Capital Region of Denmark

NEMLA

New Emplacement Method in Limestone Aquifers

A Public-Private-Innovation Project

December 2013

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A Public-Private-Innovation Project

NEMLA is a public-private-innovation project initiated and managed by the Capital Region of Denmark (CRD).

In a public-private innovative partnership the partners innovate together to find a solution to a problem. The public and the private partners should contribute equally to the project.

The NEMLA project involves nine private companies and consultants, including two from the USA, and two research institutions, GEUS and the Technical University of Denmark.

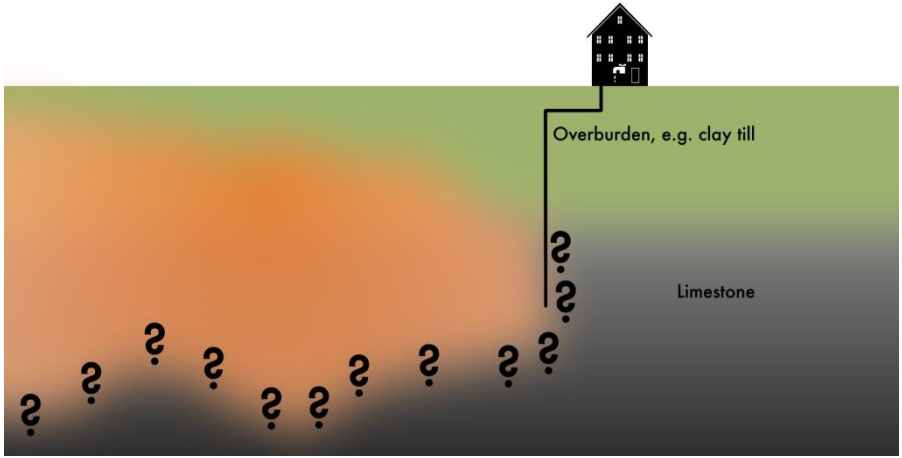
Partners in the project:

The Capital Region of Denmark
Geosyntec consultants
ORBICON
ROTEK a/s
Dansk Vand Data
ROSS ENGINEERING
DTU Environment Department of Environmental Engineering
Geoprobe Systems
KIUL & CO TASK FORCE ENGINEERING
GEO DANISH GEOTECHNICAL INSTITUTE
GEUS

Background

The Capital Region of Denmark works to protect the groundwater – and thus the Danes' drinking water – from soil contamination. In order to protect the groundwater, the CRD investigates, delineates and remediates soil contaminations.

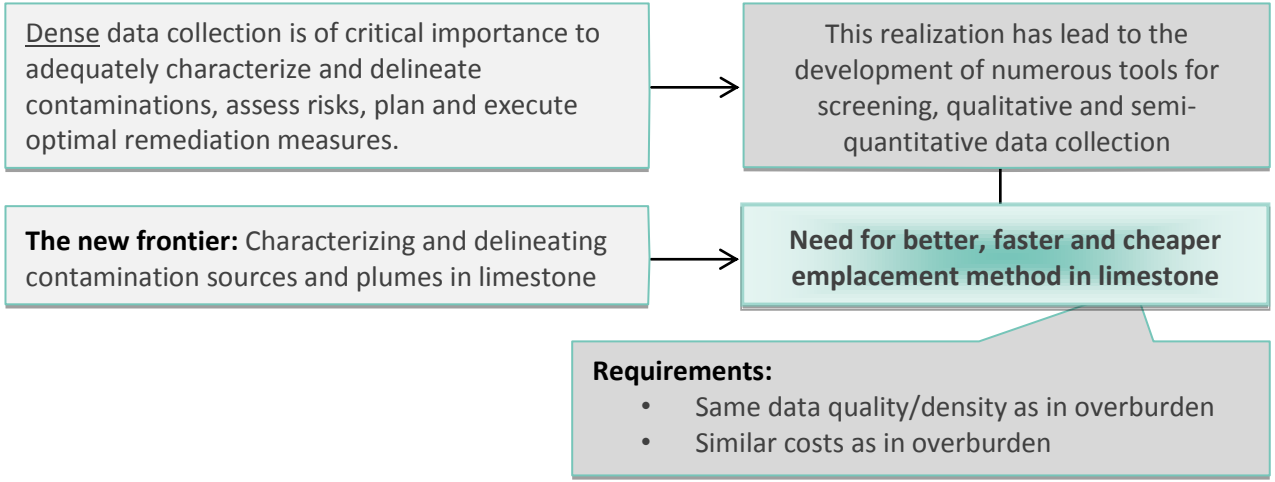
Good, cheap and fast tools for screening and sampling of contaminations exist for the upper soil layers, but we lack a method to bring these tools into the underlying limestone.



NEMLA objective

To enable utilization of existing tools for screening, qualitative and semi-quantitative data collection (traditionally emplaced in unconsolidated sediments via DPT) in groundwater aquifers situated in limestone via development of a new emplacement method.

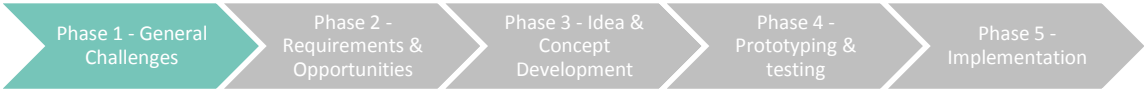
NEMLA Baseline



The development process

To ensure that the NEMLA objective was fulfilled, the development process shown below was planned. In this summary report, the results of the five phases of the project are described.

PHASE 1 – GENERAL CHALLENGES

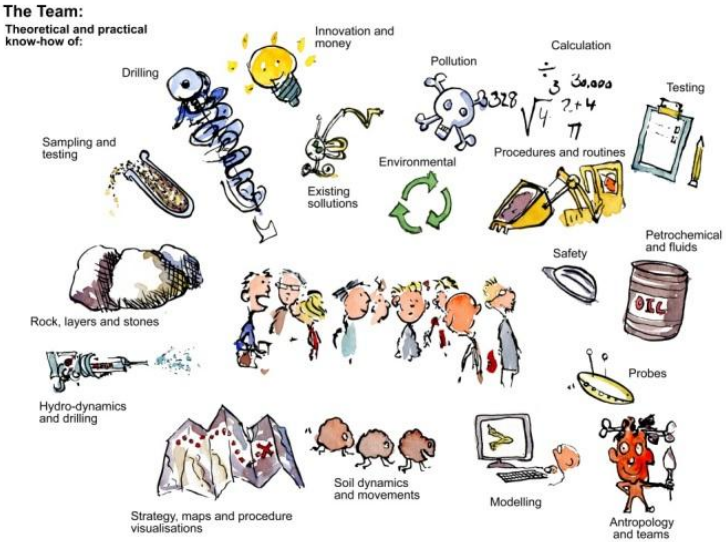


- **Kick-off**
- Inspiration Seminar
- Idea Workshop
- Prototype Workshop
- Action Plan

The purpose of the first phase was for the team members to meet and determine the overall challenges together.

Kick-off = team introduction

The kick-off workshop was the first meeting of the project team members. The workshop served to introduce the team members to each other and provided opportunity to discuss the role of each team member based on their skills and knowledge.

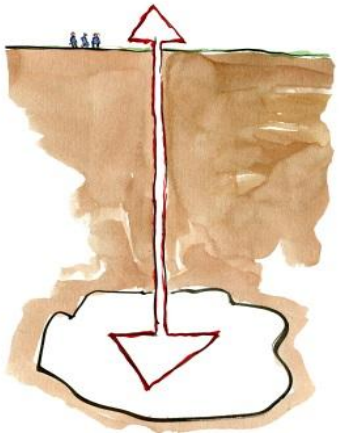


Challenges

The following challenges were identified by the team to be addressed in the NEMLA project:

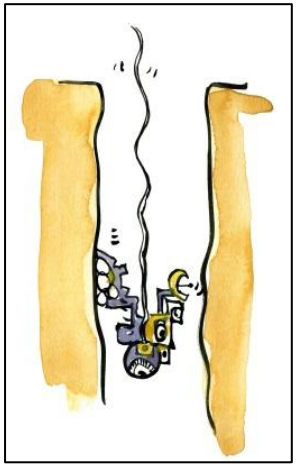
1. Combining of drilling and existing measurement devices
2. Real-time data collection during drilling
3. Chert and varying geologic properties
4. Costs
5. Collection of undisturbed samples and data
6. Recognizing differing purposes of differing borings, wells and instruments (data quality objectives)
7. Cross contamination and abandonment
8. Drilling fluids
9. Know-how of industry

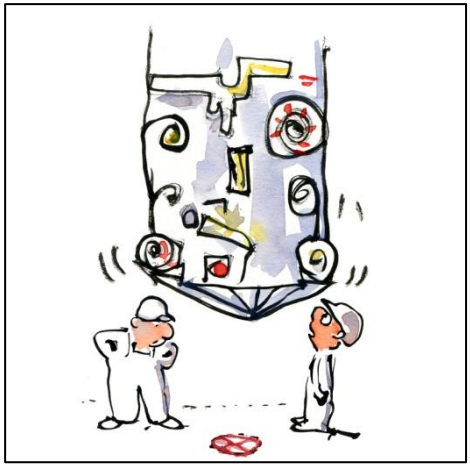
#1-4 were deemed to be the challenges with top priority. Input from the team relating to these four challenges is given on the following pages.

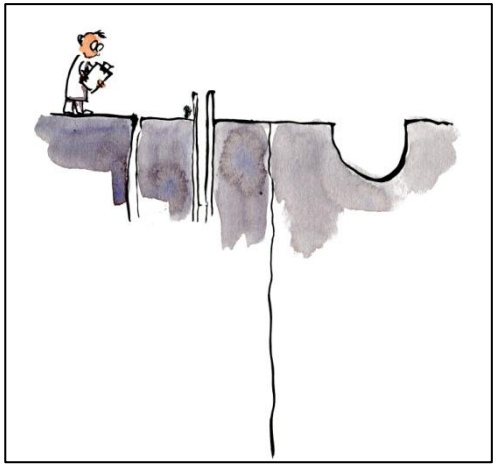


1. Combining of drilling and measurement devices
(Deployment of multiple methods and instrumentation in 1 hole)

- Important not to disturb formation or damage tools
- Drilling/coring is destructive - how to deploy measurement devices at the same time as advancing drill bit?
- How to acquire the most "true" data, while applying tool which can work while drilling
- One size fits all? Designing (systems of) boreholes/wells that can be used for geological characterization, contamination delineation, remediation, monitoring, etc.







2. Real-time data collection during drilling
(Capability /Robustness of tools when coupled with emplacement method expected to be more abrasive than DPT)

- We want real-time data to allow adaptive, dynamic sampling networks. This is achievable in unconsolidated deposits sampled by DPT/CPT. But we do not know if it is possible in bedrock.
- What to measure? Plume delineation? Source area?
- Important not to cross-contaminate with existing contamination (+ contaminate with drilling fluids) while emplacing tools

3. Costs

- Costs due to depth - Deeper drillings are more expensive
- Costs due to size/systems: minimizing borehole diameters to reduce cuttings, equipment foot print, etc. vs. larger multipurpose boreholes
- The true cost of investigating bedrock aquifers adequately may far exceed public expectations and desires
- Costs compared to traditional methods?
- Cost-effectiveness - costs should be viewed against quality and value
- Budget constraints

4. Chert and varying geologic properties
(Penetration of the limestone itself and the chert/flint layers typically associated with it)

- You have to get a hole in the ground!
- It is a great challenge to find sensitive measuring tools which can be deployed in hard formations – and to depths in excess of 50 m

PHASE 2 – REQUIREMENTS & OPPORTUNITIES

The purpose of Phase 2 was to determine the requirements for a solution, so every team member had the same understanding of a successful idea. Furthermore the purpose was to gain inspiration from the many opportunities, which could lead to a solution of the NEMLA challenges.

Whitepaper

In order to commence idea generation, a whitepaper was composed to secure a common platform for every team member. The whitepaper contained the following information:

1. Parameters to measure in limestone (in order to characterize and delineate contaminations)
2. Existing tools for data collection (in unconsolidated sediments via DPT)
3. Existing drilling methods (used in limestone/bedrock

Inspirational presentations – DPT

At the Inspiration Seminar Tom Christy gave a presentation of the capabilities of the presently DPT-based probes MIP and MIHPT. A demonstration of the existing MIP was performed by Olaf Asmussen.

Key points

- Probes hammered/pushed into unconsolidated subsurface
- Real-time data achieved
  - rapidly
  - via small hole diameter
  - at low cost

Inspirational presentations – Drilling technologies

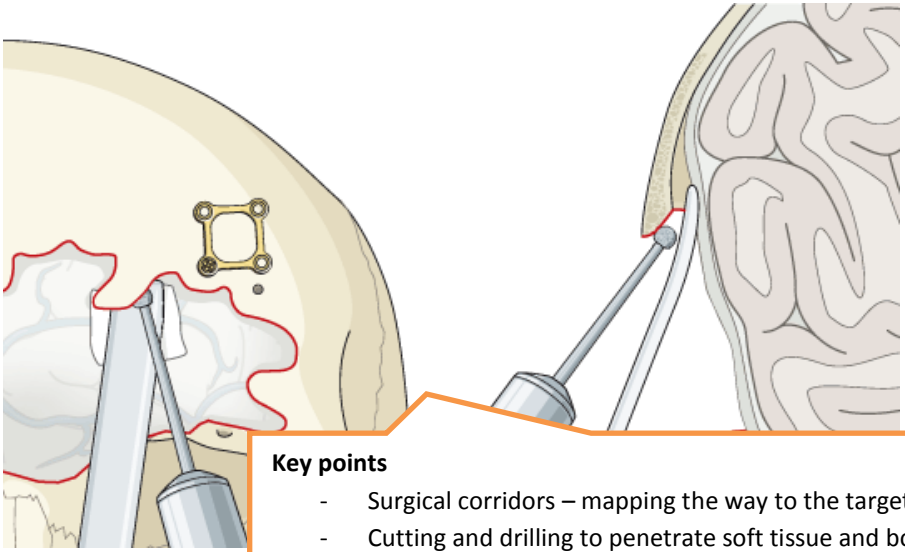
A presentation of the existing drilling equipment in limestone was performed by John Bastrup and GEO-colleagues.

Key points

- Combined bedrock drilling and DPT probing
- Cuttings from drilling available for sampling
- Acoustic televiewer provides similar info in cased borehole as optical televiewer in uncased boreholes
- Drilling at 5-600 RPM / 20-25 m in 3-4 hours
- Cost high (relative to DPT)

Inspirational presentation –Neurosurgical drilling

A presentation of how neurosurgical drilling is performed was given by MD Lars Poulsgaard from Rigshospitalet.

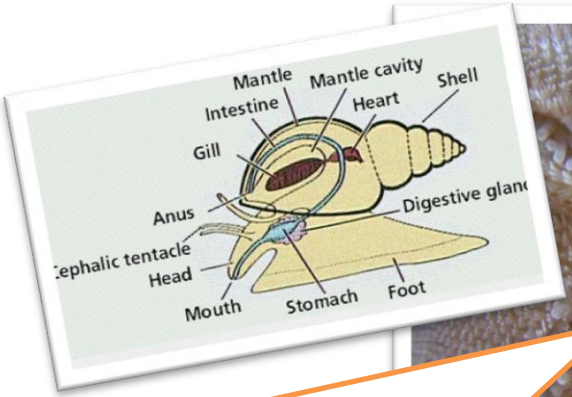


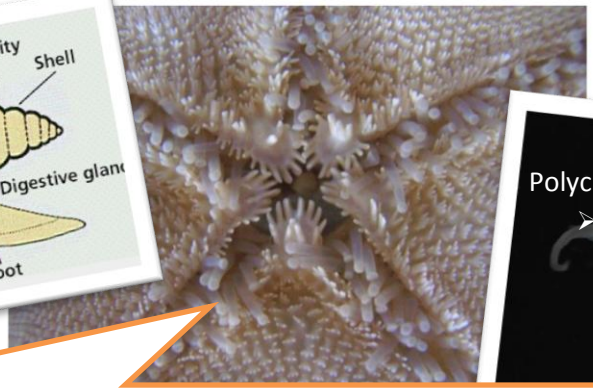
Key points

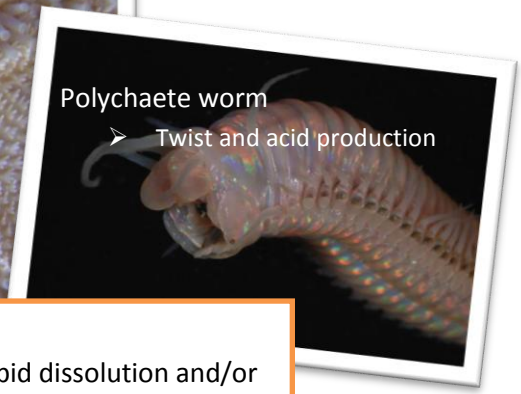
- Surgical corridors – mapping the way to the target in advance
- Cutting and drilling to penetrate soft tissue and bone
- Drilling at 70.000 RPM
- Mapping by ultrasound
- Navigation strategy

Inspirational presentation –Nature's drillers

A presentation of how natural creatures drill through different materials was given by Bo Wilhelm Rasmussen, PhD student of paleonthology at the Natural History Museum of Denmark – specializing in the zoomorphology of drilling organisms





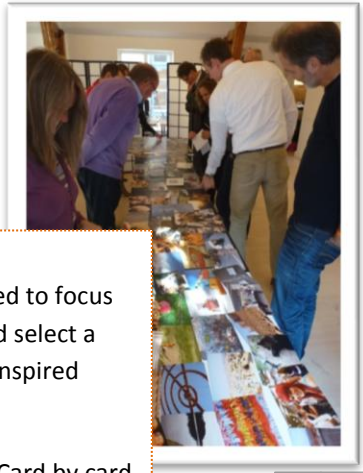


Key points

- Many marine animals have inspirational functions (for rapid dissolution and/or penetration of hard materials)
- Often combine chemical & mechanical functions – softening, dissolving, digging, rasping, drilling, hammering, harpooning…
- Easier to evolve a chemical function than a mechanical function
- The most accurate animals use receptors

PHASE 3 – IDEA AND CONCEPT DEVELOPMENT

The purpose of Phase 3 was to develop a wide range of ideas, which could solve the NEMLA challenges. The participants used different methods to uncover new innovative ideas. These methods varied and were anything from various brainstorming techniques to building on each other's ideas.



Individual inspiration: 'Pick-a-picture'

At the Idea Workshop, the team was divided into three groups, each group focused on one of the following themes:

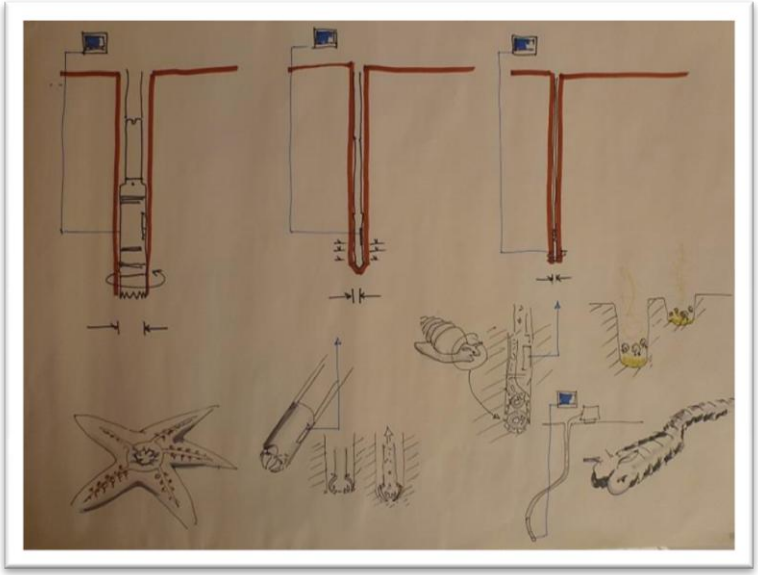
1. Manipulating the media
2. How to make a small(er) hole
3. If not a vertical hole – what then?

Task at workshop:
Each participant was asked to focus on the group's theme and select a number of pictures that inspired them within that theme

Share you inspiration - Card by card

Brainstorm in the groups

Based on the inspirational presentations and group discussions, each group was to brainstorm on ideas related to their focus. All ideas generated should have the potential to solve the NEMLA challenges.



Task at workshop:
The groups used the inspiration to brainstorm for NEW ideas/ principles – 10 per group

Initial presentations and 'Idea mingling'

Task at workshop:
Each group combined, reviewed, developed and narrowed their principles/ideas down to 3-5 ideas, which were presented to everyone

The presenter from each group stayed with the group's ideas While the rest visited the other groups and gave feedback and input on how to improve one or more ideas

Idea generation

Based on the previous brainstorm and the initial idea presentations, each group was to choose and further develop 3 ideas. Each idea was plotted on a NEMLA IDEA POSTER, containing the following:

- Idea title
- Idea description
- How does your idea solve the identified NEMLA challenges
- Challenges with this idea
- An illustration of the idea

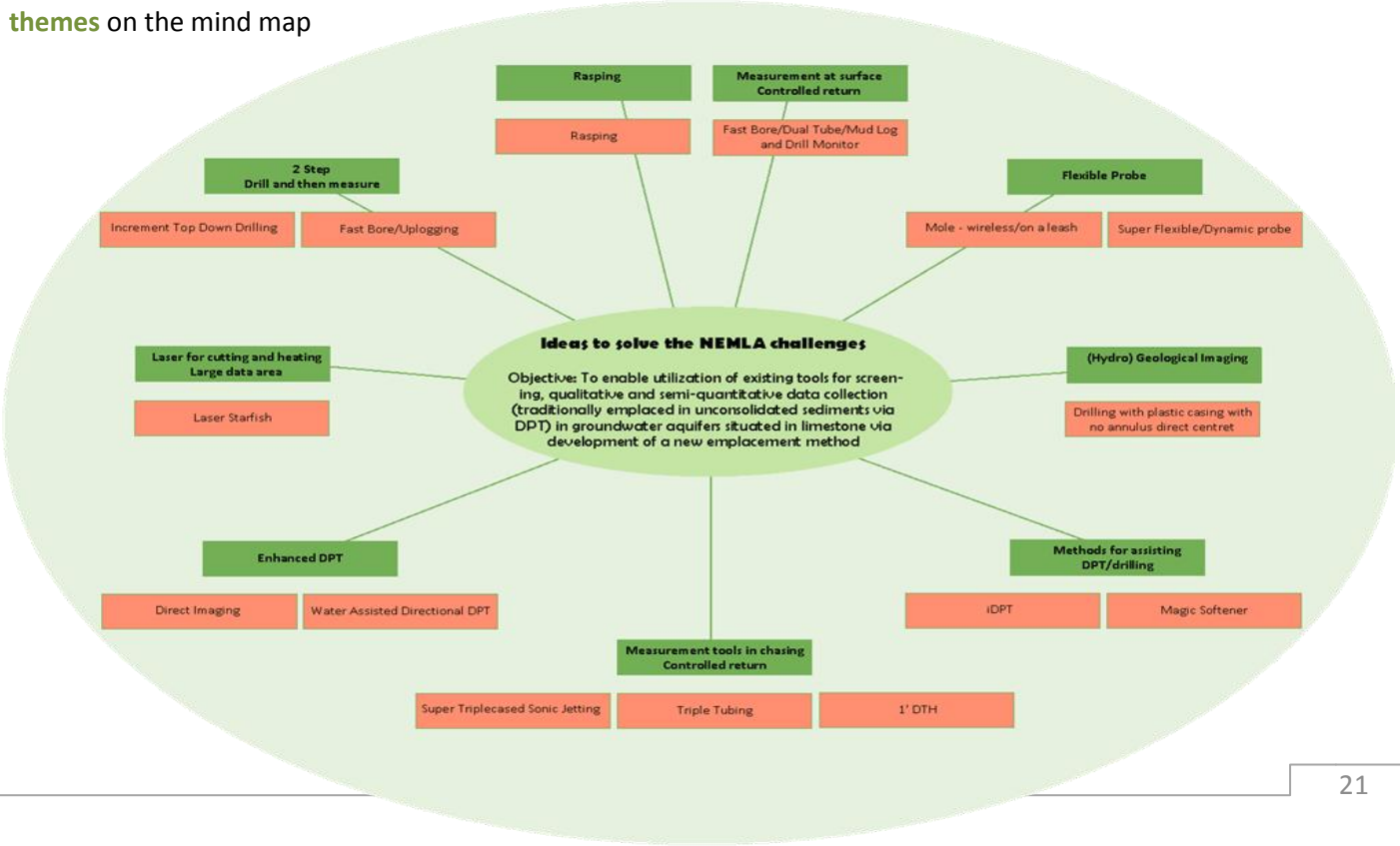
Task at workshop:
The groups matured their selected 3 ideas to bring to evaluation.

All groups were asked to have the cost-drivers in mind:

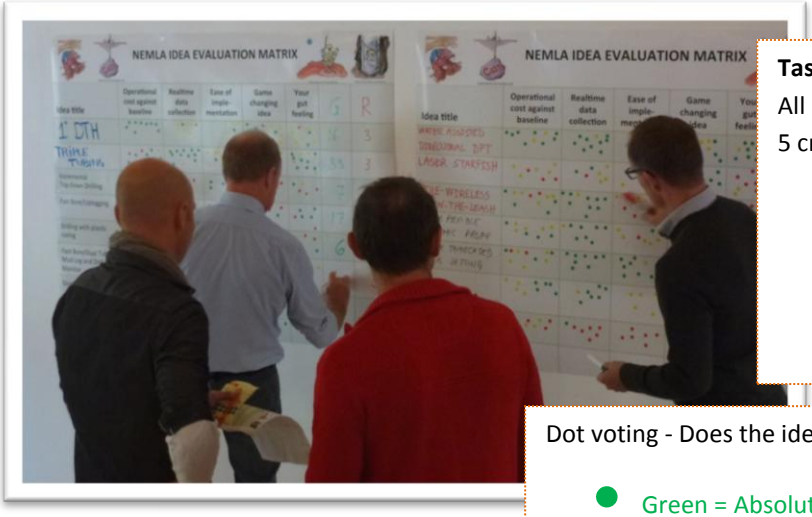
- Size of equipment
- Depth
- Size (diameter) and number of boreholes
- Time / investigation phases

Overview of ideas

The idea development sessions from the Inspiration Seminar and Idea Workshop resulted in 15 **ideas** – grouped in 9 **themes** on the mind map



Evaluation of ideas – NEMLA evaluation matrix



Task at workshop:

All participants voted on all ideas with regard to 5 criteria in an idea evaluation matrix:

- Operational cost against baseline
- Real-time data collection
- Ease of implementation
- Gamechanging idea
- Gut feeling

Dot voting - Does the idea meet the criteria?

- Green = Absolutely
- Yellow = Needs more work
- Red = NO!

No dot = More knowledge needed to assess this criterion

Matrix of potential – final placements

13 of our 15 ideas were presented and placed in the matrix of potential. The matrix contained two axes; one axe indicated the potential of the idea and the other axis indicated ease of implementation of the idea.

PHASE 4 – PROTOTYPING AND TESTING

The purpose of Phase 4 was to build and test the viability of the ideas developed in Phase 3 via prototyping, thereby maturing the ideas. The ideas and themes that were prototyped constitute the core concepts for further development in (public-private-partnering) projects in 2014.

Prototyping

At the prototyping workshop, all participants indicated which two ideas/themes they would like to prototype by placing their own pictures on top of the ideas in the matrix. To ensure that everyone prototyped their first choices, prototyping was carried out in two sessions. 4 themes/ideas made it into prototyping.

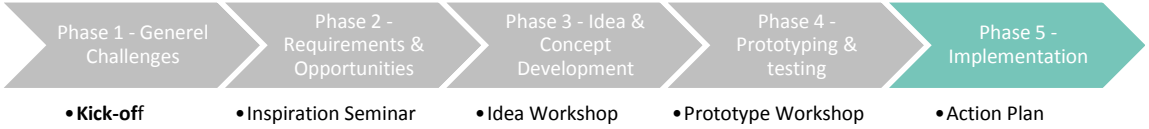
Prototyping – Session I

During Prototyping Session I, three prototypes were built.

Prototyping – Session II

During Prototyping Session II, another 3 prototypes were built.

PHASE 5 – IMPLEMENTATION



The purpose of Phase 5 was to start planning the implementation of the chosen solutions via construction of implementation plans. Therefore, the final workshop was focused on preparation for implementation by means of inspirational talks on PPI and financing possibilities, a working session utilized to describe the concepts further and a working session of brainstorming and organization of necessary activities and milestones.

Concept Description

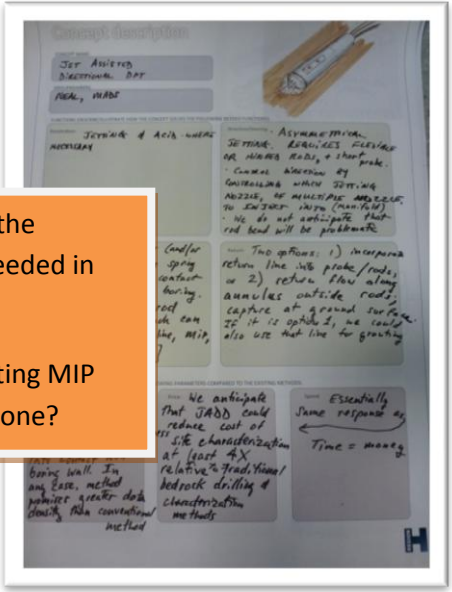
Each concept was described based on the following central elements:

1. Functions
    a. Penetration
    b. Measurement
    c. Steering/control
    d. Return

2. Important factors:
    a. Price
    b. Speed
    c. Quality of collected data

One further clarification of the measurement function is needed in all 4 concepts:

Is it possible to use the existing MIP measurement tool in limestone?



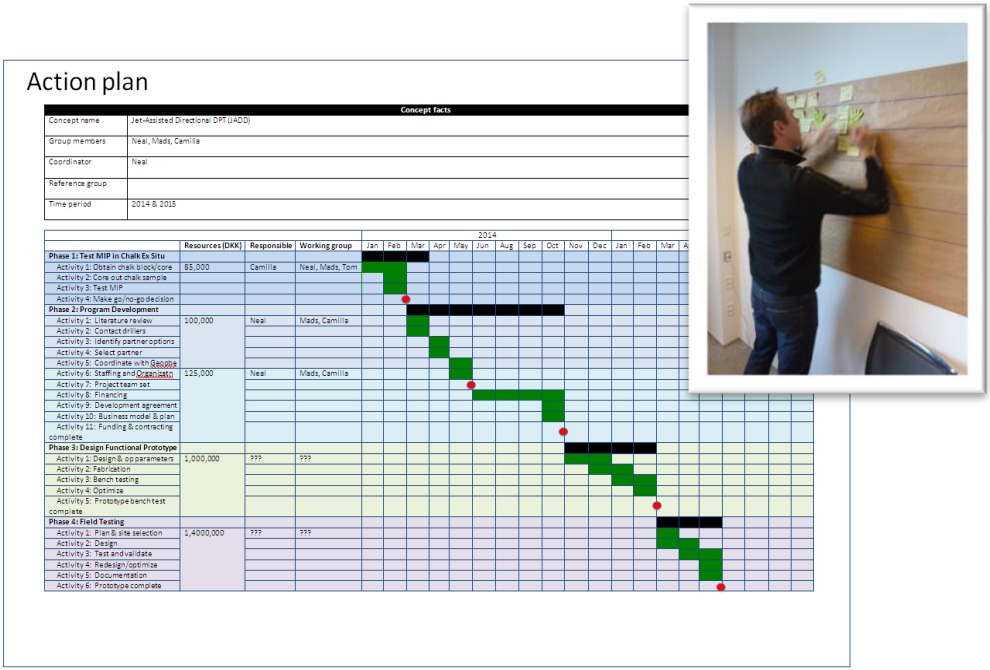
By describing each concept in the same template, it was possible to see if any of the four concepts could contribute to each other in the development process.

All four concepts require further investigation of the measurement function. This investigation could advantageously be performed in collaboration across the four teams.

Action plans

Each concept was then ready to be planned further – into an action plan in a given template. Each action plan was to outline the phases and activities of the project leading to a functional prototype and pilot testing. Each action plan contained the following headings:

1. Project facts
    a. Concept name
    b. Group members
    c. Coordinator
    d. Reference group
    e. Time period
2. Phases
    a. Activities
    b. Resources
    c. Responsible
    d. Working group
    e. Time



Action plan

Concept facts	
Concept name	Jet-Assisted Directional DPT (JADD)
Group members	Neal, Mads, Camilla
Coordinator	Neal
Reference group	
Time period	2014 & 2015

	Resources (DKK)	Responsible	Working group	2014 Jan	Feb	Mar	Apr	May	Jun	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Phase 1: Test MIP in Chalk Ex Situ																	
Activity 1: Obtain chalk block/core	85,000	Camilla	Neal, Mads, Tom														
Activity 2: Core out chalk sample																	
Activity 3: Test MIP																	
Activity 4: Make go/no-go decision																	
Phase 2: Program Development																	
Activity 1: Literature review	100,000	Neal	Mads, Camilla														
Activity 2: Contact drillers																	
Activity 3: Identify partner options																	
Activity 4: Select partner																	
Activity 5: Coordinate with Geopbe																	
Activity 6: Staffing and Organiszto	125,000	Neal	Mads, Camilla														
Activity 7: Project team set																	
Activity 8: Financing																	
Activity 9: Development agreement																	
Activity 10: Business model & plan																	
Activity 11: Funding & contracting complete																	
Phase 3: Design Functional Prototype																	
Activity 1: Design & op parameters	1,000,000	???	???														
Activity 2: Fabrication																	
Activity 3: Bench testing																	
Activity 4: Optimize																	
Activity 5: Prototype bench test complete																	
Phase 4: Field Testing																	
Activity 1: Plan & site selection	1,4000,000	???	???														
Activity 2: Design																	
Activity 3: Test and validate																	
Activity 4: Redesign/optimize																	
Activity 5: Documentation																	
Activity 6: Prototype complete																	

Next step

At present there are four different concepts all proposing to solve the same NEMLA challenge.

Before any or all concepts can become projects, a feasibility study of the use of existing measurement tools from DPT (MIHPT)in limestone is necessary.

The first common task is therefore to conduct this feasibility study.

How we will proceed after the feasibility study will depend on the results of the study.

A similar collaborative project regarding a common retraction tool (potentially with slightly varied functions) could be a possibility subsequent to the MIP-in-limestone study, before one or more fully developed projects commence (including preliminary applications for funding, etc.).

Partners

GEUS

ORBICON

Geosyntec consultants

ROTEK a/s

ROSS ENGINEERING

KULACO TASK FORCE ENGINEERING

GEO DANISH GEOTECHNICAL INSTITUTE

Dansk Vand Data

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