Securing Surface Rights for Oil and Gas field Development using state-of-the-art GIS Technology

MOHD ZUKHAIRI ABD LATEF, Fahad Mohammed Dalbouh, Majed M Abulleif, Loai H Hibshi
Kingdom of Saudi Arabia

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SUMMARY

Securing and providing embedded access to surface rights is key to the success of any onshore oil and gas field development. It is important to reach optimal subsurface targets and later extract hydrocarbons and transport them to a company's pipeline distribution network without impacting inhabitants on the ground. Saudi Aramco leverages Geographical Information System (GIS) technology from data acquisition, management, integration and analyzing land and surface rights to protect the company's field development projects within the Kingdom. While the current process has always led to successfully securing surface rights in line with state-of-the-art practices, the ongoing process improvements are expected to decrease manual interventions analyzing surface rights in relation to the expansion of a company's operations and urban growth within the Kingdom. This paper will provide an overview of challenges to securing surface rights and how Saudi Aramco uses GIS technology to secure the company's land and rights for oil and gas field development.

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1. INTRODUCTION

Saudi Arabian Oil Company, or Saudi Aramco, is state-owned company headquartered in Dhahran, Saudi Arabia and one of the largest oil producers in the world. Oil history began in 1933 with a concession agreement and first commercial oil production began in 1938 with the successfully drilled on Dammam No. 7. Since then, the foundation of the oil and gas sector in the Kingdom was realized and demand for surface rights and lands for company projects gradually increased.

As of now, the company utilizes more than 300,000sqkm surface rights and land across the Kingdom. This area was cumulative from the previous hydrocarbon exploration and production activities including new projects in renewables and green energy to meet Kingdom initiatives toward green energy in 2030. Some of development areas have overlapping footprints in an already congested area such as newly developed town plans, expansion of existing cities/towns, etc. requiring different planning and development concepts to ensure allocated surface rights have no conflicts in terms of land jurisdictions or any potential disputes.

To manage this immense area of operations, Saudi Aramco relies heavily on a state-of-the-art GIS integrated system to manage surface right and land records as well as providing surface analysis in relation to land jurisdictions in supporting company oil and gas operations. These include business processes such as well and drilling approvals, land use permitting processes, research and resolving land claims and external land inquiries and monitor illegal encroachment activities or unauthorized land use within company designated areas. To date, more than three million land records and surface rights were managed in the system for the purpose of protecting company interest in relations to oil and gas operations.

This paper will provide an overview of challenges and processes to securing surface rights and how Saudi Aramco uses GIS integrated technology to secure the company's land and rights for oil and gas field development.

2. ONSHORE FIELD DEVELOPMENT LIFECYCLE

Onshore oil and gas field development starts after an oil or gas field is discovered. The process of field development comprises of multidisciplinary technical and nontechnical entities to formulate an optimal approach to meet economical field designs such as wellsite for drilling and workovers, and surface equipment such as pipelines, facilities, gathering, compressions, etc. to maximize production capacity from subsurface and transporting to gathering stations or bulk plants.

During this process, optimal surface rights or land allocations are required to ensure the proposed or planned facilities have no conflict with existing inhabitants in terms of land ownership or safety risks. Although the company has the exclusive right to the subsurface of within the designated area, but not to the surface land, as there are cities, towns and villages with inhabitants who have the right to own and use lands in such areas.

Figure 1 shows typical oil and gas exploration and production lifecycle and types of surface right "terminology" used during field development and translated into functions and business processes and integrated into a state-of-the art system.

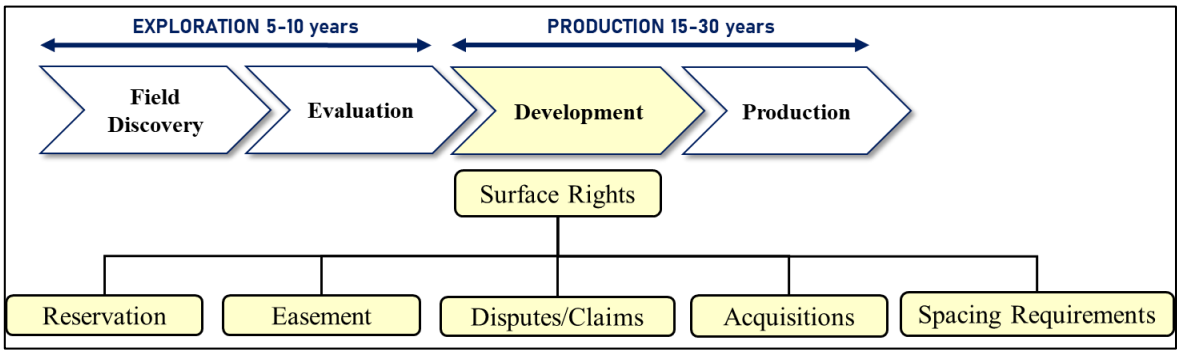

Figure 1: Field Development Process

A reservation is an area approved for the purpose of hydrocarbon exploration and production activities in the Kingdom. This underpins all required lands or surface rights to protect company interests. This area granted by the government through a royal decree allowing the company to extract and transport hydrocarbons. The area limit depends on subsurface field outline provided by geologist or reservoir engineers. The reservation sometimes may be secured beyond the subsurface limit taking into consideration of pre-development concept by multi-disciplinary teams, which required surface access or connectivity; for example, new field may have subsurface contact with nearby or existing fields or tapping into existing facilities such as Gas-Oil Separation Plant (GOSP), Bulk Plants, booster stations, pipeline networks, etc.

Figure 2 shows a typical business processes of securing surface rights involved when developing fields.

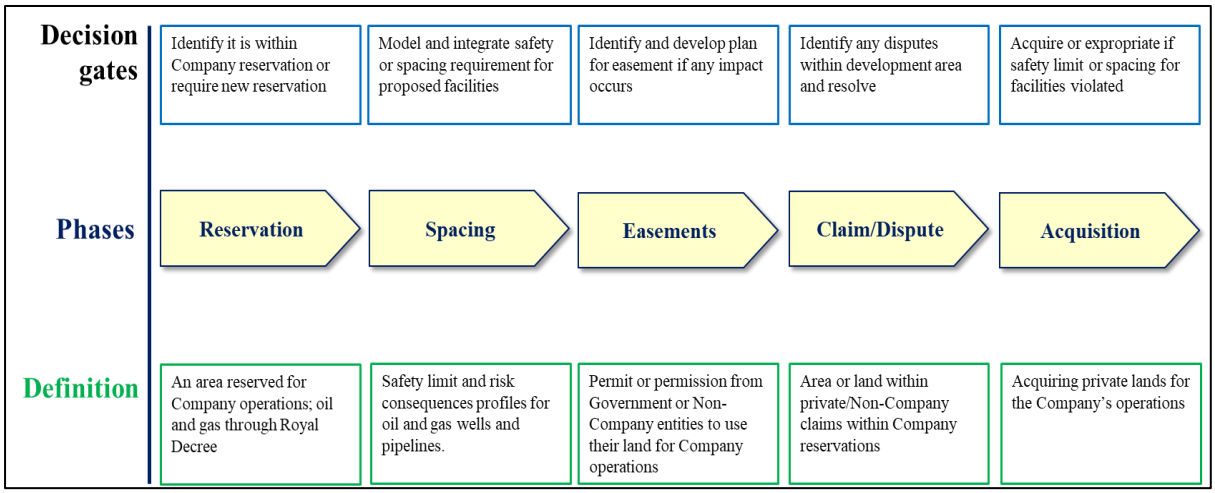

Figure 2: Securing Surface Rights Processes

The complexity arise during the development concept of well and facilities layout to ensure surface allocation reaching an optimal subsurface target. For example, proposing well sites with well spacing on it that are drilled through gas bearing formation must meet minimum requirement of wellsite safety; Rupture Exposure Radius (RER). RER refers to the horizontal distance from a leak source to specific levels of hydrogen sulfide (H2S) concentration part per million (ppm), which will later determine for example pipeline classes to be used within the project. In addition to the RER, a quantities risk assessment (QRA) will usually be conducted on the proposed or existing facilities to assess risk profiles and generated risk model for the sensitive risk receptors. RER and QRA is provided by Loss Prevention as regulators on wellsite and pipeline safety within the company. Each activity until field development concept is finalized are interconnected. Some of the land resolutions, for example legacy land disputes or claims may take years to resolve. As shown in Figure 3, interconnection between each activity required an effective data management and recording system as well as surface rights analysis.

Normally, an initial study within a field area of interest will be conducted. It involves mapping-intense tasks such as overlay and multi-criteria analysis and integrated with land or surface verifications such as conflict detections, land ownership verifications, field surveys etc. considering other aspects of land jurisdictions and other requirements such as spacing between proposed facilities and safety limits, easements from non-company or government entities, claim or dispute over the lands and acquisitions or expropriations if spacing limit are violated. Many of these data used for field development from conceptual designs, FEED, land use, imagery analysis etc. until construction and installation of the facilities, and finally as-built

surveys have geospatial components to them. Therefore, that Geographical Information System (GIS) was the correct answer for large geographic datasets management.

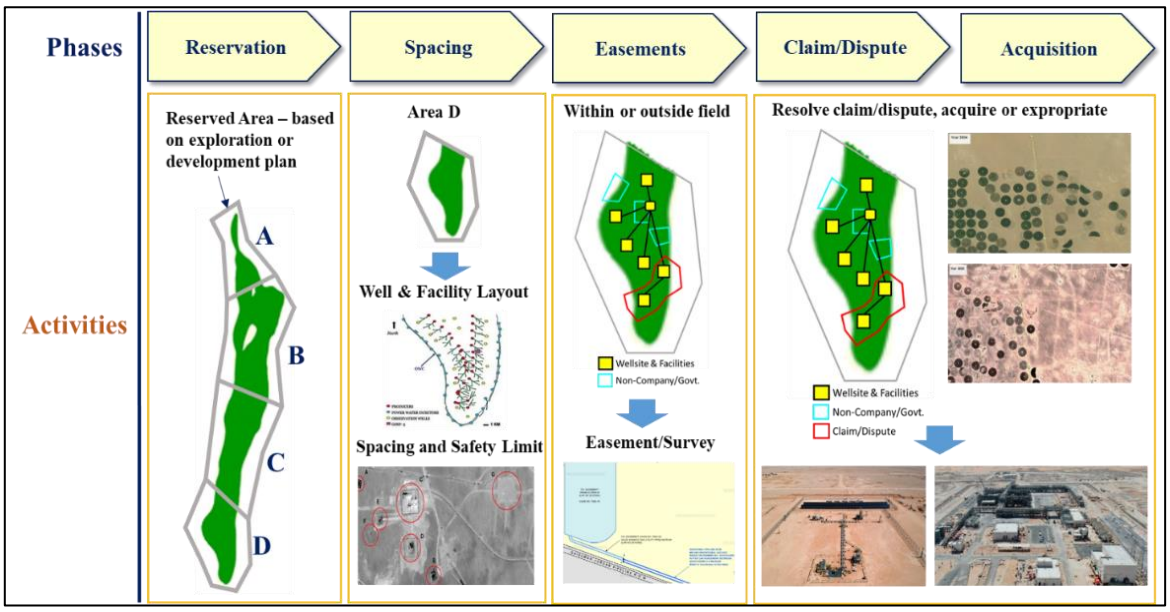

Figure 3: Example of activities involved in developing a field from surface rights and land jurisdictions

3. OVERVIEW OF CONSTRAINTS AND CHALLENGES

Congestion of land use is an ever-increasing problem everywhere, including within the Kingdom. In hydrocarbon field development, this is a particular challenge when developing oil and gas fields within inhabitant or congested areas. Some people might acquire deed to a land they knew the company might need with the hope that they would be compensated, which adds more risk to the economic value of development. Figure 4 shows some major factors that need to be controlled prior to, or during field development.

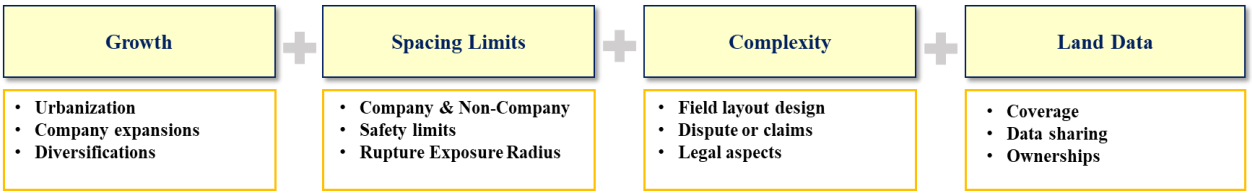

Figure 4: Major constraints on surface rights and land allocations

The need for land and surface rights is increasing with the diversification of projects in-Kingdom such as minerals, green initiatives, and quality of life contributing to surface rights

and land allocation demands and competitions among other entities. These factors co-exist between surface demands for hydrocarbon purposes for example; an allocated area required to reach maximum production zones from directional drilling and ability to connect with surface facilities such as flow lines, pipelines, gathering stations, common facilities, etc. during operations. Figure 5 shows an increase in terms of urban growth since 1982, 2004 and 2017 in the Eastern Province where the main hydrocarbon activities are located. Figure 6.0 shows net density of oil production sites within six years for one of the major oilfields with active development and production activities.

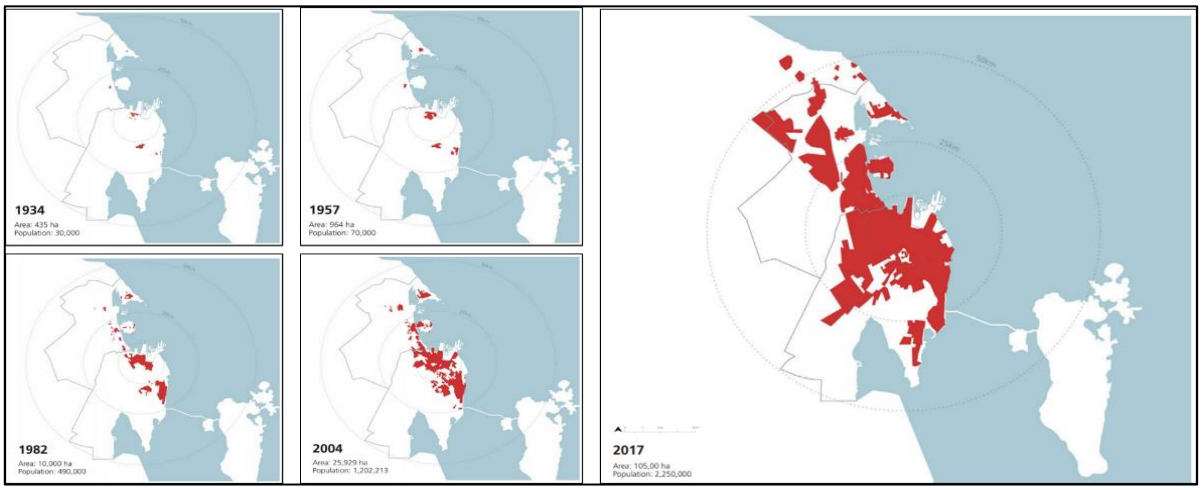

Figure 5: Urban growth stages within Eastern Province, which is one of the active hydrocarbon activities (Source: UN Habitat Dammam City Profile)

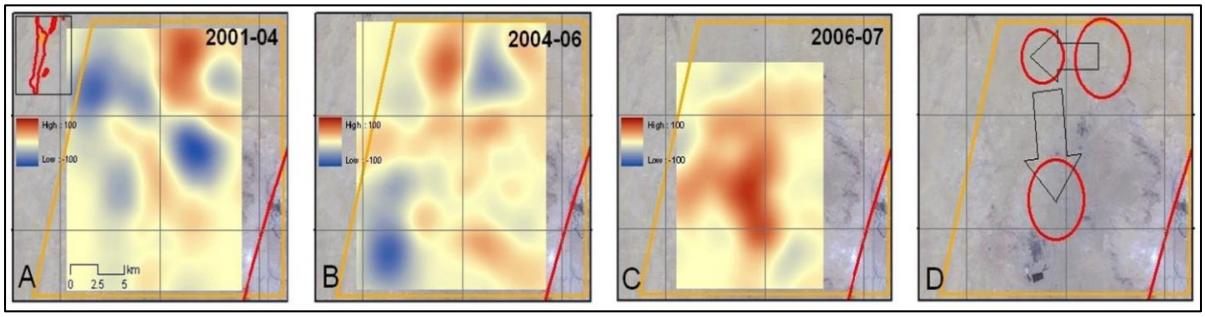

Figure 6: Density net change maps of production sites from one of the main oil producers in the Kingdom. Over a period of 6 years, more than 100 facilities were constructed and installed. Red = Increasing Activity; Blue = Decreasing Activity; Yellow = No Changes (Source: https://earsc-portal.eu)

Another challenge affecting surface rights and land allocations is the minimum spacing requirements as per company standards aligned with Kingdom standards for petroleum activities. This to ensure safety in terms of consequences. Risk profiles apply when constructing new facilities that impose risk to the inhabitant. As mentioned in the previous chapter, RER and QRA zoning criteria limits the surface rights development. Figure 7 shows an example of affecting facilities elements for wellsite placements.

All these factors are considered during the study when developing fields to ensure safety of the operations, as well as protecting the company image and interests with regards to surface rights and jurisdictions. It is translated into difference business processes representing different case types in GIS.

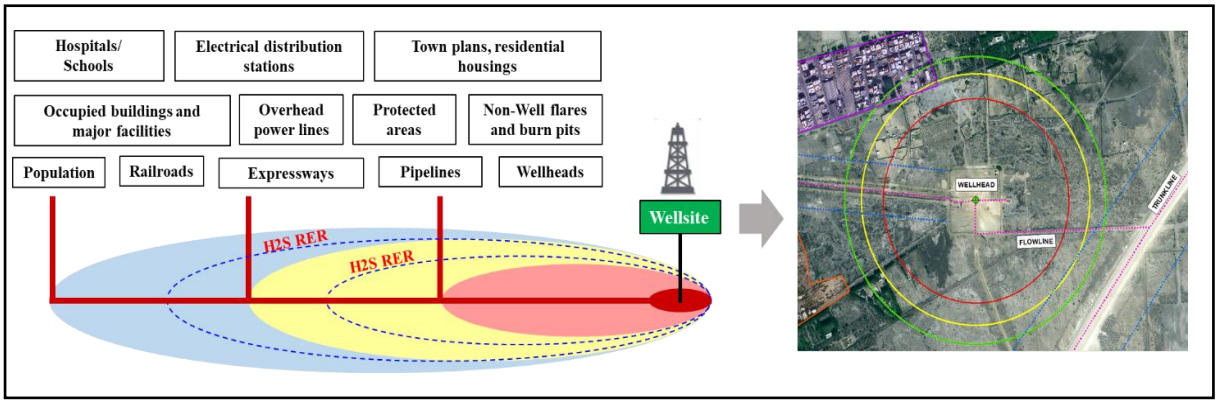

Figure 7: Example of facilities affecting spacing requirements for wellsite. Risk model in color-coded and H2S Rupture exposure radius (RER) in blue.

4. SAUDI ARAMCO SURFACE RIGHTS AND LAND MANAGEMENT

Saudi Aramco surface rights and land management falls under Land Affairs Department. This entity is entrusted to govern, manage and provide analysis in regards to land jurisdictions in relation to the need and monitoring land allocations for oil and gas operations in the Kingdom. The organization comprises of multi-discipline staff; geospatial and GIS, data management, system and IT, and land representatives.

This department is responsible to review all company projects from proponent organizations in relations to lands as well as corresponds to government and non-government entities. Figure 8 shows Saudi Aramco Land Management organizations and interactions, both internal and external.

Surface rights and land management began in the early days after oil and gas discovered in the Kingdom after Concession Agreement 1933. This agreement granted the company the exclusive right with respect to hydrocarbon exploration and production lifecycles. Major functions of the department include managing Saudi Aramco land and surface rights records (including historical) into land management system and GIS, acquiring the necessary surface rights for the company's operations, advocating and handling any land claims or disputes that impact company operations and effectively monitor and protect company operations against improper or unauthorized land use when using Change Detection System.

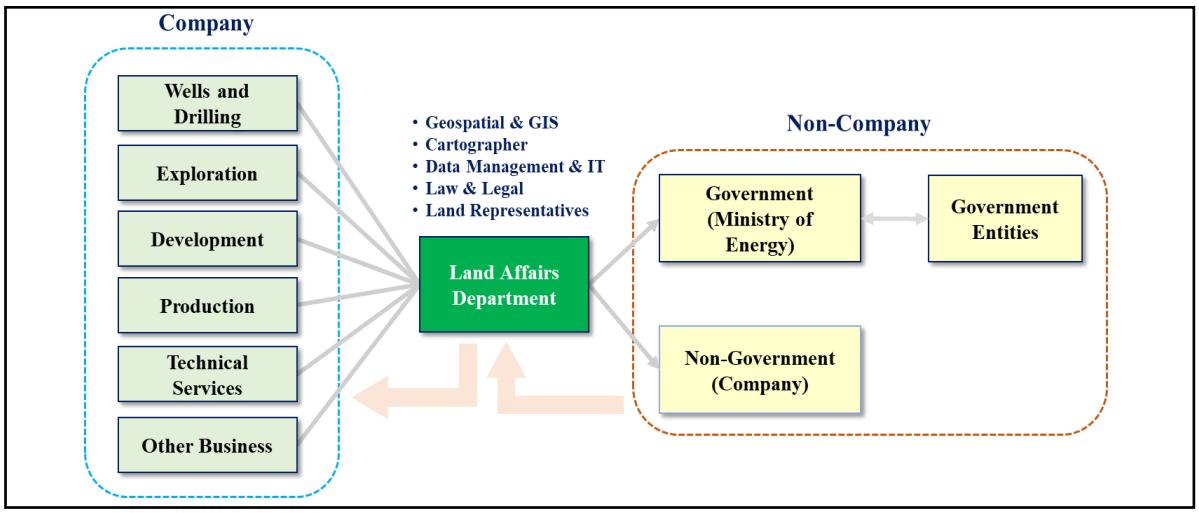

Figure 8: Saudi Aramco Land Affairs Department and interaction between proponent and stakeholders

Land issues are known for their diversity and complexity where no two issues can almost ever be identical. Therefore, land issues should be classified, recorded, reviewed, analyzed and handled on an individual basis. Many factors should be taken into consideration to determine the most appropriate course of action to be adapted to process and handle a specific case. Only through actual practice can a person understand how such complexities can be identified and the matters handled.

5. STATE OF THE ART GIS SYSTEM

Managing a large area in the context of land jurisdictions require an integrated system. Saudi Aramco relies heavily on GIS and SAP integrated systems called SAP Land Management System (SAPLMS) to manage surface rights and land records in supporting company oil and gas operations. This system is not limited to main inventory land records but includes more

than 15 business processes such as well and drilling approvals, land use permitting processes, research and resolving land claims and external land inquiries, and monitor illegal encroachment activities or unauthorized land use within company reservations or designated areas.

The core system is based on the SAP cross-application component Case Management (CM) supported by the SAP Flexible Real Estate (RE-FX) module. SAP CM will provide a single window to end users to perform all land management-related activities to automate and streamline the business processes and also allow for the storing all required documentation in a structured manner linked with geospatial datasets.

This integrated system allows us to effectively manage land record transactions, review each case from external land requests to develop company positions before or during field development study. Geospatial data leverages the value of information from the integration to support projects across the lifecycle from field surveying, geospatial data management, mapping and analysis using GIS.

5.1 Land Records and Workflow, Geospatial and Imagery Management

A successful system relies on a good data structure and management system. Geospatial datasets underpins SAPLMS with quality assured and metadata information. To date, Saudi Aramco has more than 3,000,000 land and surface rights records inherited since 1933 and Petabytes (pb) of raster datasets from satellite imageries, aerial photo and other sensors managed in centralized Spatial Data Engine (SDE) and services.

The “business processes” developed outlined the structure of geospatial data management for land management. This allows all assets to collaborate and share their field development plan to identify conflicts, mitigate risks early, and enable optimized the plan. Key elements of the data are listed below.

- Data Acquisitions:
  - For company data, surface rights and jurisdiction data comes from surveyed data provided by Geomatics Services. Wells and subsurface data comes from Upstream and engineering designs while as-built or planned infrastructures come from Facilities. These datasets were shared through GIS services.
  - Non-company data comes from government, where Saudi Aramco mandated to review all land jurisdictions within company-designated areas for private use as well as non-company projects such as electric corridors, water pipelines, and roads. These datasets will be submitted through the eGovernment system with associated geospatial datasets; maps, coordinates, drawing; CAD, KMZ or Shapefile.

- Data Management and Tracking:
  - Geospatial data is managed under Spatial Data Engine and Non-spatial data is managed inside SAP. Each feature classes in SDE have unique case identification in SAP called Case ID and are linked to geospatial components with a unique Parcel ID as shown in Figure 9. This identification will be used through any business process internally or will be integrated to other applications. Each parcel considered as "live" data will go through business processes within the company for review and final approval. Approval will then be translated into a permit to drill or authorized use of the area.

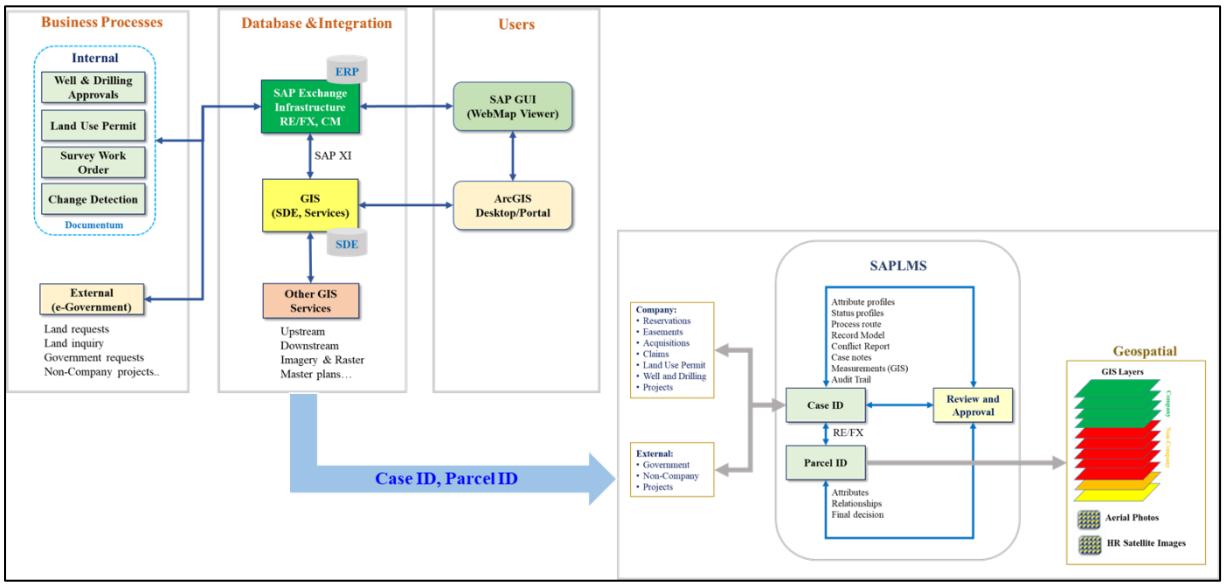

Figure 9: Saudi Aramco Integrated Land Management System - Relations between Case ID, Parcel ID and GIS layers

Each parcel with associated SAP attributes, case number and case decisions were shared and available through Land and Surface Rights Geospatial Layers accessible through ArcGIS Desktop. A customization and integration tool from ArcGIS and SAP allows seamless integration for updating attributes, either for data loading and updating or case review and decision.

The most critical process is creating values from these GIS datasets. Having optimum database ensures data can be overlaid with other layers to create a visual representative of the earth, particularly on land jurisdictions. As mentioned in Chapter 4, land issues are known for their diversity and complexity, therefore the competency level of an analyst is crucial as it requires top-down of stacked GIS layers to review and analyze each case. For example, developing a new pipeline route or selecting suitable sites for facilities placement within a field development area typically required multicriteria analysis. A number of methods were used, for example as

shown in Figure 10; a simplified approach is conflict detection where it is based on sequential and pre-defined rule-based analysis from stacked GIS layers or Weighted Overlay Analysis where each layer will be assigned with weighted factors, for example when the company deeds land and approves a land use permit it will have more weightage compared to easement or non-company right-of-way (ROW).

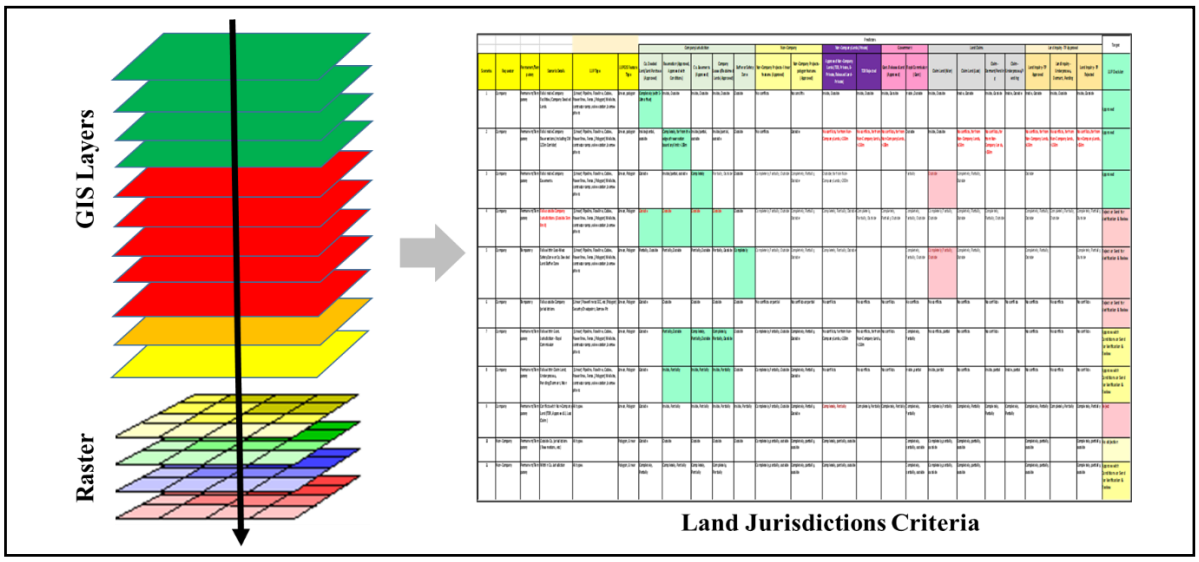

Figure 10: Geospatial layers and golden rules for land jurisdiction criteria

5.2 SAPLMS and GIS System

Within SAPLMS, a unique workflow has been developed for different land case types. Each case type is related to registered land parcels associated with its geospatial data and status or documents. Five components within the system enable the integration through the business processes; Case Management, Correspondence Tracking, Document Management, AuditTrail, and Reporting and Dashboard. Figure 11 shows SAPLMS interface – Case display, linked objects, audit trail, and map viewer. This integration eliminates the need for analysts to access multiple systems to perform their daily job related to land jurisdictions. It provides interface and accessibility for each land documents, correspondences and automatically generates conflict reports based on geospatial data to resolve any land cases, for example land claims or disputes with proposed field development areas.

ArcGIS Desktop is the core application used for geospatial data and analysis. The software is fully integrated with SAP with customized toolbar enabling seamless integration between SAP and GIS. In addition, it is used for reviewing cases and performing conflict detection, surface rights and land jurisdiction analysis. Change detection (CD) workflow added to the desktop by accessing satellite imageries services with change detection objects to perform further study

and verify legitimate land use activities. GIS Portal is used for data sharing across the project team allowing collaboration through web-map applications, story maps, etc. Mobile GIS is used to assist field crews or land representatives to collect data from the site, for example to identify and verify potential encroachments from the CD system, site survey for land expropriations, etc. Figure 12 shows the GIS system and tasks that were used to perform land data management and analysis. Figure 13 shows GIS applications for the field development process to secure and protect surface rights.

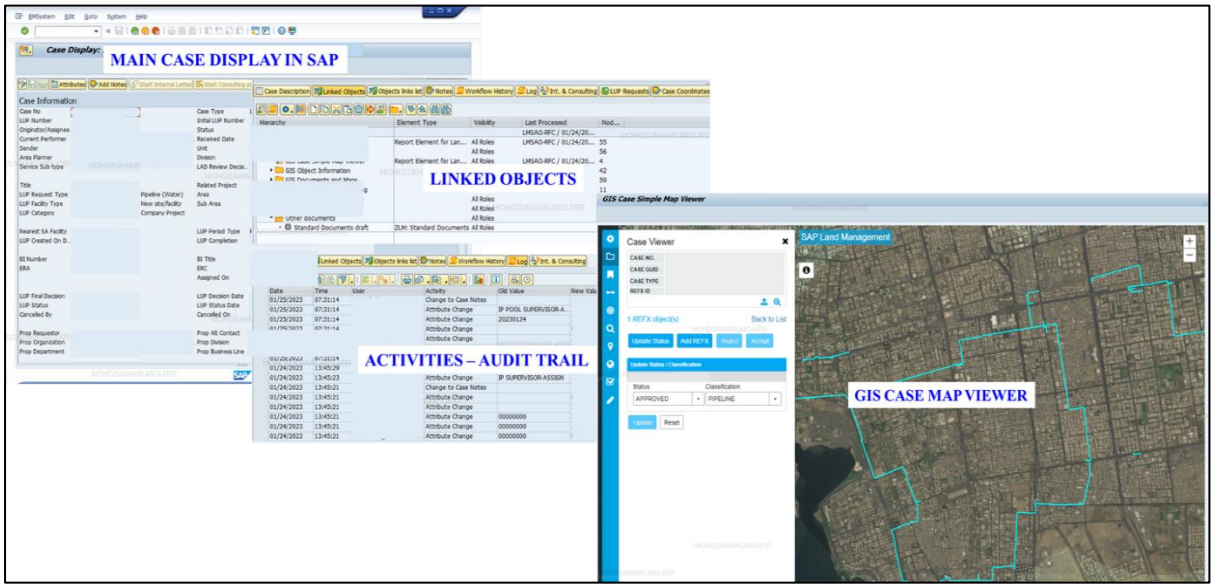

Figure 11: SAPLMS interface – Case display, linked objects, audit trail, map viewer

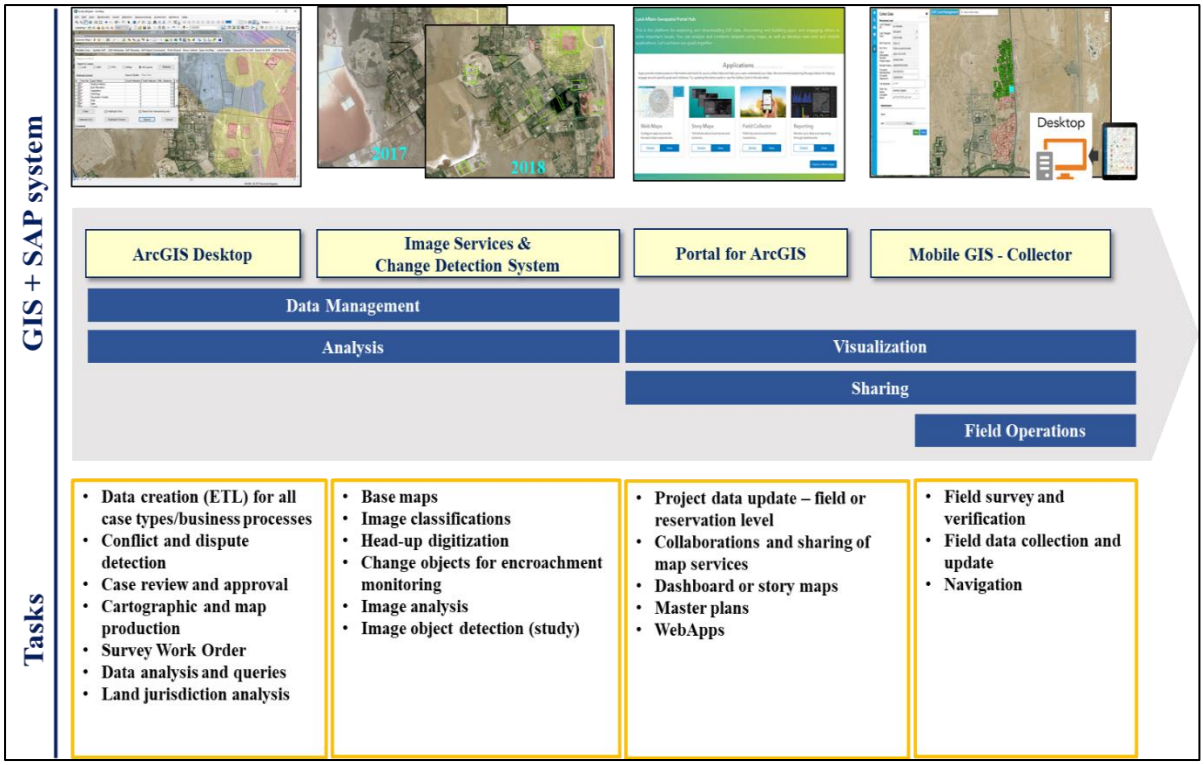

Figure 12: GIS system used for data management and analysis; Desktop, Portal and Mobile

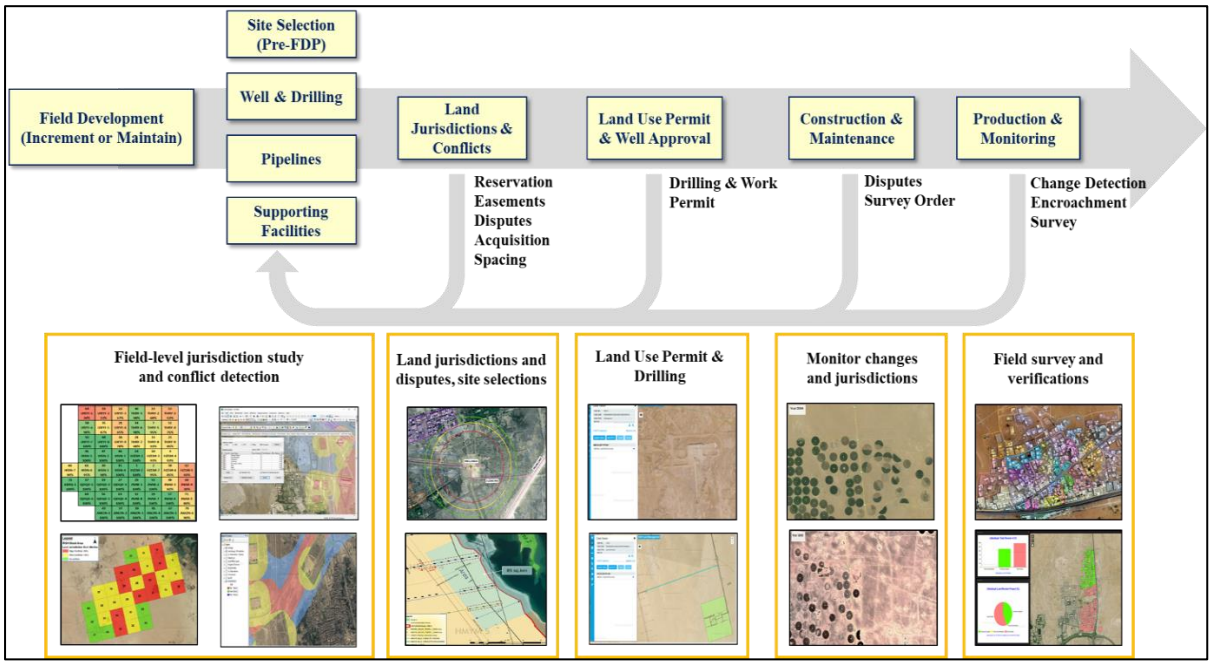

Figure 13: GIS application for securing surface rights through field development

7. CONCLUSIONS AND FUTURE ADVANCEMENTS IN GIS

Allocating lands or surface rights for onshore oil and gas projects are becoming more challenging with the growing demands on lands requirements by other entities as the Kingdom of Saudi Arabia moves toward diversification of its economy. Saudi Aramco streamlined the surface rights and land management processes into a state-of-the-art GIS technology to support ongoing and future oil and gas field development across the Kingdom.

GIS plays an important part in the process where it uses the capability of geospatial components to integrate with business decisions. Spatial analysis had helped to perform conflict detection, spatial distributions and relationships with surface rights and urban growth or encroachment patterns from imageries to find optimal sites and right-of-way to develop hydrocarbon fields.

While geospatial data on land records become more diversified and complex, Saudi Aramco Land Department is aligning our GIS strategy to tap into Digital Transformation pipelines such as Artificial Intelligence, Machine Learning or Deep Learning to enhance our surface or land data and analysis to secure surface rights supporting company on land or surface rights allocations.

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Biographical Notes

Mohd Zukhairi B Abd Latef is a Geospatial Specialist within Saudi Aramco Land Department, Geospatial & System Support Division. He has more than 18 years of experience working in geomatics and GIS, specifically in the petroleum industry with various job assignments both onshore and offshore. He joined Saudi Aramco in 2015 and led to a number of successful implementations in modernizing Geospatial and GIS aspects for surface rights and lands across exploration and production lifecycle within the company. He is a member of the Royal Institutions of Surveyor's Malaysia (RISM) and a lifetime member of the Association of Petroleum Surveyors and Geomatics (APSG)

Contacts
Mohd Zukhairi B Abd Latef
P.O. Box 5786
Saudi Arabian Oil Company
31311 Dhahran
Kingdom of Saudi Arabia
Email: mohdzukhairi.abdlatef@aramco.com

Fahad Mohammed Dalbouh is an accomplished Survey Engineer who is now concentrating on the Geospatial Sciences with more than ten years of extensive experience in various principles, instruments, technology and techniques used in spatial data collection, processing, quality control and management as well as image processing. He joined Saudi Aramco recently in 2021 and led to a number of successful integration with external entities throughout mapping services which eventually enable Land Affairs employee and application builders to combine and mash up ArcGIS services with their existing data in order to gain more insight into the surface rights and lands that might conflict with Company project.

Contacts
Fahad Mohammed Dalbouh
Saudi Arabian Oil Company
31311 Dhahran
Kingdom of Saudi Arabia
Email: fahad.dalbouh@aramco.com