata details, archive reports, scans, samples etc.). The modelling process on version 1 was finished in September 2004.

6.2 Strata details (BML2)

The modelling process for version 2 of the BML was a continuation of version 1 by adding a model for strata details to the header data, describing the geological profile and its version as well as the details on rock type, stratigraphical unit, genesis, carbonate content, compactness, and consistency of each layer interval. The main progress was made in establishing key lists to describe the units by code or by text. BML2 was finished and published under www.infogeo.de/borehole in April 2007.

6.3 Technical data (BML3)

In version 3 of the BML the main focus was set on modelling the data derived from the drilling process and the installation of technical equipment. Also geotechnical and geophysical data of logging and sampling have to be included in order to get a comprehensive view on borehole data. However, these data are specific for drillings and

no other standard could help including them, except parts of the POSC-WITSML standard for physical data of E&P-wells [10]. The main fields of application in geological context managed by the geological surveys are hydrogeology, engineering geology, mineral resources, and mining. Borehole information from these fields normally comes with the necessary data to be included into the databases of the responsible geological survey organisation.

6.3.1 Drilling details

The geological survey organisations do not keep extended files of technical details from the drilling process, however, a minimum set of details is available in most cases and useful for exchange. This includes the drilling method, the drilling tool, diameter and flushing type. The main purpose is to give estimates of sample quality and reliability of interval identification.

6.3.2 Filling details

Information on whether a borehole is filled or kept open is necessary to know for inspection according to the mining law. BML3 also keeps records on the material of filling and the filling interval.

6.3.3 Installation and casing

Most of the data relevant for hydrogeological purposes are those from test and production wells with filters and measuring equipment. BML3 therefore includes:

Description and installation date, casing type and space fill material with interval, segment and diameter, casing material and wall thickness with interval information.

6.3.4 Ground water measurements

Two kinds of groundwater data are handled here: First, groundwater data at time of drilling with start level, end level, balanced level and datetime. Second, groundwater observation data from monitoring with observation kind, level and datetime.

6.3.5 Logging

Geotechnical and geophysical borehole investigations are reported here with kind of investigation and measured interval. Reports on geophysical logging including deflection measurements are part of the investigation table. However, the values of measurement themselves are not included here.

6.3.6 Sampling

Any samples taken and kept for further processing or for storage can be described by sample kind and sampling purpose with sampled interval. Data from analysing are not part of BML3.

6.4 Laboratory data (BML4)

It is intended to expand the current structures of BML by geotechnical parameters resulting from laboratory tests.

A variety of information is considered in order to obtain the required parameters of the different soil and rock layers for geotechnical purposes. Some of the most important

information is listed below:

1. Structure: type of structure (building, dam, slope, etc.), function, main dimensions, loads, foundation depth
2. Laboratory tests: classification, compaction, permeability, compressibility, shear strength etc.
3. Interaction data: simulation and monitoring of the interaction between subsoil and structure

The results of laboratory tests play an important role in the process of evaluating subsoil parameters. A handicap of many geotechnical projects is the small number of samples of the subsoil that can be tested in the geotechnical laboratory. That is, why the data basis is often not large enough for a statistical evaluation and it is subsequently necessary to compare the results with the values of similar subsoil samples. A collection of test results can be very useful for this purpose.

A further motivation for the development of such databases comes from Eurocode 7 *Geotechnical design - Part 1 General rules* (EC 7-1). The term “comparable experience” has particular significance in EC 7-1. It is defined as “documented or other clearly established information related to the ground being considered in design, involving the same types of soil and rock and for which similar geotechnical behavior is expected, and involving similar structures. Information gained locally is considered to be particularly relevant”. The term is to be found in each section as comparable experience must be taken into account in all geotechnical designs. Comparable experience has a particular part to play in the specification of the characteristic ground parameters used in calculations. It is stated in EC 7-1 that “the selection of characteristic values for geotechnical parameters shall be based on results and derived values from laboratory and field tests, complemented by well-established experience”.

While a great deal of experience on the geology of different locations in Germany is available in the form of geological maps which have been compiled over many decades owing to legal regulations, no such pool of data has yet been compiled from laboratory tests on soil and rock samples. Ground investigations and laboratory tests on soil and rock are expensive so that only the minimum number of investigations stipulated is ever performed. In such situations geotechnical engineering consultants will try to check the few test results available for a project against comparable experience when specifying soil parameters.

The extension of borehole data with the geotechnical values from laboratory tests is very gainfully for the geological and the engineering disciplines. It is expected that there will also be synergy effects on other disciplines. The structures providing the data exchange format will be defined in the **Geotechnical Value Markup Language** (GeoValML).

7. Finishing BML3 in a standard-based approach

Currently the BML3 data model is only available as concept model with referenced codelists in form of a dictionary with a short identifier and the geological term. An BML3 application schema has still to be developed as data structure for the WFS. Within the Project “Interoperable Borehole Data” the model will be integrated into the INSPIRE modelling framework as far as possible to follow a standard-based approach in geodata modelling.

As described in the Generic Concept Model [14], it is planed to make use of the implemented Consolidated UML model [15] which is based on several ISO-standards and

other OGC standards for data encoding to ensure interoperability. So the first step is the model formalisation to embed it into existing geostandards like metadata (ISO 19115) or geometry feature types in GML (ISO 19136).

For quality reasons and further development, a revision control system must be installed for a multi user development community. After versioning the model and its validation it finally needs to be implemented in GML by a transformation of the UML-model.

To achieve these goals, the same software tools are used like in the INSPIRE data specification process:

- Enterprise Architect for UML-modelling on the domain model level
- Subversion as revision control system
- ShapeChange for transforming UML (XMI) into GML-application schema (XML-Schema)

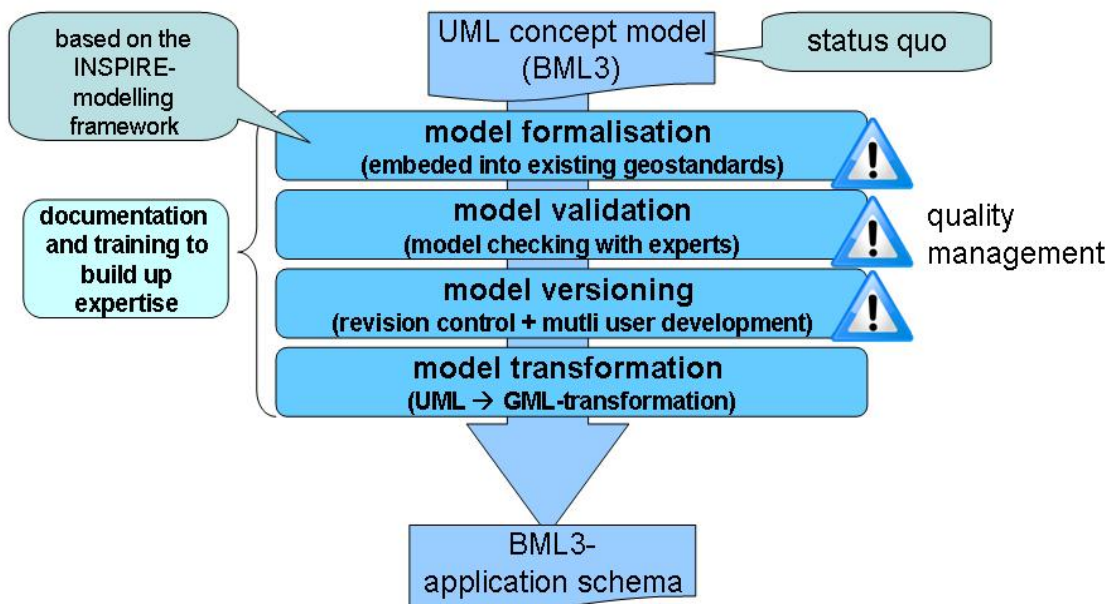


Figure 2: The standard-based development of the BML3-Schema

Figure 2 summarises the steps to a standard-based BML3 application model which will be set up during the Project “Interoperable Borehole Data”. It is expected that the validated version of BML3 application schema will be available in September 2010. Subsequently the integration of GeoValML into BML3 will start.

Possible interfaces to GroundwaterML will have to be investigated.

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