Optimum location of Wells using Multi-Criteria Analysis and Satellite Imagery

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Determining Optimum Location in itself is a tough task (in this fast & congested development environment) and when it has to satisfy certain conditions then finding the optimum location becomes next to impossible. Optimum location of wells initially depends on various data types including surface facilities like pipeline, power lines, roads, hospitals, schools, et al., Digital Elevation Model (DEM), slope, satellite imagery and most importantly Rapture Exposure Radius (RER) to identify the density analysis impact on populated places caused by toxic Hydrogen Sulphide (H_2S). These different considerations make the process complex and as such there might be confusion in decision making. Multi-Criteria analysis prevents imposition of limits and provides opportunities and analysis for decision makers to a final decision. GIS provides a single platform for combining these data types for visualization, mapping, analysis and decision making. The use of GIS and Multi-Criteria analysis helps to achieve desired and more accurate results. This paper aims to provide well location based on multi criteria analysis, satellite imagery and DEM.

INTRODUCTION:

Tasks involving spatial decision-making such as site selection and land use allocation are challenges that are multi-facetted by nature. They usually involve not only technical requirements, but also economic, social, environmental and geographical dimensions. Solutions for such challenges frequently involve highly complex spatial decision-making processes that require simultaneous use of several decision support tools such as Geographic Information Systems (GIS) and Multi-Criteria Decision Making (MCDM) techniques. Integration of the capabilities of these tools is crucial to the feasibility of reaching a final solution. Therefore, developing efficient integration strategies becomes very important for an optimum solution.

GIS plays a significant role in the natural environment over man-made features on the landscape. In GIS we can define our need, based upon the data availability for various sources, such as (e.g., aerial photography, satellites imagery, GSP, surveying and remote sensing) interactively with a tabular database.

Saudi Aramco has utilized the GIS in a variety of sectors to serve them in field development in terms of subsurface and surface facilities. however, One of the significant sectors is well site approval to define suitable well pad surface site relative to bottom hole location (subsurface) and find out the possibility for drilling the well as vertical- or horizontal-based, on the spacing requirement, to maintain Loss Prevention safety guidelines from populated places and existing man-made features, when drilling new wells.

GIS combines a variety of data sources, such as (e.g., aerial photography, DTEM, satellite imagery and vector data) on a platform database (SDE) to build a surface model for finding optimum well location.

GIS & MCDM:

GIS and Multi Criteria Decision Making (MCDM) are one of the common spatial decision support tools used to solve spatial decision-making problems. GIS is a computer-based technology for collecting, managing, analyzing, modeling, and presenting spatial geographic data for a wide range of applications. MCDM techniques are decision support tools designed to analyze decision problems, generate useful alternative solutions, and evaluate alternatives based on the decision maker's values and preferences. The general objective of these methods is to assist the decision-maker in selecting the best alternative from the number of feasible alternatives under the presence of multiple choice criteria and diverse criteria priorities [1, 2].

Well location presents a scenario for GIS and MCDM to be used utilized for planning and analysis.

Problem Statement:

- Difficulties finding suitable surface location due to fast infrastructure development.
- Minimize possibility to drilling as vertical gas wells which cause complexity in the well friction process.
- Difficulties reaching some of the potential reservoir targets because there is no suitable surface location that can reach the reservoir bottom hole.

Aramco Standards/Limitations:

Loss Prevention Department is a key player in providing and implementing safety regulations for all Aramco Organizations. They have safety guidelines and precautions for drilling Oil and Gas wells, based on H_2S rate, well pad, and burn pit during the drilling operation.

Well location Planning

The task of planning for a well location begins with defining the selection and display criteria for existing surface facilities that are in close proximity to the future well location. The future wells could be oil/gas based on the petroleum engineers' requirements and the field's development. The feature data is stored as a geodatabase feature class in SDE.

After plotting the coordinates, depending on the type of the well, different size rig pads are placed.

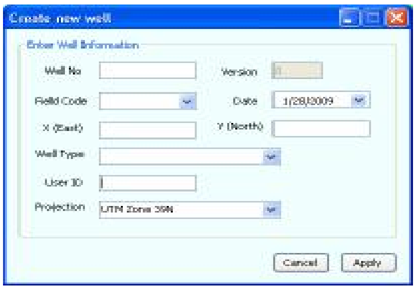

Fig. 1: Future well information

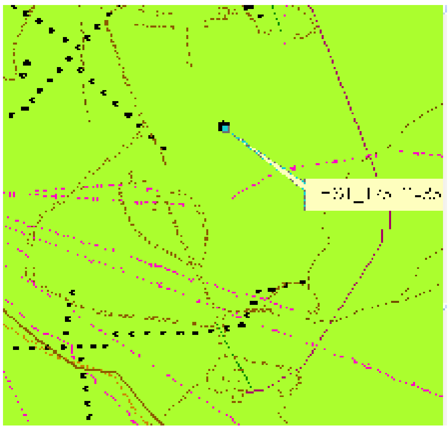
Fig. 2: Proposed well location and surface facilities

Rig Pad:

Rig pad is a compacted area of marl located at the well site. The drilling pad is required to be level for use by drilling and work over rigs. Existing or proposed surface facilities should not cross these rig pads. For different types of wells these rig pad size will differs.

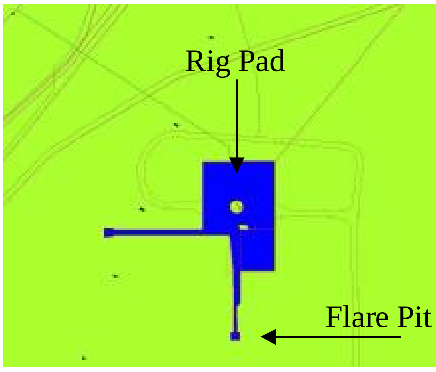

Fig. 3: Rig pad

Surface Facility Analysis:

As already mentioned, the Loss Prevention Department is the key to safety for Aramco Organizations for analyzing surface facilities based on H_2S rate, well pad, and burn pit during the drilling operation.

Surface facilities like pipelines, roads, buildings and other ARAMCO facilities hinder's the location of future wells. These multiple feature in nature and varying standards pose a complex problem for facilitating the optimum location. The interface will help us to quickly analyze future well location with respect to existing surface facilities.

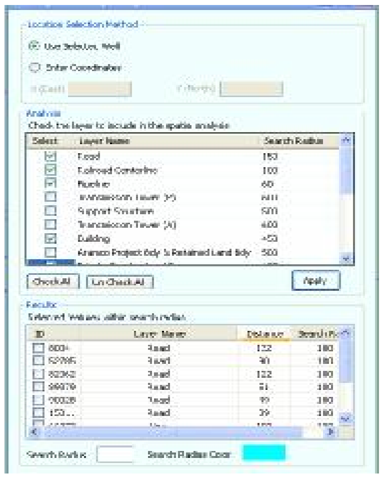

Fig. 4: Facilities

The analysis process can be done as follows:
Firstly, the future well is selected to be analyzed, then the surface facility is checked and the distance provided as per the Loss Prevention standards. Using the ArcGIS Spatial analysis buffer is created for all the surface facilities taken in consideration as per the Aramco standards.

The application would take these facility types in consideration and provides information of the facilities conflicting with specified distances. The information provided would be in terms of distance that would help to move the future well location based on these information. Once this criterion is satisfied,then the future well location has to satisfy the Rupture Exposure Radius criteria as well as Elevation.

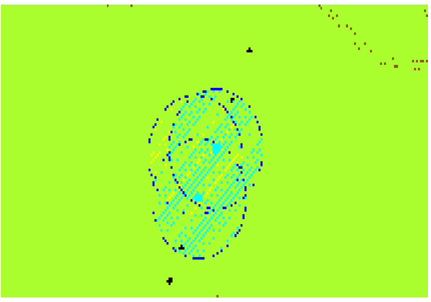

Fig. 5: Facility Analysis Results

Rupture Exposure Radius (RER):

Three concentric circles representing the three rupture exposure radii - 30 ppm, 100 ppm hydrogen sulfide (H_2S) and ½ lower flammable limits (LFL) are plotted for the well's proposed surface location.

- For toxic effects, the rupture exposure radius refers to the horizontal distance from a leak source to a specified level of hydrogen sulfide (H_2S) concentration in parts per million (ppm).
- For a flammable gas hazard, the rupture exposure radius refers to the horizontal distance from a leak source to the ½ Lower Flammable Limit (LFL).

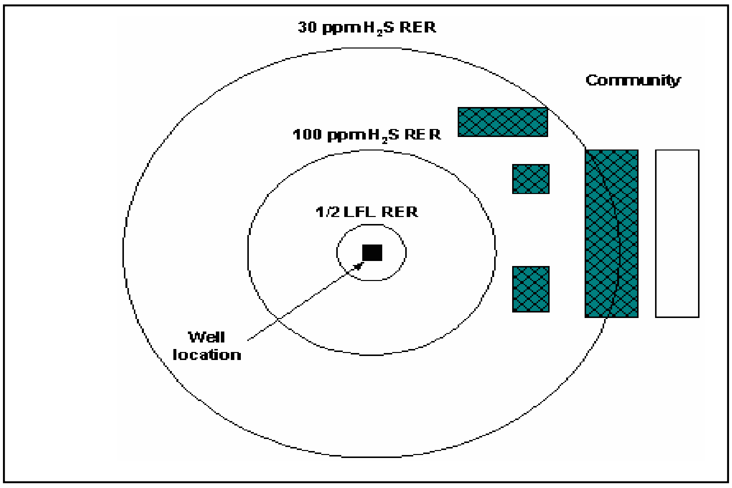

Fig. 6: RER Radius

A well is in a populated area if the population density index within the 30ppm H_2S rupture exposure radius exceeds 20, or if a school, hospital, hotel, penal institution, retail shopping mall, or major facility, existing or planned, is included within the 30ppm H_2S rupture exposure radius of that well.

Once vector data analysis with respect to surface facilities is over and for further engineering requirement and analysis, elevation and satellite imagery is utilized to support the spatial decision.

DIGITAL ELEVATION MODELS

Modern aerial photography and satellite remote sensing started to provide continuous surface information by means of optical cameras, radar or laser beams, and the derivation of terrain elevation was made possible by stereoscopy and interferometry. Our ability to perceive and analyze the physical features of the Earth's surface has, since, been greatly expanded. Today, the elevation information is represented in computers as elevation data in a digital format. This format is usually called digital elevation models (DEM). Thus a DEM is a computerized representation of the Earth's relief. Different formats exist, among the most usual are triangulated irregular networks (TIN), regular grids, contour lines and scattered data points.

DEM and Geographical Information Systems

A GIS is an information system designed to acquire, store, process and display data referenced by spatial or geographical coordinates. DEMs can be used together with other spatial data, image data in geographic information systems (GIS). GIS advance capabilities of producing high quality maps, along with a database with specific capabilities for spatially referenced data, and also perform a set of operations for processing and analyzing the data. The DEM provides a basic spatial reference system to the GIS spatial data set. Images or vector information can automatically be draped over and integrated with the DEM for advanced analysis.

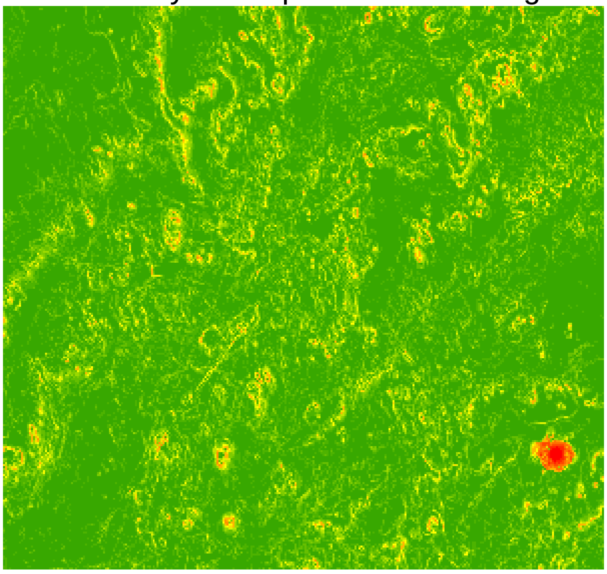

Fig. 7: Slope derived from DEM

Spatial Analysis Tools to build a Cost Surface

The first steps toward building a cost surface for the well location can be done based on either the well selected from the database, i.e., from SDE or future well location, based on coordinates. Once the location selection method is finalized, the layers involved in the topographic analysis are added to build the spatial model.

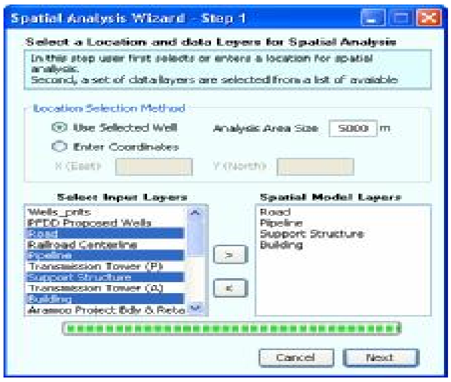

Fig. 8: Building a Surface Model

Cartographic Modeling for the layers involved in the spatial model builder is done and symbolized based on the distance from the proposed future well to the surface facilities.

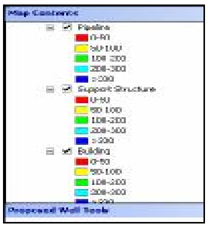

Fig. 9: Classified Symbology for Spatial Layers

The next step involved in the development of a cost surface model is rating for layers. The ratings or weighted analysis provide the suitability for weighted datasets to have more influence in the development of the model. Higher values for datasets are given to those attributes that are considered more suitable within each dataset. If all datasets are equally important then simply combining them together. It is preferable to locate future wells far away from buildings than pipelines, roads and other surface facilities. Hence giving higher percentage ratings to pipelines, roads and other surface facilities rather than residential buildings, the higher the percentage, the more influence that particular dataset has in the model.

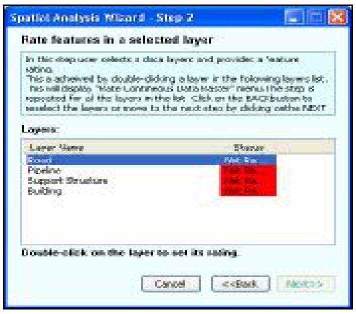

Fig. 10: Rating for layers

A weighted overlay process evaluates two or more input rasters. The input raster values must be on a common scale. Scale values may be assigned in a weighted overlay dialog box. Each input raster is then assigned a proportional weight. The output raster displays areas according to suitability, risk or some other similar assessment.

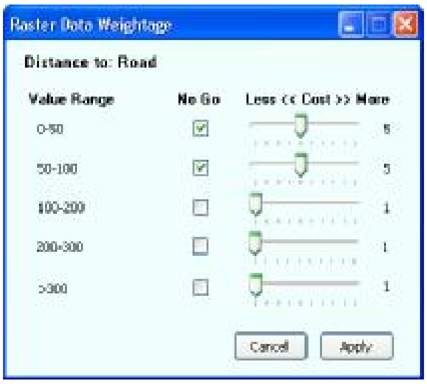

Fig. 11: Rating for layers

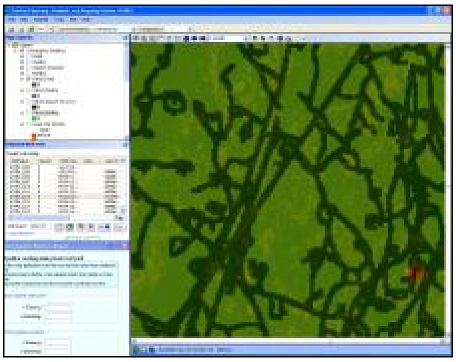

Fig. 12: weighted road

Figures 11 and 12 provide the layers involved and the weight each layer carries, for the surface analysis, here as a sample, only one screen shot was done. As it demonstrates, both distance to the road and the cost are analyzed. As distance increases, construction cost increases. Depending upon the facility engineer's requirement, these settings can be modified to satisfy one's needs.

Once the ratings are done and the model run, we will see the weighted surface for all the datasets involved in the model builder. Here is an example for a weighted road, showing the surface with the most suitable locations for future wells.

Subsequent to this development, the remaining part is combining all the cost weighted datasets to build a least-cost surface.

Least-Cost Surface:

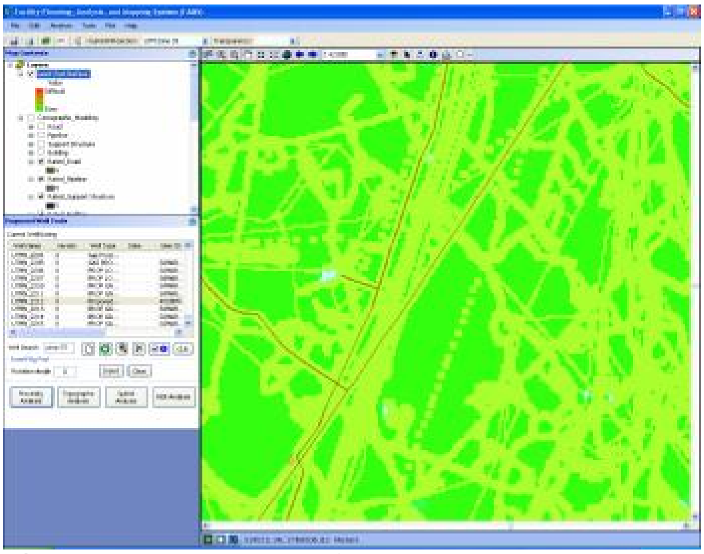

Fig. 13: Lease-Cost Surface

The final output provides the Lease-Cost Surface for optimum location of future wells in terms of surface facilities. The analysis generated will help petroleum or facility engineers with a suitable surface location, based on Loss Prevention Standards as well as a topographic analysis.

Satellite Imagery to show the final decision:

To show the vector as well as the raster data analysis, cartographic maps are generated along with the latest satellite imagery for decision support. These maps help in analyzing location, both in terms of terrain and surface facilities.

Fig. 14: Satellite Imagery with RER

Cost Saving using Customized Developed Tools

There is a huge cost savings by using the customized tools, developed using ArcGIS, in terms of time, money, effort, speed and more importantly, coming to a decision based on clear and logical reasons.

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Conclusions:

The coupling of decision support tools, like GIS and MCDM techniques, is necessary for reaching optimum solutions for complex spatial problems.

The incorporation of MCDM and customized GIS application in well location planning has proven to be less time consuming, reduced the cost associated with the traditional method of planning, and increased efficiency in finding the optimum location.

With increasing numbers of wells and growing oil production, customized tools will decrease cost, improve efficiency and aid in making sound decisions.

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