Siting concessions for methane exploitation on Lake Kivu

Data Environnement – april 2011

PREAMBLE

The geographical layout of the concessions offered in the « Management Prescriptions for the development of Lake Kivu Gas Resources » (MPs) is based on the premise that each concession must have access to the deepest layers of the lake. This concept leads to a star-shaped structure (or pie) for concessions that converge on the area of the lake situated at 480 m depth.
It appears that this division would lead to absurd situations, especially during the end of the operation. Each owner of each franchise should dispose of a gas pipeline running from its site as far as the deepest point of the lake, this to have its share of the few remaining gas km^3. It seems obvious that the last volume of water containing methane should be operated by a single concession: one whose situation will be most conducive to the establishment of a pipeline.
This proposal is not reasonable. It is also not fair for those concessions located at significant distances from this point of convergence.

We believe that we must address the selection of potential sites concessions in a pragmatic and flexible manner, allowing more latitude to governments, who will ultimately decide on allocation of concessions after their regional policy for the management of energy.
We present below criteria for selection of sites for potential concessions. Our study is based on the use of bathymetric maps established by Osae and Lahmeyer (1998) which, although imperfect, have the merit to exist.

PROPOSALS FOR THE SELECTION OF CONCESSIONS – VARIOUS SCENARIOS

Criteria for site selection:
An important prerequisite: we will select the locations of concessions regardless of the location of future plants to soil (possible connection to an electric high tension, favorable terrain, road links ...).
This part "Access to the ground" requires information and consultations with various technical departments of the governments concerned.

Assessing the quality of a concession is based on the following main criteria:

- • Water depth available for the extraction, and possibility for future extensions to greater depths (vertical gradient of the lake on the floor area);
- • Distance from platforms to shore (length of the pipeline);
- • Lateral extent of the favourable zone on the lake bottom in the exploitation area;
- • Ease of attachment of extraction platforms and of underwater pipeline.
- • Position relative to methane rich layers (we will see the necessity to differentiate the water column between 265 m and 315 m, which is relatively poor in gas, and the part situated below 315 m, which is gas-rich).

Quantifying the "value" of a concession would necessitate a involving all the criteria cited above, with weights adjusted. At this stage of our reflections, we do not venture on this terrain. A first estimate of the quality of a concession may already result from a compromise between available depth and distance to shore.

Several scenarios can be put forward to set boundaries to concessions:

- • based on various possible geometric contours,
- • based on their sizes,
- • based on the accessible depths,
- • based on the power of the electric stations.

i) Geometric contours of concessions

The following ideas can be studied comparatively, in advantages and disadvantages.

- On the coast east and west of the lake, the limit of each concession might be constituted by two straight east-west lines (north latitude and south latitude) and two lines representing the minimal depth and the maximal depth in the area of operation . These last two lines might be straight segments, leading to a simple quadrilateral shape for some concessions.
- The areas on the northern shores of Lake - area near Gisenyi and Goma Keshero coast - should be treated separately, the concessions being no longer limited by lines of equal latitude.
-A line of minimal depth could simply consist in the shore itself.
- The community of concessions doesn't have to cover the whole lake surface: it would not cover the entire lake surface. Concessions certainly should be disjoint, but not necessarily contiguous.

ii) Demarcation of concessions based on accessible depths

The limit lines, on the side of maximal depths, could consist in equi-level depth lines, known from the bathymetric map of the lake.

Now, let's consider the results from studies which determined, for each depth P, which proportion R of the total resource of the lake is contained between the main gradient (265 m) and the considered depth. Here are the values of R for some values of P:

Depth P (mètres)	% of the accessible resource R
360 m	**68 %**
380 m	**79 %**
400 m	**87 %**
420 m	**94 %**

Initially, a depth limit of 380 m seems a reasonable value, with nearly 80% of the resource available.

We may consider adding to the distant future the issue of exploitation of 20% of the resource contained in the layers down to the bottom of the lake (485 m).

iii) Various sizes for power plants

- • Large plants (producing between 60 and 100 MW)

We can then consider using combined steam cycle turbines. This choice has several disadvantages: these machines resent the frequent power cuts, and failure or maintenance outage creates a major disruption on the network (these machines are unitary).

- • Average plant: 15/20 MW - 50 MW

A unit can be modular, with engines of around 5 to 6 MW, which allows to always having a replacement engine, in particular for the maintenance periods.

- • Small plant (<20 MW)

We gain in flexibility and ease of installation, but we lose much in investment costs for a given power unit.
A comprehensive study should involve the performance of machinery, the investment cost, flexibility of use, etc. It is likely that the optimal solution will result from a compromise between all these factors.

PROPOSED METHODOLOGY

Research and characterization of operating locations

The lake is formed by an ancient valley of the Nile flowing northward: this valley has been split by the island of Idjwi and therefore has south-north direction in the Rwandese sector, south-west - north in the western, Congolese sector. On its north end, the valley is blocked by the dam formed by the volcanic Virunga chain. The north coast of the lake is a steep escarpment from the volcanic foothills on which are built the cities of Goma and Gisenyi. When watched southward, starting from the north coast, the valley rapidly widens to a very large and deep main pool, with a maximum depth of 485 m on the Congolese side and 465 m on the Rwandese side. Further southward, the valley splits and gets narrower on both sides of the island of Idjwi, whilst it's floor very slowly raises. A North-South profile of the lake bottom is asymmetrical, with a steep slope from the north, a long traversal of the almost flat bottom of the pond, then a very gradual ascent directed to the south in the east branch of the lake, and to the south-west in the western branch.

This profile is taken into account in assessing the possibilities of locating the extraction of gas stations.
i) Great depths are available at short distances from the shore in the northern part of the lake. These locations are favourable for the extraction of gas and their lateral extent is considerable: several mining areas can be located side by side.
ii) Heading to the south, accessible depths become less important and their distances from the ground augment. The east coast of the lake is extremely divided, the west coast a little less. The slope of the land is steep and erosion valleys reach deep into the land. It is on the floor of these valleys that we can spot favourable sites for the extraction, i.e. gas-rich layers at a short distance from shore. The lateral extent of these sites is usually very limited.

Physico-chemical description of the deposit

The deposit of usable methane is divided vertically in two distinct layers:

- The "upper layer" (Upper Resource Area: URZ) is located between the main gradient, situated at around 265 m deep, and a secondary gradient, at around 315 m. Methane content there is around 0.32 L_{gas} / L_{water}.

The total quantity of methane contained in the URZ is 16 km^3.

- The "lower layer" (Lower Resource Area: LRZ) is located below the secondary gradient. Methane content is about 0.41 L_{gas} / L_{water}.

The total quantity of methane contained in the LRZ is 30 km^3.

For a given geometry of an extraction installation, the flow of gas obtained in the LRZ is about 1.5 times higher than that obtained from the URZ.
When we consider the various exploitable sites, we can usually identify which of the URZ or LRZ layer the site is aimed at.

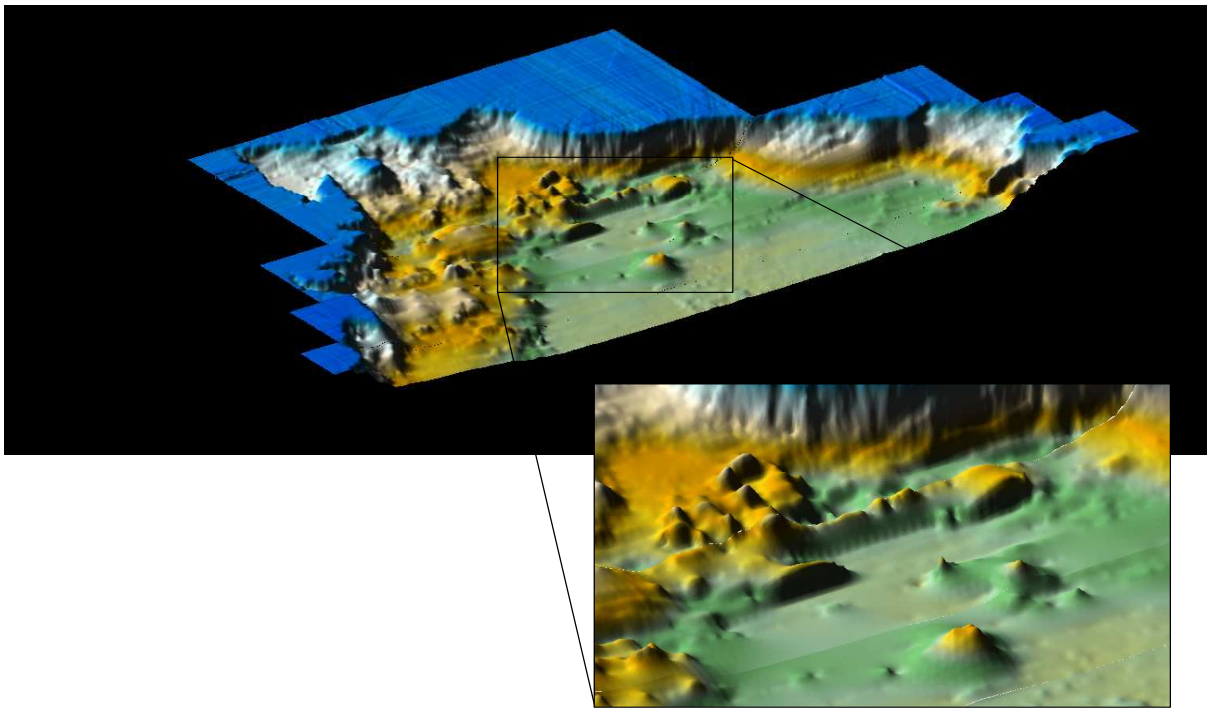
Assessing the value of a site will require a compromise between two opposing criteria:

- areas of operations of the URZ of course are closer to the shore than the LRZ,
- production of gas, for a given geometry of an installation, will be significantly lower in the URZ.

THE DIGITAL FILE OF THE LAKE BATHYMETRY (LAHMEYER, 1998)

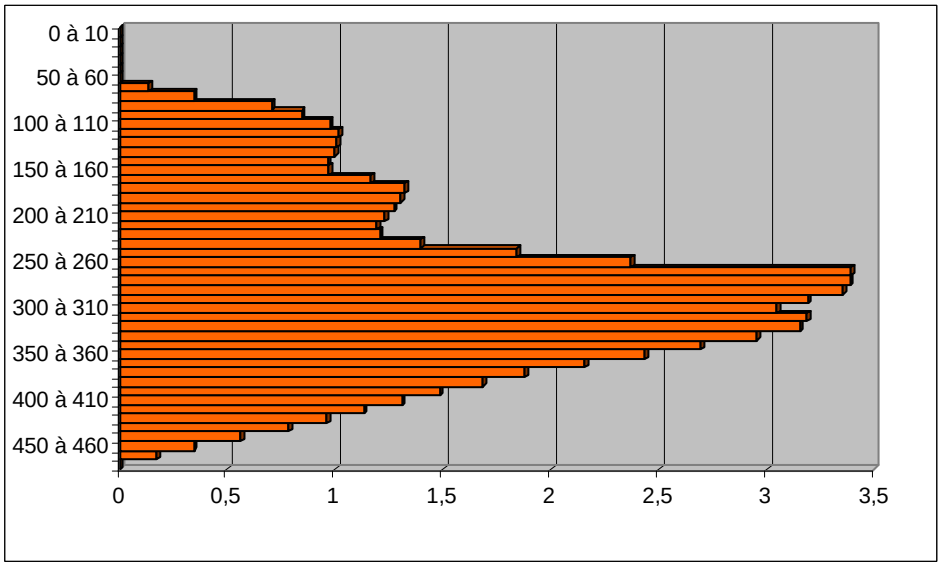
Bathymetric maps of Lake provided by Lahmeyer are not usable for various complex studies and presentations, such as 3D views, surface measurements at various depths, water volume histogram in function of the depth (hypsometric curves), profile the lake bottom along a given route, etc. Moreover, the maps are hard to scan because the equi-level curves are not continuous but consist of disjoint segments.

In 2004, we managed to find the reference of the Company which conducted the bathymetric campaign in 1998. We bought all the raw data in 3D, with a 10m x 10m horizontal resolution. It was for us to investigate the presence of ancient volcanoes
On the lake floor, and we localized some (see figure below).



Underwater volcanoes in the north area of Lake Kivu

The use of this file also allowed us to obtain the curve giving the surface of a cut at a given depth (hypsometric curve). Finally, combining this curve with the gas concentration measurements made in 2003, we obtained the histogram giving the volume of methane as a function of depth, and finally the total capacity of methane in the lake. Before 2004, this capacity was estimated at 50 km^3. We found 65 km^3, which represent an increase by 30% to the commonly accepted value.

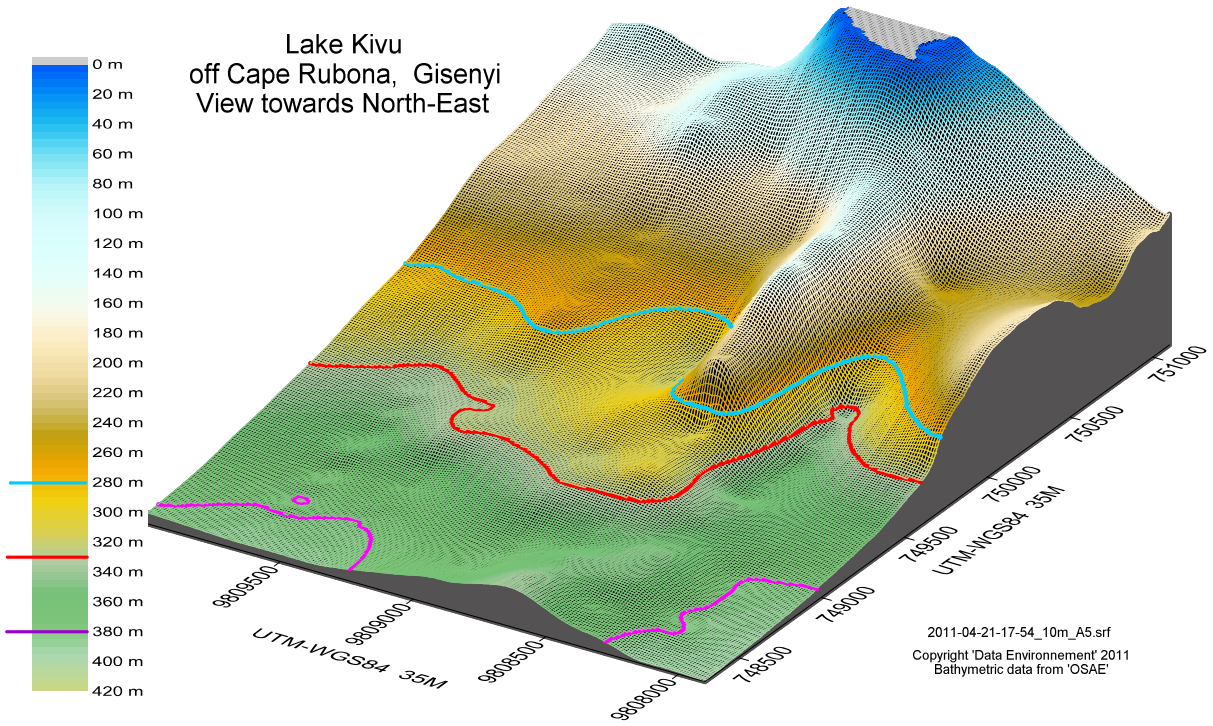


Histogram of the volume of methane in* km^3 *per 10 m thick slices (km^3/10 m)

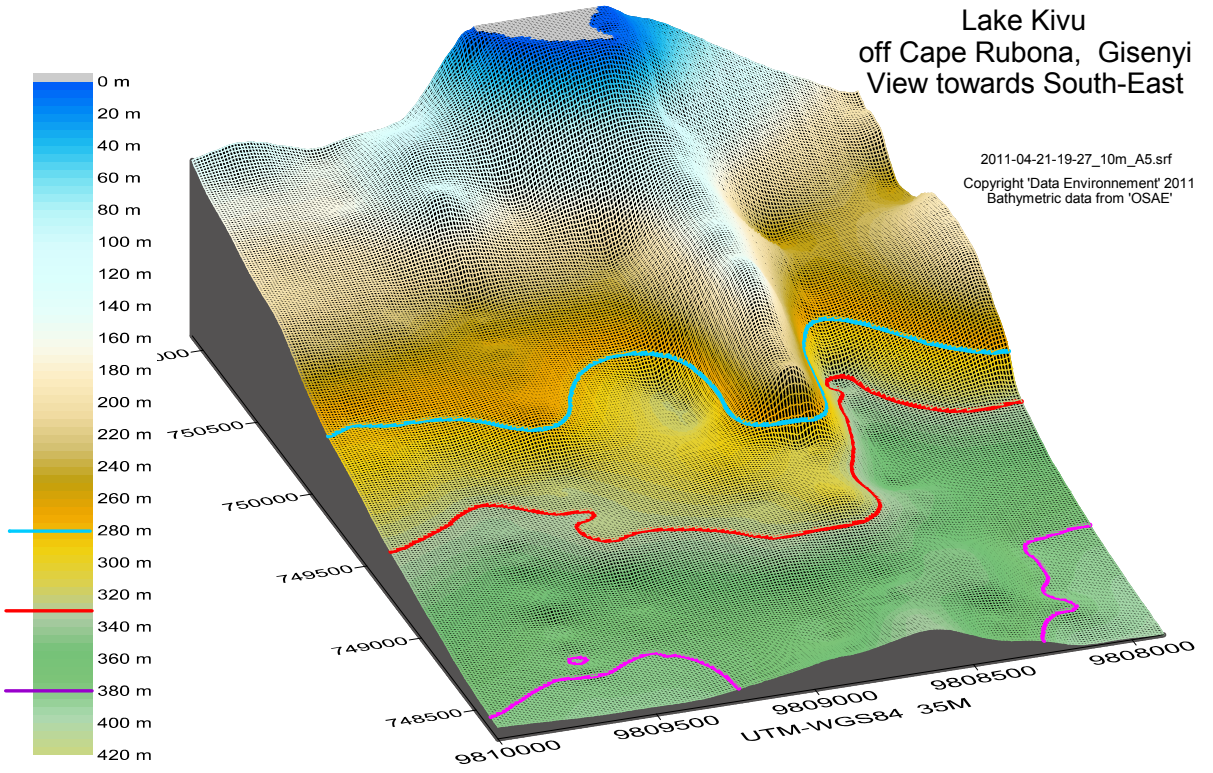
The examples described above – 3D perspective of the underwater landscape and histogram of the volume of methane dissolved in function of depth - were available only because of the availability of a digital file of bathymetric data.

In conclusion, for any study of sub-lake topography, availability of the 3D file is indispensable.

EXAMPLES OF USE OF THE DIGITAL TERRAIN MODELING FILE

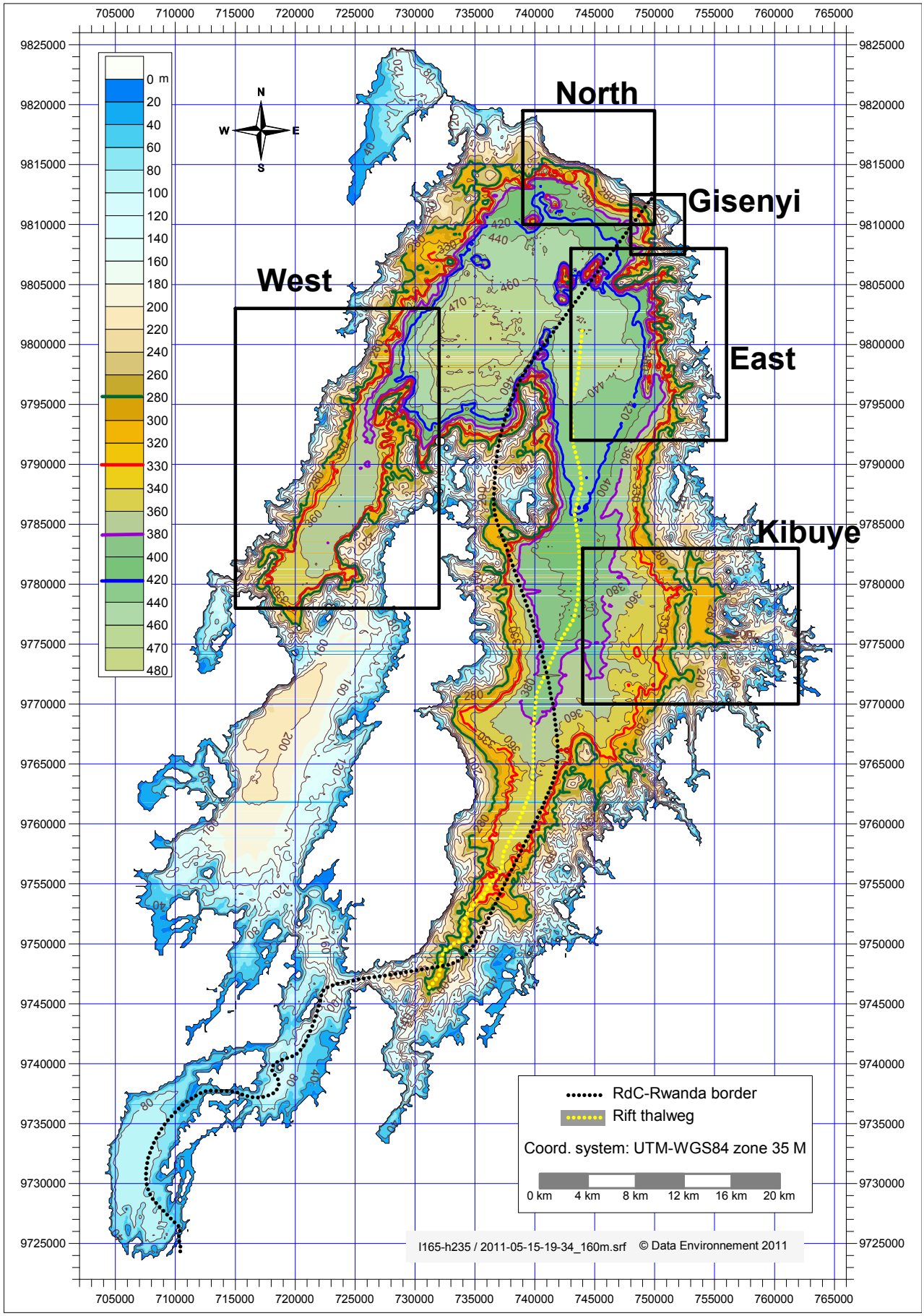


Perspective image of the area of Cape Rubona - View towards North East



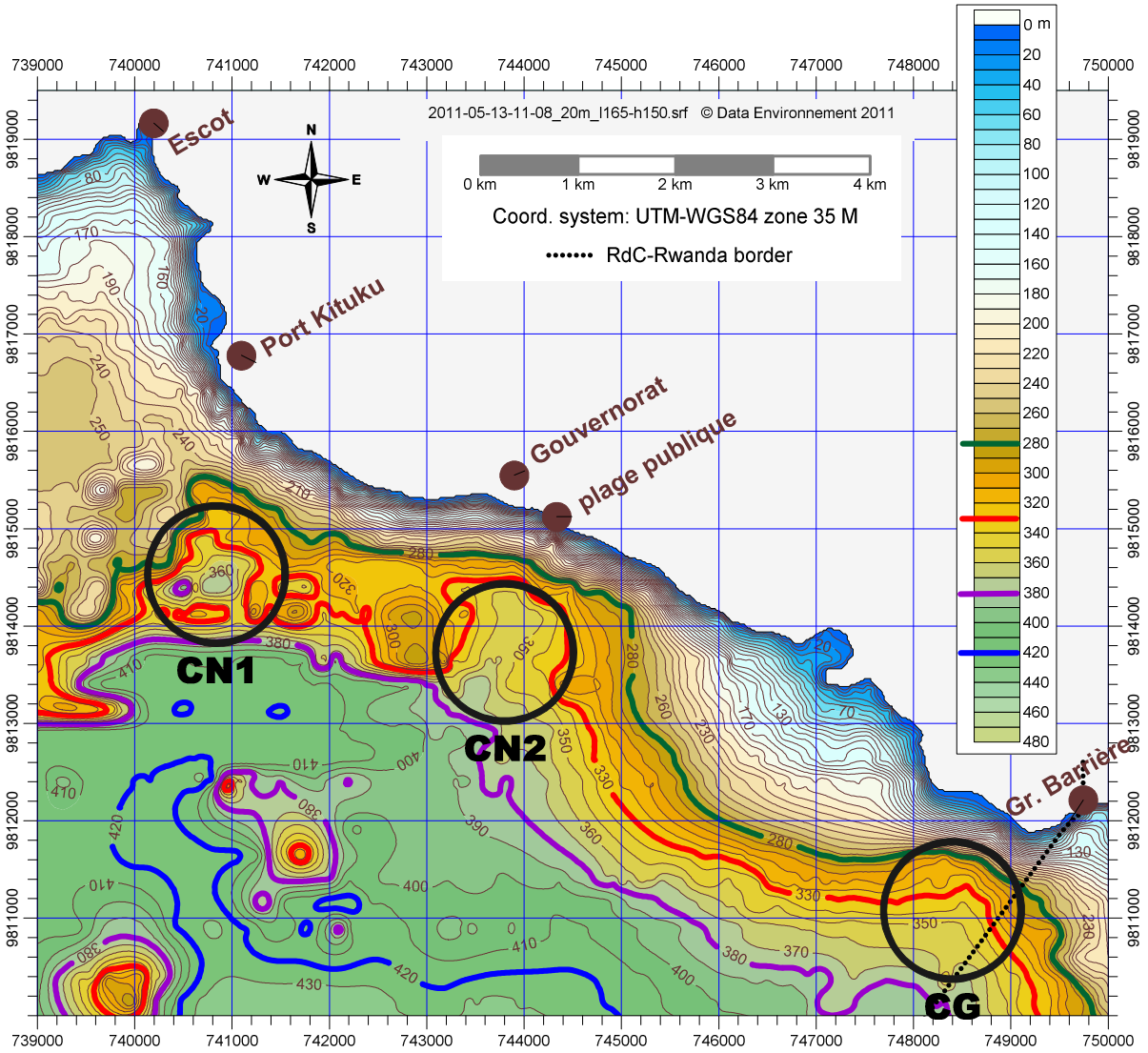
Perspective image of the area of Cape Rubona - View towards South East

AREAS OF CONCESSIONS DETAILED IN THE FOLLOWING



NORTH SHORE OF LAKE IN DRC (BETWEEN GOMA AND KESHERO)

This area is mainly the Democratic Republic of Congo. The city of Goma has seen exponential population growth during the last decade is desperately short of electricity (current needs are estimated at more than 20 MW). Moreover, there are plans to connect the electrical network to other cities in North Kivu (Lubero, Butembo, Beni, ...).



Given the steep slope in this area of the lake, it is economically interesting to directly head at exploiting the deep layer (LRZ), the more gas-rich, easily accessible near the shore.

A detailed study of the position of this layer relative to the shoreline was conducted on the north shore of Lake Kivu. By moving about 10 km from east to west, one sees that the 330 m level lies near the coast at the Great Barrier, which is the border between Rwanda and the DRC, then moves somewhat away from the coast, and then comes back close to the coast at two places: near the Gouvernorat and near to the point called Port Kituku.

A detailed study of the bathymetry of the lake allows locating three sites favourable to the establishment of an extraction station. We describe them below, indicating their distances to the shore.

Site of the Great Barrier CG

It is located a few hundred meters from the border with Rwanda, which may cause some political problems. Sublacustre topography is very steep: the depth of 330 m is reached at 1000 m from shore. The area has a limited lateral dimension (about 500 m). Finally, we are in a highly urbanized zone, where the location of a plant may pose problems of expropriation.

Site Governorate - Public Beach CN2

This is a truly exceptional site: indeed, there is a kind of sublacustre gulf at a depth of 320 m to 360 m approaching the far shore:

- at 700 m from the coast, is 320 m ;
- at 750 m from the coast, the depth is 340 m;
- at 850 m from the coast, the depth is 350 m.

The landing point of the pipeline should be between the Governorate and the public beach, about 1 km further east. The lateral extension of this zone is about 1 km.

Site Port Kituku CN1

This site is located further west, at about 6 km from the port of Goma. Again, the deep layers of the lake advance towards the shore.

- at 800 m from the coast, the depth is 320 m deep,
- at 1150 m from the coast, the depth is 330 m deep,
- at 1300 m from the coast, the depth is 340 m deep,

In terms of the criterion of the bathymetry, this site is less favourable than before (e. g. the layer 340 m is 1300 m from the shore, compared with 750 m at the site of the Governorate). The lateral extension of the interesting area is relatively limited (about 500 m)

Nevertheless, it is in a much less urbanized area, which can facilitate the implementation of the power plant.

A curiosity that may possibly have an interest in the case of intensive exploitation of methane: there is a location situated 1850 m from the coast, where depth is a considerable 390 m.

Placing the power plant

Site of the Great Barrier CG :

As was noted before, the main drawback of this location is its proximity to the border with Rwanda: the ending point of the pipeline would be 400 m from the border. Moreover, the line separating the territorial waters of the DRC could also give rise to disputes between the two countries. Clearly, the establishment of a station in this area would necessarily involve an agreement between the two countries, or even the proposal of a station operated jointly by the DRC and Rwanda.

Location of selected sites operating

Site Governorate - Public Beach CN2 :

There is an extensive site that could be dedicated to implementing a high-capacity power plant. It is a State field belonging to the Régie des Voies Aériennes (RVA). It is located in Katindo district, near the city center and the main transformer between the high voltage line (110 kV) from the Ruzizi and the medium voltage lines (15 kV) feeding the neighborhoods of the city. The choice of this location would necessitate the construction of a 2 km pipeline to bring gas from the public beach. Note that the transformer 110 kV - 15 kV is less than a kilometre far from the RVA field from the road to Sake. The electricity produced by the plant could be fed directly to the main transformer without going through the 110 kV line.

We believe it would be desirable to find a field near the landing point of the pipeline. In the figure below we have identified two undeveloped lands located a few hundred meters from the ending location of the pipeline.

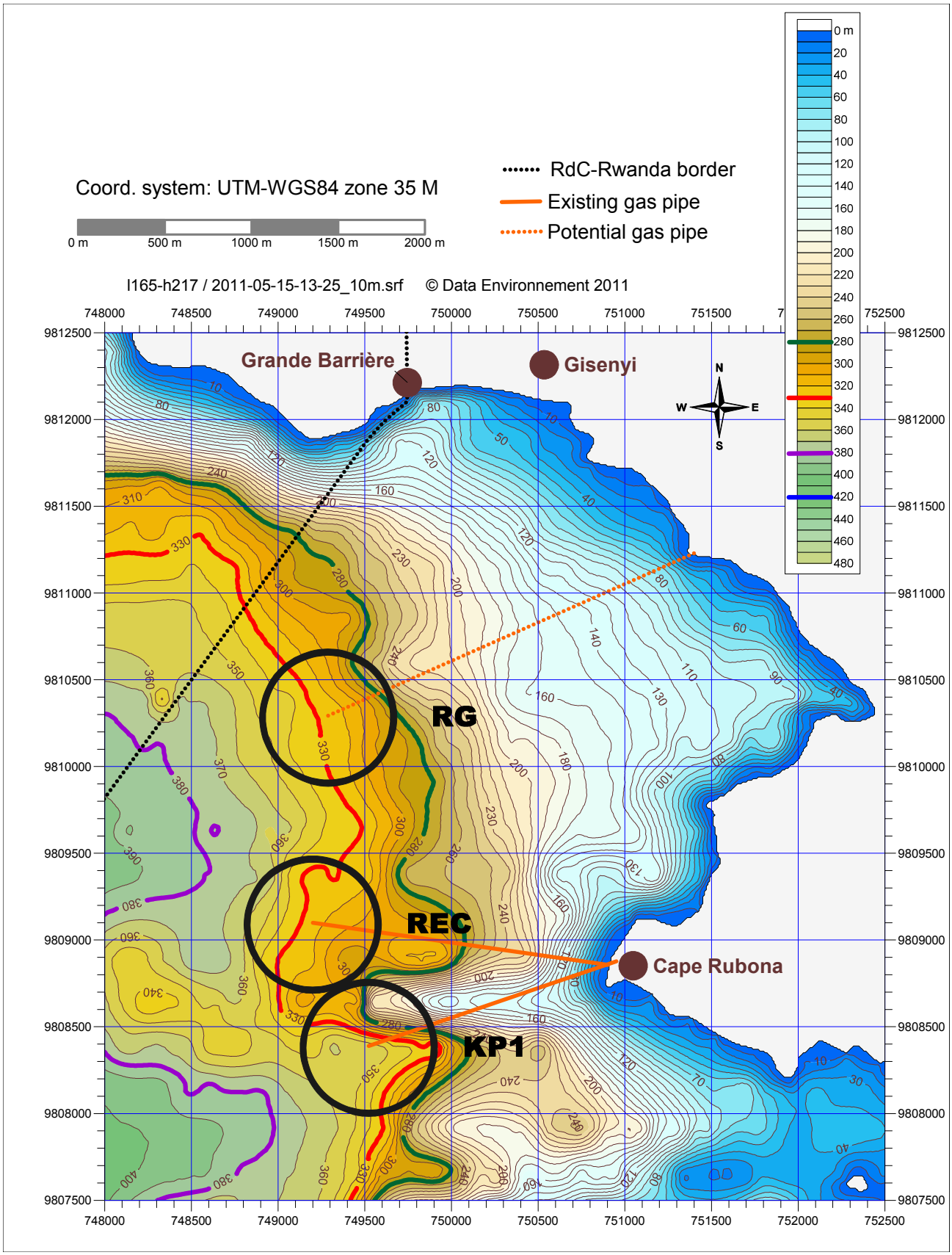
Possible locations for the installation of a power plant (shown in grey on the figure)

Site Port Kituku CN1 :

The location of a factory should not be a problem. There are many undeveloped lands in this area. Note the old coffee roasting plant SOTRAKI located close to Port Kituku.
For cons, the 110 kV line is furthest from this site that from the former.

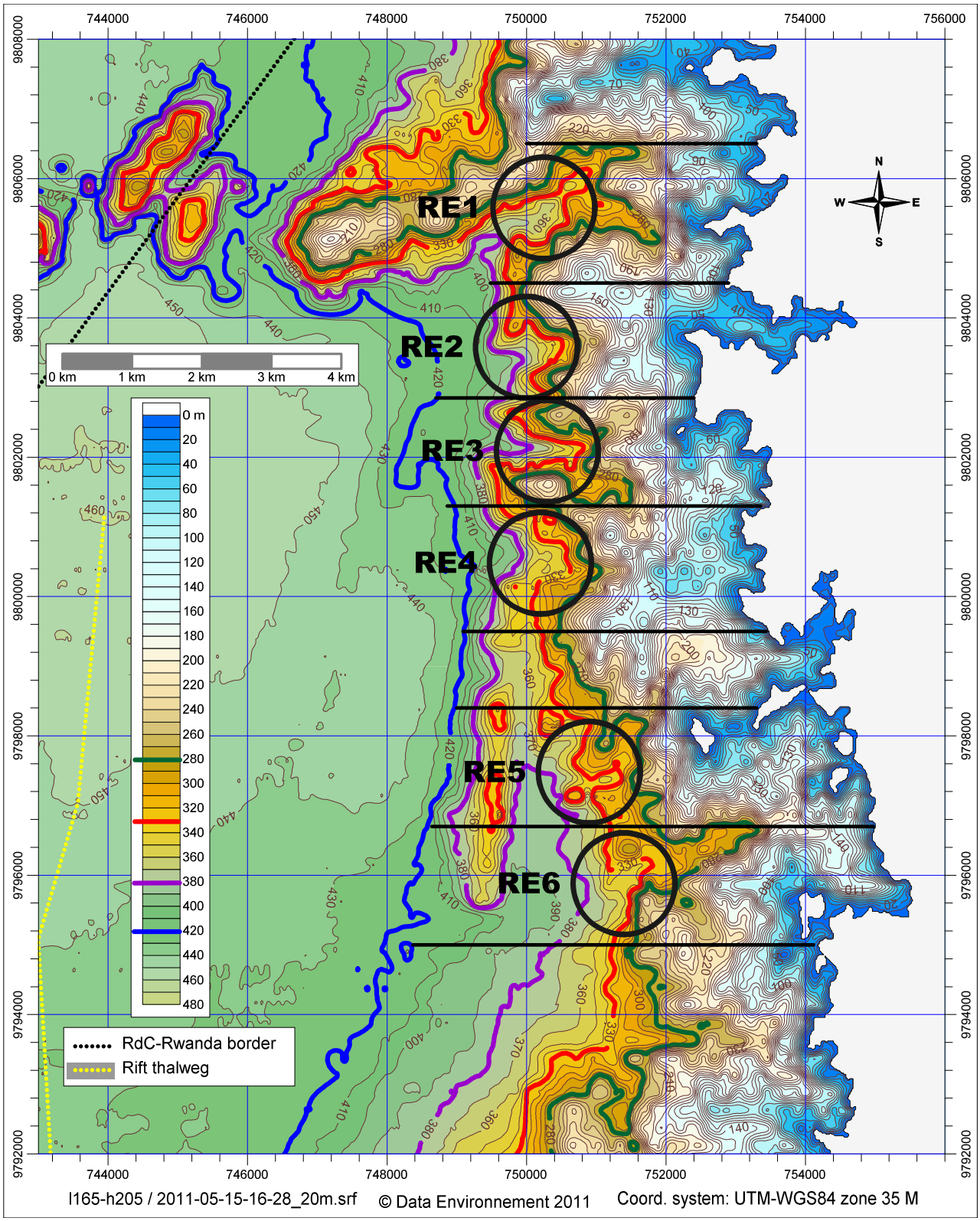
ZOOM ON GULF OF GISENYI

We put on the bathymetric chart below two existing stations (KP1 and REC). RG site was added because it was located in a not heavily urbanized area of the town of Gisenyi.



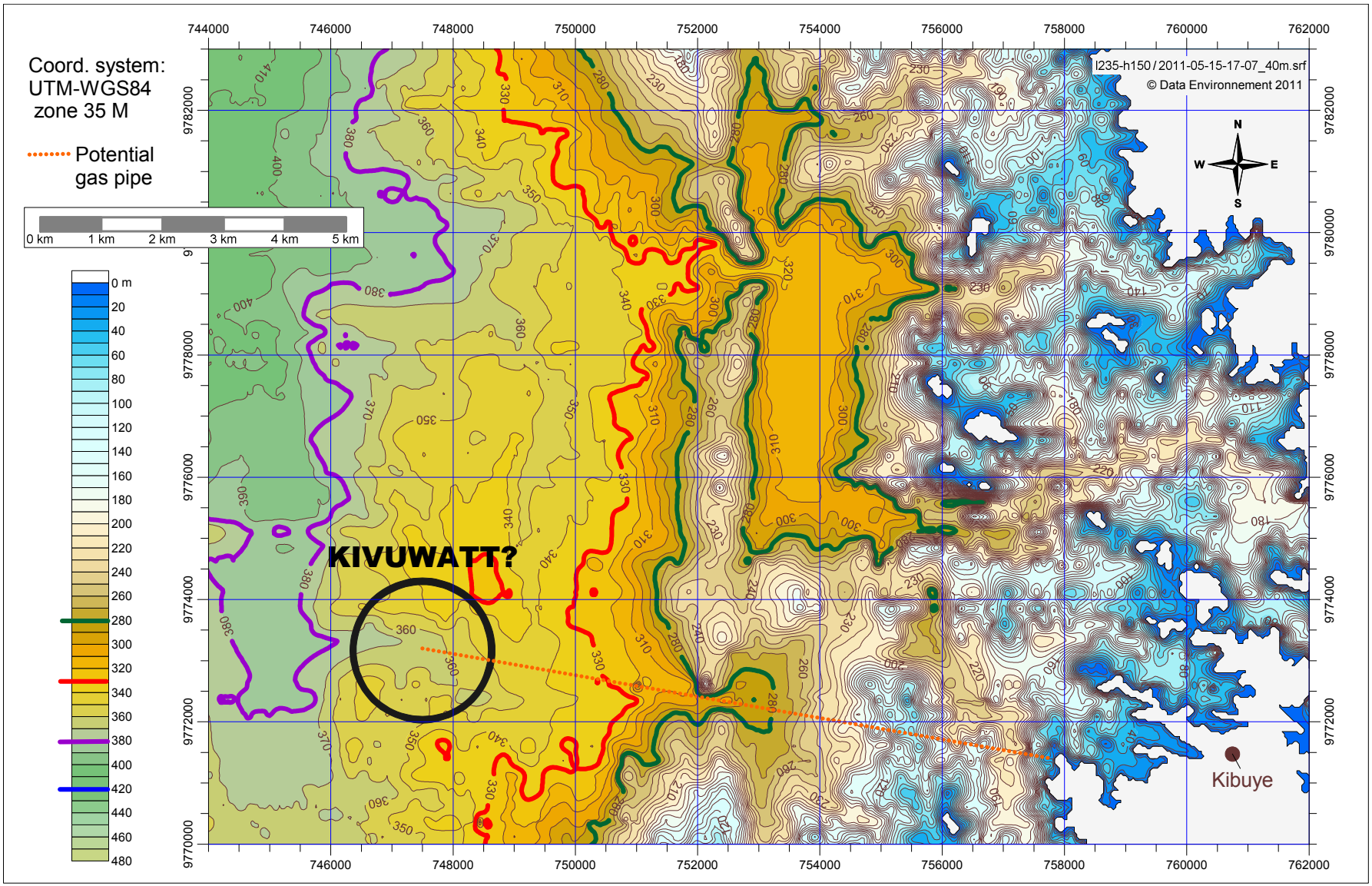
EAST COAST OF THE LAKE IN RWANDA

The siting of concessions on the east coast of the lake is relatively complex. It is indeed an extremely indented coast, with bays that penetrate deep into the cliffs along the lake. We have identified six sites (identified by the notations of RE1 to RE6) that could be interesting; but we insist that it would be necessary before making a choice to check the local bathymetry on these sites using a high resolution sonar.
Note that a coastal road is currently under construction and that some small companies operate on coffee on this coast.



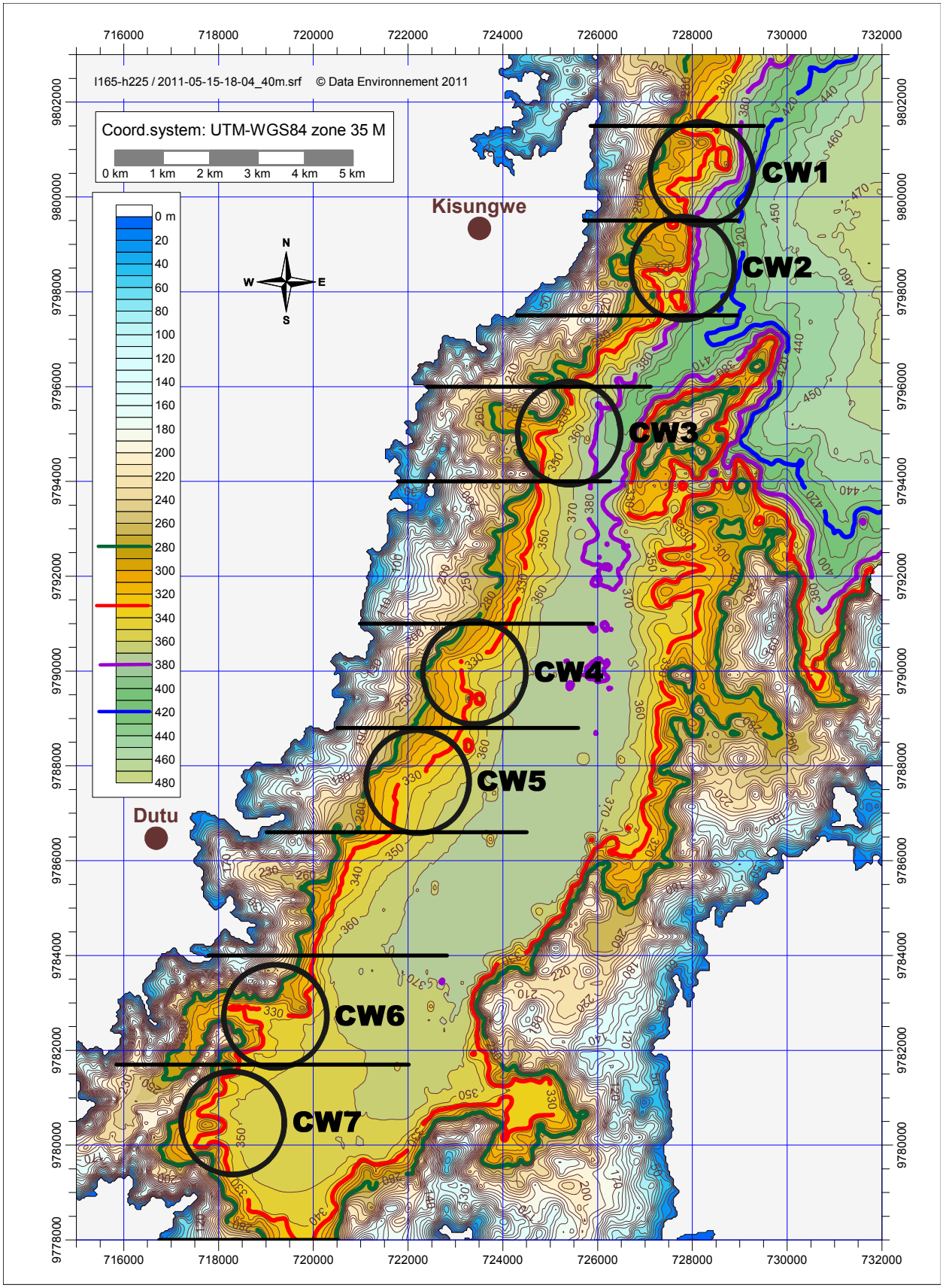
SITE IN KIBUYE

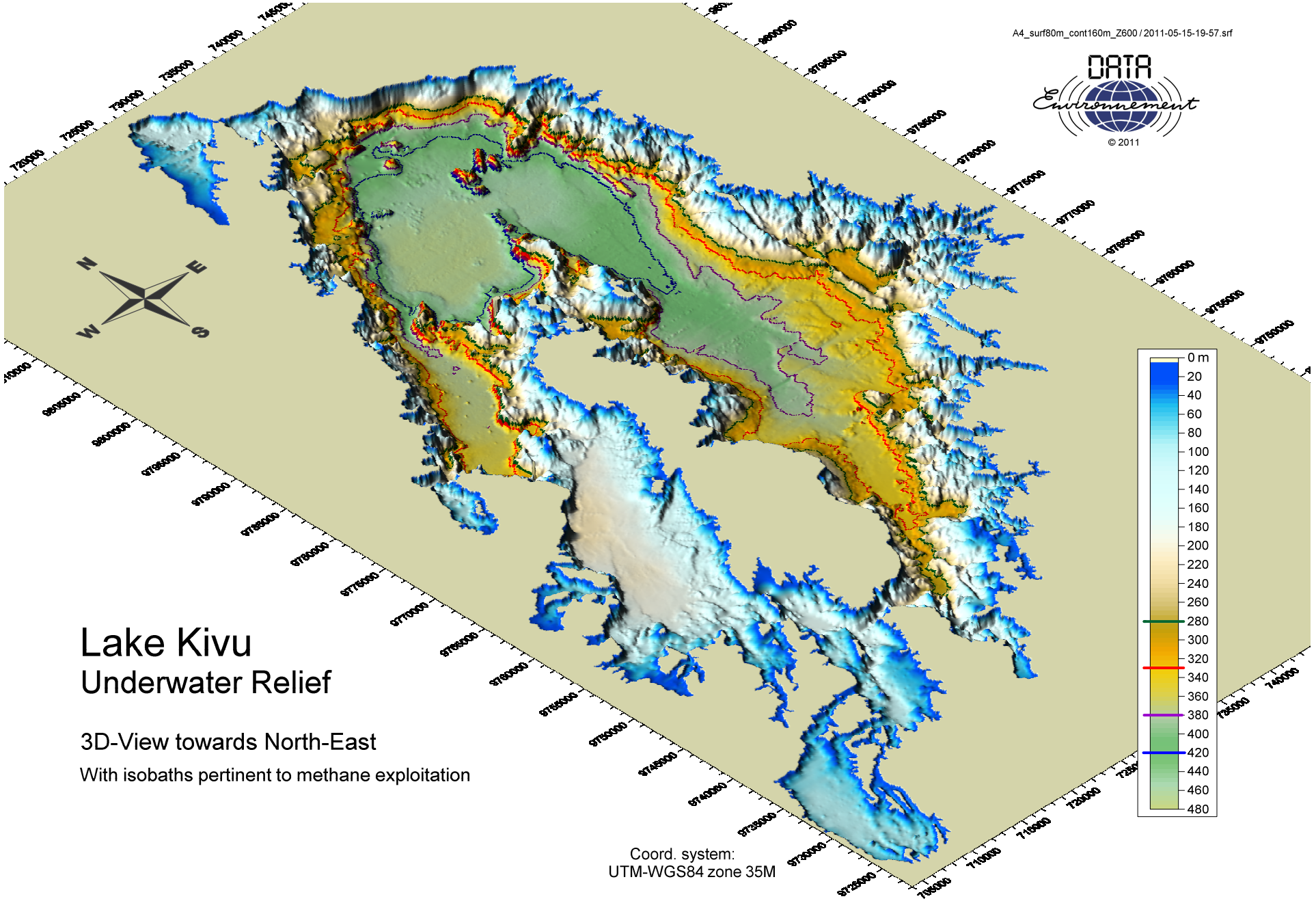
The site in Kibuye being located further south on the lake, access to deeper layers is farthest from shore (> more than10 km to reach the depth of 350 m). We show on the map the presumed site of the station KivuWatt (under construction)



WEST COAST OF LAKE IN DRC (BETWEEN NYAMASASA ET KANIAPINGA)

These sites labelled CW1 to Cw7 were selected because of the proximity of the N2 national road. We believe that these sites could someday be used by ores processing, factories, which are very energy greedy. The South Kivu province is rich in minerals of high value (Colombo-tantalite, Wolframite, Cassiterite, gold...).

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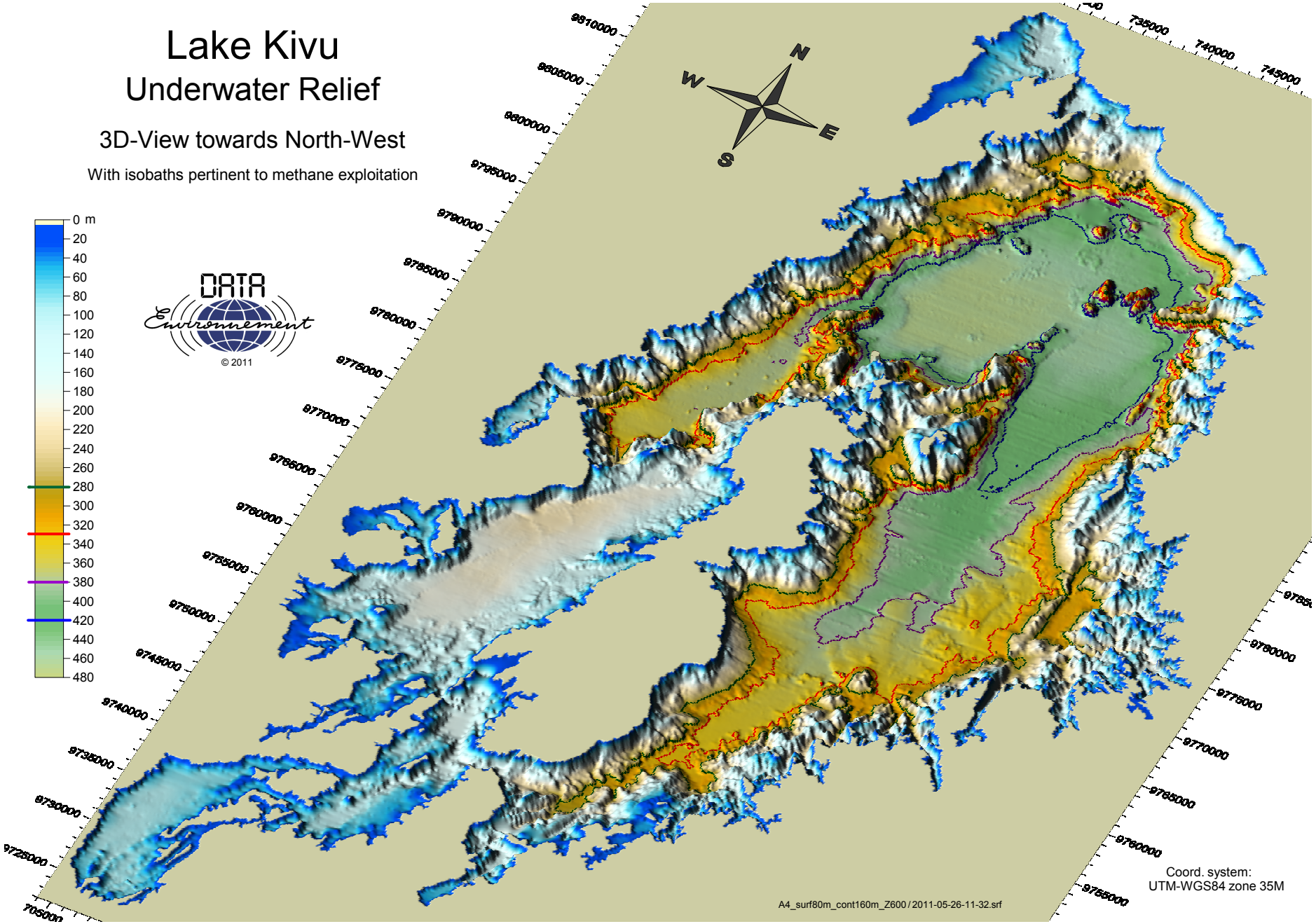
Lake Kivu
Underwater Relief
3D-View towards North-East
With isobaths pertinent to methane exploitation
Coord. system:
UTM-WGS84 zone 35M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3D-View towards North-West
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