DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2006/52

Installation of on-site stimulation set-ups within the Central Refueling Station at the Kluczewo Airfield, Poland

Deliverable D8

Bertel Nilsson, Thomas Brøker, Bill Slack, Thomasz Kasela & Knud Erik Klint

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ABOUT THIS DOCUMENT

This report is a technical report of the deliverable D8 of the STRESOIL Project.

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1. Scientific Summary

This report covers the work performed in Work package 2 (Task 2-3) of the STRESOIL project. A drilling rig and mixing equipment dedicated for hydraulic fracturing have been designed, constructed and tested on operational field scale by the Danish STRESOIL partner Broeker (drilling company). The American subcontractor Bill Slack, FrX has provided knowledge transfer on detailed construction principles of the rebuild drilling rig and mixing equipment.

In five experimental 10x10m test cells 21 hydraulic fractures have been installed during a 2 months period in 2005 (April-May 2005). Only two of the embedded fractures failed due to bypass to terrain of injected slurry (blow out) most likely along historical installations in the subsurface performed in the past by the military within the central Refuelling Station at the Kluczewo Airfield in Poland. Hydraulic fractures installed in the basal till unit (Unit 4) have a horizontal to sub horizontal fracture orientation. In the flow till unit (Unit 3) fractures show sub-horizontal to saucer shaped features with an upward propagation of the fractures until an almost horizontal propagation along the interface between Unit 2 and 3. Hydraulic fractures installed at 2-2.5 meter depth in Unit 2 (lacustrine deposits) show heterogeneous non-horizontal features, including slurry venting on terrain in almost all cells. The preliminary spatial extension of the fractures has been identified using uplift data in all cells and drilling activities in 3 of 5 cells (Cell 1, 4 and 5). The mapping will be further specified when T1 and T2 sampling are available in Cell 1 and T2 sampling is ready in Cell 4.

2. Introduction

This report was written as part of the STRESOIL project - Work Package 2. The report summarise the work done on installation of hydraulic fractures in three test cells within the Central Refueling Station, or CRS facility at Kluczewo airfield in Poland.

This report covers the documentation of the following deliverable:

- D8: Systems of hydraulic fractures installed on Cell 1, 2 and 4. The title has been rephrased to "Installation of on-site stimulation set-ups within the Central Refueling Station at the Kluczewo Airfield, Poland".

The report was prepared according to the following milestone:

- M5: Guidelines for establishment of hydraulic fractures at the Kluczewo site
- M14: Remediation set-up installed on Cell 1 and 4

2.1 The STRESOIL project

The "fractured soil" stipulated in the STRESOIL project title (In Situ STimulation and RE-mediation of contaminated fractured SOILs) is glacial till – one of the most common geological sediments in the European countries. The low permeable, fractured till – while contaminated – represents a great challenge for environmental cleanup procedures. Particularly, if the contamination is present in the unsaturated zone removal of the pollutants becomes very difficult.

A combination of field experiments involving various approaches, laboratory, and investigation of soil and water samples as well as computer simulations will be employed to solve the problem. A combined effort of a team from Greece, France, Poland, Denmark and USA should within a three years period result in selection of a suitable method for cleanup of the Kluczewo site in NW Poland – the site selected by STRESOIL for field experiments. It is expected that findings of the project will have significant practical applicability in several Community countries and else at other places in the world with similar geological setting.

2.2 Goals and scope

The scope of Work Package 2 is to design and install hydraulic fractures in three locations within the CRS facility in Kluczewo. Originally it was planned to vary the degree of fracturing in between the three test cells, however in the initial project start it was discussed and decided to keep the degree of fracturing more of less the same in the three cells and instead vary the purposes of the three cells: Cell 1 aiming bioremediation; Cell 2 aiming hydraulic testing and Cell 4 aiming steam injection. A Cell 3 was failing due to sever blow out to terrain of injected sand & guar through unknown obstacles in the subsurface (most likely abandoned wells). Moreover, a Cell 5 was constructed for training purposes of preparing subsurface features, which facilitate a better hydraulic connection between injection and extraction points in the test cells (here named "Mickey Mouse" ears).

The following tasks are specified in WP2:

2.2.1 Task 2-1 Soil mechanics and hydraulic fracture propagation

- Employment of fracture propagation models to establish numerical databases correlating the input parameters
- Determination of geotechnical and textural properties of the glacigenic clayey deposits

The reporting of this task will part of the reports D4 and this report D8.

2.2.2 Task 2-2 Development of stimulation protocols

- Formulation instructions for optimal adjustment of directional permeability in the low permeability soils

The reporting of the stimulation protocol is identical with the report D4 (Nilsson et al, 2006a)

2.2.3 Task 2-3 Installation of on-site stimulation set-ups Cell 1, 2 and 4

- Installation of a number of induced fractures in the three test cells
- Documention of surface uplift to predict spatial distribution and geometry of the established hydraulic fractures

The reporting of this task is identical with this report D8.

2.2.4 Task 2-4 Hydrogeological characterisation of the hydraulic conditions in Cell 1, 2 and 4

- Documentation of hydraulic conditions before and after installation of the hydraulic fractures in the three cells

The reporting of this task is given in the joint the report D5 (before installation) and D14 (after installation) (Nilsson et al., 2006b).

3. Planned field work

3.1 Implementation schedule

The American subcontractor FrX has provided knowledge transfer on detailed construction principles of the drilling rig and mixing equipment to Broeker. During September 2004 to March 2005 Broeker designed, constructed and initially tested all new equipment for making hydraulic fractures on operational field scale. A drilling rig was rebuild by replacing the drill head with a special hydraulic hammer, for hammering steel casing to target depth for establishing hydraulic fracture (Figure 1).

Figure 1. The reconstructed drilling rig.

A slurry mixer was designed and builded by Broeker. The mixing device consists of a mixing tower and a fully adjustable electrical feeding and mixing auger, and a number of small pumps for delivering different additives (guar, cross-linker and enzyme breaker) to the coloured sand materials (Figure 2). All materials are made of stainless steel. The mixing device was built in January 2005 and turned out to have an excellent ability to mix the fracturing fluid. The high viscosity slurry with up to 70 % sand was injected into the fracturing well using a hydraulic driven mono-pump with adjustable outlet.

Figure 2. Mixing equipment with tower for sand mixing at the left and in the middle a fully adjustable electrical feeding and mixing auger

All together more than 30 tons of equipment consisting of water tanks, electrical generators, and several hundred meters of steel casing, stainless steel pipes and filters have been assembled. 7.5 tons of special coloured sands and a workshop container have been transported between the Broeker workshop facility in Denmark to the Kluczewo field site in Poland. A 12 tons hydraulic crane was mounted on a trailer for handling the heavy equipment.

A significant number of hydraulic fractures (in total 21) have been installed at five locations within the refuelling area at the Kluczewo airfield in Poland. Figure 3 shows a map of the area, including the location of the five fracturing locations (named cells).

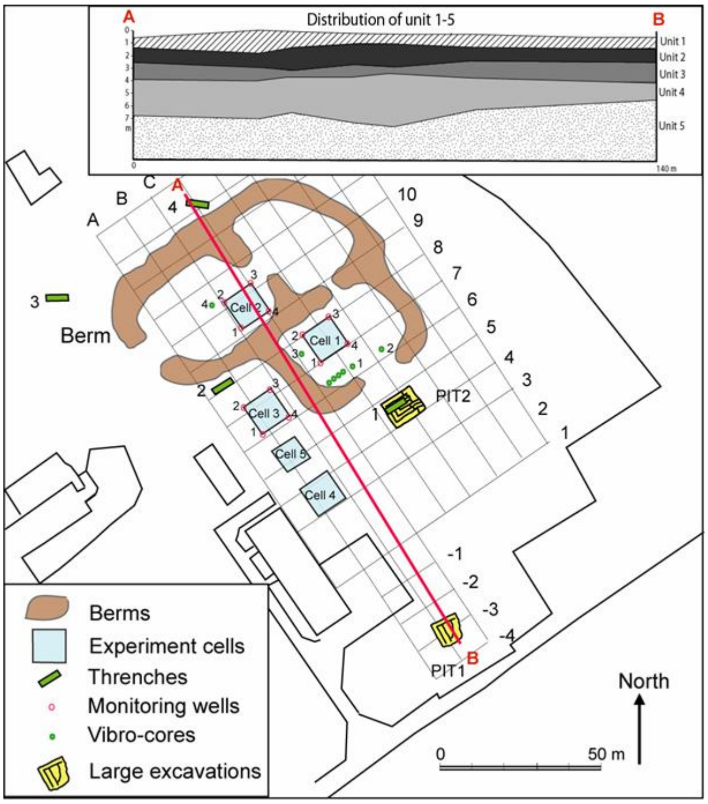

Figure 3. Map of the test site with location of the three test cells (Cell 1, 2, and 4) together with the abandoned Cell 3, pilot Cell 5, and investigation pits and trenches, described in Klint et al. (2005).

3.2 Staff & time schedule

A combined crew of personnel (Partners) created the different hydraulic fractures during April and May 2005:

- Cell 2 and 3. Three fracturing wells were installed in Cell 2 and four in Cell 3 on 26. April 2005 by T. Broeker staff and Bill Slack (FrX).
- Cell 3. Bill Slack (FrX); T. Broeker staff; HGT staff. Period: 27-28. April 2005.
- Cell 4. Bill Slack (FrX); T. Broeker staff; GEUS staff (Bertel Nilsson); HGT staff. Period: 29. April to 1. May 2005.

- Cell 5 – Mickey Mouse ears. Bill Slack (FrX); T. Broeker staff; GEUS staff (Bertel Nilsson); HGT staff. Period: 3. - 4. May 2005.
- Cell 4 – Mickey Mouse ears. T. Broeker staff; GEUS staff (Bertel Nilsson – part time); HGT staff. Between 10. and 12. May 2005.
- Cell 2. Broeker staff; HGT staff; GEUS staff (Mette Amfelt, GEUS / Geological Institute, Copenhagen University). Period: 17 - 24 May 2005.
- Cell 1. T. Broeker staff; HGT staff; GEUS staff (Knud Erik Klint). Period: 24 - 31 May 2005.

4. Methods

The fractures were created according to methods outlined by the United States Environmental Protection Agency as the result of technology demonstration projects conducted in the late 1980s and early 1990s. In summary, these steps include (1) installing a dedicated well by hammering to desired depth a piece of steel pipe fitted with a drive point, (2) dislodging the drive point downward to expose a short section of open hole, (3) cutting a thin notch in the wall of the borehole by means of a horizontal hydraulic jet, (4) pressurizing the notch with liquid so as to nucleate a horizontal fracture from the hoop that constitutes its outer edge, (5) delivering sand-laden slurry to the open hole section of the well so as to propagate the fracture, and (6) monitoring the injection pressure and surface deformation, which permits deduction of the fracture form.

4.1 Fracture Wells

Fracture wells were installed by a direct-push / vibratory method. The drilling machine weighed 12 ton and had a stroke of 6.2 meters, so wells shallower than 6 meters (all wells for this work) could be constructed with a single length of casing. Still, deeper wells utilized multiple pieces of casing welded together, and some shallower wells were composed of welded multiple sections to realize efficiencies in casing use. The well casings were nominal 3-inch thick wall (1/4 inch) ferrous pipe. In preparation of well construction, each casing was fitted with a steel drive point at the lower end (Figure 4), and the upper end was fitted into the socket of a vibratory hammer. After confirming vertical orientation, the casing was inserted by application of the machine weight and hammer vibration. The hammer vibrated up to 500-600 vibrations per min (or 9-10 Hz), but the speed of advancement and frequency were varied to optimize installation. Insertion of casing typically required less than 30 seconds. When casing segments needed to be joined, the hammer was move upwards, and a jig attached to the upright casing to align the subsequent section. A blacksmith welded the pieces together with an electric arc. When the casing was installed to target depth, the drive point was dislodged to expose a short segment of open hole, and a stub of threaded thick-wall pipe was welded onto the upper end of the casing to provide for subsequent attachment of hoses, etc. Cutting and welding could be performed at will to adjust the stick-up – the elevation above ground surface – for each well.

The drive points in these wells were dislodged 20 cm downwards to expose 10 cm of open borehole. Two-inch PVC filter and riser were installed in the wells in Cell 2 so that preliminary pneumatic conductivity tests could be performed (Deliverable D5 in Nilsson et al. (2006b)).

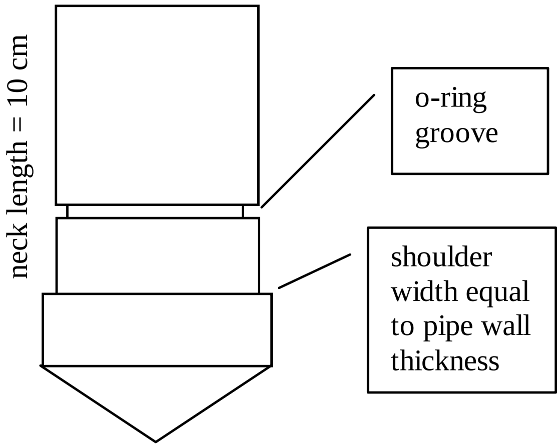

Figure 4. Schematic of Drive Point

4.2 Mixing and Injection Equipment

Fracturing slurry was prepared according to typical practices. Guar solution was prepared and allowed to hydrate in 600 litre mud-mixing vats. Borax and breaker solutions were prepared in 20 litre buckets. Sand was staged in an elevated hopper. Guar, sand and additives were mixed in an inclined screw conveyor that could be variously positioned and operated at a range of speeds to obtain desirable consistency. Guar was fed to the mixer at constant rate by a variable speed positive displacement pump, while sand was metered from the hopper by means of a variable speed screw feeder. Additive solutions were transferred by small pumps, and their rates adjusted by valves integral to variable area flow meters. All of these components derived power from electric motors.

The slurry discharged from the mixer into a small receiving hopper fixed to the inlet of a progressing cavity pump. The discharge of the pump was conducted by either 10cm (4-inch) or 5 cm (2-inch) hose to the injection well. The pump was driven by hydraulic power.

4.3 Coated sand filling

The three coloured sand fill materials have all been coated with an epoxy impregnation, that are resistant against the types of petroleum products and aviation gasoline, which are contaminating the field site. The grain size range between 0.9 and 2.0 mm and has a grain size distribution as shown in Figure 5.

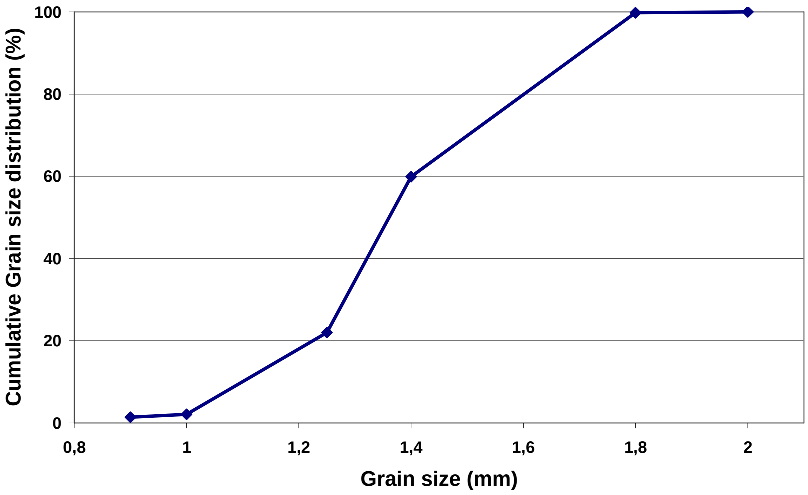

Figure 5. Cumulative grain size distribution of the sand materials that are used in the hydraulic fractures.

4.4 Notching

Notching was accomplished by a trio of horizontal hydraulic jets operated at 150 to 200 bar driven by a 5kw pump. The nozzles were mounted symmetrically such that the stand-off (distance from the face of the nozzle to the face of the borehole) was about 1 cm. For each fracture, the jets were operated at the target elevation and at a second elevation 1 cm above the target for a total of five minutes. Notching activity produced a stream of soil particles suspended in water. The soil particles were generally characteristic of the particular unit targeted. The produced stream was discharged to ground surface where biodegradation can be expected to consume any contaminating fuel/oil discharged.

4.5 Monitoring

Fracture creation was monitored by two sets of measurements, pressure and uplift. Injection pressure was indicated by a gauge (0-10 bar) fixed to the discharge of the progressing cavity pump, and injection well head pressure was sensed by an electronic pressure transmitter (0-6 bar). The electronic signal was recorded by a data logger, which later was queried by a computer. Uplift was monitored by surveying with a Sokia auto level and a collection of graduated staffs that were driven a few centimetres into the ground and extended ~150 cm upwards (Figure 5a). Surface elevations were recorded before and after fracture creation at as many as 19 locations, which were distributed along six symmetrically placed rays that emanated from or near the injection well. The uplift array was oriented with north-south generally parallel to the long wall of the service building; a compass indicated this nominal north to be approximately N12°W.

Figure 5a. Survey measurements of terrain uplift during injection of hydraulic fractures in the subsurface

5. Fracturing results

Fractures were created at multiple elevations within the five test cells. Table 1 summarizes the purpose of the cells, number of hydraulic fractures, colour of sand and depth of the individual fractures installed. Table 2 summarizes the quantity of material used to create each fracture and provides notes about the consequences of fracturing. Particulars of each fracture are discussed below. Pressure and uplift data are presented in Appendix A.

Table 1 Purpose, number and colours/depth of the individual hydraulic fractures installed during April to May 2005 in Kluczewo, Poland.

	Purpose	Hydraulic Fractures	Depth and sand colour[2]
Cell 1	Biorem. (Airinjection / Vacc. Extraction)	3	**2.1m , 3.6m and 4.2m**
Cell 2	Reference (Hydraulic tests)	3	**2.5m, 3.5m and 4.5m**
Cell 3	Abandoned (will be excavated later on)	4 (one failed)	**2.0m, 3.0m and 4.0m**
Cell 4	Steam injection / Vacuum Extraction	9 (one failed)	**2.0m+2xMM[1], 3.0m+2xMM[1], 3.6m and 5.2m**
Cell 5	Pilot cell for "Mickey Mouse ears"[1]	2	2 @ **2m**

[1] MM ("Mickey Mouse ears") in Cell 4 (steam injection) are additional fractures installed for evaluation of connectivity / efficiency between injection wells placed along fracture periphery with and without additional stimulation facility.
[2] Bold specify white sand material. Red sand material and green sand material.

Table 2. Fracture Summary

Cell	Fracture	Fracture ID	Depth (m)	Sand (kg)	Gel (l)	Comments
1	1	C1-f1	4.2	500 - green	550	
1	2	C1-f2	2.1	125- white	175	Vented about 50kg sand as slurry from hole 2 m south
1	3	C1-f3	3.6	350 - red	400	
2	1	C2-f1	2.5	100 - white	100	Vented 10kg sand as slurry from hole 2 m south
2	3	C2-f2	4.5	450 - green	500	
2	2	C2-f3	3.5	150 - red	215	Vented 10kg sand as slurry from hole 2 m south
3	1	C3-f1	2	300 - white	300	
3	2	C3-f2	3	350 - red	450	
3	3	C3-f3	4	450 - green	450	Vented 50kg sand as slurry from hole 4 m SE
3	4	C3-f4	5	0	0	Communicated immediately to C3-f3 while loading well with water & gel - abandoned
4	1	C4-f1 or A	5.2	300 - white	400	Screen out w/ 50 l slurry remaining in hose & well
4	2	C4-f2 or B	2	275 - white	300	
4	3	C4-f3 or C	3.05	300 - red	400	Vented ~15 liters from hole 2 m west
4	4	C4-f4 or D	4.3	0	30	Communicated to C3-f3 within 1 minute - abandoned
4	5	C4-f5 or E	3.6	300 - green	400	Vented ~6 liter from hole 2 m west
4	6	C4-f6 or B´ - east	2.0	175 - white	175	
4	7	C4-f7 or B´´ - west	2.0	175 - white	175	
4	8	C4-f8 or C´ - west	3.05	175 - red	175	
4	9	C4-f9 or C´´ - east	3.05	175 - red	175	
5	East	C5-east	2	400 - white	500	Vented <1m NE & abandoned
5	West	C5-west	2			Received most of the injection

Depth is in meters below ground surface (bgs)

5.1 Installation of hydraulic fractures

5.1.1 Cell1 – Bioremediation (bioventing / SVE)

Cell 1, C1-f1, Green Sand 4.2m bgs – The fracture was created in Cell 1 at 4.2 m depth using 500kg of green sand and 550 liters of gel. The parent well was the first and north westernmost of the three fracturing wells installed in Cell 1. Uplift data are given in Appendix A. The pressure followed trends of typical horizontal fractures. A somewhat symmetric and broad uplift pattern (Figure 6) was observed, with centre of uplift close to the position of the nucleation well.

Cell 1, C1-f2, White sand 2.1 m bgs - The fracture was created from a nucleation depth of 2.1 m with 125 kg white sand and 175 liters of gel from a well installed as the south easternmost in Cell 1. The uplift data are given in Appendix A. A non-symmetrical uplift was observed with centre of the uplift situated southeast of the nucleation well. A small diameter doming feature raised and a single doming crack was observed running toward the southeast until slurry vented from the crack to the surface about 2 meters apart from the parent well. The crack and venting hole was afterwards cemented.

Cell 1, C1-f3, Red sand 3.6 m bgs – The fracture was nucleated from a well installed at 3.6 m depth with 350kg red sand and 400 liters of gel. The uplift data are given in Appendix A. The magnitude of observed uplift data was relatively small but showed an oval shaped broad uplift feature with the long axis oriented NW-SE and centre of uplift placed 2-3 m to the south of the nucleation point.

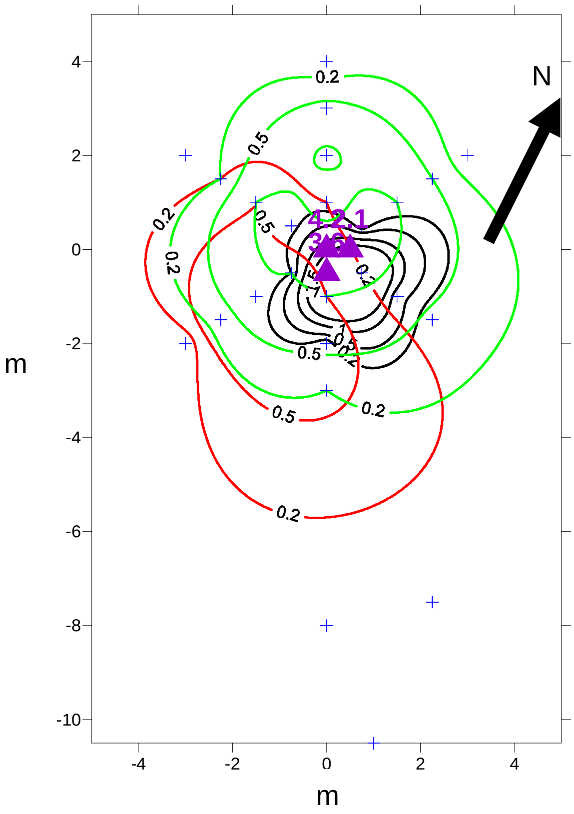

Figure 6. Contoured uplift data of hydraulic fractures installed in Cell 1 (bioremediation). Green contours: green sand (4.2m); Red contours: red sand (3.6m); Black contours: white sand (2.1m). Blue crosses show the position of graduated staffs for surveying measurements. All contour levels are in cm.

5.1.2 Cell 2 – Reference (Hydraulic test)

Cell 2, C2-f1, White sand 2.5m bgs – The fracture was created from a nucleation depth of 2.5m depth with 100kg white sand and 100litres of gel, which is a rather small fracture to establish. The uplift data are given in Appendix A. The parent well was the south-westernmost of the three wells installed in Cell 2 (see Fig. 8). A non-symmetrical small uplift was observed with centre of the uplift situated 0.5m in north-eastern direction of the nucleation well (Fig. 7). A small diameter doming feature was produced and a single doming crack was observed running toward the south-east until slurry vented from the crack about 2 meters apart from the parent well after 4 minutes of injection. The crack and venting hole was afterwards cemented.

Cell 2, C2-f2, Green sand 4.5m bgs – The fracture was created at 4.5m depth using 450kg of green sand and 500 litres of gel. Uplift data are given in Appendix A. The parent well was the north-easternmost of the three wells installed in Cell 2.The pressure followed trends of typical horizontal fractures. A somewhat symmetric and broad uplift pattern (Figure 7) was observed, with centre of uplift close to the position of the nucleation well.

Cell 2, C2-f3, Red sand 3.5m bgs – The fracture was created from a well installed to a depth of 3.5 m bgs with 150kg red sand and 215 litres of gel. The uplift data are given in Appendix A. The parent well was placed in the middle of the three fracturing wells installed in Cell 2 or 30-40cm apart form the 2.5 and 4.5m wells. A non-symmetrical relatively small uplift was observed with centre of the uplift situated 0.5-1m in north-eastern direction of the nucleation well. A small diameter doming feature was produced and a single doming crack was observed running toward the south-east. After 4 minutes of injection time slurry vented from the crack about 2 meters apart from the parent well. The crack and venting hole was afterwards cemented.

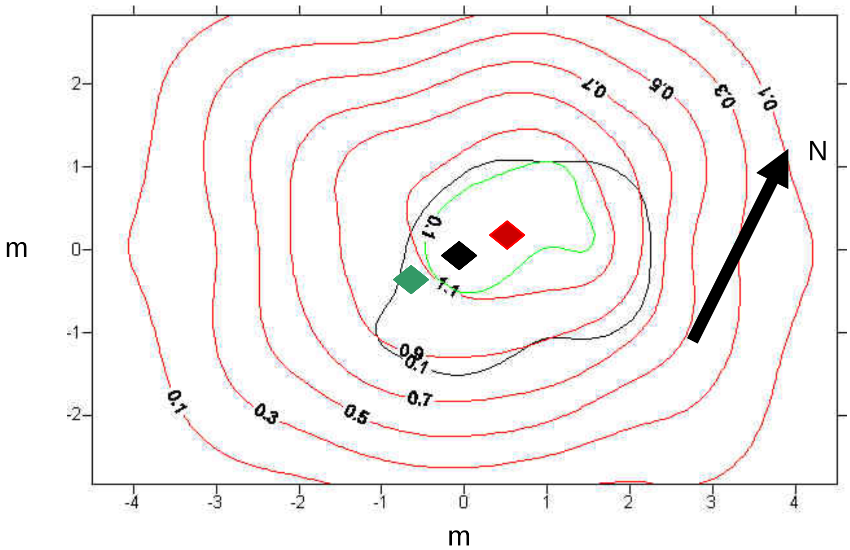

Figure 7. Contoured uplift data of each hydraulic fracture in Cell 2. Red contours: Green sand (4.5m) when injecting in well at (0,0); Black contours: red sand (3.5m); Green contours: white sand (2.5m). Contour levels are in cm.

Figure 8. Field instrumentation of Cell 2 for pneumatic tests (see also Nilsson et al, 2006b). Yellow circle: Fracturing wells at 2.5 (left), 3.5 (mid) and 4.5m (right). All other white plastic pipes are monitoring wells for hydraulic testing. Arrow points to the North.

5.1.3 Cell 3 – Abandoned (will be excavated later on)

Soil conditions in Cell 3 did not prove to be conducive to the creation of all the fractures. During the creation of the third fracture, injection slurry vented to the surface. Further diagnosis of the vent revealed a mixture of material from the second and third fracture. Furthermore, the attempt to crate a still deeper fracture demonstrated near-wellbore communication among the different elevations. Thus, Cell 3 was abandoned, and subsequent work was done in another area, which is denoted herein as Cell 4.

Cell 3, C3-f1, White Sand 2m bgs – The first fracture was created at a depth of 2 m bgs using 300 kg of white sand. The parent well was the north westernmost of four already installed in Cell 3. Pressure and uplift data are shown in Appendix A. The pressure followed trends typical of horizontal hydraulic fractures. A somewhat symmetric uplift pattern was observed, but the approximate centre of uplift was offset a meter to the northwest. Also, very little uplift was noted to the southeast. Doming cracks (cracks formed as a result of tension induced by the dome-shaped deformation of soil above the fracture) were observed extending westward and north-westward from the parent well. These results are not surprising given that the wells for deeper fractures had been already installed to the east and south of the well used to create this fracture. The existing deeper wells acted as reinforcement rods and suppressed fracture formation to the southeast.

Cell 3, C3-f2, Red Sand, 3m bgs – The fracture was nucleated from a well installed to a depth of 3 m and created with 350 kg of red sand and 450 litres of gel. The pressure data follow trends typical of horizontal or sub-horizontal fractures. The southern placement of the parent well among the four wells installed permitted southern expression of uplift, with the centre located approximately 1.5 m south of the injection well. A single doming crack was observed running toward the southeast. About a meter beyond the discernible extent of this crack, a small dome and collection of doming cracks about 1 m in extent seemed to have developed.

Cell 3, C3-f3, Green Sand, 4m bgs – The fracture was nucleated from a well installed to a depth of 4 m and created with 450 kg of green sand and 450 liters of gel. The pressure log shows declining pressure for about 20 seconds after breakdown followed by pressure increase over the next minute. The minute of increasing pressure could be the result of sand grains accumulating in the fracture or could be an indication of the fracture propagating steeply away – probably upwards – from the target elevation. Limited uplift data were collected, and a symmetrical pattern can not be described. After nine minutes slurry vented from a hole located about 4 meters southeast of the parent well. Injection was halted, but restarted to purge the equipment and well of sand because the planned volume had already been fed to the mixer.

Exploration of the vent revealed a hole about 5 cm diameter inclined 30° from horizontal. The hole seemed to extend underneath the dome noted during the creation of the fracture Cell3-f2. Excavation of the dome with a shovel caused the expulsion of green and red sand from the hole and revealed green and red sand commingled along a tilted plane that included the axis of the hole.

Cell 3, C4-f4, White Sand, 5m bgs – The notching procedure was applied as described above. While loading the hole with gel, fluid returns were noted from Cell3-f3. Further fracture was not deemed worthwhile – injection could be expected to readily communicate to 4 m and 3m fractures. No sand or gel was injected as a fracture. Cell 3 was abandoned as fracturing location.

About 20 minutes after the fracturing attempt, fluid levels were measured in the wells. Water was encountered 1 m bgs in Cell3-f2 despite the water filled trench at the vent 4 m southeast. In Cell3-f3, water stood at 2.8m bgs, also in contrast to the water in the trench and in the 3m well.

5.1.4 Cell 4 – Steam injection / Vacuum extraction

Cell 4, C4-f1 or A, White Sand 5.2m bgs – The fracture was created from a well installed in a borehole constructed to collect an exploratory core sample of Cell 4. Thus the first fracture in Cell 4 was nucleated at a depth of 5.2 m bgs. 300kg of white sand were used. The mass of sand was limited intentionally out of concern that larger volumes of red and green sand had vented in Cell 3 and that the well installed to 5 m in Cell3 had communicated readily with overlying fractures. The sand was transported in 400 litres of gel. The proportion of sand in the slurry was increased four times during the creation of this fracture. The consequence of increased loading can be seen in the pressure log; pressure increased substantially as a result of increased effective viscosity after an initial breakdown. Just as the last of the sand was dispensed to the mixer, the injection pressure rapidly increased to the maximum capabilities of the equipment. Such a screen-out condition developed because the fracture aperture could not accept the proportion of sand injected and sand accumulated (bridged) in the injection well and hose.

Limited uplift was observed. Elevation change of 1 mm was noted at each location 1.5 m from the injection well, and locations 3m north and northwest also showed 1 mm. Otherwise no changes were detected. These limited data vaguely suggest an elliptical fracture forming somewhat northwest of the injection well.

Cell 4, C4-f2 or B, White Sand 2m bgs – This fracture was created from a well installed to a depth of 2 m bgs at a location 60 cm south of the well used to create the fracture at 5.2 m bgs. 275kg of white sand were transported in 300 litres of guar gel. As in Cell 3, the pressure followed trends typical of horizontal hydraulic fractures while a somewhat symmetric uplift pattern was observed. Uplift was displaced southward, consistent with the northern presence of the well to 5.2 m.

Cell 4, C4-f3 or C, Red Sand 3.05m bgs – The fracture was created from a well installed to a depth of 3.05 m bgs at a location 65 cm south of the well used to create the fracture 2 m bgs (1.25 m south of well to 5.2 m.) Three hundred kilograms of sand were transported in 400 litres of guar gel. The pressure log was consistent with the creation of a gently dipping or horizontal fracture. The increase of injection pressure after an initial breakdown can be attributed to the increased effective viscosity of the slurry and the resistance of flow offered by the fracture aperture. Symmetrical and broadly distributed uplift was noted. This fracture vented about six litres of slurry from a hole about 2 m west of the injection locations (Figure 9). The vent hole later proved to be an ancient and uncharted boring.

Figure 9. Venting of red coloured sand (Cell 4) due to shortcut via an ancient and uncharted boring in the subsurface constructed in the past by Russian military.

Cell 4, C4-f4 or D, No Sand, 4.3m bgs – A well was constructed to a depth of 4.3 m bgs at a location 60 cm south of the well used to create the 3 m fracture (1.85 m south of the well to 5.2 m.) Although initial injection pressure indicated successful initiation of a horizontal fracture, substantial fluid vented from the 3 m well within 1 minute, presumably due to the small spacing between the wells. Injection was terminated before and sand could be introduced. No uplift was detected. This well was replaced by a shallower well.

Cell 4, C4-f5 or E, Green Sand, 3.6m bgs – This replacement for the aborted 4.3 m fracture was nucleated from a well set to a depth of 3.6 m bgs at a location 60 cm south of the well used for the 4.3 m attempt (2.45 m south of the 5.3 m well.) The notch process lasted 3 minutes and produced a very silty / sandy slurry with a strong diesel smell. Only one notch was cut, as opposed to the practice of cutting two notches a centimetre apart. After two minutes of injection, slurry of red sand (in contrast to the injected colour) vented from the hole about 2 m west where the fracture at 3 m had vented. Presumably the red slurry was material contained within the ancient boring. The vent ceased for a few minutes, then resumed but discharged slurry of green sand. In total, about 20 litres of slurry vented to the surface. This fracture also exhibited symmetric and broad uplift associated with horizontal fractures.

Four small size fractures were installed with 2 fractures at 2 m depth with white sand (C4-f6 and C4-f7) and 2 fractures at 3 m depth with red sand (C4-f8 and C4-f9). These four fractures are also named the Mickey Mouse ears. Installation of these fractures follows the procedure outlined in Section 5.1.5. The exact position where the two pairs of fractures should be most optimal placed along the periphery were decided after coring the C4-f2 and

C4-f3 fractures in advance of nucleating the “Mickey Mouse ears” at 2.0 and 3.0 m depth in Cell 4.

Cell 4, C4-f6 and C4-f7, both White sand, 2.0m bgs – The two fractures were individually installed at 2.0 m depth with a spacing of 2.5m between the locations. The drive points were dislodged 18cm to open an 8cm borehole. Each well was notched for 2 minutes with a single jet that was rotated only 60 degrees pointing against Well B (at 2 m depth, see Figure 10). A tee was installed on the injection line so that slurry could be injected simultaneously to each well. About 175 kg of white sand and 175 litres of gel was injected in each well. A broad uplift was observed with an overlap of C4-f2 and the combined C4-f6 and C4-f7 fractures (Figure 10).

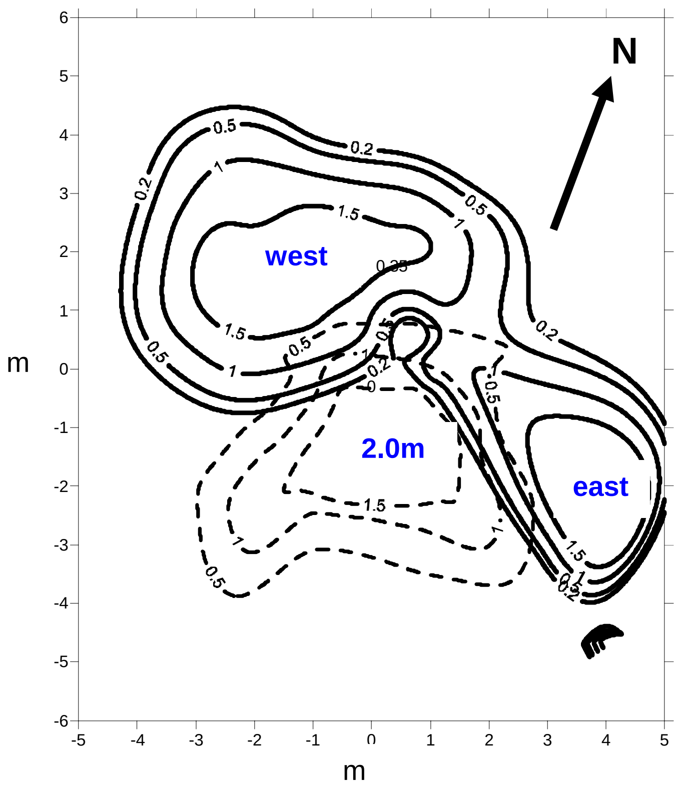

Figure 10. Contoured uplift data from the installation of the 2.0m deep Mickey Mouse ear (solid contour lines) and the 2.0m deep fracture C4-f2 (dashed contours). “East”, “West” and “2.0m” indicates an approximate position of the three nucleation wells C4-f2, C4-f6 and C4-f7. Contour levels in cm.

Cell 4, C4-f8 and C4-f9, both Red sand, 3.05 m bgs – The two fractures were individually installed at 3.0 m depth with a spacing of 2.25m between the locations. The drive points were dislodged 18cm to open an 8cm borehole. Each well was notched for 2 minutes with a single jet that was rotated only 60 degrees pointing against Well C (at 2 m depth, see Figure 11). A tee was installed on the injection line so that slurry could be injected simultaneously to each well. About 175 kg of white sand and 175 litres of gel was injected in each well. A broad uplift was observed with an overlap of C4-f3 and the combined C4-f8 and C4-f9 fractures (Figure 11).

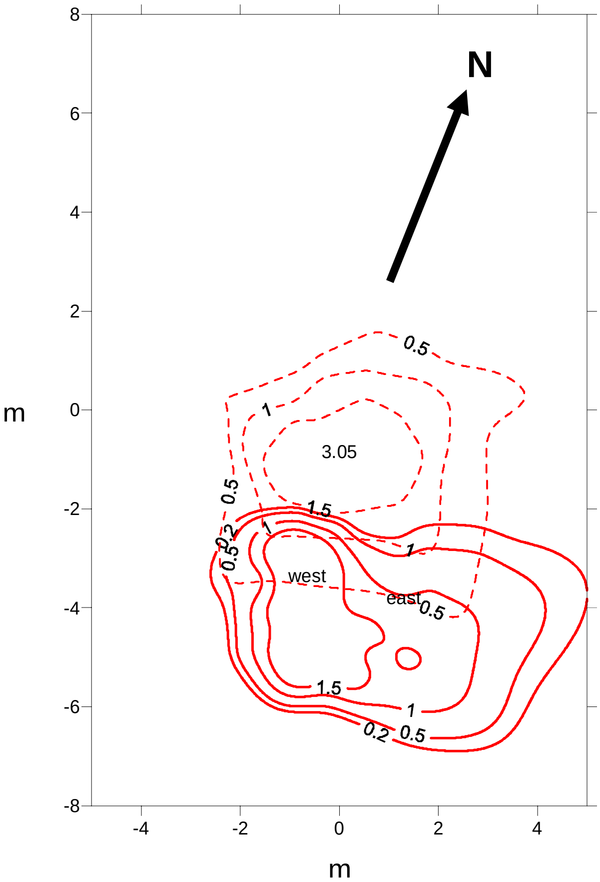

Figure 11. Contoured uplift data from the installation of the 3.0m deep Mickey Mouse ear (solid contour lines) and the 3.05m deep fracture C4-f3. “West”, “East” and “3.05” indicates approximate position of the three nucleation wells C4-f3, C4-f8 and C4-f9. Contour levels in cm.

Location of sample borings in Cell 4 are shown in Figure 12 and the uplift patterns are shown in Figure 13.

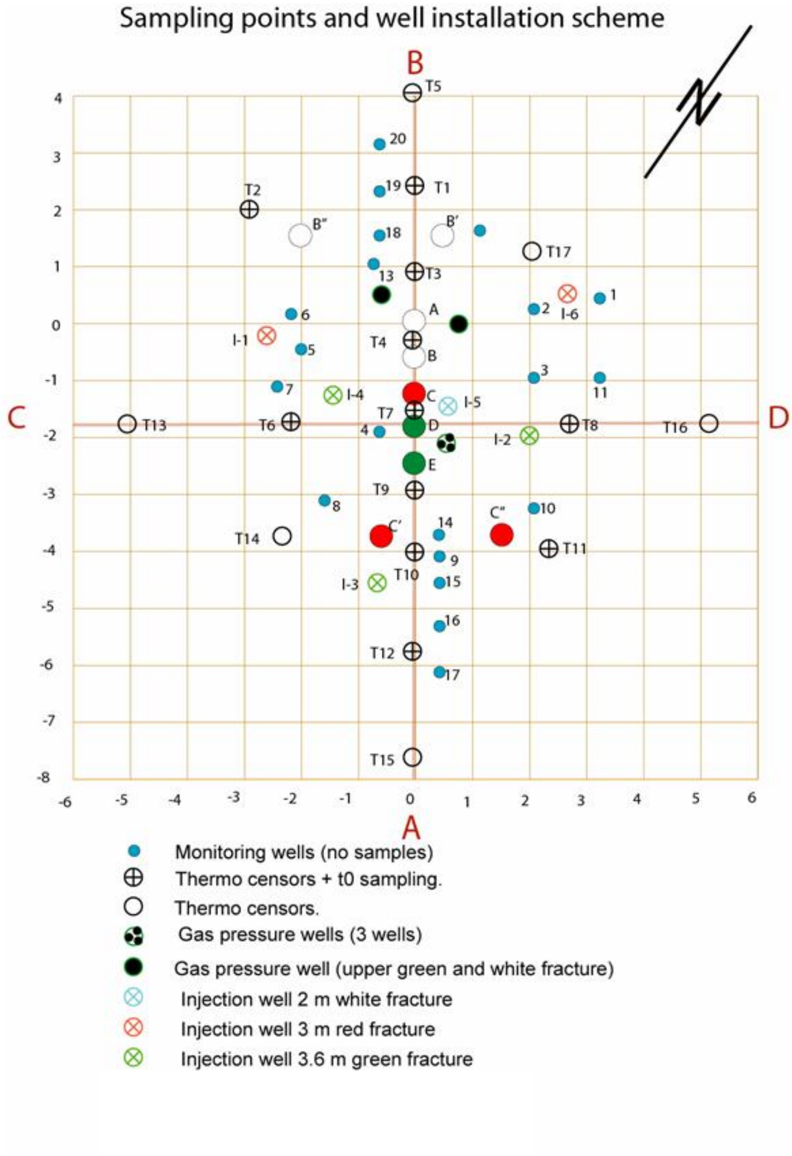

Figure 12. The location of sample wells (blue dots), thermo couple wells, injection wells and fracturing wells in Cell 4.

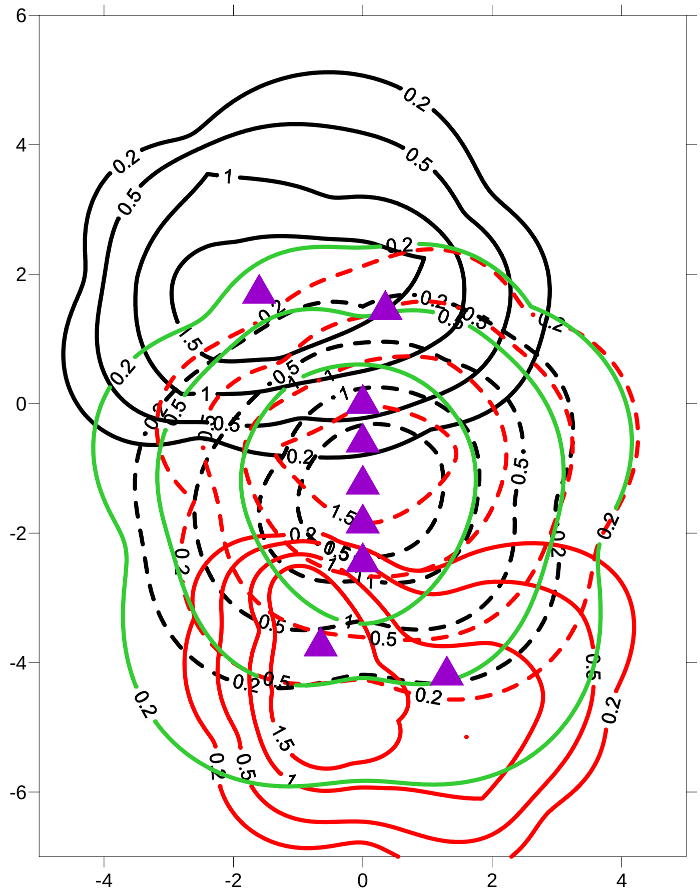

Figure 13. Contoured uplift data of each hydraulic fracture in Cell 4 (steam injection). Black solid contours: white sand (2.0m); Red contours: red sand (3.0m); Green contours: green sand (3.6m) and Black dashed contours: white sand (5.2m). Purple triangles injection / vacuum extraction wells. Contour levels in cm.

5.1.5 Cell 5 – Pilot cell for creating Mickey Mouse Ears

Cell 5, C5frx 1, White Sand, 2m bgs (Mickey Mouse Ear Test) – This fracturing process tested whether a single fracture could be created by the collasence of simultaneous injection into two wells. The configuration of a single fracture and two compentently connected wells can be useful for processes that require both injection into and recovery from the same fracture. For example, one well could be used to inject steam while the other recovers condensate, thereby forming a heat-radiating plane in the subsurface.

Two wells were constructed a few meters north of Cell 4. These locations define another cell – Cell 5. The wells were constructed as in other cells and installed to depth of 2 m with a spacing of 2.15 m between the locations, which were arranged along an east – west line. The drive points were dislodged 18 cm to open an 8 cm borehole. Each well was notched for 2 minutes with a single jet that was rotated only through the 90° arc facing the opposing well. A tee was installed on the injection line so that slurry could be injected simultaneously to each well.

Injection started with uncrosslinked gel, and a short lack of sand loaded slurry ensued while crosslinker was provided. After a minute, a significant vent of guar and some sand was noted about 0.6 m northeast of the eastern injection well. After another minute, the vent obviously consumed the delivery of the injectin pump, so injection was terminated while plumbing was rearranged to inject the remaining slurry to the western well. Upon restart, injection proceeded normally for three minutes when a significant discharge developed from the uncappeed eastern well – injection had successfully connected the two wells. About 400 kg of sand and 650 liters of guar gel were pumped, but as much as 100 kg and 150 liters were wasted by re-plumbing or vented. Although broadly distributed uplift was noted, the vent near the eastern well rendered several ponts meaningless. The centermost uplift staff collapsed, and the sod surrounding the eastern well was clearly inflated with several centimeters of liquid.

Subsequent excavation revealed the wells were installed near an ancient trench and that venting followed lines of weakness defined by that excavation.

5.2 Fracture identification

5.2.1 Cell1

The spatial distributions of the three hydraulic fractures in Cell 1 were mapped as part of the initial background soil sampling (T0). 12 hand drilled wells were created including geological description continuously to more than 5 m bgs.. The T0 sampling is more thoroughly described and discussed in Deliverable D12.

The geological description of soil material and lithological unit identifications was transferred to two cross-sections along the North-South (CD) and East-West (AB) directions in Figure 15. The horizontal extension was evaluated based on identifications of the different coloured fractures (Figure 14). In addition occurrences of sand layers/lenses were done by the HGT staff establishing the sampling wells. The three colours of white, green and red can be recommended for future research projects when they have shown to be very easy to recognise in both the hand drilled samples and in core samples using the Vibro Core Technique (Figure 16).

The individual coloured sand fillings and natural sand layers/lenses were determined with an accuracy of 2-3 cm in vertical direction. The hydraulic fractures were generally possible to correlate in between the individual wells. However, the horizontal extension of the cm thick sand layers / lenses varies very much at the field site with a few horizons that can be correlated horizontally in between most the sampling wells. But the majority of the embedded sand layers / lenses in Unit 2-4 has a length smaller than the shortest distance between many of the sampling wells (i.e. smaller than 0.5 m in horizontal direction).

The 3.6 m (red) and 4.2 m (green) deep fractures are very likely horizontal to sub horizontal oriented. The two fractures are meeting at least one place at the interface between Unit 3 and 4 at 3m depth (near the T0 sampling wells ID# 4, 9 and 11). Initial hydraulic tests have given evidence for direct hydraulic connection between these two fractures (Nilsson et al, 2006b). The upper white sand fracture nucleated at 2 m depth has a more uncertain extension in the subsurface. It was venting on terrain app. 2 m SE of the injection well. The fracture form is most likely saucer shaped to vertical as indicated in Figure 15.

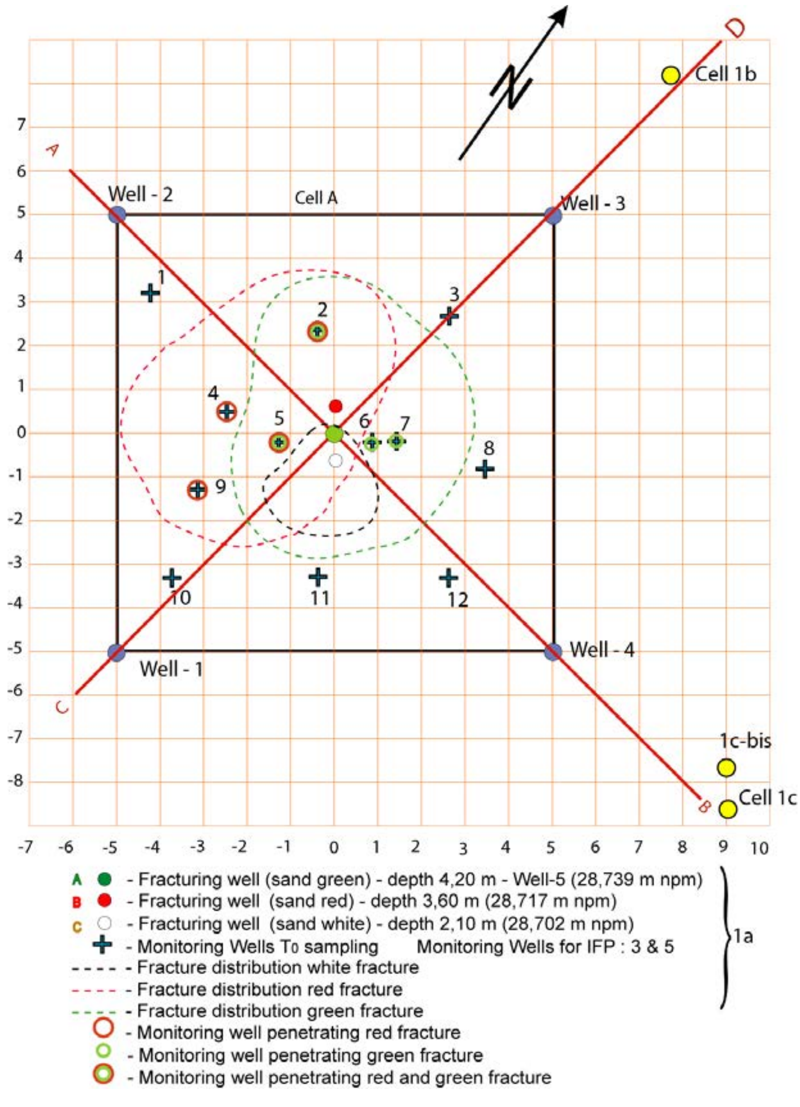

Figure 14. The location of T0 sample wells (blue dots), injection / extraction wells and fracturing wells in Cell 1. The cross sections AB and CD are shown in Figure 15.

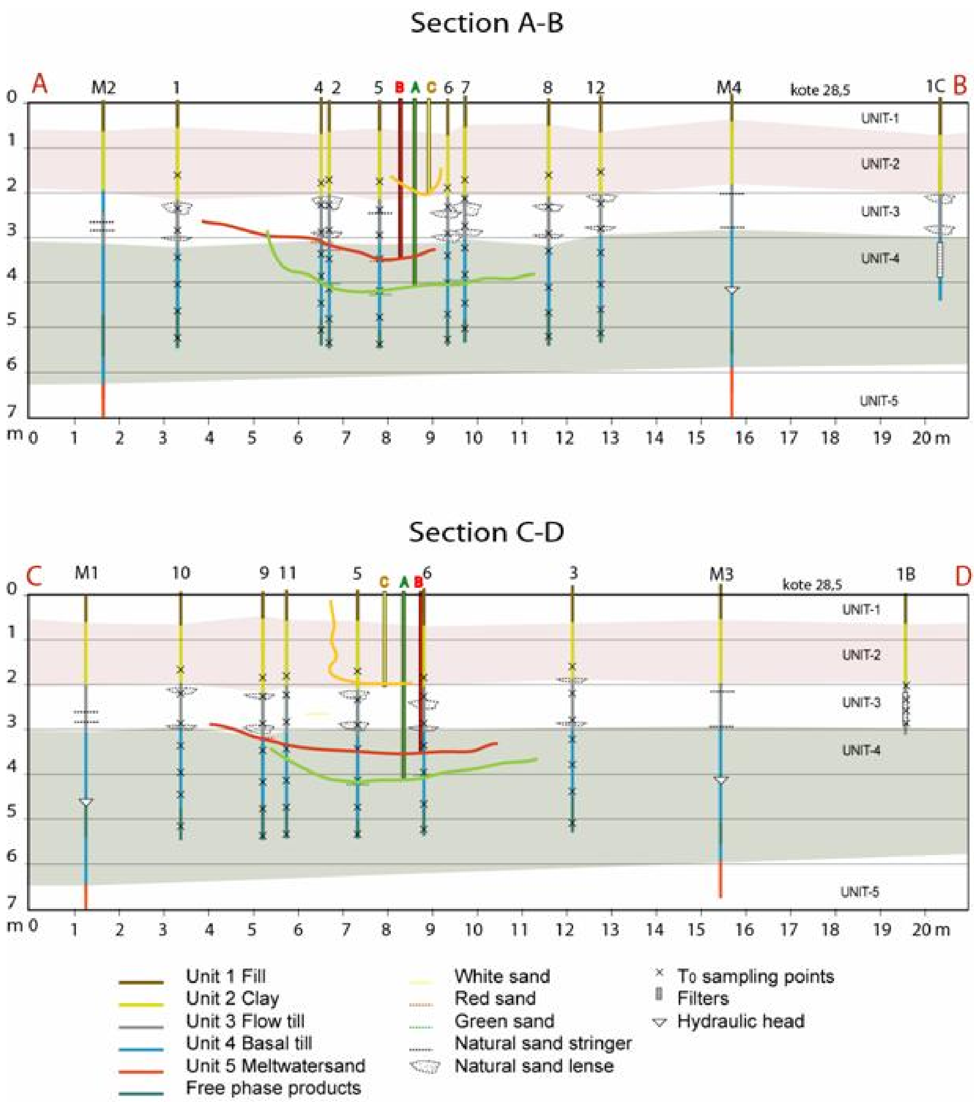

Figure 15. Cross sections of Cell 1 based on hand drilling information. Position of AB and CD are shown in Figure14.

5.2.2 Cell 2

The extensions of the three hydraulic fractures in Cell 2 have not yet been identified. An excavation of the fractures in Cell 2 is planned to be performed in fall 2006 at the same time, as the steam injection cell (Cell 4) will be mapped by excavation.

5.2.3 Cell 3

Fractures are not yet identified in Cell 3. They will be excavated together with Cell 2 and Cell 4 in Fall 2006.

5.2.4 Cell 4

The hydraulic fractures in Cell 4 have been identified based on geological information collected in a significant number of wells drilled in Cell 4. In total 56 wells have been drilled in an area covering approximately 7 x 7 m. In Table 3 is given statistics and purpose of different well types are listed. All wells are described geologically with a nearly full recovery of cores sampled in average to 5.5 m depth.

Table 3. Well statistics of drilled wells in Cell 4 used for fracture identification

Well type	**Purpose**	**Number**
Thermo couple wells	Temperature monitoring	17
Vibro Core wells	Intact soil sampling	20
Gas pressure wells	Gas pressure monitoring	5
3-4 inch injection / extraction wells	Establishing hydraulic fractures and injection/extraction of steam	14
Total		**56**

The accuracy and frequency of natural sand lenses or layers observed in Cell 4 are similar to that of Cell 1. The horizontal and vertical extensions of different hydraulic fractures are evaluated in Figure 17 and on the two cross sections in Figure 18. The deepest fracture at 5.2 m depth (white sand) show a very limited extension with an oval sub horizontal shape (diameter: 1-3m). The purpose of the fracture is to create a permanent drawdown of the free products seeping from the underlying aquifer through the bottom sediments. The efficiency of the free product drainage is quite uncertain.

The green fracture at 3.6m depth has an almost horizontal orientation along the interface between unit 3 and 4 with a diameter on 5-6 m.

The red fracture(s) do shown more sub horizontal to saucer shaped features with a diameter of the complex fracture distributions of totally 4-6m. The red fractures are nucleated in the middle of Unit 3 (flow till) and propagate shortly after upward to the interface between Unit 2 and 3 where a more horizontal propagation continues. The 3 m deep red Mickey

Mouse ears are probably not directly connected to the parent fracture nucleated from Well C. This means that the attempt to connect the additional fractures to the parent fracture has not been fully successful. However, hydraulic tests performed later on have shown satisfying hydraulic connection between the steam injection wells C´ & C´´ and the steam extraction Well C at the same depth.

The upper complex of white fractures is all nucleated in the middle of unit 2 and shows an almost sub-horizontal fracture orientation. The fracture mapping of the individual white coloured fractures do not show appearance of one major single fracture consisting of the parent fracture grown together with the so called Mickey Mouse ears. The Mickey Mouse fractures has not propagated in exactly the same depth as the parent fractures arising in overlapping white fractures (10-20 cm apart in vertical direction). Hydraulic tests has on the other hand shown satisfying hydraulic connection between the three white fractures at 2 m depth.

Figure 16. Coring of the hydraulic fractures in Cell 4 using Vibro Core Technique.

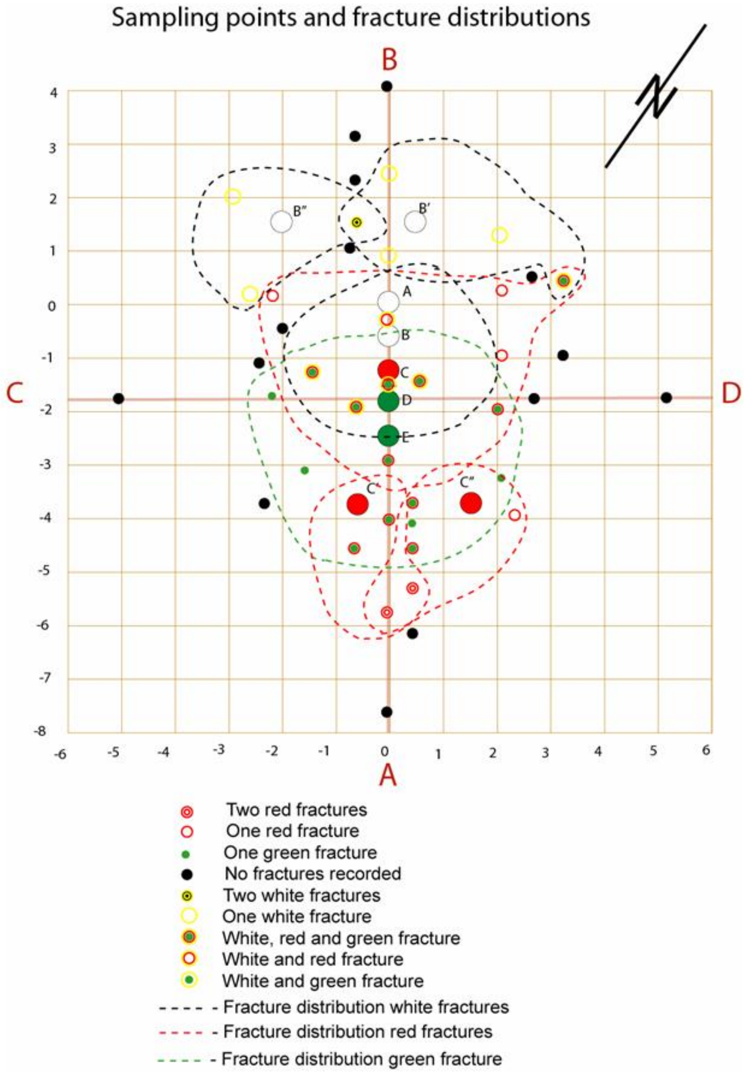

Figure 17. Horizontal fracture distribution in Cell 4.

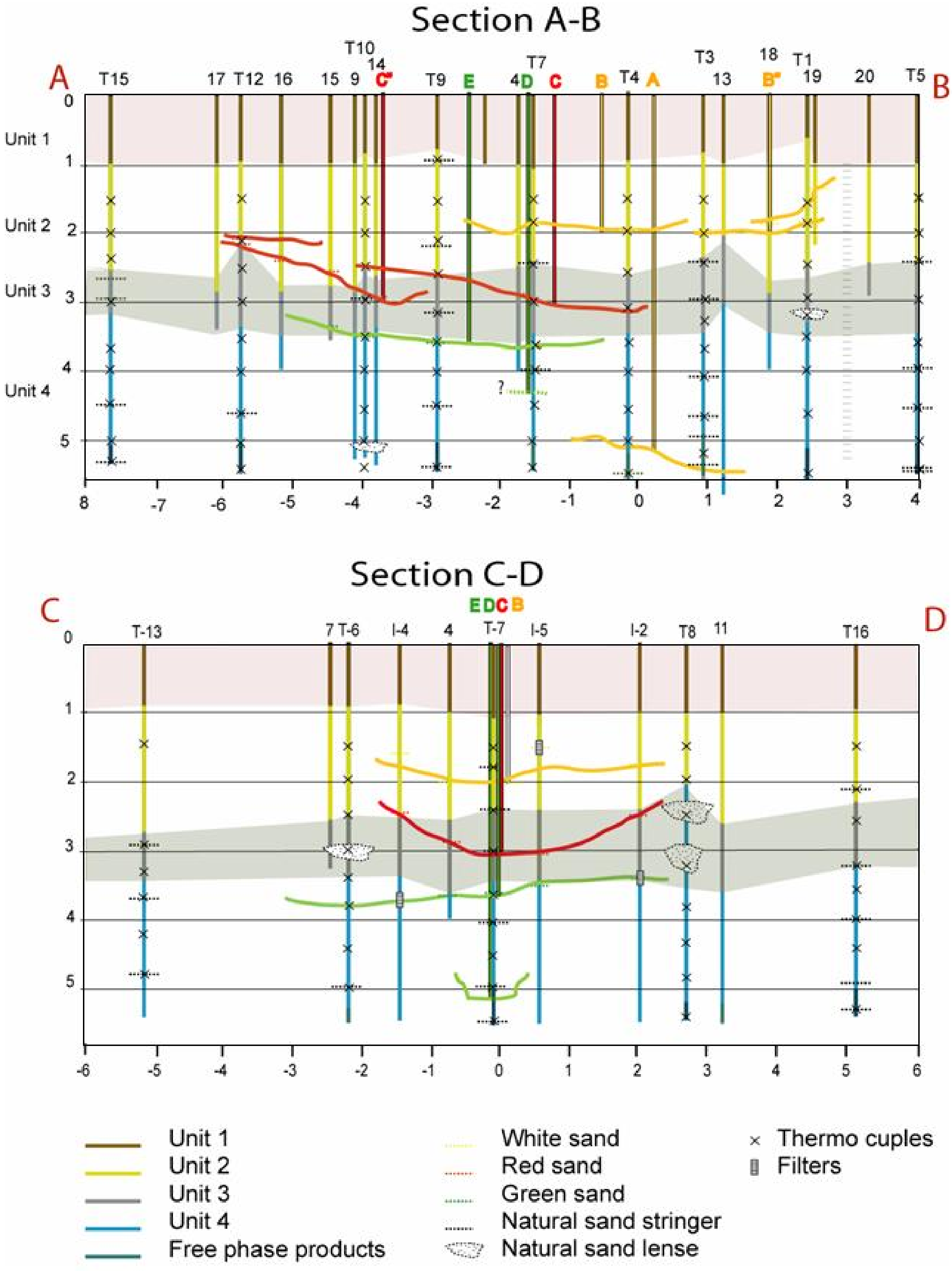

Figure 18. Cross sections of Cell 4 based on hand drilling information. Position of AB and CD are shown in Figure 12.

5.2.5 Cell 5

A 14 m long trench to one meter depth was excavated between Cell 3 and 5. The subsurface was investigated for occurrences of man ways underground (1 to 3 meters depth) like the one passing from the building underneath the toilet**.** No signs of former trench features were noted, so we don't believe there are occurrences of man ways underneath the steam cell (Cell 4). However, various other water pipes and electrical cables were observed perpendicular to the trench. Only one minor copper cable was seen with extension in direction below Cell 4 at 1m depth. That means there may be a trench through Cell 4 but it is assessed not to have any influence on the steam injection experiment.

Parallel to the E and W injection wells (Cell 5) a 1 m deep trench with a 2 inch water pipe + a heavy size electrical cable is found in the bottom of the trench. Just beside the E injection well (in the bottom of the trench) a 30-40 cm wide vertical cylindrical construction (probably abandoned digged well) is examined to more than 2.0 m depth.

The long trench was extended to 2-2.25 m depth 2 meters north of the two injection wells.

Photo of the excavation of the almost horizontal white sand-filled hydraulic fracture at 2-2.5m depth in Cell 5 is given in Figure 19. The width of the white coloured sand fracture varies between a few mm to 5 cm.

Figure 19. Excavation of Cell 5, where the Mickey Mouse ear procedure was trained (See text). The photo shows an almost horizontal white sand-filled hydraulic fracture at 2-2.5m depth. The width of the white coloured sand fracture varies between a few mm to 5 cm.

6. Discussion

Fracture propagation
Venting of the injected sand as slurry on the ground has been observed when injecting fractures in Unit 2 and 3 but not in Unit 4. In Unit 2 venting was seen in most of the cells (Cell 1, 2, 4 and 5) and in Unit 3 venting was seen only in Cell 4 and 5. This can most likely be explained by lack of over-consolidation of the lacustrin and flow-till which the sediments in Unit 2 and 3 consists of. In Unit 4 the fracture mapping show that the injected fractures are propagating in an almost horizontal direction as expected for an over-consolidated type of sediment.

Fracture Form
Mapping of fracture geometry in the heterogeneous geologic media of Kluczewo has shown that the accuracy of delineating the fracture structures on horizontal length scale is less than 0.5 m and in vertical scale between 2 and 5cm in accuracy. It has been interesting to experience how difficult it is to delineate the fracture structure in space. Even with a (concerning) high number of wells (approximately 60 wells) distributed on a 50 m^2 area in Cell 4 the experienced geologist are left with headache correlating unit boundaries, hydraulic fractures of different coloured sand and natural horizontal layered sand stringers in 2D and 3D geological models. This study indicate that the horizontal correlation length of natural layered sand layers or lenses are typically smaller than 0.5 m in all three units (Unit 2-4) at the Kluczewo field site. It is important to keep in mind that both the emplaced hydraulic fractures and the natural sand lenses will together with the vertical fracture network impact the flow paths of both the air injection / extraction in the bio cell (Cell 1) and the steam injection / hot air extraction in Cell 4.

7. Conclusion

Main findings of installing hydraulic fractures at the field site in Kluczewo in Poland can be summarised as follows:

- A drilling rig and mixing equipment dedicated for hydraulic fracturing have been designed, constructed and tested on operational field scale by Danish STRESOIL partner Broeker (drilling company). The American subcontractor Bill Slack, FrX has provided knowledge transfer on detailed construction principles of the rebuild drilling rig and mixing equipment.
- In five experimental 10x10m cells 19 fractures out of 21 hydraulic fractures have been installed successfully during a 2 months period in 2005 (April-May 2005). Only two fractures failed due to bypass to terrain of injected slurry arising from installations in the subsurface performed by the military at the site.
- Hydraulic fractures installed in the basal till unit (Unit 4) show a horizontal to sub horizontal fracture form. In the flow till unit (Unit 3) fractures show sub-horizontal to saucer shaped features with an upward propagation of the fractures until an almost horizontal propagation along the interface between Unit 2 and 3. Hydraulic fractures installed at 2-2.5 meter depth in Unit 2 (lacustrin deposits) show heterogeneous non-horizontal features with venting on terrain in almost all cells.
- The preliminary spatial extension of the fractures has been identified using uplift data in all cells and drilling activities in 3 of 5 cells (Cell 1, 4 and 5). The mapping will be further specified when T1 and T2 sampling arise in Cell 1 and T2 sampling arise in Cell 4.
- A novel fracturing process (Mickey Mouse ears) have been tested to investigate if a single fracture could be created by the coalescence of simultaneous injection into two wells. The configuration do show promising results to create a single fracture and two competently connected wells can subsequently be useful for processes that require both injection into and recovery from the same fracture.

8. Acknowledgement

The present work was carried out within the project In Situ STimulation and REmediation of contaminated fractured SOILs (STRESOIL). The project is funded by The European Commission (Contract Number SSPI-CT-2003-004017) within the Sixth Framework Programme (Global change and ecosystems).

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Appendix A

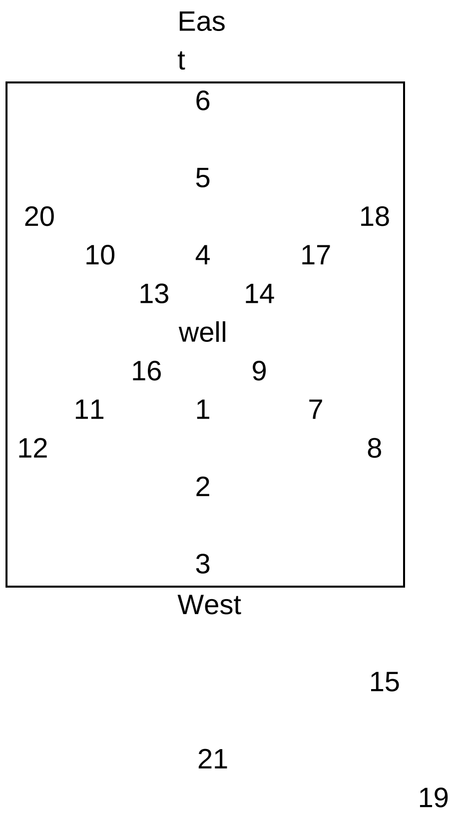
Pressure and uplift data

Appendix A1. Cell 1
Appendix A2. Cell 2
Appendix A3. Cell 3
Appendix A4. Cell 4
Appendix A5. Cell 5

Appendix A1 (Cell 1)

Date	20.MAY.2005
	3,6 m
Cell	1
depth	3,6
colour	red
amount of sand injected	350kg
amount of guar injected	400l
flow rate	1,8m3/h
pressure	1,9-3,0bar
injection time	12 min

Cell 1
sticks configuration
distance between neighbour sticks in the same line 1,0m



	Cell 1 fracture 4,2 m, green							
	time [h:min]							
	14:32	14:37	14:40	14:50	15:02	15:32	16:32	
Stick	level [cm]							uplift
3	86,1	86,1	85,8	85,8	85,8	85,9	85,9	0,2
2	90,0	89,9	89,3	89,2	89,3	89,3	89,4	0,6
1	79,6	79,5	78,7	78,4	78,5	78,6	78,6	1,0
4	71,6	71,7	70,5	70,6	70,7	70,8	70,9	0,7
5	68,7	68,4	67,3	67,4	67,5	67,5	67,6	1,1
6	71,5	71,4	70,8	70,8	70,9	70,9	70,9	0,6
12	70,3	70,1	69,9	69,9	69,9	70,0	70,0	0,3
11	74,3	73,6	73,3	73,2	73,3	73,3	73,4	0,9
16	54,2	53,6	53,2	53,0	53,1	53,1	53,2	1,0
14	43,6	42,8	42,0	42,1	42,1	42,2	42,2	1,3
17	64,4	63,8	63,2	63,2	63,3	63,4	63,4	1,0
18	74,0	73,6	73,3	73,4	73,4	73,4	73,5	0,5
20	60,7	60,6	60,4	60,4	60,4	60,5	60,5	0,2
10	68,6	68,2	67,5	68,4	67,5	67,5	67,6	1,0
13	6,8	6,2	5,4	5,2	5,3	5,4	5,5	1,3
9	75,8	75,5	74,4	54,6	54,6	74,7	74,7	1,1
7	84,2	83,9	83,1	83,2	83,3	83,4	83,4	0,8
8	85,3	85,2	84,8	84,8	84,9	84,9	84,9	0,4
								0,0
21	82,0	82,0	82,0	82,0	82,0	82,0	82,0	0,0
19	81,8	81,8	81,8	81,8	81,8	81,8	81,8	0,0
15	5,0	5,0	5,0	5,0	5,0	5,0	5,0	0,0

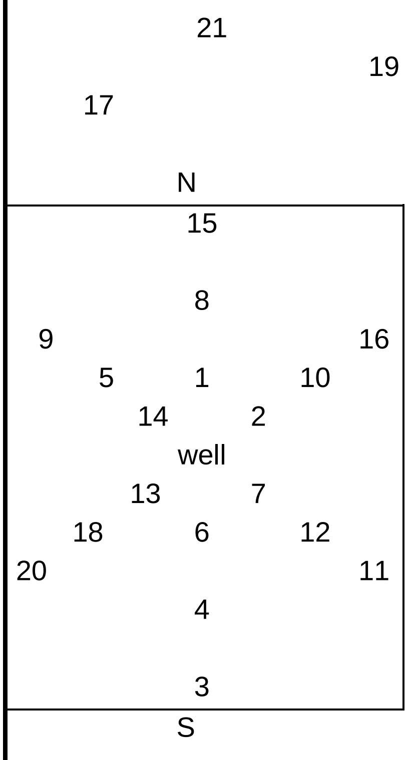
Cell 1 fracture 2,1m, white							
	time [h:min]						
	17:04	17:09	17:30	18:00	18:30	19:00	
Stick	level [cm]						uplift
3	85,9	85,9	85,9	85,9	85,9	85,9	0,0
2	89,4	89,4	89,4	89,4	89,4	89,4	0,0
1	78,6	78,2	75,3	75,5	75,6	75,8	2,8
4	72,0	71,9	71,9	71,9	71,9	71,9	0,1
5	67,6	67,5	67,5	67,6	67,6	67,6	0,0
6	76,1	76,1	76,1	76,1	76,1	76,1	0,0
12	70,0	70,0	70,0	70,0	70,0	70,0	0,0
11	73,4	73,4	73,4	73,4	73,4	73,4	0,0
16	53,2	53,0	53,0	53,0	53,0	53,0	0,2
14	42,2	42,1	42,1	42,1	42,1	42,2	0,0
17	63,4	63,4	63,4	63,4	63,4	63,4	0,0
18	73,5	73,5	73,5	73,5	73,5	73,5	0,0
20	60,5	60,5	60,5	60,5	60,5	60,5	0,0
10	67,7	67,5	67,6	67,6	67,6	67,6	0,1
13	5,5	5,4	5,4	5,4	5,4	5,4	0,1
9	74,7	71,1	70,5	70,7	70,9	71,0	3,7
7	83,4	82,4	82,5	82,5	82,6	82,7	0,7
8	84,9	84,9	84,9	84,9	84,9	84,9	0,0
							0,0
21	82,0	82,0	82,0	82,0	82,0	82,0	0,0
19	81,8	81,8	81,8	81,8	81,8	81,8	0,0
15	5,0	5,0	5,0	5,0	5,0	5,0	0,0

	Cell 1 fracture 3,6 m, red								
	time [h:min]								
	13:13	13:15	13:20	13:30	13:43	14:13	14:43	15:13	
Stick	level [cm]								uplift
3	75,8	75.7	75,2	75,0	75,1	75,2	75,2	75,2	0,6
2	78,7	78,6	78,0	77,7	77,8	78,0	78,0	78,1	0,7
1	69,9	69,9	69,4	69,1	69,2	69,2	69,4	69,4	0,5
4	61,7	61,5	61,4	61,4	61,4	61,5	61,5	61,5	0,2
5	57,3	57,3	57,2	57,2	57,2	57,3	57,3	57,3	0
6	59,3	59,3	59,2	59,2	59,2	59,3	59,3	59,3	0
12	65,4	65,2	64,2	64,1	64,2	64,3	64,4	64,5	1
11	69,4	69,2	68,3	68,1	68,2	68,4	68,5	68,5	0,9
16	42,6	42,5	41,8	41,6	41,7	41,9	41,9	42,0	0,7
14	42,6	42,5	42,4	42,5	42,5	42,5	42,5	42,6	0,1
17	8,0	8,0	8,0	8,0	8,0	8,0	8,0	8,0	0,0
18	59,2	59,2	59,2	59,2	59,2	59,2	59,2	59,2	0
20	49,0	48,8	48,6	48,6	48,6	48,8	48,8	48,8	0,2
10	57,9	57,8	57,3	57,3	57,3	57,2	57,4	57,5	0,5
13	9,0	8,9	8,5	8,5	8,5	8,6	8,7	8,7	0,3
9	62,6	62,3	62,1	62,2	62,2	62,3	62,4	62,4	0,2
7	69,9	69,8	69,7	69,7	69,8	69,8	69,8	69,8	0,1
8	74,0	73,9	73,8	73,9	73,9	73,9	73,9	73,9	0,1
									0,0
21	72,2	72,2	72,2	72,2	72,2	72,2	72,2	72,2	0,0
19	72,0	72,0	72,0	72,0	72,0	72,0	72,0	72,0	0,0
15	5,2	5,2	5,2	5,2	5,2	5,2	5,2	5,2	0,0

Appendix A2 (Cell 2)

date	24.MAY.2005		
Cell	2	2	2
depth	2,6	3,6	4,6
colour	white	red	green
amount of sand injected	100kg	150kg	450kg
amount of guar injected	100l	215l	500l
flow rate			
pressure	2,1bar	3,2-5,0bar	3,2-4,0bar
injection time	4 min	4 min	14 min
temp		22	22

Cell 2
sticks configuration
distance between neighbour sticks in the same line 1,5m



Cell 2					
fracture 2,6m, white					
			time	[h:min]	
	09:56	10:05	10:35		
Stick	level (cm)				uplift
15	69,2	69,2	69,2		0,0
8	73,8	73,8	73,8		0,0
1	76,0	76,0	76,0		0,0
6	83,7	83,6	83,6		**0,1**
4	97,6	97,6	97,6		0,0
3	91,7	91,7	91,7		0,0
20	68,3	68,3	68,3		0,0
18	78,8	78,8	78,8		0,0
13	19,0	19,0	19,0		0,0
2	87,6	87,6	87,6		0,0
10	91,5	91,5	91,5		0,0
16	75,7	75,7	75,7		0,0
11	98,8	98,8	98,8		0,0
12	92,9	92,9	92,9		0,0
7	87,6	87,5	87,5		**0,1**
14	63,3	63,3	63,3		0,0
5	72,7	72,7	72,7		0,0
9	68,0	68,0	68,0		0,0
17	68,5	68,5	68,5		0,0
21	57,3	57,3	57,3		0,0
19	48,5	48,5	48,5		0,0
come up to the surface - 10:00					

Cell 2					
fracture 3,6 m, red					
		time	[h:min]		
	15:17	15:20	15:25	16:00	
Stick		level	[cm]		uplift
15	61,4	61,4	61,4	61,4	0,0
8	66,1	66,1	66,1	66,1	0,0
1	68,2	68,2	68,2	68,2	0,0
6	76,0	75,8	75,8	75,8	**0,2**
4	89,8	89,8	89,8	89,8	0,0
3	84,0	84,0	84,0	84,0	0,0
20	60,5	60,5	60,5	60,5	0,0
18	71,0	71,0	71,0	71,0	0,0
13	11,3	11,3	11,2	11,2	**0,1**
2	79,8	79,8	79,8	79,8	0,0
10	83,8	83,8	83,8	83,8	0,0
16	68,0	68,0	68,0	68,0	0,0
11	91,1	91,1	91,1	91,1	0,0
12	85,2	85,2	85,2	85,2	0,0
7	79,9	79,8	79,8	79,8	**0,1**
14	43,0	42,9	42,9	42,9	**0,1**
5	64,9	64,9	64,9	64,9	0,0
9	60,3	60,3	60,3	60,3	0,0
17	60,8	60,8	60,8	60,8	0,0
21	49,5	49,5	49,5	49,5	0,0
19	40,6	40,6	40,6	40,6	0,0
come up to the surface - 15:21					

	Cell 2 fracture 4,6 m, green								
	time [h:min]								
	12:37	12:40	12:45	12:50	13:20	13:50	14:20	14:50	
Stick	level [cm]								uplift
15	61,4	61,4	61,3	61,3	61,3	61,4	61,4	61,4	0,0
8	66,4	66,3	66,0	66,0	66,0	66,1	66,1	66,1	0,3
1	69,1	68,9	68,2	68,0	68,2	68,2	68,2	68,2	0,9
6	77,0	76,7	76,0	75,8	76,0	76,0	76,0	75,8	1,2
4	90,2	90,2	89,8	89,7	89,8	89,8	89,8	89,8	0,4
3	84,0	84,0	83,9	83,9	84,0	84,0	84,0	84,0	0,0
20	60,6	60,6	60,5	60,5	60,5	60,5	60,5	60,5	0,1
18	71,3	71,2	71,1	70,9	71,0	71,0	71,0	71,0	0,3
13	12,2	12,1	11,5	11,1	11,3	11,3	11,3	11,3	0,9
2	80,8	80,7	80,0	79,6	79,8	79,8	79,8	79,8	1,0
10	84,3	84,2	83,8	83,6	83,8	83,8	83,8	83,8	0,5
16	68,1	68,1	68,0	67,9	68,0	68,0	68,0	68,0	0,1
11	91,2	91,1	91,0	91,0	91,1	91,1	91,1	91,1	0,1
12	85,7	85,4	85,0	85,0	85,1	85,2	85,2	85,2	0,5
7	81,0	80,4	79,7	79,8	79,9	79,9	79,9	79,8	1,2
14	43,8	43,4	42,8	42,9	43,0	43,0	43,0	42,9	0,9
5	65,2	65,1	64,8	64,8	64,9	64,9	64,9	64,9	0,3
9	60,3	60,3	60,2	60,2	60,3	60,3	60,3	60,3	0,0
17	60,8	60,8	60,8	60,8	60,8	60,8	60,8	60,8	0,0
21	49,5	49,5	49,5	49,5	49,5	49,5	49,5	49,5	0,0
19	40,6	40,6	40,6	40,6	40,6	40,6	40,6	40,6	0,0

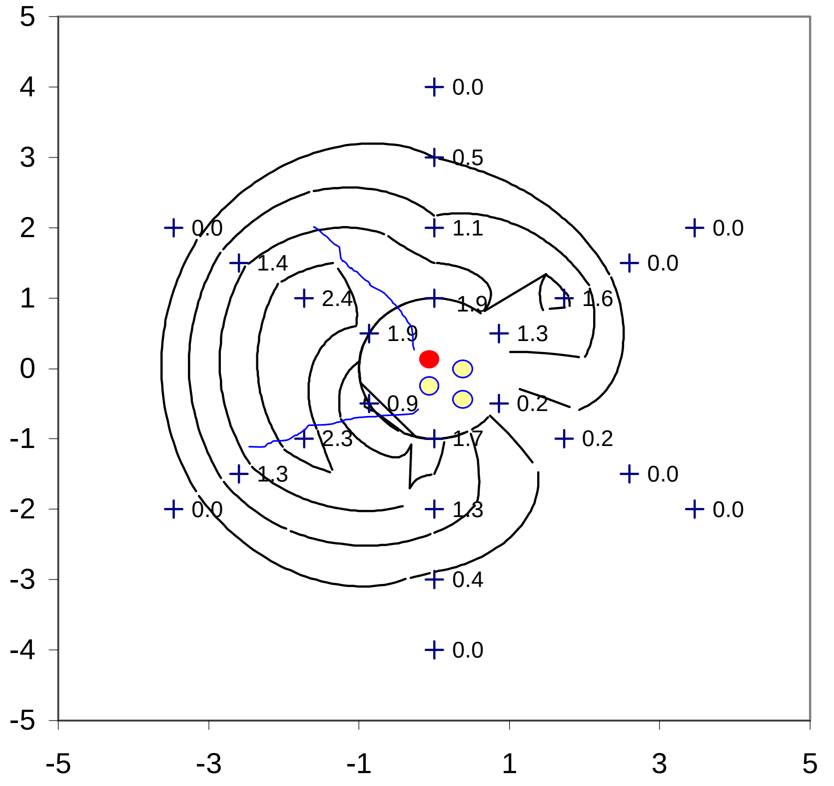
Appendix A3 (Cell 3)

Uplift Data

Project:	Kluczewo
Frac ID:	Cell 3 f1 2m bgs
Date:	4/27/2005
Time:	PM

Proppant:	300 kg	white sand
Gel:	300 liter	

Name	R	θ	NS	EW	Z
N1	1	0	1	0	1.9
N2	2	0	2	0	1.1
N3	3	0	3	0	0.5
N4	4	0	4	0	0
NE1	1	60	0.5	0.87	1.3
NE2	2	60	1	1.73	1.6
NE3	3	60	1.5	2.6	0
NE4	4	60	2	3.46	0
SE1	1	120	-0.5	0.87	0.2
SE2	2	120	-1	1.73	0.2
SE3	3	120	-1.5	2.6	0
SE4	4	120	-2	3.46	0
S1	1	180	-1	0	1.7
S2	2	180	-2	0	1.3
S3	3	180	-3	0	0.4
S4	4	180	-4	0	0
SW1	1	240	-0.5	-0.9	0.9
SW2	2	240	-1	-1.7	2.3
SW3	3	240	-1.5	-2.6	1.3
SW4	4	240	-2	-3.5	0
NW1	1	300	0.5	-0.9	1.9
NW2	2	300	1	-1.7	2.4
NW3	3	300	1.5	-2.6	1.4
NW4	4	300	2	-3.5	0

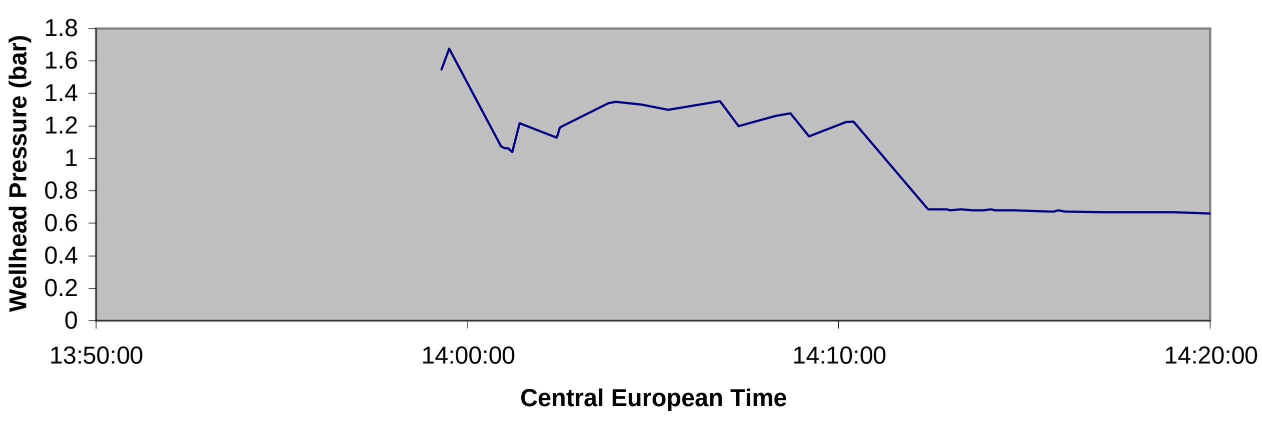


Uplift measured at locations indicated by + and recorded in cm. Axes indicate north / south and east / west distances in meters from center of uplift array. Injection occurred at the center of the array or at a location indicated by ●. Contours drawn by bi-linear interpolation in an orthogonal r-θ reference frame among sets of selected locations. Contour intervals are specified below.

0.5	1	1.5	2

Uplift Volume	0.355 m3
Injection Volume	0.412 m3
Uplift:Inj Ratio	0.861

Comments: Fracture nucleated 2 m bgs from well installed at red, solid circle. Other wells to 3, 4, & 5 m shown as shaded blue circles. Doming crack noted from center of array westward and northward, as shown as light blue lines.



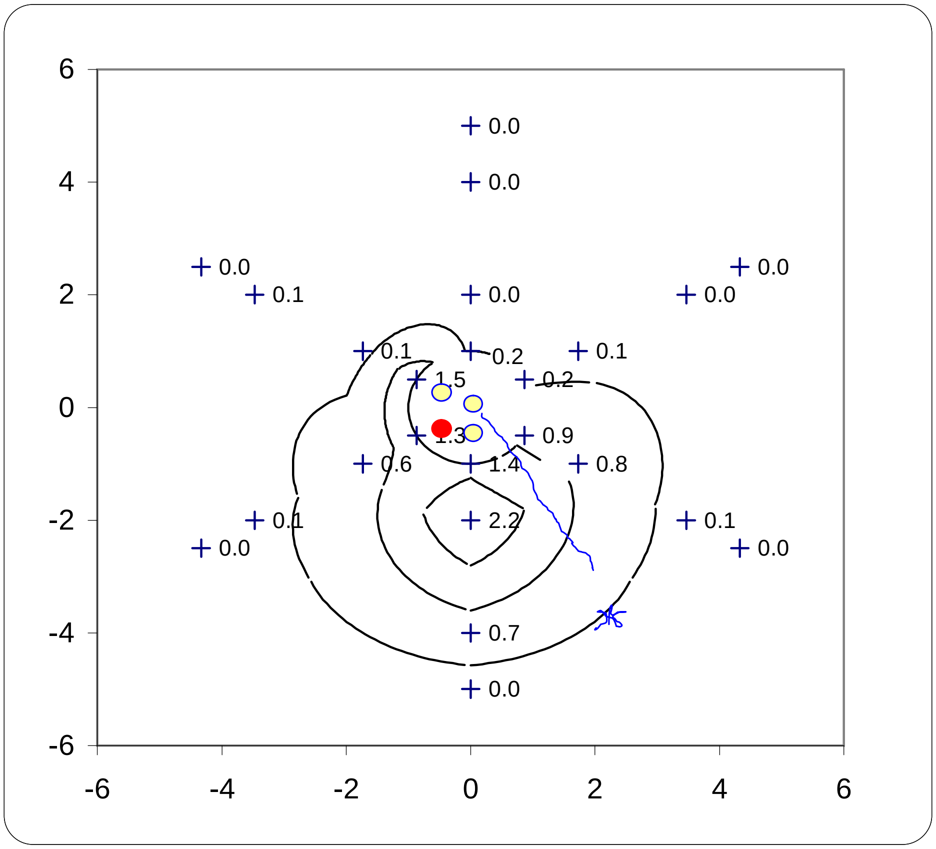
Uplift Data

Project:	Kluczewo
Frac ID:	Cell 3 f2 3m bgs
Date:	4/28/2005
Time:	AM

Proppant:	350 kg	red
Gel:	450 liter	sand

Name	R	θ	NS	EW	Z
N1	1	0	1	0	0.2
N2	2	0	2	0	0
N3	4	0	4	0	0
N4	5	0	5	0	0
NE1	1	60	0.5	0.87	0.2
NE2	2	60	1	1.73	0.1
NE3	4	60	2	3.46	0
NE4	5	60	2.5	4.33	0
SE1	1	120	-0.5	0.87	0.9
SE2	2	120	-1	1.73	0.8
SE3	4	120	-2	3.46	0.1
SE4	5	120	-2.5	4.33	0
S1	1	180	-1	0	1.4
S2	2	180	-2	0	2.2
S3	4	180	-4	0	0.7
S4	5	180	-5	0	0
SW1	1	240	-0.5	-0.9	1.3
SW2	2	240	-1	-1.7	0.6
SW3	4	240	-2	-3.5	0.1
SW4	5	240	-2.5	-4.3	0
NW1	1	300	0.5	-0.9	1.5
NW2	2	300	1	-1.7	0.1
NW3	4	300	2	-3.5	0.1
NW4	5	300	2.5	-4.3	0

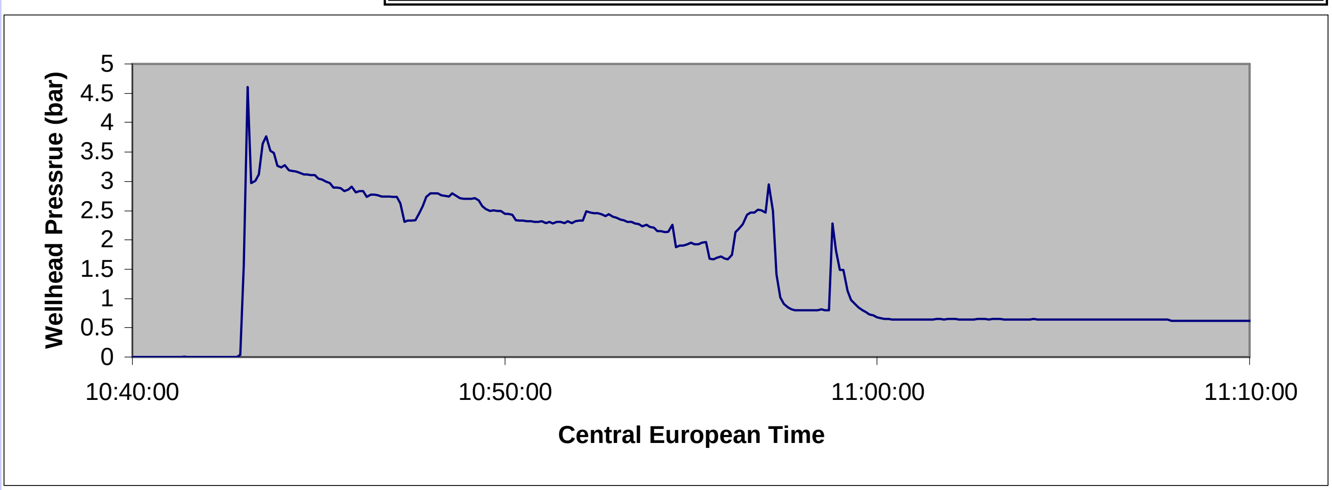
Uplift Volume	0.235 m3
Injection Volume	0.581 m3
Uplift:Inj Ratio	0.405



Uplift measured at locations indicated by + and recorded in cm. Axes indicate north / south and east / west distances in meters from center of uplift array. Injection occurred at the center of the array or at a location indicated by ●. Contours drawn by bi-linear interpolation in an orthogonal r-θ reference frame among sets of selected locations. Contour intervals are specified below.

0.3	1	1.6

Comments: Fracture nucleated 3 m bgs from well installed at red, solid circle. Other wells to 2, 4, & 5 m shown as shaded blue circles. Doming crack noted from center of array to apparent bubble ~4m SE, shown as light blue lines.

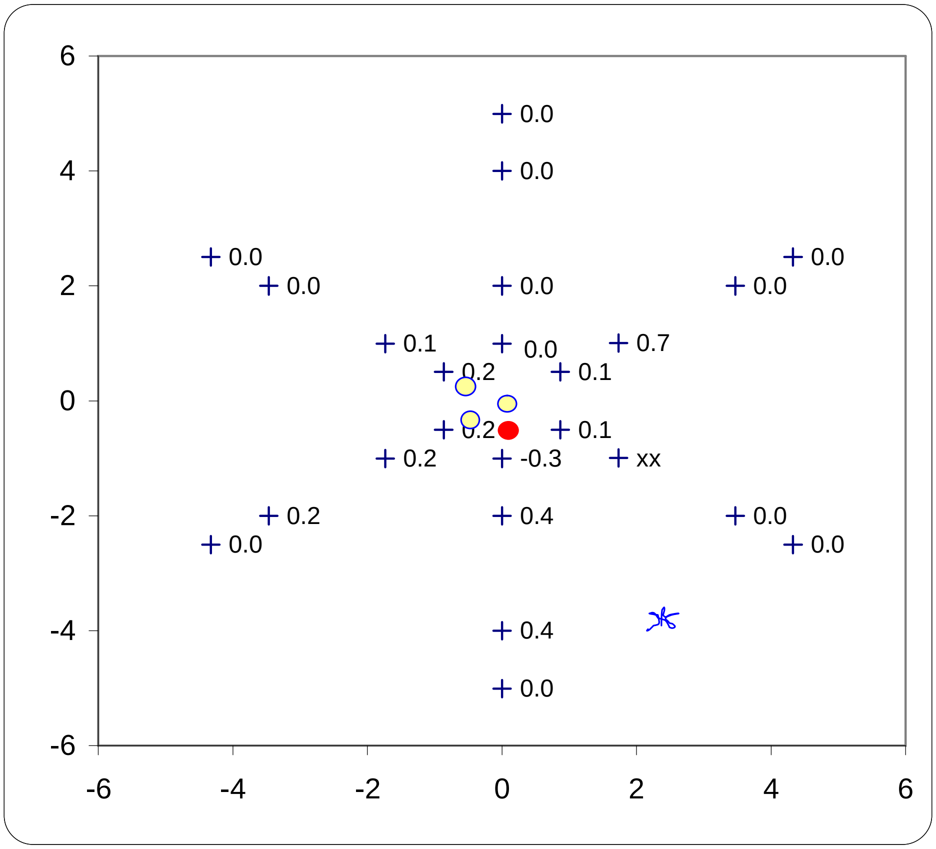


Uplift Data

Project:	Kluczewo
Frac ID:	Cell3 f3 4m bgs
Date:	4/28/2005
Time:	PM

Proppant:	450 kg	green sand
Gel:	450 liter	

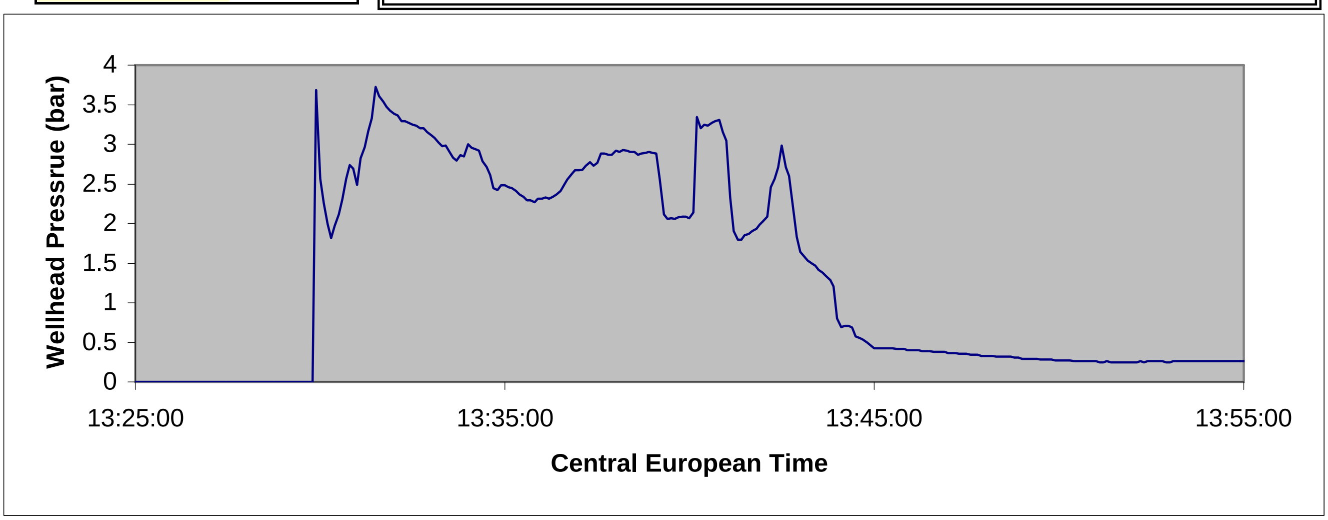
Name	R	θ	NS	EW	Z
N1	1	0	1	0	0
N2	2	0	2	0	0
N3	4	0	4	0	0
N4	5	0	5	0	0
NE1	1	60	0.5	0.87	0.1
NE2	2	60	1	1.73	0.7
NE3	4	60	2	3.46	0
NE4	5	60	2.5	4.33	0
SE1	1	120	-0.5	0.87	0.1
SE2	2	120	-1	1.73	xx
SE3	4	120	-2	3.46	0
SE4	5	120	-2.5	4.33	0
S1	1	180	-1	0	-0.3
S2	2	180	-2	0	0.4
S3	4	180	-4	0	0.4
S4	5	180	-5	0	0
SW1	1	240	-0.5	-0.9	0.2
SW2	2	240	-1	-1.7	0.2
SW3	4	240	-2	-3.5	0.2
SW4	5	240	-2.5	-4.3	0
NW1	1	300	0.5	-0.9	0.2
NW2	2	300	1	-1.7	0.1
NW3	4	300	2	-3.5	0
NW4	5	300	2.5	-4.3	0



Uplift measured at locations indicated by + and recorded in cm. Axes indicate north / south and east / west distances in meters from center of uplift array. Injection occurred at the center of the array or at a location indicated by ●. Contours drawn by bi-linear interpolation in an orthogonal r-θ reference frame among sets of selected locations. Contour intervals are specified below.

Uplift Volume	0.343 m3
Injection Volume	0.618 m3
Uplift:Inj Ratio	0.555

Comments: Fracture nucleated 4 m bgs from well installed at red, solid circle. Other wells to 2, 3, & 5 m shown as shaded blue circles. ~50 kg green sand vented from small diameter hole ~4 m SE as indicated by blue star. Excavation reveled green and red sand commingled.



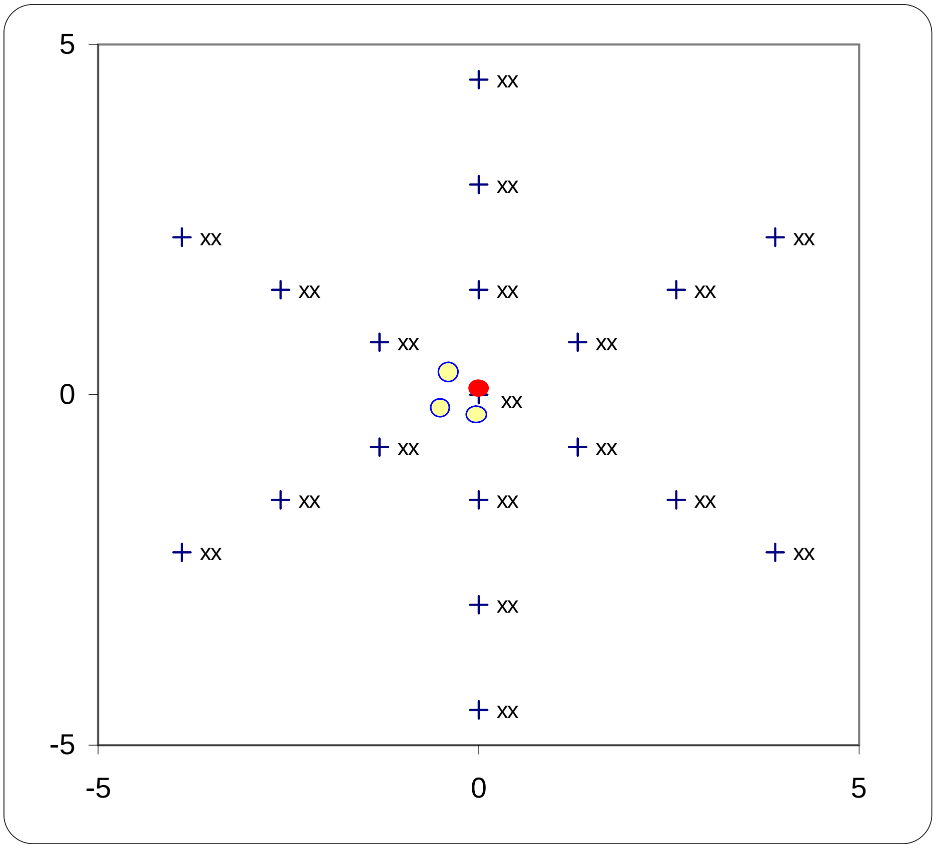
Uplift Data

Project:	Kluczewo
Frac ID:	Cell 3 f4 5m bgs
Date:	4/28/2005
Time:	PM

Proppant:	none
Gel:	

Name	R	θ	NS	EW	Z
Well	0	270	0	0	xx
N1	1.5	0	1.5	0	xx
N2	3	0	3	0	xx
N3	4.5	0	4.5	0	xx
NE1	1.5	60	0.75	1.3	xx
NE2	3	60	1.5	2.6	xx
NE3	4.5	60	2.25	3.9	xx
SE1	1.5	120	-0.7	1.3	xx
SE2	3	120	-1.5	2.6	xx
SE3	4.5	120	-2.2	3.9	xx
S1	1.5	180	-1.5	0	xx
S2	3	180	-3	0	xx
S3	4.5	180	-4.5	0	xx
SW1	1.5	240	-0.8	-1.3	xx
SW2	3	240	-1.5	-2.6	xx
SW3	4.5	240	-2.3	-3.9	xx
NW1	1.5	300	0.75	-1.3	xx
NW2	3	300	1.5	-2.6	xx
NW3	4.5	300	2.25	-3.9	xx

Uplift Volume	0.000 m3
Injection Volume	0.000 m3
Uplift:Inj Ratio	#DIV/0!



Uplift measured at locations indicated by + and recorded in cm. Axes indicate north / south and east / west distances in meters from center of uplift array. Injection occurred at the center of the array or at a location indicated by ●. Contours drawn by bi-linear interpolation in an orthogonal r-θ reference frame among sets of selected locations. Contour intervals are specified below.

#N/A

Comments: Subject well indicated by red, solid circle. Other wells to 2, 3, & 4 m shown as light blue circles. While cutting notch, well communicated with overlying fracture. No fracture attemped.

No fracture attempted - no pressure log.

Appendix A4 (Cell 4)

date	12.MAY.2005
	2,0 m
Cell	4 Mickey Mou-se)
depth	2
colour	white
amount of sand injected	175kg
amount of guar injected	175l
flow rate	1,8m3/h

60degrees notching against 2.0m extraction well

Cell 4 (2m Mickey Mouse)
Stick configuration
distance between sticks in the same line 1,0 m

North

	21			9				17	
		14			10		1		
19	5		**well W**	12		**well E**		13	16
		7	6		8		4		
						well 5.2			
	11			2		well 2.0		3	

South

Scale: 0.5 m, 0.5 m

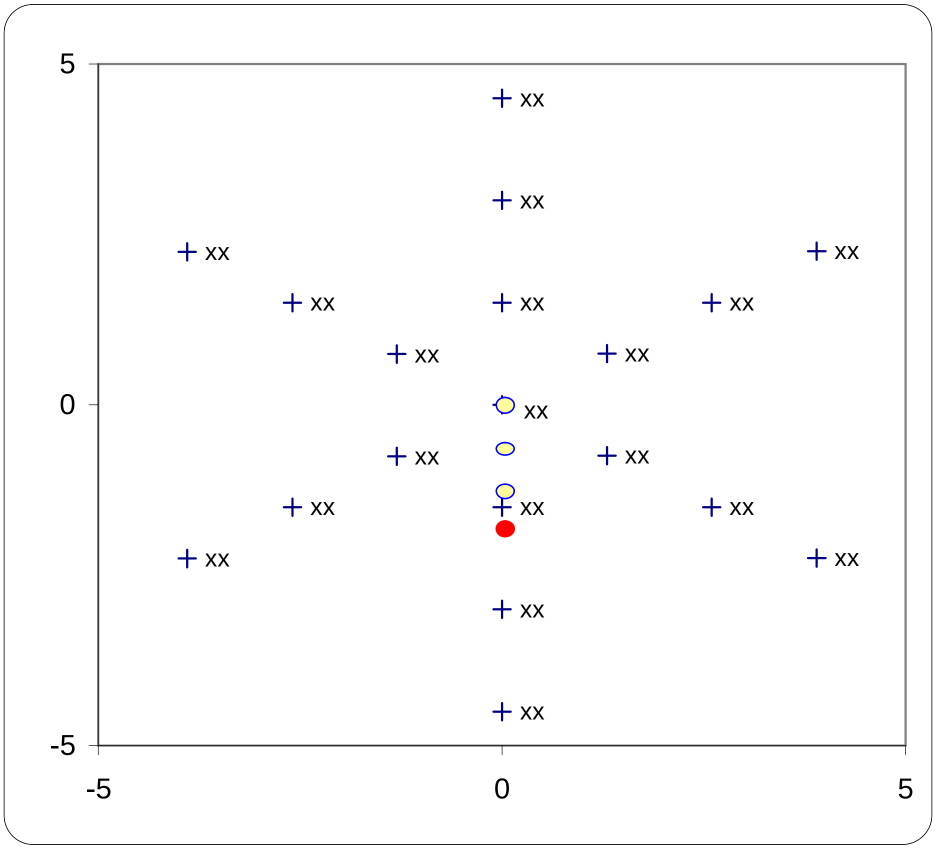
Uplift Data

Project:	Kluczewo
Frac ID:	Cell 4 f4 4.3 m bg
Date:	5/1/2005
Time:	PM

Proppant:	0 kg	sd#1
Gel:	30 liter	

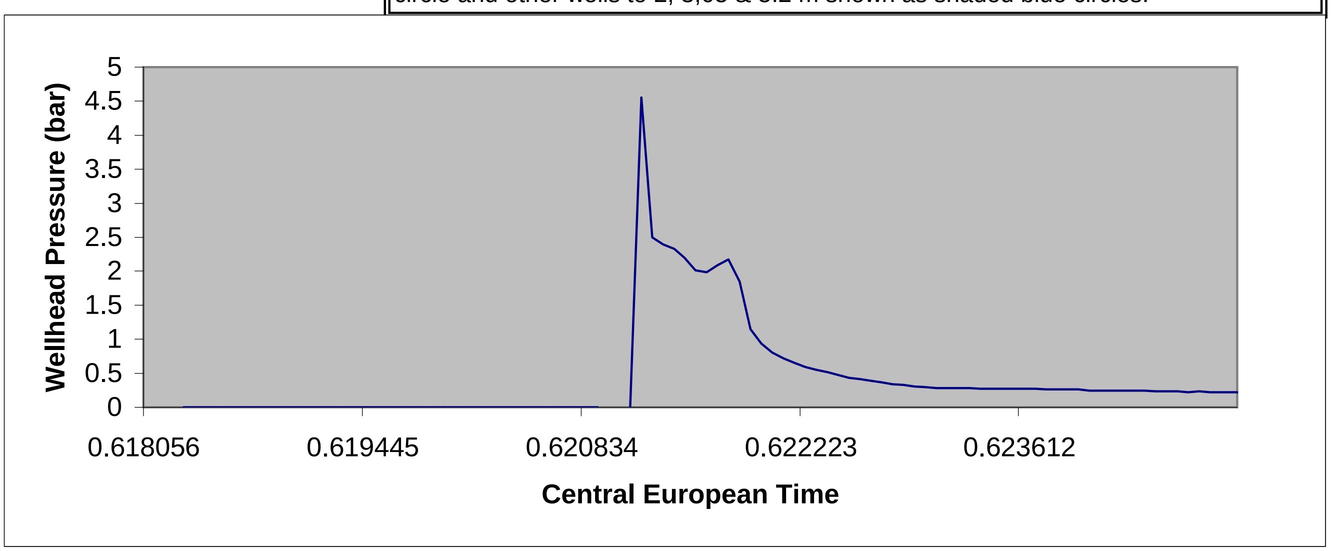
Name	R	θ	NS	EW	Z
Well	0	270	0	0	xx
N1	1.5	0	1.5	0	xx
N2	3	0	3	0	xx
N3	4.5	0	4.5	0	xx
NE1	1.5	60	0.75	1.3	xx
NE2	3	60	1.5	2.6	xx
NE3	4.5	60	2.25	3.9	xx
SE1	1.5	120	-0.7	1.3	xx
SE2	3	120	-1.5	2.6	xx
SE3	4.5	120	-2.2	3.9	xx
S1	1.5	180	-1.5	0	xx
S2	3	180	-3	0	xx
S3	4.5	180	-4.5	0	xx
SW1	1.5	240	-0.8	-1.3	xx
SW2	3	240	-1.5	-2.6	xx
SW3	4.5	240	-2.3	-3.9	xx
NW1	1.5	300	0.75	-1.3	xx
NW2	3	300	1.5	-2.6	xx
NW3	4.5	300	2.25	-3.9	xx

Uplift Volume	0.000 m3
Injection Volume	0.030 m3
Uplift:Inj Ratio	0.000



Uplift measured at locations indicated by + and recorded in cm. Axes indicate north / south and east / west distances in meters from center of uplift array. Injection occurred at the center of the array or at a location indicated by ●. Contours drawn by bi-linear interpolation in an orthogonal r-θ reference frame among sets of selected locations. Contour intervals are specified below.

Comments: Fracture nucleated from well installed to 4.3m bgs at location 0.6 m S of well to 3.05m bgs fracture (1.85 m S of center of array) Fluid vented from 3m fracture within 1 minute of injection . No uplift data collected. Injection well shown as solid red circle and other wells to 2, 3,05 & 5.2 m shown as shaded blue circles.



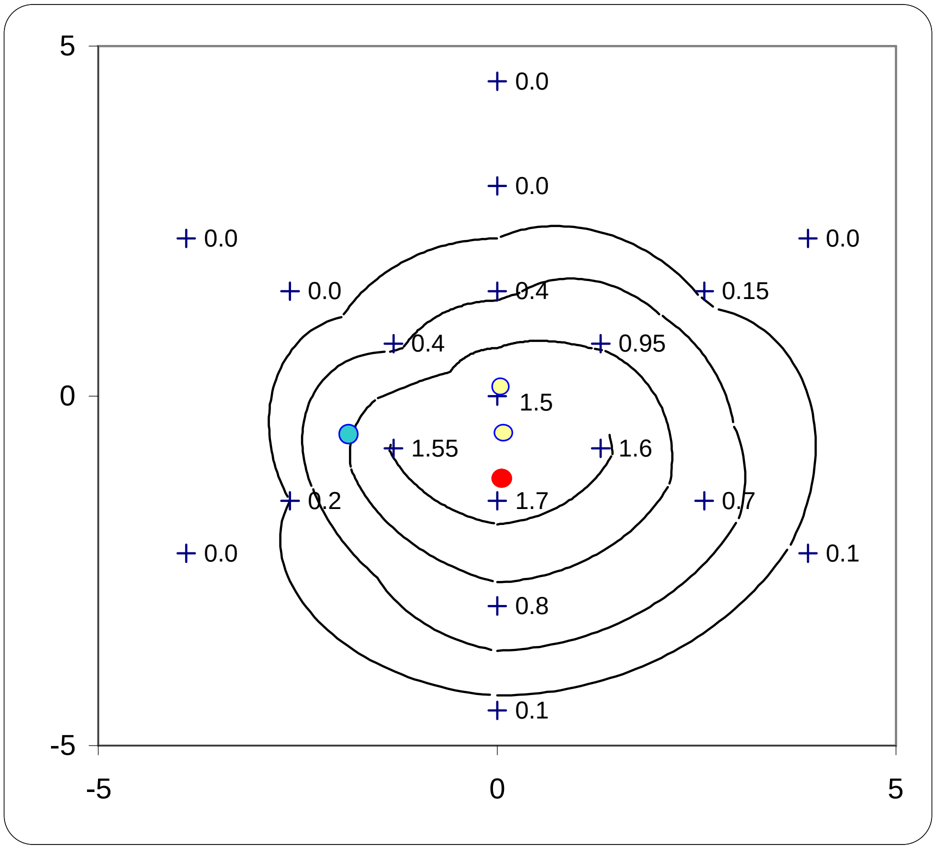
Uplift Data

Project:	Kluczewo
Frac ID:	Cell 4 f3 3 m bgs
Date:	5/1/2005
Time:	AM

Proppant:	300 kg	red sand
Gel:	400 liter	

Name	R	θ	NS	EW	Z
Well	0	270	0	0	1.5
N1	1.5	0	1.5	0	0.4
N2	3	0	3	0	0
N3	4.5	0	4.5	0	0
NE1	1.5	60	0.75	1.3	0.95
NE2	3	60	1.5	2.6	0.15
NE3	4.5	60	2.25	3.9	0
SE1	1.5	120	-0.7	1.3	1.6
SE2	3	120	-1.5	2.6	0.7
SE3	4.5	120	-2.2	3.9	0.1
S1	1.5	180	-1.5	0	1.7
S2	3	180	-3	0	0.8
S3	4.5	180	-4.5	0	0.1
SW1	1.5	240	-0.8	-1.3	1.55
SW2	3	240	-1.5	-2.6	0.2
SW3	4.5	240	-2.3	-3.9	0
NW1	1.5	300	0.75	-1.3	0.4
NW2	3	300	1.5	-2.6	0
NW3	4.5	300	2.25	-3.9	0

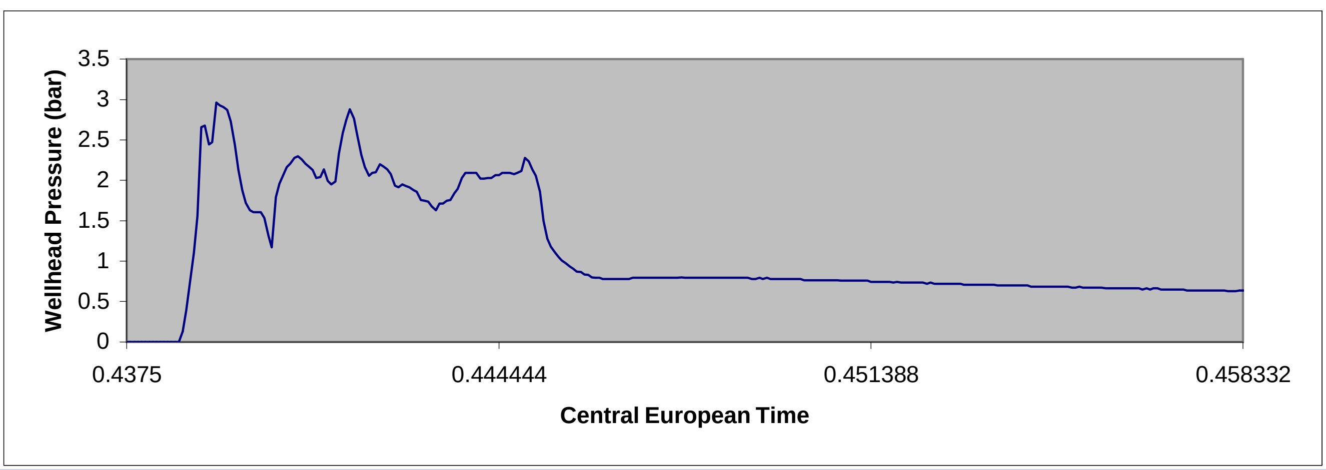
Uplift Volume	0.284 m3
Injection Volume	0.512 m3
Uplift:Inj Ratio	0.555



Uplift measured at locations indicated by + and recorded in cm. Axes indicate north / south and east / west distances in meters from center of uplift array. Injection occurred at the center of the array or at a location indicated by ●. Contours drawn by bi-linear interpolation in an orthogonal r-θ reference frame among sets of selected locations. Contour intervals are specified below.

0.2	0.5	1	1.5

Comments: Fracture nucleated from well (solid red circle) installed 3.05 m bgs at location 1.25 m S of center of array, which coincides with well (shaded blue circle) to 5.2 m bgs. Well to 2 m bgs shown as another shaded blue circle 0.6 m S of center of array. This fracture vented ~6 liter slurry from hole 2 m west, as indicated by filled blue circle.

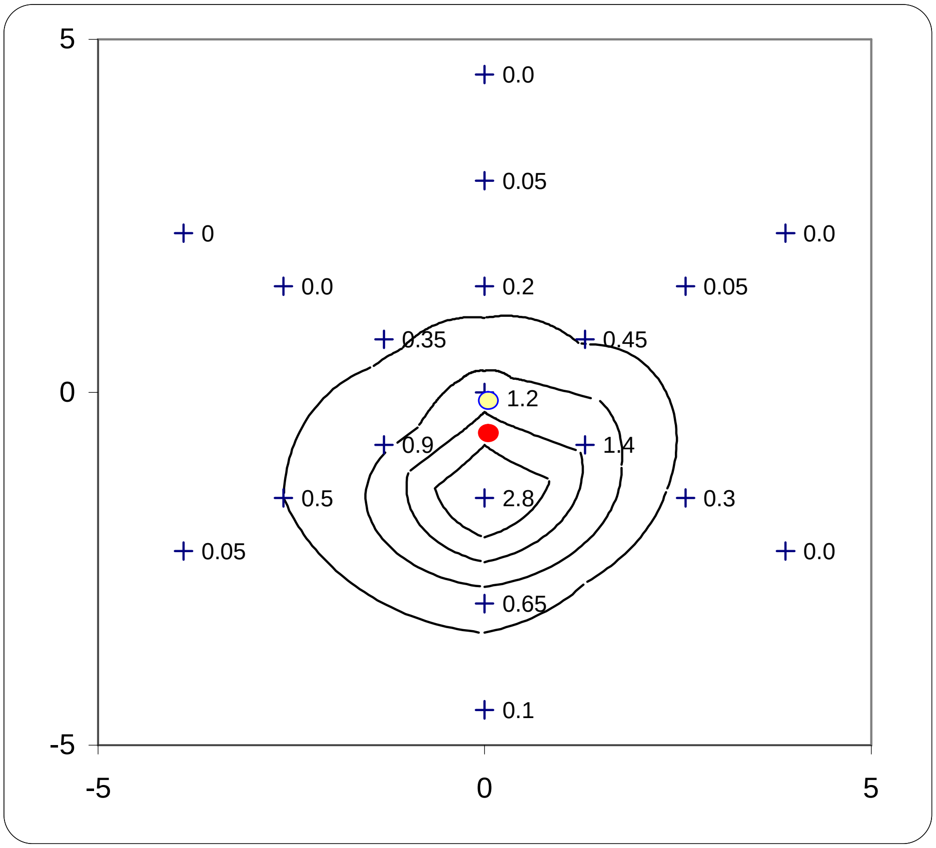


Uplift Data

Project:	Kluczewo
Frac ID:	Cell 4 f2 2m bgs
Date:	4/30/2005
Time:	PM

Proppant:	275 kg	white sand
Gel:	300 liter	

Name	R	θ	NS	EW	Z
Well	0	270	0	0	1.2
N1	1.5	0	1.5	0	0.2
N2	3	0	3	0	0.05
N3	4.5	0	4.5	0	0
NE1	1.5	60	0.75	1.3	0.45
NE2	3	60	1.5	2.6	0.05
NE3	4.5	60	2.25	3.9	0
SE1	1.5	120	-0.7	1.3	1.4
SE2	3	120	-1.5	2.6	0.3
SE3	4.5	120	-2.2	3.9	0
S1	1.5	180	-1.5	0	2.8
S2	3	180	-3	0	0.65
S3	4.5	180	-4.5	0	0.1
SW1	1.5	240	-0.8	-1.3	0.9
SW2	3	240	-1.5	-2.6	0.5
SW3	4.5	240	-2.3	-3.9	0.05
NW1	1.5	300	0.75	-1.3	0.35
NW2	3	300	1.5	-2.6	0
NW3	4.5	300	2.25	-3.9	0

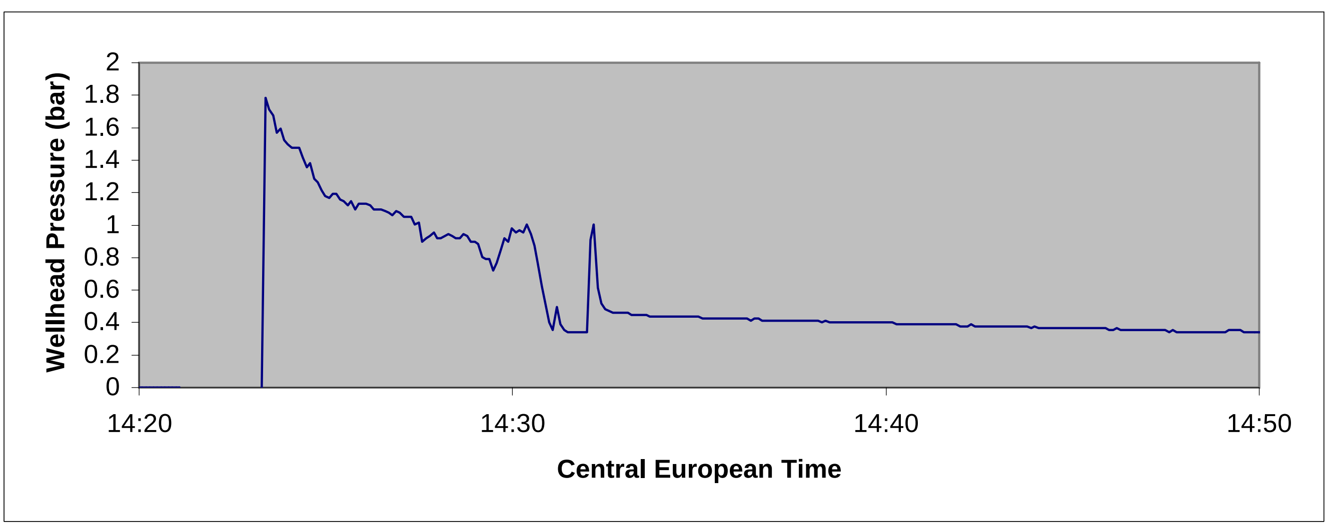


Uplift measured at locations indicated by + and recorded in cm. Axes indicate north / south and east / west distances in meters from center of uplift array. Injection occurred at the center of the array or at a location indicated by ●. Contours drawn by bi-linear interpolation in an orthogonal r-θ reference frame among sets of selected locations. Contour intervals are specified below.

Uplift Volume	0.250 m3
Injection Volume	0.403 m3
Uplift:Inj Ratio	0.620

0.5	1	1.5	2

Comments: Fracture nucleated from well installed to 2 m bgs located 0.6m s from center of uplift array, which coincides with well to 5.2 m bgs. Well to 5.2 m shown as light blue circle.

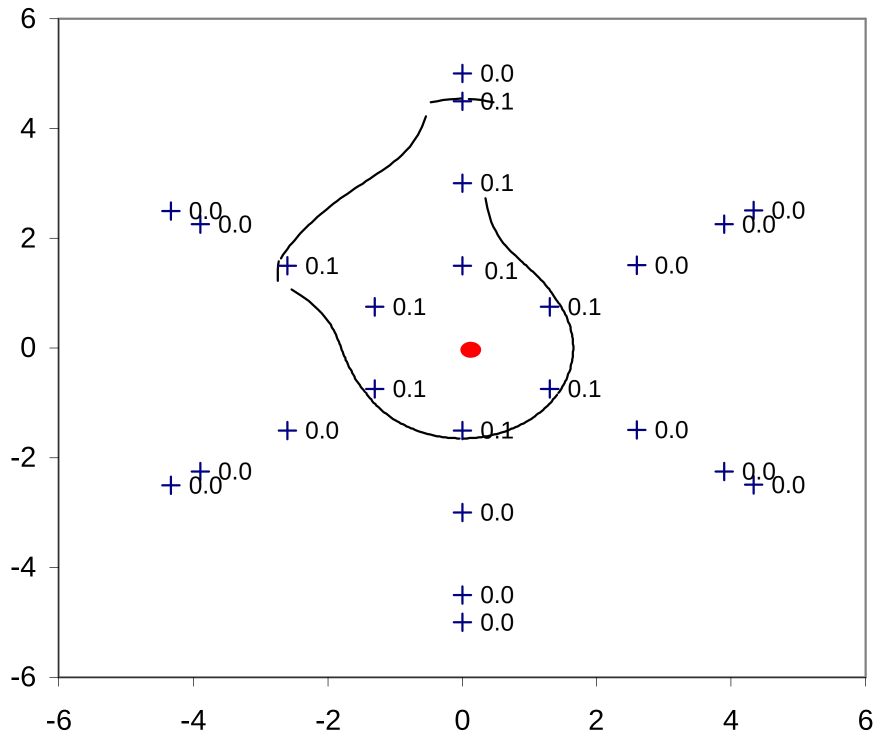


Uplift Data

Project:	Kluczewo
Frac ID:	Cell 4 f1 5.2m bgs
Date:	4/29/2005
Time:	PM

Proppant:	300 kg	white sand
Gel:	400 liter	

Name	R	θ	NS	EW	Z
N1	1.5	0	1.5	0	0.1
N2	3	0	3	0	0.1
N3	4.5	0	4.5	0	0.1
N4	5	0	5	0	0
NE1	1.5	60	0.75	1.3	0.1
NE2	3	60	1.5	2.6	0
NE3	4.5	60	2.25	3.9	0
NE4	5	60	2.5	4.33	0
SE1	1.5	120	-0.7	1.3	0.1
SE2	3	120	-1.5	2.6	0
SE3	4.5	120	-2.2	3.9	0
SE4	5	120	-2.5	4.33	0
S1	1.5	180	-1.5	0	0.1
S2	3	180	-3	0	0
S3	4.5	180	-4.5	0	0
S4	5	180	-5	0	0
SW1	1.5	240	-0.8	-1.3	0.1
SW2	3	240	-1.5	-2.6	0
SW3	4.5	240	-2.3	-3.9	0
SW4	5	240	-2.5	-4.3	0
NW1	1.5	300	0.75	-1.3	0.1
NW2	3	300	1.5	-2.6	0.1
NW3	4.5	300	2.25	-3.9	0
NW4	5	300	2.5	-4.3	0

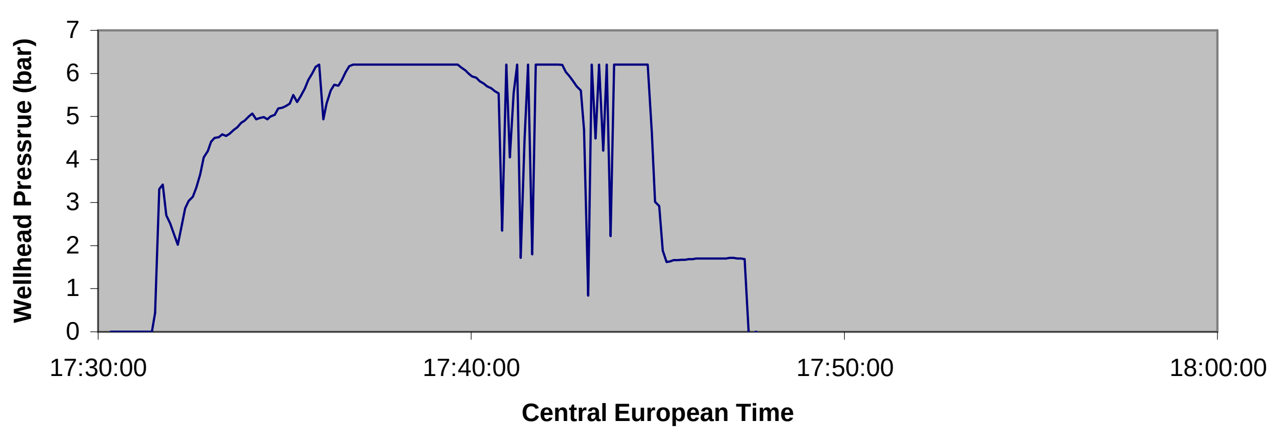


Uplift measured at locations indicated by + and recorded in cm. Axes indicate north / south and east / west distances in meters from center of uplift array. Injection occurred at the center of the array or at a location indicated by ●. Contours drawn by bi-linear interpolation in an orthogonal r-θ reference frame among sets of selected locations. Contour intervals are specified below.

0.09

Uplift Volume	0.023 m3
Injection Volume	0.512 m3
Uplift:Inj Ratio	0.045

Comments: Fracture nucleated from casing installed to depth of 5.2 m bgs, which was inserted into a sampling boring. Uplift array centered on the injection well. Injection slurry composed of increasing greater proporation of sand, and injection terminiated when screen-out conditions (rapidly esclating pressure and accumulation of sand in jection hose and well) occured. Approximately 50 liters of slurry remined in



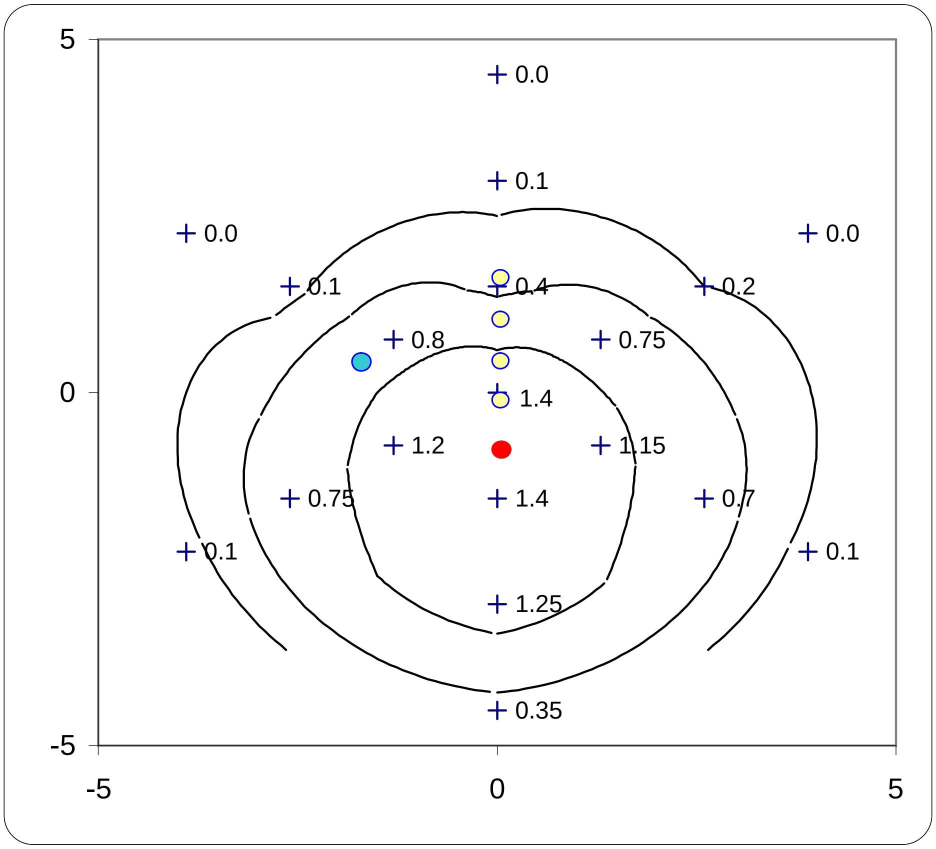
Uplift Data

Project:	Kluzewo
Frac ID:	Cell 4 f5 3.6 m bg
Date:	5/1/2005
Time:	PM

Proppant:	300 kg	green
Gel:	400 liter	sand

Name	R	θ	NS	EW	Z
Well	0	270	0	0	1.4
N1	1.5	0	1.5	0	0.4
N2	3	0	3	0	0.1
N3	4.5	0	4.5	0	0
NE1	1.5	60	0.75	1.3	0.75
NE2	3	60	1.5	2.6	0.2
NE3	4.5	60	2.25	3.9	0
SE1	1.5	120	-0.7	1.3	1.15
SE2	3	120	-1.5	2.6	0.7
SE3	4.5	120	-2.2	3.9	0.1
S1	1.5	180	-1.5	0	1.4
S2	3	180	-3	0	1.25
S3	4.5	180	-4.5	0	0.35
SW1	1.5	240	-0.8	-1.3	1.2
SW2	3	240	-1.5	-2.6	0.75
SW3	4.5	240	-2.3	-3.9	0.1
NW1	1.5	300	0.75	-1.3	0.8
NW2	3	300	1.5	-2.6	0.1
NW3	4.5	300	2.25	-3.9	0

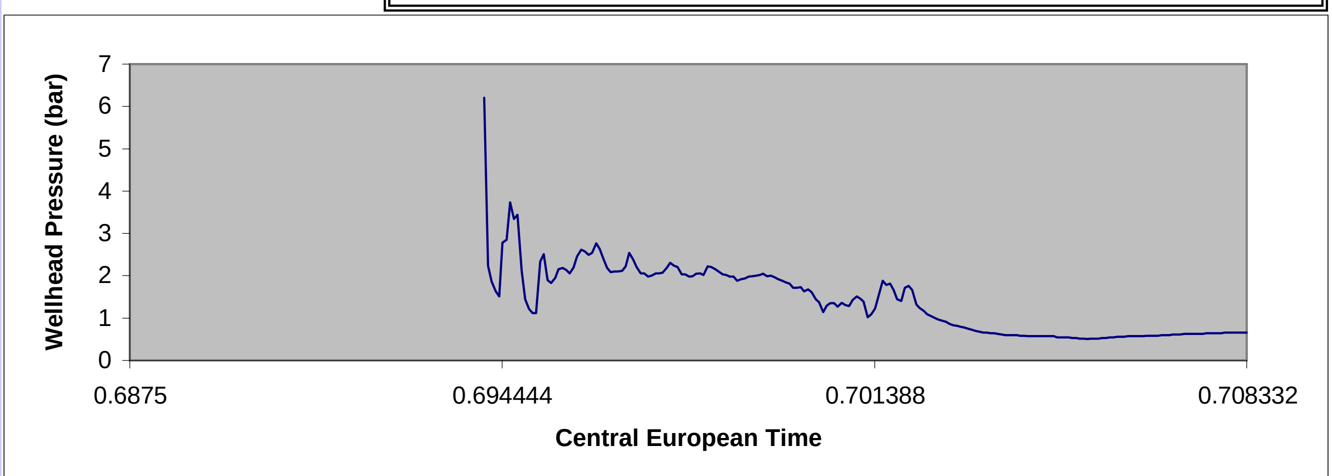
Uplift Volume	0.331 m3
Injection Volume	0.512 m3
Uplift:Inj Ratio	0.646



Uplift measured at locations indicated by + and recorded in cm. Axes indicate north / south and east / west distances in meters from center of uplift array. Injection occurred at the center of the array or at a location indicated by ●. Contours drawn by bi-linear interpolation in an orthogonal r-θ reference frame among sets of selected locations. Contour intervals are specified below.

0.2	0.5	1	1.5

Comments: Fracture nucleated from well installed 3.6 m bgs at location 0.95 S of center of array. Well to 5.2, 2, 3.05, 4.3 m bgs shown a shaded blue circles along NS axis. This fracture vented ~20 liter slurry from hole 2 m northwest, as indicated by filled blue circle.



Cell 4
fracture 2,0 mbgs (Mickey Mouse), white

	time [h:min]													
	10:55	11:12	11:21	11:30	11:36	11:45	11:51	11:58	12:36	13:15	13:33			
Stick	level [cm]											uplift	NS	EW
16	74,5	74,5	73,9	74,0	74,0	74,0	74,0	74,0	74,0	74,0	74,1	0,4	1,15	2,35
13	18,3	18,2	16,8	16,8	16,9	17,0	17,0	17,0	17,1	17,2	17,2	1,1	1,30	1,35
17	94,4	94,4	93,7	93,8	93,8	93,8	93,8	93,8	93,9	94,0	94,0	0,4	3,00	1,65
1	95,1	94,5	93,1	93,3	93,3	93,4	93,4	93,5	93,5	93,6	93,6	1,5	2,25	0,95
10	94,7	94,1	92,8	92,8	92,6	92,6	92,6	92,6	92,9	93,0	93,1	1,6	2,35	0,00
9	87,3	86,5	86,5	86,5	86,1	86,1	86,1	86,2	86,3	86,4	86,4	0,9	3,30	-0,45
21	69,5	68,4	69,3	69,2	68,2	68,2	68,3	68,3	68,4	68,5	68,5	1,0	3,55	-2,40
14	72,5	72,5	72,5	72,5	70,5	70,5	70,5	70,5	70,9	71,0	71,1	1,4	2,65	-2,00
5	92,6	89,5	92,4	92,4	90,9	90,2	90,3	90,3	90,6	90,8	90,8	1,8	1,85	-2,60
7	94,6	94,4	94,4	94,3	93,2	92,4	92,5	92,5	92,8	92,9	92,9	1,7	0,90	-2,20
11	92,4	92,3	92,3	92,3	91,5	91,0	91,0	91,1	91,3	91,3	91,4	1,0	0,15	-2,80
6	90,1	89,4	89,3	89,3	88,6	88,2	88,2	88,2	88,4	88,5	88,5	1,6	0,80	-1,30
2	90,3	90,0	89,9	89,9	89,7	88,0	89,5	89,5	89,7	89,7	89,7	0,6	-0,05	-1,00
8	91,5	90,5	90,2	90,3	90,2	90,1	90,0	90,0	90,2	90,3	90,3	1,2	0,70	-0,35
4	94,5	94,5	94,2	94,3	94,3	94,3	94,3	94,4	94,6	94,6	94,6		0,55	0,65
3	82,4	82,1	82,1	82,1	82,1	82,1	82,3	82,2	82,2	82,2	82,2	0,2	-0,40	1,05
12	92,9	92,1	91,4	91,4	90,8	90,6	90,6	90,6	90,9	91,6	91	1,9	1,60	-0,65
19	77,1	77,1	77,1	77,1	76,3	75,7	75,8	75,8	75,9	76,2	76,2	0,9	1,95	-3,60

date	12.MAY.2005
	3,0 m
Cell	4
depth	3
colour	red
amount of sand injected	175kg
amount of guar injected	175l
flow rate	1,8m3/h
60degrees notching against 3.0m extraction well	

Cell 4 - 3.0m (Mickey Mouse)
Stick configuration
distance between sticks in the same line 1,0 m

North

	21		18			9		4		17	
					well 3.6						
		14					10		1		
19	5		**well W**			12		**well E**		15	16
		7		6			8		13		
							well 5.2				
	11					2				20	

South

Scale: 0.5m
0.5 m

Cell 4
fracture 3,0 mbgs (Mickey Mouse), red

	time [h:min]												
	14:10	14:30	14:40	14:45	14:55	15:02	15:10	15:18	15:32	16:17	16:50		
Stick	level [cm]											uplift	NS	EW
2	90,4	89,9	89,0	89,1	89,1	89,1	89,1	89,1	89,1	89,1	89,1	1,3	-5,65	-0,15
11	95,5	95,5	95,5	95,4	95,3	95,0	95,0	95,1	95,1	95,2	95,2	0,3	-5,20	-2,05
4	92,2	92,2	91,6	91,6	91,7	91,7	91,7	91,7	91,7	91,8	91,8	0,4	-2,60	1,75
8	90,0	89,3	88,7	88,4	88,4	88,7	87,8	87,8	87,9	88,5	88,5	1,5	-4,90	0,55
6	90,4	87,6	87,1	87,1	87,2	85,7	85,9	86,1	86,1	86,2	86,3	4,1	-4,65	-0,40
7	93,0	92,8	92,8	92,8	92,9	91,0	91,0	91,2	91,4	91,5	91,5	1,5	-4,45	-1,40
16	78,6	78,1	77,4	77,5	77,5	77,5	77,6	77,6	77,6	77,7	77,8	0,8	-4,60	3,25
13	35,1	33,1	33,1	33,4	33,5	33,5	33,5	33,5	33,5	33,6	33,6	1,5	-5,15	1,60
12	84,1	83,3	83,1	83,2	83,2	82,4	82,6	82,6	82,6	82,7	82,8	1,3	-3,95	0,30
5	89,6	89,4	89,5	89,5	89,4	88,3	88,4	88,5	88,6	88,7	88,7	0,9	-3,50	-1,65
19	68,1	68,1	68,1	68,1	68,1	67,6	67,7	67,8	67,8	67,9		0,2	-3,30	-2,60
1	87,6	87,0	86,4	86,5	86,6	86,6	86,5	86,6	86,5	86,7	86,7	0,9	-3,45	2,00
10	89,7	89,3	88,8	88,8	88,8	88,7	88,8	88,9	88,9	89	89	0,7	-3,25	1,05
14	68,8	66,7	66,7	66,7	66,7	66,2	66,2	66,3	66,3	66,4	66,4	2,4	-2,80	-1,00
17	86,6	86,1	85,9	85,9	86,0	86,0	86,0	86,1	86,1	86,1	86,2	0,4	-3,05	3,60
20	92,5	91,0	91,2	91,3	91,4	91,4	91,4	91,4	91,4	91,5	91,5	1,0	-6,10	1,85
9	89,3	89,3	89,3	89,3	89,4	89,3	89,3	89,3	89,3	89,4	89,4	-0,1	-2,30	0,70
18	78,9	78,9	78,8	78,8	78,8	78,6	48,7	78,7	78,7	78,9	78,9	0,0	-2,05	-0,30
21	69,6	69,6	69,6	69,6	99,5	69,6	69,6	69,5	69,7	69,8	69,8	-0,2	-1,85	-1,25
15	94,5	93,5	92,5	93,6	93,1	93,1	93,1	93,2	93,2	93,3	93,3	1,2	-4,40	2,30

Appendix A5 (Cell 5)

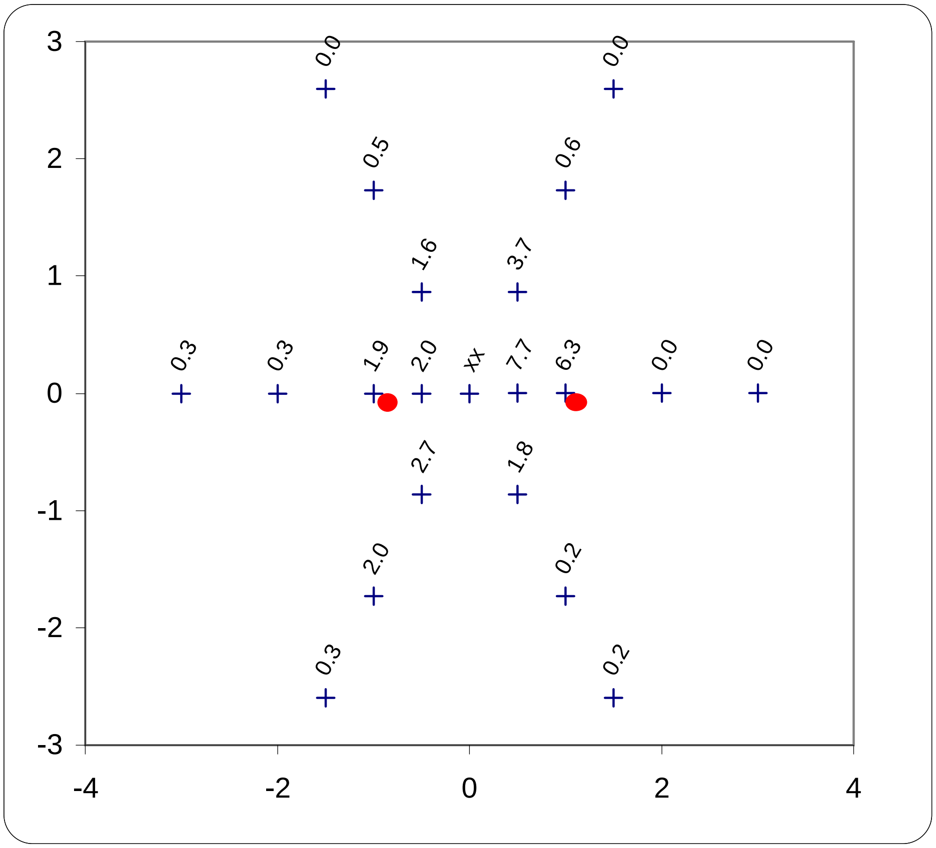
Uplift Data

Project:	Kluczewo
Frac ID:	Cell f mm
Date:	5/4/2005
Time:	PM

Proppant:	300 kg	white
Gel:	550 liter	sand

Name	R	θ	NS	EW	Z
Cente	0	0	0	0	xx
W1	0.5	270	-0	-0.5	2
W2	1	270	-0	-1	1.9
W3	2	270	-0	-2	0.3
W4	3	270	-0	-3	0.3
NW1	1	330	0.87	-0.5	1.6
NW2	2	330	1.73	-1	0.5
NW3	3	330	2.6	-1.5	0
NE1	1	30	0.87	0.5	3.7
NE2	2	30	1.73	1	0.6
NE3	3	30	2.6	1.5	0
E1	0.5	90	0	0.5	7.7
E2	1	90	0	1	6.3
E3	2	90	0	2	0
E4	3	90	0	3	0
SE1	1	150	-0.9	0.5	1.8
SE2	2	150	-1.7	1	0.2
SE3	3	150	-2.6	1.5	0.2
SW1	1	210	-0.9	-0.5	2.7
SW2	2	210	-1.7	-1	2
SW3	3	210	-2.6	-1.5	0.3

Uplift Volume	
Injection Volume	0.662 m3
Uplift:Inj Ratio	0.000



Uplift measured at locations indicated by + and recorded in cm. Axes indicate north / south and east / west distances in feet from center of uplift array. Injection occurred at two locations indicated by ●. Contours drawn by bi-linear interpolation in an orthogonal r-θ reference frame among sets of selected locations. Contour intervals are specified below.

0.25	1	2

Comments: Simultaneous injection into both wells resulted in significan venting from the eastern well and gorssly disturbed surface. Uplift in excess of 2 cm obviously due to free liquid beneath surficial sod.