Bridging the Oracle REM database with a customised Geographic Information System

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EXECUTIVE SUMMARY

The Radioactivity Environmental Monitoring (REM) database was set-up within the Institute for Environment and Sustainability (IES) of the Joint Research Centre (JRC) of the European Commission (EC) in 1988 to store in a harmonized way environmental radioactivity data produced in the aftermath of the Chernobyl accident. The purpose of the database (REMDB) is twofold: to keep a historical record of the Chernobyl accident for further scientific studies and to store the radioactivity monitoring data of the Member States (MS) of the European Union in order to prepare monitoring reports (1) informing the MS of the radioactivity levels in the environment as stated in art. 35 – 36 of the Euratom Treaty (2). At the moment, more than 1,500,000 data sets are stored in REMDB and represent mainly radioactivity measurements made in air, water, milk, meat and vegetables. REMDB can be accessed and queried by the public via the internet; data are then downloaded in text formats.

Because all measurements have a temporal and a spatial dimension, providing users of REMDB with tools for exploring these dimensions would greatly facilitate the analysis of the data stored: measurements wrongly located could be better identified if displayed on the top of geographic layers, outliers would appear more obviously to the eye if shown with symbols. Overall, spatio-temporal relationships would be easier to understand using maps and plots, information that is currently not yet provided to users and managers of REMDB.

It is the purpose of this report to present means and methods developed for coupling REMDB with a Geographical Information System (GIS) facilitating the handling of the data. To underline the potential offered by such a coupling, a graphical user interface (GUI) was developed to explore possible correlations between radioactivity measured in river water and the radioactivity released in water as reported by the nuclear industry.

The user interface as described in this report was implemented with Visual Basic for Applications (VBA) using ArcObjects. The reader will find in the Technical Annexes of this report further information regarding the purely technical aspects in implementing and maintaining such a tool.
1. When REMDB goes GIS

1.1 Introduction

One way to bring easily data from the REM database (REMDB) on maps is by creating an easy-to-use interface derived from a Geographic Information System (GIS). Such an interface should not only function as a gateway to the radioactivity measurements stored in the REM database, taking into account their spatial (and temporal) contexts, but the data should also be retrieved by the help of a real-time connection facilitating the automatic detection of any changes made to the database.

Apart from generating input maps that can be used for more advanced spatial analyses, a graphical user interface (GUI) further needs to be well conceived in a way that the exploration and the visualisation of the information is not only straightforward to non-experts but also that the retrieval of information is automated as much as possible.

Compared to many web mapping applications, the approach adopted here needs to allow users to further investigate the information generated by the tool. In other words, results need to be directly used as a source for further analyses.

In order to have such a GUI working properly when linked to REMDB, a new spatial component needs to be introduced into the database as the data stored in REMDB has no spatial properties that can be directly used by a GIS. A significant effort needs thus also to be done for ensuring the proper use of the measurements stored in REMDB.

1.2 A quick look at the Graphical User Interface

While the GUI designed here has been tailored mainly for analysing measurements made in surface water, its architecture and concept have be chosen in a way that it can be easily adapted for the analysis of any kind of data stored in REMDB.

The GUI was integrated into the widely used GIS software ArcGIS. It can be launched simply by double-clicking on a prepared map document. This is a file, where program settings, layer selection and symbolizations are being stored and additional features can be included. The interface proposed has been customised to satisfy what is believed to match the needs of a standard end-user, which is someone with a good idea on the contents of REMDB with no particular experience in GIS.

At launch, the common ArcGIS toolbars are hidden, and a new one has been added. This toolbar is divided into groups of menu items, namely *File*, *Map* and *Navigation* (Fig. 1). For all items, a

![Figure 1: The toolbar of the user interface consists of the item groups File, Map and Navigation. Query results can be exported as an image or file.](image-url)
description of any functionality can be obtained by leaving the cursor of the mouse over a button. In the Navigation item group, users can navigate with common, intuitive tools such as fixed zoom in/out, zoom to an extent and pan. Focusing directly on a country is also possible by selecting one from the country list. Going back to the European map can be done at any time by using the world symbol. The File item group further allows the opening and the saving of the documents.

The core of the interface however, is the Map item group which has different functions. In the Layer menu, users can choose to display rivers with or without their names, show the locations of nuclear power plants and even view a satellite image of the displayed area. While zooming into the map, the behaviour of the map layers changes: While the general map extent of Europe by default shows country borders and major rivers only, zooming in the map will systematically increase the amount of information shown: minor rivers will start to appear and at the scale of 1:6 million, a more detailed version of the river network appears. When chosen to display a satellite image as background layer, until the scale of 1:1 million, the «Spot Vegetation Global Mosaic» dataset produced by the Global Vegetation Monitoring Unit of the JRC (3) is shown. Zooming further into the map will display a mosaic of Landsat satellite image instead. This data is provided by the Land Management Unit of the JRC «Image 2000 Project», (4), see also chapter 2.4. The satellite images are expected to help to verify the locations of measurements and highlight locations of nuclear sites. Figures 2 and 3 provide typical screenshots of the GUI.

Selecting the information button enables the user to retrieve further information about map elements. Clicking on a nuclear power plant (NPP) for example, informs the user about its name, type and capacity (see Fig. 2 top). A more expert GIS user might want to rearrange the layer’s order or even change the appearance of map symbols. This can easily be done in the Table of contents (see Fig. 2 bottom, on the left), which is toggled on/off by pressing the Legend button. Here, the legend for measurement visualizations (see below) can also be seen.

A map composition created by the user can be exported using the export button in the toolbar launched at start-up. Either, the current map extent can be saved as an image file, or selected features from the measurements layer (see below) can be saved as a shapefile, a standard map format used in the GIS industry. The appropriate selection tool – select features, select features on screen and clear selected features – can be found in the export toolbar. If desired, the tabular information can be explored on its own by opening the created dbf file in MS Excel, for example.
Figure 2: Two screenshots of a GIS interface coupled to REMDB: The GUI is functioning here as a gateway to spatial (and temporal) information compounds of the database. Any kind of background map and query can be made to interrogate REMDB, visualize the results of the query and export these results in different formats.
1.3 Querying REMDB

To overlay selected data from REMDB on the top of maps, a dialog box as shown in Figure 4 is used to select the radionuclide as well as time of the measurement. This dialog box appears when using the create button from the toolbar.

The first option in this dialog box allows the user to choose the desired radionuclide (e.g. CS-137, SR-90, H-3 or CO-60). The time scale of the measurement can be defined in three different ways:

1. **As a point in time**: this results in the display of the averaged measurement value for the corresponding month or year using proportional symbols (circles).
2. **As a time period**: time periods are displayed by means of bar diagrams, one bar representing one month or year. The maximum number of bars is limited to twelve.
3. **As a change over time**: in order to highlight possible changes in the measurement values over a certain time (months or years), two layers are created: red proportional symbols will point to increasing values over time while the green colour will show decreasing concentrations over time.

For each of the three options above, a schematic preview is available that adapts to the current selection. Further options allow the user to define if only those measurements should be queried that are above a detection limit (values below are stored with a «less than» attribute), i.e. an absolute value could be diverted, and choose between different measurement units. Lastly, a sample type (here: river water) can be selected.
Figure 4: In the dialog box to symbolize the measurement values the user can chosen between different radionuclides, time scales, measurement attributes and sample types.

The symbol colour, in case of the time option being a point in time or a time period, changes with the nuclide selected, i.e. blue stands for CS-137, green for H-3, etc. (Fig. 5), as used in previous reports on environmental radioactivity by the REM group (5). To ease a comparison between different maps, the absolute size of a proportional symbol always stands for the same amount of radioactivity, whereas the range is adjusted for the individual radionuclides (Fig. 5). A drawback of this approach is that exceptional values cannot be displayed adequately. A legend showing these absolute values can be seen in the table of contents.

Before creating a new map layer, the user’s inputs are automatically checked against logical consistency errors (e.g. an end date coming before a begin date) and corrected where necessary. For display, only locations with appropriate information available are selected and drawn on the map.
1.4 Case study: comparing measurements in surface water with effluent data in the Rhône catchment area

The implementation of the described spatial data infrastructure together with the designed user interface can be used for analysing measurements taken from river water amongst others. As a first example of use, a feasibility study was carried out for comparing river measurements with data about effluents coming from the nuclear industry. Small amounts of radioactive liquids originating from water of reactor coolant dryers, soluble activity of sludge tanks or active laundry e.g. are discharged into the aquatic environment in a controlled manner after filtration and treatment has taken place (e.g. 6).

Data about these discharges for the time period 1998-2003 were provided in a tabular format to REM by the Directorate General for Transport and Energy (DG TREN) of the EC. Discharge values for 84 sites in Europe were averaged by year and comprise 43 different radionuclides. After the storage of the data within REMDB and linkage to their nuclear sites, these could be used for analyses.

For the feasibility study discussed here, the catchment area of the river Rhône was chosen. The area covers approximately 100,000 km$^2$ and accommodates 5 NPP (Tricastin, Cruas, Saint-Alban, Bugey and Creys-Malville). About 50 locations could be found in REMDB where measurements in river water have been carried out between 1998 and 2003 for the radionuclides under survey – CS-137, CO-60, SR-90 and H-3. The choice of these radionuclides is justified as these are the most frequently measured radionuclides and also because significant amounts are presumably to be found in river water.
The user interface described in this technical note accomplishes the task of retrieving data about the measurements in a very comfortable way. It was observed that the range of discharge values given was very large. Discharges of H-3 lie around 40 000 GBq with little variability for the three further downstream sites, while for Creys-Malville values between 0.2 and 16.5 GBq are indicated. Among all sites the range spans approx. 8 powers for the four radionuclides under survey.

Before looking further at the data, some prior data treatment was indispensable. A more detailed inspection of the measurement locations revealed some irregularities. With the help of satellite images and internet navigation maps, it could be found out e.g. that one location was shifted north by one degree and another one was supposed to be situated in another country. A few other locations had to be excluded and the remaining ones were harmonized with the existing river GIS layer, i.e. moved onto the stream courses. For the river system, the main rivers from the GISCO database provided by EUROSTAT were taken and extended by some minor rivers where necessary. Finally, the Rhône river catchment was created using the «River and Catchment Databases» by the former Soil and Waste Unit of the JRC (see 7).

Fig. 8 (top) illustrates a visualization of the discharge values for H-3 (1998 to 2003); in Fig. 8 (bottom) measurement values for H-3 in 2003 are shown. It can be easily seen that the highest values were measured in the north-western part of the catchment around the research institute Valduc. The given discharge values are similar and show some variations but no general trend, except for Creys-Malville (see above); for Valduc no information about discharges are given. River water from the northern part of the catchment (including the Valduc area) reaches the Rhône between Bugey and St. Alban. At the nearby measurement locations, no significant changes can be seen. On the contrary: All measurements for H-3 taken along the Rhône in the year 2003 show very similar values. An increase towards the river mouth ascribed to accumulating discharges along the river cannot be detected either. It can therefore be concluded that from looking at the measurements and discharges on the map, no clear correlation could be observed. The following discussion will try to give some reasons for this.

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1 However, since the implementation of the Oracle stored procedure necessary for this purpose was not finished at the time when the study was carried out (see chapter 3), the according queries were carried out by hand.
Figure 8: Visualization of discharges by the nuclear industries into the river Rhône (top, of H-3, 1998-2003) and of measurement values in the catchment area (bottom, H-3, 2003).
A general issue that has to be kept in mind is the fact that discharges are given as absolute numbers (amount of radioactivity per year) while measures are taken relatively (amount of radioactivity per liter/m$^3$). Therefore, the amount of water the discharges are mixed with has to be taken into account. The amount of water passing by a certain place is the runoff measured in m$^3$/s. Information on the runoff at the measurement location should consequently be acquired for further analyses (as a first contact point the «Global Runoff Data Centre» can be consulted, 8). It is very likely to be the case that such data is not available for all measurement locations. For a European wide model, however, it would be sufficient to apply a linear (or alike) interpolation between given runoff stations. It is also imaginable to make an approximation based on the sizes of catchments of lower order leading into the river under survey (see Fig. 9 top-right, explained further below).

Another general problem is the low temporal resolution of the two datasets. Effluent data are provided per year, but discharges do not take place continuously: depending on the nuclear site, tanks are emptied for example once or twice a week, whereas the process of discharging may take a few hours (6, 9). The absolute amount of radioactivity released between two discharges is also likely to vary. For a comprehensive study, more detailed information on discharge events is desirable.

Regarding the monitoring of radioactivity in rivers, only very few stations can provide continuous information on the various radionuclides with a high temporal resolution. In the Rhône catchment there is an average of circa 12 locations with measurement data for H-3 for the time period of 1998 to 2003, but they distribute among 50 individual locations. Only a few of them can exhibit more than one or two measurements per year. For this reason, it is very unlikely that discharges can be detected in the collected data.

The use of few well-located stations measuring continuously and automatically together with more detailed information on discharges would be desirable for an accurate study of the correlation between the effluents and the measurements. Such a study could be based on a very simple model that takes into account the amounts of water runoff in a river network as illustrated in Fig. 9. An improvement would be to include the approximate time needed for the effluents to reach the measuring stations. On a European scale, such an approach could be used as a good first approximation. The effort necessary for a data harmonization and preparation should not be underestimated. A river network should be established with flow directions and travel times appended to the segments. In such a network, the dispersal of discharges could be mapped and predictions about the spreading of radioactivity in the case of an emergency would be possible. An interactive animation tool visualizing changes over time could also be implemented. An automated system for monitoring and detecting discharges through real-time measurements is only feasible with the according base data provided. In a highly scalable system, the mentioned fixed stations would also measure the runoff and the flow velocity.

To obtain a still higher accuracy, more complex models and smaller sample taking intervals are required. While such studies can be carried out over a limited time period or for a restricted area, the feasibility on a European scale has to be questioned. A Swiss survey for the rivers Aare and Rhine (9) reverts to 20 to 40 daily measurements at three stations downstream of nuclear power plants. A projection taking into account the average monthly runoff and the time period of sampling can prove between 50% and 80% of the discharges of CO-58, overestimates the amount of discharged CO-60 and predicts more activity of CS-137 than discharged.
Measurements of sedimentations do not seem to correspond to the discharges but to correlate with the runoff (higher activity where the runoff is less).

A combined hydraulic and chemical model for prediction of the arrival time and the pollutant concentration of toxic substances was validated using radiocobalt as tracer in three field experiments at the rivers Aare and Rhine between 1994 and 1998 (10). The model implemented into the program package «Aquasim» considers not only constant runoff measurements and information on river bathymetry but also takes into account sorption and organic complexation. The predicted amount and arrival time of radiocobalt matched the measurement results well and a high accuracy of the model was concluded.

**Figure 9:** Illustration of a simple model for correlating discharge values with measurement results. Measurement values are multiplied with the river runoff and then compared with the accumulated discharge values.
2. Technical Background

2.1 Spatial Database

The above described tool uses different technical approaches and requires a modification of the existing relational, table based towards a spatial data infrastructure. So far, the spatial information content of measurement locations was stored in a tabular way in REMDB, using columns for latitudes and longitudes holding decimal degree values. Although ArcGIS can retrieve this information via an established ODBC gateway and create so-called «event layers» that represent geometries, restrictions are combined with is procedure: To properly work with these layers, they have to be exported into the GIS' data format meaning that a real-time connectivity is lost. More convenient is the introduction of a spatial data type in the database system itself that can be directly accessed by the GIS and used just like any other (proprietary) layer. Like this, an always up-to-date infrastructure can be maintained. Also, there is only one place where information is stored and maintained – the database.

The Oracle Enterprise database version 9i used by the REM group already has a built-in so-called «Locator» feature that enables the storage and query of spatial data (11). This version has certain restrictions compared to the more advanced «Oracle Spatial» version of the database (e.g. no transformations between coordinate systems, 12), but this did not mean a significant disadvantage for the desired purpose so that the existing Locator feature could be used. Spatial data is stored in a field type called sdo_geometry that can be part of any standard Oracle table. The geometry object has the form:

(sdo_gtype, sdo_srid, sdo_point, sdo_elem_info, sdo_ordinates)

The sdo_gtype is a number defining the geometry type (e.g. 2001 stands for a two-dimensional point), the sdo_srid holds a number that refers to a coordinate system (e.g. 8307 stands for plain latitude/longitude coordinates). A point is defined using an sdo_point_type object storing x, y and z values – in this case, the latter object types are null. Spatial data inserts as well as queries can be realized using standard SQL syntax:

```
insert into geo_location values (...,
  mdsys.sdo_geometry(2001, 8307,
  mdsys.sdo_point_type(1.16, 52.06, null)));
```

```
select id from geo_location g where g.shp_loc.sdo_point.x > 0
```

A spatial query may, of course, also return a geometry result. The handling of such depends on the client requesting it. While older database interfaces fail to handle geometries properly, modern ones (like SQL Navigator 4, e.g.) are able to process the object and show their values. ArcGIS can display them like their proprietary file formats (when using ArcSDE, see below).

In the REM database, a new table for the measurement location was created containing all the existing fields plus one for the geometry. This was then filled using an update statement that refers to the existing table data on latitude/longitude values.

2.2 Gateway to Spatial Database

Using ArcGIS, it is possible to connect to an Oracle database via an ODBC interface. However, the application is not able to handle the spatial data type by itself. For this purpose, ArcSDE works as a gateway between ArcGIS and the relational database system (13). It handles requests
from ArcGIS and is installed on top of the database in a rather circumstantial way. After the actual installation, a post installation has to be launched that defines the tablespaces needed by SDE and creates a repository (14). Also, the desired geometry type can be defined. Apart from Oracle’s sdo_geometry type, it is possible to use an ArcSDE compressed binary or a «well known binary» format according to the Open GIS Consortium standard which are stored as «long raw». While the latter two can be of advantage in some cases, the Oracle format was chosen in this case as suggested by (15) and in (16).

After authorization, a «Spatial Database Connection» can be established using ArcCatalog. The naming convention of the therefore needed service name and user password can be verified in the online help (17). Now, the Oracle tables can be seen through the database connection in ArcCatalog. In order for an Oracle table to be recognized as being spatial, however, there are a few more steps necessary:

For a comprehensive access to the data, SDE manages a set of metadata for all tables with spatial data fields. They include the name of the table and its spatial field, the spatial reference id as well as information about the data extent and tolerance. A metadata update is necessary when creating or modifying spatial tables (18), e.g.:

```sql
insert into user_sdo_geom_metadata values
(‘geo_Location’, ’shp_Loc’, mdsys.sdo_dim_arry(
    mdsys.sdo_dim_element(‘X’, -180, 180, 0.0001),
    mdsys.sdo_dim_element(‘Y’, -90, 90, 0.0001)
    ), 8307)
```

For performance reasons, it is advisable to create a spatial index for each spatial table. While Oracle provides different options for this, the R-tree spatial index is the most commonly used one (14), e.g.:

```sql
create index idx_geo_location on geo_Location (shp_loc)
indextype is mdsys.spatial_index
```

The final step is to register a table as a feature class layer with ArcSDE. This can be done with the command sdelayer that is called from the command prompt. The id column that is being used for registration must be of the type number with a precision of 38 digits. When necessary, the length has to be changed. For a basic registration, the following parameters have to be set (for more details refer to 19):

```bash
sdelayer -- command
-o register -- operation: register
-l owner.geo_location,shp_loc -- business table, spatial column
-e p -- entity type allowed: p = point
-C id[,USER] -- column for registration, handling
-u username  -- connection username
-p password@schema -- connection password
-i sde:oracle9i -- instance: ArcSDE service name
```

Having followed the described procedure, it is now possible to see the geometry table displayed as such in ArcCatalog (Fig. 6). To integrate an existing structure of GIS layers – such as rivers, administrative boundaries and sites of nuclear power plants – into the database, an import routine has to be applied. In order to be able to run spatial queries on the database level later on, additional precaution has to be taken. First of all, the data should be transferred into one consistent coordinate system using appropriate tools. The actual data import is carried out in
Figure 6: The locations of measurements can be seen in ArcCatalog, the application connects via ArcSDE to the spatially enabled Oracle database.

ArcCatalog using the Feature Class to Feature Class dialog, where the database can be selected as output location. When importing data into Oracle using ArcGIS/ArcCatalog, the spatial reference id (SRID), however, is not created in the same way as when creating spatial data inside Oracle. Therefore, it is necessary to first drop the spatial index created during the import routine, update the entry for the SRID of the newly created table, update the metadata about this table and finally re-create the spatial index as shown by the following example code for the layer of country boundaries:

```sql
drop index a58_ix1; -- name of index created by SDE
update geo_countries a -- table name
set a.shape.sdo_srid = '8307'; -- desired srid
update mdsys.user_sdo_geom_metadata a
set srid = '8307' -- desired srid
where a.table_name = 'geo_countries'; -- table name
create index idx_geo_countries -- new index name
on countries (shape) -- name of table, spatial column
indextype is mdsys.spatial_index; -- index type
```

As a result, spatial queries among any related tables in the database can be carried out directly on the database level. For simple query tasks like “In which county does a certain location lie in?”, it is no more necessary to consult a proper GIS application that would be far too inordinate for this purpose. A query returning the name of a country a specific location is lying in would be:

```sql
select c.name
from geo_countries c, geo_location l
where sdo_geom.relate(l.shp_loc, inside, c.shape, 0.0001) != 'false'
and l.loc_id = '522'
```
2.3 Implementing the Graphical User Interface

The graphical user interface as described in the first chapter was implemented with Visual Basic for Applications (VBA) using ArcObjects. ArcObjects is an object model framework designed for programming with ArcGIS applications. It builds the platform for any ArcGIS application like ArcMap or ArcCatalog too, i.e. they exist of these objects themselves (20). Altogether, there are more than 2 700 objects that can be accessed with an object-oriented programming language like VBA, which is already embedded within ArcGIS.

With VBA the program flow can be maintained: Menus and menu items, dialog forms and user input boxes can be created and moreover, conditions and loops can be formulated. ArcObjects on the other hand carries out commands related to ArcGIS functionality like performing a zoom, querying a table or changing a layer’s symbology. An example can be used to explain this interaction:

Clicking on the world symbol in the Navigation item group calls a click-event procedure that is calling another procedure named `zoomToBookmark` and passes the parameter «Europe» (VBA inherent). In the latter procedure, the map layers «Countries» and «CountrySelected» in the group layer «backgroundLayers» are chosen and become so-called `IFeatureLayer` objects (ArcObjects, VBA loops and conditions are used for this). The visibility attribute of the layer with the selected country is set to false, i.e. is hidden, and the selection is cleared by setting the layer’s query definition to null, using the `IFeatureLayerDefinition` interface (ArcObjects).

Now, the bookmark called «Europe» is chosen from the list of bookmarks and a zoom to this bookmark is performed (ArcObjects, using VBA loops and conditions). Finally, the active view and the table of contents have to be refreshed (ArcObjects). For the complete source code of this example see Appendix B.

Displaying the measurement values on the map involves the usage of Oracle stored procedures. A stored procedure can be thought of as a subprogram that uses the PL/SQL procedural programming language and is stored in the database. It can be called with an SQL block and receive parameters that are to be defined in the procedure (21). In ArcObjects the `IWorkspace: ExecuteSQL` method can be used to execute a stored procedure on the database server over an established database connection, but no result sets can be retrieved in this way (22). Therefore, it was not possible to program a procedure that directly returns the locations attached with the measurement values as a result set. Instead, the procedure has to fill a result table that can be used by the application afterwards.

For each time scale an individual procedure was created. The procedure `timepoint` receives the input values nuclide, sample type, measuring unit, date and two Booleans indicating if values with a less than attribute should be considered and if monthly or yearly values are requested. Inside the procedure, cursors pointing at query results according to the committed parameters and temporary tables (for the locations and the attribute values) and results needed by the procedure are defined. After truncating the temporary tables and the result table, the temporary tables are filled according to the input parameters and using the defined cursors. Finally, the result table is filled with the information from the temporary tables and the geometry is added.

Having explained the individual techniques necessary for the user interface, the connections between them should be pointed out (Fig. 7). Inside the ArcGIS application, a user interface
application was build using VBA for program flow and ArcObjects for GIS functionality. In a dialog box the user can chose which data to display and how to visualize it. When clicking on the «create map» button, a query text with the appropriate parameters is build and executed. Hence, one of the three stored procedures timepoint, timeperiode and timechange programmed with PL/SQL is processed. Those use temporary tables and store the query result – attributes combined with point geometries – in a result table. After completion, the VBA/ArcObjects application connects to this table via the spatial database gateway ArcSDE. Symbolization is applied to the measurement data according to the time scale chosen using different renderers. The absolute size of the proportionally sized symbols is comparable throughout all maps created by the application and adjusted for the individual radionuclides. Finally, the map and the table of contents are updated.

2.4 Data storage

As mentioned in Chapter 2.1, the storage of the spatial information from measurement locations not only has the advantage that it can be accessed by the GIS without loosing a real-time connectivity but also that data is kept and maintained in one single place. This is the case when the data is stored on a central server that can be connected to over an existing local network. While at this stage of the implementation, some of the base data is stored locally on the hard drive, the situation could be enhanced by transferring more spatial data (e.g. country boundaries, rivers, etc.) into the database.

Another technical solution is used in the case of the satellite images of higher spatial resolution from the «Image 2000 Project». A dataset of mosaic Landsat images covering the whole of Europe is likely to have the size of many gigabytes. Because this layer is only used as background information for the visualization of the measurement data, it does not make sense to transfer this data onto the client side and provide it with the installation CD/DVD. It would be more
comfortable if only the currently needed map extent would be provided by a service over the network or internet. This is the concept of a Web Map Service. Information about the desired map extent and map service, amongst others, is sent to a Map Server via the requesting URL. The server processes this information and renders an according raster image file that is then returned back to the client. The «Image 2000 Project» provides such a service, hosted at the JRC’s Map Server (http://mapserver.jrc.it). In ArcCatalog it can be accessed just like any other GIS layer using the «Add WMS Server» command. When such a layer is loaded in a map document, ArcGIS performs a get map request whenever the current map extent is changed.

The base URL for the request is:

http://mapserver.jrc.it/wmsconnector/com.esri.wms.Esrimap/img2k_453_mos?

This is a good example of how to handle large data sets in an efficient way and of how to integrate existing ready-to-use solutions. Moreover, the responsibility for the maintenance of the data is transferred back to the data provider.
3. Outlook and further developments

The introduced GUI can be used as a tool to easily access the spatial (and temporal) information component of the data stored in the REMDB. It is a first time approach to connect the data on environmental radioactivity provided to the EC with a customised GIS application. While the implementation of the system is mainly completed, a few further steps must be undertaken before it is ready to be utilised by the end-users. The stored procedures described in chapter 2.3 for a time period and a time change still have to be implemented, the time point procedure has to be adapted for dealing with yearly inputs. Also, the time currently needed for execution is very long; some effort should be made to optimize the code. Appendix C discusses the desired structure of these procedures.

At the current stage, the interface can only be used by one person at a time. Endeavours should be made to establish a multi-user environment, for example introducing user handling on the database level. While this study mainly focused on measurements taken from river water, an enlargement towards a sample type independent dialog box should be considered. Sample types and the corresponding nuclides and measurement units could be read from the database and adjusted to the user’s current selection. Ready-to-use layouts for printing high quality maps with a legend and additional map items could also be offered to the user for a more convenient use of the tool. It should also be thought of to transform the interface into a stand-alone application, while license issues must be considered carefully.

The created spatial infrastructure should not only be seen as a necessity for the implementation of the GUI. It can rather be seen as a structural base for further spatial analyses and query activities within the REM group. The spatial infrastructure can for example be used to advance the data input by the MS. During the input, spatial queries could be carried out that control the logical correctness of the information. For this the implementation of corresponding procedures in Oracle is advisable. Also, the user could be informed about his input of coordinates by a small map send to him in real time. It would also be thinkable to let the user pin the location of a measurement taken onto a map in an integrated web mapping application or visually select existing locations to be used again for new data inserted into REMDB.

The introduced spatial structure of REMDB can also be used to scan the spatial information component for errors. Simple queries can be carried out that for example select locations with the same coordinates or only a very small distance in between them. Like this, a harmonization of the location data could be achieved. A further integration of existing spatial base data into the Oracle database is desirable and would enrich the possibilities of spatial analyses and lead to a more coherent data infrastructure.
References

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    index.cfm?fa=knowledgebase.techarticles.articleShow&d=26488
Appendix A: Installation & Software Requirements

In order to use the GUI, the user needs to have ArcGIS (version 9) installed on his computer. Also, the Oracle Client application has to be installed and a connection to the alpha server, on which REMDB is running, has to be guaranteed, i.e. the user must have access to the local network of the REM group (the name of the SDE instance is sde:oracle9i). At this stage of implementation, the default language chosen for the Oracle Client should be English; otherwise a small modification in the source code has to be carried out in the function monthToLetters (uTimePointMonth).

The content of the installation CD has to be copied directly onto the C: partition of the local hard disc. A free disk space of at least 138 MB is necessary, more is advised. The GUI is launched by double-clicking onto the file remDBinterface.mxd that is situated in the base folder.
Appendix B: Code sample: zoom to the extent of Europe

Private Sub nav_clearZoom_Click()
    zoomToEuropeBookmark ("Europe")
End Sub

' clears the county selection and zooms to the bookmark passed
Public Sub zoomToEuropeBookmark(bookmarkName As String)

    Dim pMxDoc As IMxDocument
    Dim pMxMap As IMap
    Dim pLayer As ILayer
    Dim pGroupLayer As IGroupLayer
    Dim pCompLayer As ICompositeLayer
    Dim pFLayerBack As IFeatureLayer
    Dim pFLayerFront As IFeatureLayer
    Dim pEnumLayer As IEnumLayer
    Dim pCurrentLayer As IFeatureLayer
    Dim pFClass As IFeatureClass
    Dim pFeature As IFeature

    Set pMxDoc = ThisDocument
    Set pMxMap = pMxDoc.FocusMap

    ' get layer group by name
    Dim i As Integer
    For i = 0 To pMxMap.LayerCount - 1
        Set pLayer = pMxMap.Layer(i)
        If pLayer.name = "backgroundLayers" Then
            Set pGroupLayer = pMxMap.Layer(i)
        End If
    Next i
    Set pCompLayer = pGroupLayer

    ' get layers by name
    For i = 0 To pCompLayer.count - 1
        Set pLayer = pCompLayer.Layer(i)
        If pLayer.name = "Countries" Then
            Set pFLayerBack = pCompLayer.Layer(i)
        ElseIf pLayer.name = "CountrySelected" Then
            Set pFLayerFront = pCompLayer.Layer(i)
        End If
    Next i

    Dim pEnv As IEnvelope
    Dim pActView As IActiveView
    Dim pFCursor As IFeatureCursor
    Dim pQFilt As IQueryFilter
    Set pActView = pMxDoc.activeView

    ' hide layer
    pFLayerFront.Visible = False

    ' delete selection
    Dim flDef As IFeatureLayerDefinition
    Set flDef = pFLayerFront
    flDef.DefinitionExpression = ""

End Sub
' zoom to bookmark
' Access the Map object through its IMapBookmarks interface
Dim pMapBookmarks As IMapBookmarks
Set pMapBookmarks = pMxDoc.FocusMap
' get an enumeration of bookmarks
Dim pEnumBookmarks As IEnumSpatialBookmark
Set pEnumBookmarks = pMapBookmarks.Bookmarks
pEnumBookmarks.Reset
Dim pBookmark As ISpatialBookmark
' parse the enum
Set pBookmark = pEnumBookmarks.Next
Do While Not pBookmark Is Nothing
    If pBookmark.name = bookmarkName Then
        pBookmark.zoomTo pMxDoc.FocusMap  ' zoom to bookmark
        pMxDoc.activeView.Refresh
        Exit Sub
    End If
    Set pBookmark = pEnumBookmarks.Next
Loop
' redraw
pActView.Refresh
pMxDoc.UpdateContents

End Sub
Appendix C: Stored procedures – what is missing?

As outlined in chapter 3, the implementation of the Oracle stored procedures was not yet completed at the moment of publication of this technical note. The procedure `timepoint()` has to be adapted for the generation of yearly measurement values. The procedures `timeperiod()` and `timechange()` still have to be implemented completely. However, code fragments stored in REMDB and the structure of the first implemented procedure can be used for the development. For a convenient implementation of the missing parts, the structure of the procedures is shown in the following:

**timepoint():**

Input parameters:
- `radionuclide` (varchar2)
- `date` (date)
- `monthly` (boolean)
- `sampletype` (varchar2)
- `lessthan` (boolean)
- `measurementunit` (varchar2)

Fields used in the result table:
- `sgl_value`
- `sgl_count`

**timeperiod():**

Input parameters:
- `radionuclide` (varchar2)
- `begindate` (date)
- `enddate` (date)
- `monthly` (boolean)
- `sampletype` (varchar2)
- `lessthan` (boolean)
- `measurementunit` (varchar2)

Fields used in the result table:
- `multi_01_value` ...
- `multi_12_value` ...
- `multi_01_count` ...
- `multi_12_count`

**timechange():**

Input parameters:
- `radionuclide` (varchar2)
- `firstdate` (date)
- `seconddate` (date)
- `monthly` (boolean)
- `sampletype` (varchar2)
- `lessthan` (boolean)
- `measurementunit` (varchar2)

Fields used in the result table:
- `change_value`
- `change_value_abs`
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