USE OF GEOGRAPHIC INFORMATION SYSTEMS (GIS) IN PREVENTION AND MANAGEMENT OF PIPELINE RELEASE INCIDENTS

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Abstract

Pipelines are integral part of our lives, transferring various media over long distances. Operating such structures carries risks for its operators, for the population and the environment in its vicinity, particularly in areas where organised criminal gangs target petroleum product pipelines. The product being transferred, the proximity of urban areas, site topography, geology and hydrogeology, sensitivity of any receptors and other environmental sensitivities will govern the degree of risk. All of which will vary over time and/or along the route of a pipeline. This paper presents GIS-based approaches to such risk assessment and management, describing the complex processes of assessing the pipeline route sections from various aspects, priority and acceptable risk determination leading to development of incident response plans and eventual incident management. Benefits of the tool are demonstrated on a case-study when 90,000 litres of petrol was released following a criminal activity. Rapid incident management delivered cost-savings for the operator's insurance cover. Aerial surveys of proposed and operational pipeline routes are routine. Using recorded images, third-party data and details of natural phenomena GIS can be used to assess potential impact from a pipeline and to aid rapid decision-making. Whilst these processes can be applied to existing pipelines, GIS-based Geofilm™ software can also assist in determining a route with minimum risks at the pipeline planning stage.

Introduction

Whilst Environmental Impact Assessments (EIA) study would consider the impact that a pipeline would have on the environment, it is (to date) unable to assess what influence a potential release would have on the surrounding area. The aim of our approach is such analysis was to provide pipeline operators with this very information and to identify areas where construction modifications should be considered to reduce the risk of a potential release. During an incident on a petroleum product pipeline it is not just the environment that could be at risk, it is also human life that might be threatened. Any decision-making therefore has to be swift, effective and reflect all potential risks, if the potential consequences of a release are to be reduced to minimum. The goal was to develop a tool that would enable the pipeline operator to prioritise incident response activities at specific locations according to the identified risks.

Methods

To achieve this goal the use of Geographical Information System (GIS) was considered ideal. In this case we used ArcInfo for multi-criteria analyses and ArcView as a front-end for the operator (for its ability to work in the heterogeneous computing environments - Unix and Microsoft Windows).

Prior to the analyses all the main risk categories were determined. These categories were identified within an area that was established on the basis of empirical knowledge of the travel zone of the released media (petroleum product) following an incident. The risk categories were determined to capture all environmental risks without mutually overlapping. For mapping purposes we used maps with 1:10,000 scale for surface categories and 1:50,000 scale for sub-surface categories. All categories utilised a seven-point scale to determine the degree of risk that they represent. Risk categories considered were: risk to urban areas; risk to land drain systems, landscape protection, area use, surface water vulnerability and groundwater vulnerability. Input parameters into the each category are shown on Figure 1.

The fundamental problem that remained to be resolved was how to transpose these categories (available in area format) into the pipeline route. A simple overlay is not usable in this case because

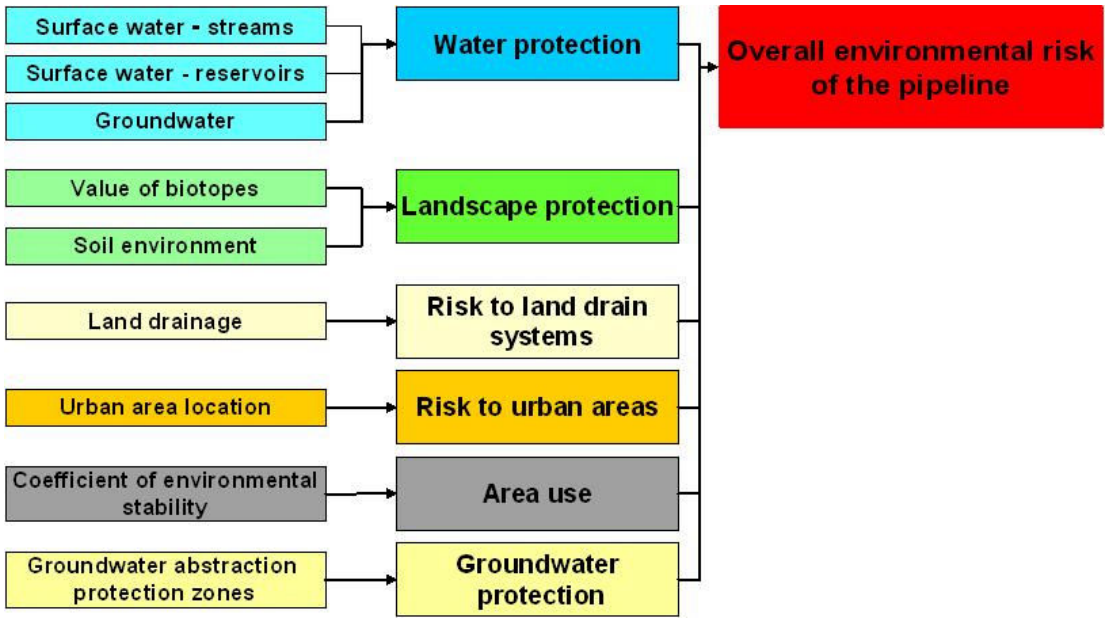


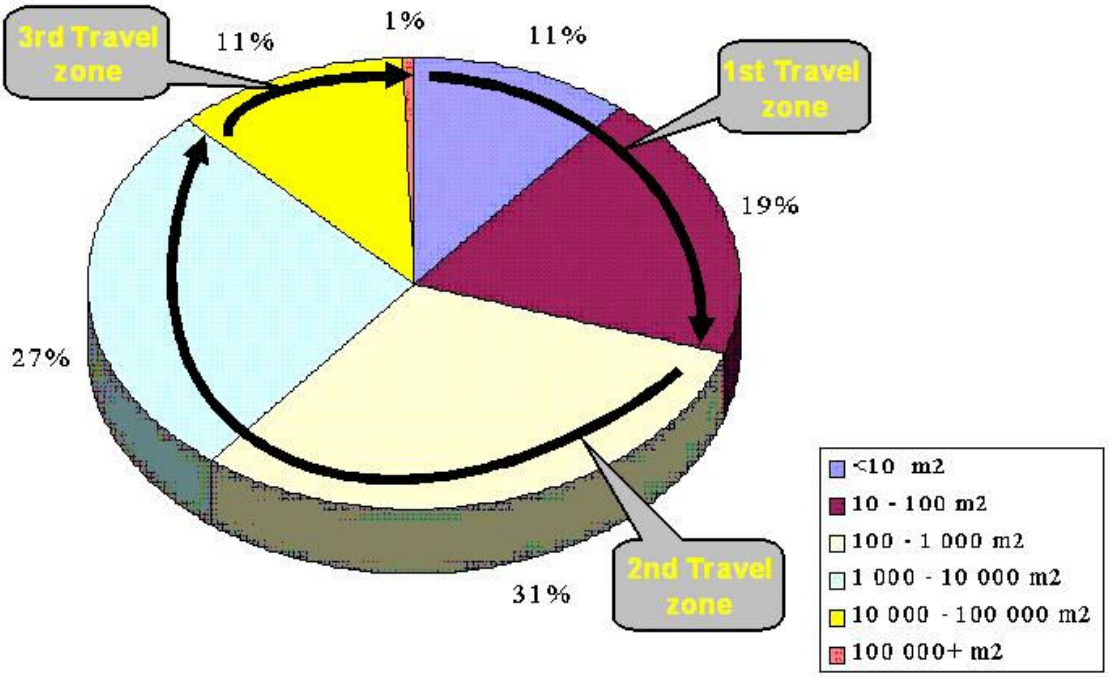
Figure 1 - Risk Parameters Data Input

the released medium does not remain at the release point and travels at variable velocity (dependent on gradient and surface properties of the given terrain, weather conditions at the time of release, type of released media, vegetative cover, soil permeability, etc.). As each risk category covers the whole area under assessment (with changing parameters/severity along the pipeline route i.e., it is not a discontinuous factor), we have created series of fictitious releases at 100m intervals along the pipeline route. A volume of released product was modelled at each fictitious release point, travelling down topographic gradient and impacting the environment. To identify the trajectory of the release we used a digital 3D model of the terrain based on contours from 1:10,000 scale maps. To establish how far the released product will travel (travel zone) the following parameters were used: terrain relief, land use and existing watercourses. We have developed a retardation factor (COST) for each different land use (e.g. woods, arable land, pastures, marshland, gardens, urban areas, etc.) and each watercourse type (maintained stream, man-made stream, temporary stream, culvert and river). Model then determined, from the terrain contours, the trajectory and topographic gradient. Consequently, retardation factor was applied to this data in a grid form, delivering the Travel zone.

- First Travel zone – COST less than 300
- Second Travel zone – COST = 301 ~ 600
- Third Travel zone – COST = 601 ~ 1200

A 100m wide corridor (uncertainty buffer) was applied to the modelled trajectory (50m either side of the trajectory), to allow for local terrain variations, thus we generated a conservative model. We then interpreted data published in the 1998 CONCAWE Report[1]. The chart (Figure 2) showing the spill frequency in relation to the affected area was divided into three sections:

- First Travel Zone – equates to an area of up to $100m^2$, will always be affected, regardless the volume of the release
- Second Travel zone – equates to statistically most frequent impact area of up to $10,000m^2$. According to our interpretation the likelihood is high that a potential release would impact an area of this size.
- Third Travel zone – the maximum possible extent of impact, low likelihood of being affected. It captures a hypothetical catastrophic spill when technology and/or human factor fail.



Report No. 2/98 **Western European cross-country oil pipelines 25-year performance statistics;** CONCAWE Oil Pipelines Management Group, June 1998

Figure 2 - Assessment of Affected Area

The identified travel zones determine the severity for each risk category and that is reflected back into fictitious release point on the pipeline route – red indicating very significant risk, blue indicating quite negligible risk. Travel zones are shown on Figure 3. Weighted coefficients were then determined for each individual risk category before multi-criteria analyses of all input parameters were undertaken. Weighted coefficients for each risk category range from 0.4 (risk to urban areas – highest priority) to 0.0X (value of biotopes).

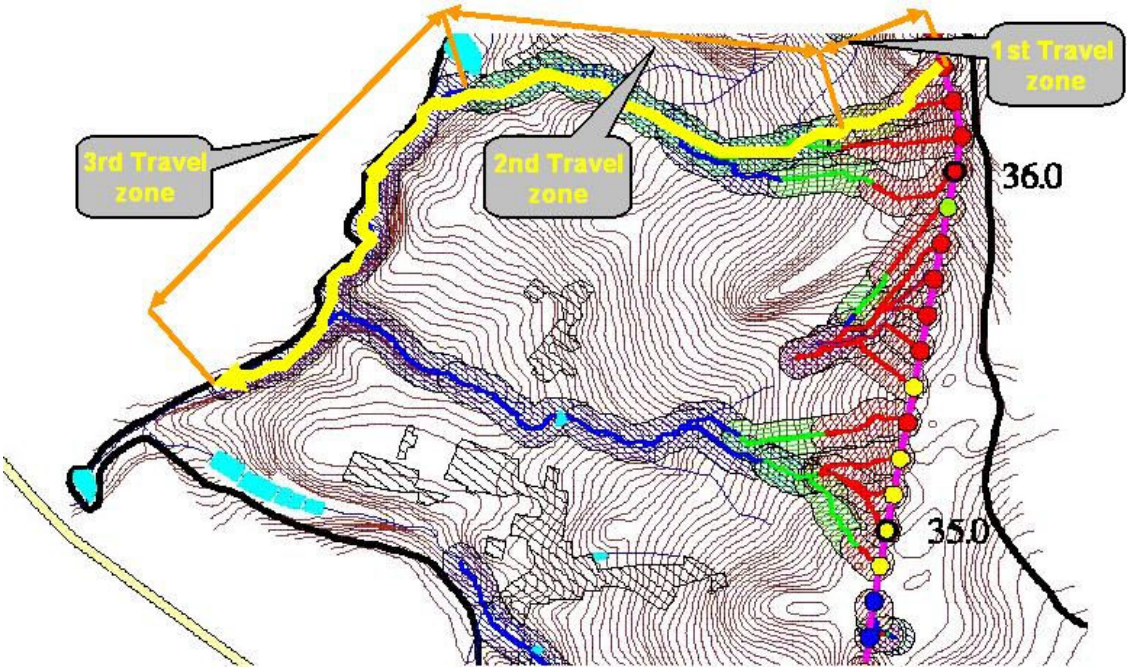


Figure 3 - Travel Zone Trajectory

Results
The results of the multi-criteria analyses (shown of Figure 4) then indicate the degree of risk of a potential release from the pipeline. This is available to the pipeline operator including all the map data within ArcView. Data can therefore be used by professionals (analysing further individual risk categories) and operational staff alike. In the event of a release incident, it can be determined which environmental category is most under threat and measures can be taken to minimise the damage.

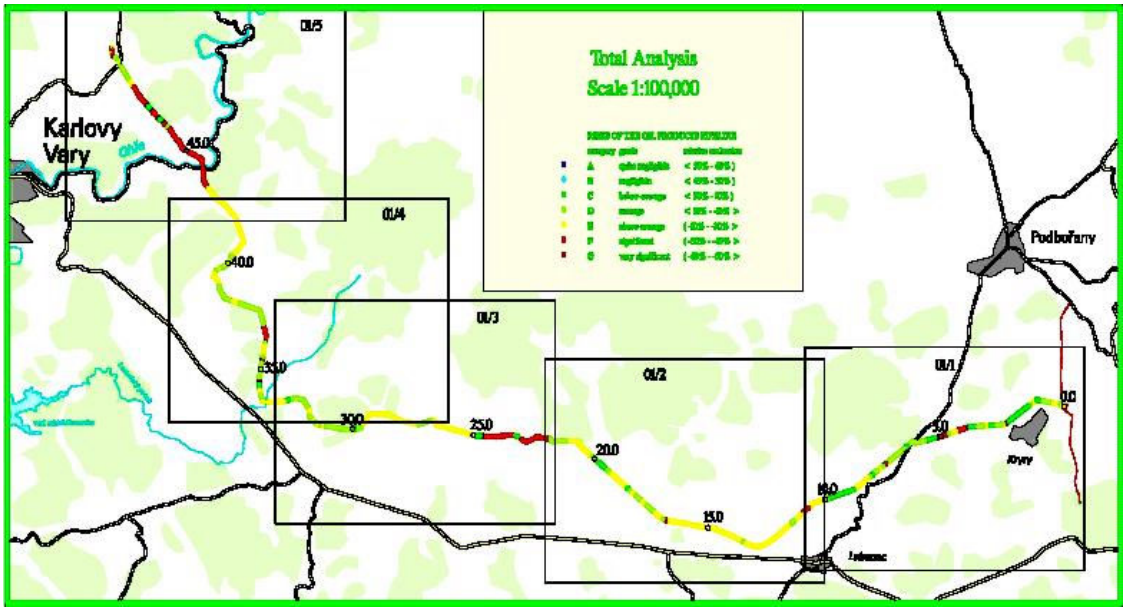


Figure 4 - Result of Overall Analysis

Benefits of this tool are best demonstrated on a case study when 90,000 litres of unleaded petrol was released from a pipeline following a criminal attack. This tool has enabled much faster and more focused incident response management, better risk prediction and prioritisation and better spill containment through targeted subsurface investigation. This in turn delivered a cost-effective incident response and reduced environmental impact. Furthermore, the tool was successfully used to demonstrate to the insurance company that all practicable measures were taken by the pipeline operator to prevent unnecessary costs and the insurance claim was settled in full.

Discussion
The aim of the above GIS is, in the event of a release incident, to provide all the available environmental sensitivity information to assist in post-incident damage limitation i.e., we have a risk-based decision-making tool. In addition, it can be used to analyse model situations to help determine priorities, identify weaknesses and implement additional engineering and/or operational measures to alleviate the existing risk. Whilst the system is able to stand alone, it can be easily incorporated into other GIS-based pipeline management tools to deliver truly comprehensive pipeline management package. RSK ENSR Group has extensive experience in implementing such systems for both new and existing pipelines.

Geofilm, a real-time link of linear asset video and a map (Figure 5), greatly simplifies the pipeline route selection process. Video recordings taken at different times can assist in assessing post-construction activities and compensation claim awards.

Pipeline Manager (PM) has all the conventional GIS capabilities to manage pipeline documentation like background maps (Figure 6), basic pipeline information (e.g., route, land parcel ownership/occupiers, third-party service crossings, rail, road and water crossings, emergency services contact details, etc.). The tool has been developed with a number of modules to provide management of a variety of issues relating to asset management.

- PM Activity Manager – is a complete tool for controlling activities around the pipeline including third-party communications; permit issue, management and historical analysis.

- PM Observer – stand alone or integrated GPS driven system for field surveillance, ensuring a rapid, cost-effective delivery of activities along the pipeline. Combined with Activity Manager can easily determine unauthorised activity along the pipeline.
- PM Cathodic Protection for data management and analysis.
- PM Leak Locator – provides real time interface between pipeline management and process control systems, reducing a risk of a potential human error in determining a leak on the pipeline.

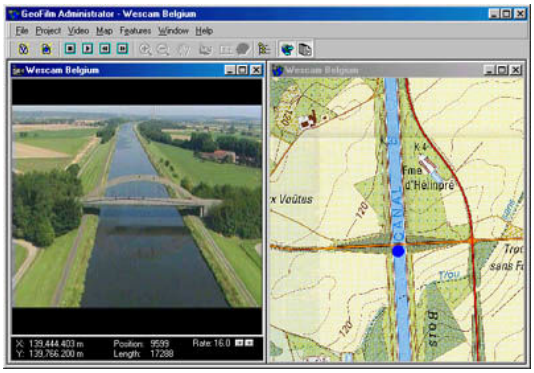


Figure 5 - Geofilm Screen

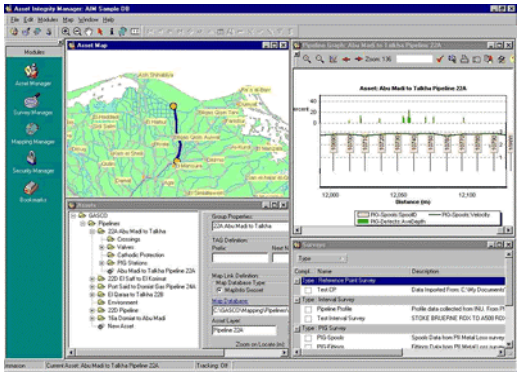


Figure 6 – Pipeline Manager Screen

Conclusions

The above described system of multi-criteria analysis has universal applicability. It can be used for environmental risk assessment of any linear asset in its widest sense.

Geographical Information Systems can deliver substantial savings for pipeline operators by integrating multi-disciplinary data with environmental focus. The cost-savings can be delivered at various stages of pipeline life cycle:

- Design and Planning stage – faster/cheaper pipeline route selection and reduced risk exposure by eliminating the high risk routes;
- Pipeline Operation
  - Incident Prevention – development of emergency planning and optimisation of control and maintenance activities;
  - Incident Management – risk-based decision making and prioritisation;
- Reduced Insurance Rating – cheaper insurance premiums.

References

(1) CONCAWE, Oil Pipeline Management Group, Western European Cross-Country Oil Pipelines 25 Year Performance Statistics, Doc. No: 2/98, (June 1998).