Thematic Geoportal Dashboard Connectivity to Optimize Planning Phase of Trans Sumatera Toll Road

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Key words: Trans Sumatera toll road, GIS, thematic geoportal, spatial data

SUMMARY

The government through Presidential Regulation assigned Hutama Karya to carry out the operation of the 2,789 km Trans Sumatra Toll Road consisting of 5 main stages: funding, planning, construction, operation, and maintenance. The planning stage is the stage to determine the alignment of the Trans Sumatra toll road, based on readiness criteria. In the initial stage, Hutama Karya uses various spatial data sourced from Indonesian Ministries and Agencies. The spatial data needed as secondary data to support planning stages are forest zones data, existing roads, distribution of peat hydrological areas, information on rocks and geological formations, and any other data from various other agencies. To optimize the use of spatial data from Ministries and Agencies, Hutama Karya implemented GIS by creating the thematic geoportal containing spatial data and toll road alignment. The geoportal is prepared using the ArcGIS Enterprise platform from ESRI. The toll road alignment is converted into a feature class and shared as a web layer. Each data from the Government is connected through access to Web Map Service. Spatial data in the form of points, lines, and polygons are displayed as a point of interest and zone. The spatial data obtained from the Ministry and Agencies are the latest spatial data from the server of each institution, as the planning analysis will become more complex and the decision-making process can be carried out more quickly and precisely. Through the thematic geoportal, Hutama Karya could optimize the planning stage by early identifying objects and strategic areas crossed by toll road alignment. Further identification of peatlands, pipeline routes, electricity transmission routes, existing roads, and any other objects will be used for field surveys to check their existing conditions so that it becomes a consideration for the planning team to afford the designs that consider these objects the function of the existence. Obtained object and area information will be a consideration to increase tourism potential, regional income, and so on, due to the toll road alignment that crosses tourist areas, rest areas, synergies with special economic zones or economic areas that have the potential to increase value for Hutama Karya and Indonesia.

1. INTRODUCTION

1.1 Background

PT Hutama Karya (Persero) is one of the leading state-owned enterprises in Indonesia that focuses on the development and construction of roads and bridges. The mega-projects undertaken include the implementation of the Trans Sumatra Toll Road, which stretches from Bakauheni to Banda Aceh (Republik Indonesia, 2015). In the development process, Hutama Karya's scope includes planning, funding, construction, operation, and maintenance.

The first stage of the business process is the planning stage, where toll road design is arranged according to the Geometric design that has been regulated by the Ministry of Public Works and Housing, Directorate of Highways. Various main aspects have to be considered in the preparation of the design, i.e. topography, land use land cover, environment, geology, hydrology, climate, and social (Dirjen Binamarga, 2021).

The toll road design process has to fulfill the aspects specified by the regulator to deliver safe, economical, effective, and efficient toll roads. To establish the toll road which met the readiness criteria, Hutama Karya hired design consultants to analyze and acquired toll road alignment to occupy the geometric design. The process will involve Hutama Karya as the project owner and the Ministry of Public Works and Housing as the regulator.

There are more than one consultants in the existing conditions to establish the design stage of the Trans Sumatera toll road sections.

In the planning phase, the consultant will have an exhaustive analysis using secondary and primary data to establish the optimum toll design. Secondary data can be used as initial data to determine the scope of the primary survey. The spatial data that can be used as preliminary data are land use land cover data, topographic data, geological and geo structure map, road network, forestry zones, the ecological function of peatland area, etc.

Some of the problems found at the planning stage are the incomplete database and various data sources and data types among the consultants. The impact of those issues will lead to an improper design, furthermore, it could lead to a replenishment of the design, such as an increased potential of re-work in primary survey, several structural constructions, design realignment, and cost escalation.

Thus in terms to support toll road optimization at the planning stage, Hutama Karya implemented one map policy through Geoportal. It utilizes GIS technology to compile spatial data from legal source from Ministry and Agencies, and also visualized and manage the data which could be accessed by Hutama Karya management and the related person in charge. The incorporation of various spatial data from various sources of ministries and agencies will produce a more complete and more comprehensive design and analysis of toll road alternative alignments.

1.2 Objectives

The objectives of this research are:

1. Collecting, centralizing, and visualizing various geospatial data from Ministry/Agency.
2. Enhance the design process by analyzing the toll road design with overlaid data from Ministries and Agencies to align it with the medium-term or long-term national development plan.

1.3 Benefits of research

The benefits obtained from this research are:

1. Simplify the data analysis and visualization process at the toll road planning stage.
2. More accurate and precise design process.
3. Minimizing re-design & re-work in the use of data sourced through one map policy to optimize the budget.

2. METHODOLOGY

2.1 Data Source

The data used in this study are:

1. Spatial data from Ministries/Agencies
2. Toll road plan design
3. Toll road construction stage recap

2.2 Tools

The software used in this project are ArcGIS Enterprise, including ArcGIS Pro, ArcGIS Server, ArcGIS Dashboard, and ArcGIS Online.

2.3 Project Location

The project location is in the Sumatra area within the scope of the Trans Sumatra Toll Road project.

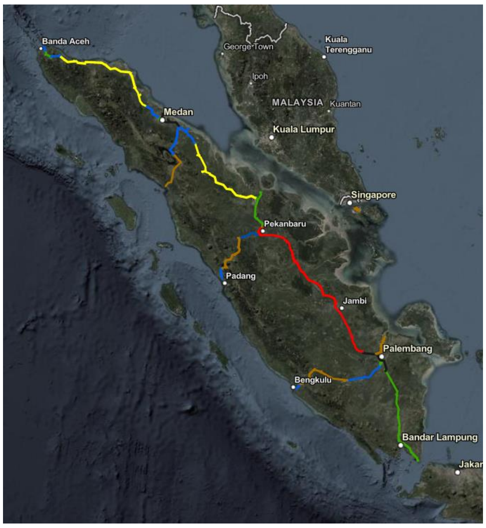

Figure 1 Trans Sumatera Toll Road Location, Indonesia

2.4 Workflow

The workflow of the project implementation can be displayed below:

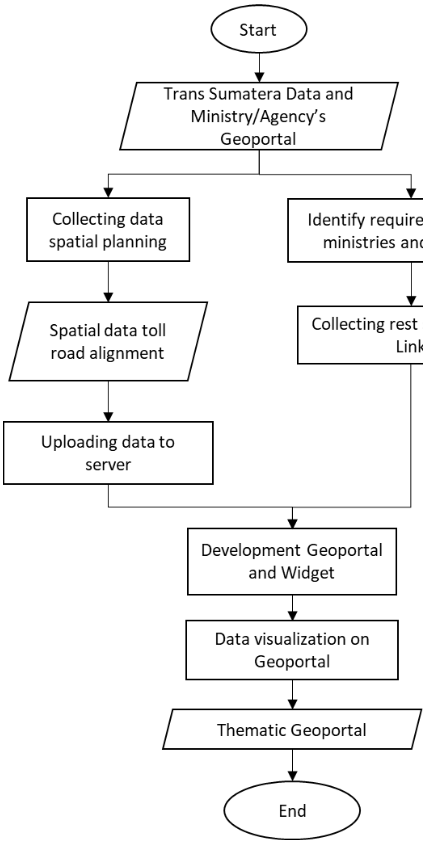

Figure 2 Workflow of the Thematic Geoportal

2.5 Methodology

2.5.1 Identify required data from Ministries/Agencies

According to the geometric design guidance from the Ministry of Public Works and Housing, Hutama Karya already identified the data custodian from each agency. The list of the spatial data needs from Hutama Karya to Related Ministry is displayed below in Table 1.

Table 1. Ministries and Agencies Related to Secondary Data at the Planning Stage

Ministry/Agency	Data
National Geospatial Agency	Land Use Land Cover Map, Administrative Borderline Map, National Geospatial Agency Geodetic Network, CORS Network Location
Ministry of Environment and Forestry	Forest Zones (Forest types i.e. production forest, conservation forest, protected forest, nature conservation zone, forest management unit, nature reserve zone, other usage area)
Ministry of National Development Planning	National Mid-term Development Plan
Ministry of Public Works and Public Housing	National Road Network and Infrastructure
Ministry of Agrarian and Spatial Planning/National Land Agency	Land Value Zoning Maps and National Spatial Plans
Peatland Restoration Agency	Peatland Ecological Area
Ministry of Energy and Mineral Resources	SUTT Network Maps, Oil and Gas Pipeline Networks, Lithological and Geostructural Geological Maps
Indonesian Agency for Meteorological, Climatological and Geophysics	Map of seismicity, map of ground acceleration, distribution of weather observation stations, information on rainfall and temperature, flood area map
Ministry of Agriculture	Distribution of peatlands area, swamps area, soil maps, types of rice fields, and rainfall classes
Ministry of Transportation	Existing railroad and future planned railroad in Sumatera Region

External spatial information such as pipelines, transmission lines, road networks, peatlands areas, swamps, etc., are secondary data obtained from Ministries/Agencies. These data will be utilized as initial identification to specify the survey location before the primary survey is determined. The data also will be used to examine the toll road alignment both horizontal and vertical due to the safety and efficient cost, and also support the development of exclusive zones in the Sumatera Area.

2.5.2 REST Service URL and Development in Geoportal

Geoportal services are built using and exposed as web services, which are self-contained, self-describing web applications that can be invoked over the web using messages encoded in XML (eXtensible Markup Language) and transmitted over an HTTP connection (Maguire and Longley, 2005). REST Service (Representational State Transfer) is a resource-based architectural service that abstracts data and services as resources and is accessed using HyperText Transfer Protocol (HTTP) (Leng *et al.*, 2018). The REST server provides access to data resources and/or spatial data, while the REST Client accesses resources and displays or uses the data. The resource of the map service is in the form of text but various formats such as JSON and XML.

Web Map Service (WMS) is a standard from Open Geospatial Consortium that is used to share and received through HTTP protocol (Budiawan and Ir. Muchammad, 2010). The map then spatially referenced data dynamically from geographic information. Map service is a portrayal of geographical information as a digital image file suitable for display on a computer screen (OGC Inc., 2009). The Open Geospatial Consortium (OGC) already manage the standards of web service request such as Web Map Service (WMS), Web Feature Service (WFS), Web Map Tile Service (WMTS), etc (Leng *et al.*, 2018).

The relations between data sharing through web services using REST services can be defined in Figure 3 below:

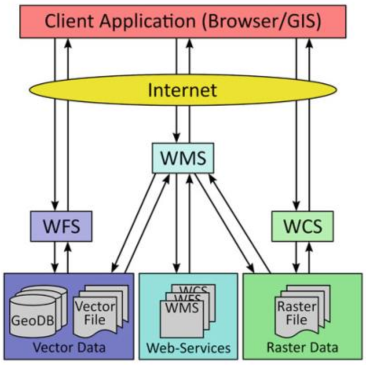

Figure 3 Scheme of OGC-web-services (Pászto et al., 2019)

In this stage, Hutama Karya collaborates with Ministries and Institutions to gain access to Rest Service to utilize spatial data information owned by each custodian. The enabled format data sharing from each custodian mostly are in the form of Web Map Services.

2.5.3 Collecting Data Spatial Planning and Uploading Data to Server

The next stage after collecting the REST services is compiling the spatial toll road alignment for each section. Each alignment is collected in Shapefile format and compiled in a Geodatabase. Geodatabase in this case can represent geographic data, store shapes of features to provide functions for performing spatial operations such as finding objects, model topologically integrated sets of features, and present multiple versions so that many users can use and edit the same data (Zeiler, 1999). Toll road alignment spatial data is then submitted to the Hutama Karya server which uses PostgreSQL and PostGIS, by creating an enterprise geodatabase. All data are integrated into Enterprise Geodatabase (EGDB) and then uploaded to the ArcGIS Enterprise platform.

2.5.4 Development Geoportal and Widget

The geoportal is essentially a master website, connected to a web server that contains a database of metadata information about geographic data and services. Spatial Data Infrastructure (SDI) can be defined as a framework of policies, institutional arrangements, technologies, data, and people that enable the sharing and effective usage of Geographic Information (GI) by standardizing formats and protocols for access and interoperability (Tonchovska and Stanley, 2012).

Geoportal and SDI have major contributions to simplifying access to GI and have helped encourage and assist people who want to use GI concepts, databases, techniques, and models in their work (Maguire and Longley, 2005). Spatial data from Hutama Karya and Ministry are compiled using Web Map Builder in ArcGIS through ArcGIS Dashboard. Each WMS data are added using a URL and defined by the layer name.

Through the map services, Hutama Karya could have the latest version and information data from the ministry that can be used for visualization. The following attribute information is also attached in the WMS, such as depth, length, name, type, data structure, bill, etc that would help the user to gain more information.

The architecture system for an SDI Geoportal can be displayed in Figure 3 below :

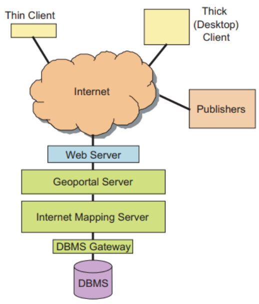

Figure 4 The architecture of Geoportal (Maguire and Longley, 2005)

Data from ministries and agencies are connected through the internet and added to geoportal using web map services and displayed in geoportal using ArcGIS Dashboard.

2.5.5 Data Visualization on Geoportal

The geoportal is built using world wide web infrastructure technology and commercial GIS software, which the network communication between client and web server are using HyperText Transfer Protocol (HTTP). SDI and Geoportal are being developed by many countries as an enabling platform to improve access, sharing, and integration of spatial data and services as a way to better manage and utilize their spatial data assets as such information is one of the most critical elements that underpin decision making across many disciplines (Crompvoets *et al.*, 2008).

Geoportal connectivity will facilitate links and coherence with many institutional servers and portals and it will provide online access to collections of spatial data and services supplied by multiple public and private organizations (Bernard *et al.*, 2005). Data visualization in geoportal is done by using ArcGIS Dashboard tools. In the stage of data visualization, Hutama Karya uses ArcGIS Dashboard to display the data from ministry and toll alignment. In this stage, the widget function of the Geoportal will be added such as zoom in/out, search location, legends, changing base map, and information related to the Geoportal are complemented.

3. OUTPUT AND RESULT

The output of this work is a geoportal that overlays planning alignment data and spatial data from Ministries/Agencies. Various variations of the data are used to perform analysis and decision-making related to planning. The User interface of the geoportal itself can be displayed as below:

1. Main Map Visualisation
2. Standard Widget
3. Filter Data
4. Title
5. Legends
6. Base Map
7. Contact and Information

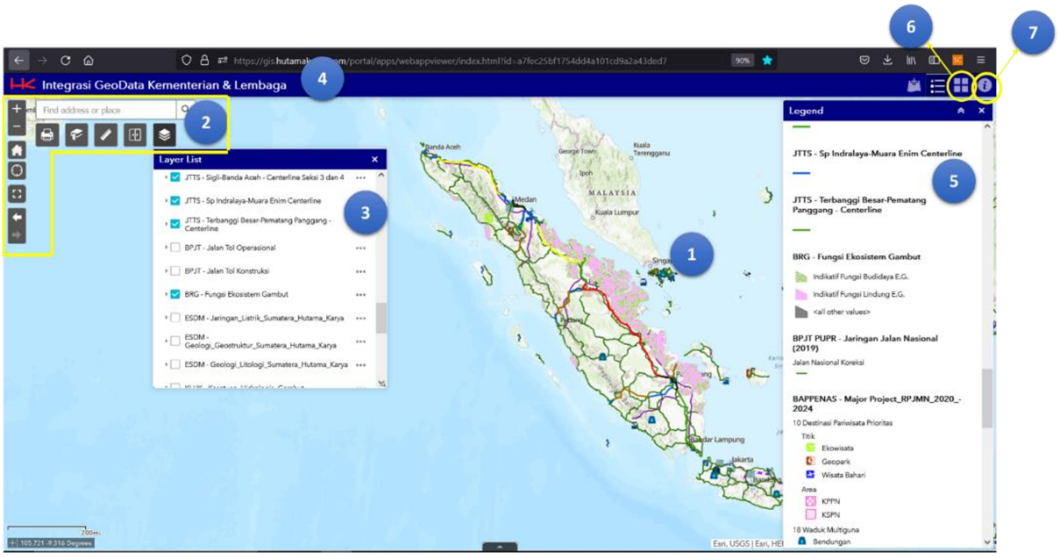

Figure 5 Geoportal Information

Some examples of case studies completed through this geoportal are:

3.1 Realignment of Betung – Jambi Section

The planned route of the Betung – Jambi toll road is planned for 168 KM which stretches along the east coast of Sumatra starting from Betung, South Sumatra Province to Jambi city, Jambi Province.

One of the toll segments adjacent to wildlife conservation (part of the forest area of the Ministry of Environment and Forestry) and palm oil plantation in hilly terrain condition. Considering the Toll Road Right of Way (ROW), the challenge is to deal with the terrain and designed the road horizontal alignment to avoid intersections with the restricted area.

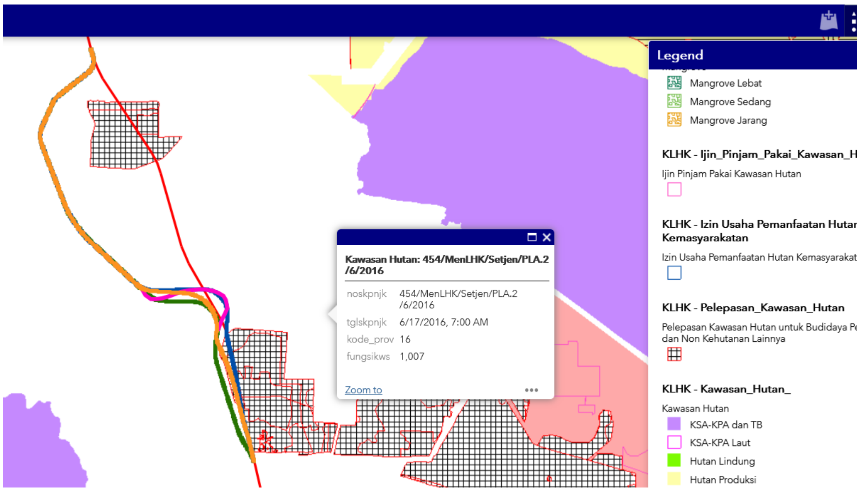

Figure 6. Data Information about the Recent Status of Forestry Area

After overlaying the toll road alignment with the forest area from the Ministry of Environment and Forestry through WMS, identified that the former wildlife conservations have been classified as another used area. Therefore, the conservation wasn't a problem anymore and the toll road alignment could be designed over there. The impact for the technical and financial aspects, the shorter alignment will increase the cost-efficiency.

3.2 Analysis of Determining the Access Route to the Arun Special Economic Zone in Aceh.

The planned alignment for the Lhokseumawe – Sigli length is about 156 KM in the Aceh Province. At the location of the planned toll road, there is a master plan from the Ministry of National Development Planning to develop a Special Economy Zone (SEZ) at Arun, Lhokseumawe, as displayed in the figure below. Spatial information of Arun SEZ was provided by the Ministry's Geoportal which integrated to Hutama Karya's Geoportal through Web Map Services.

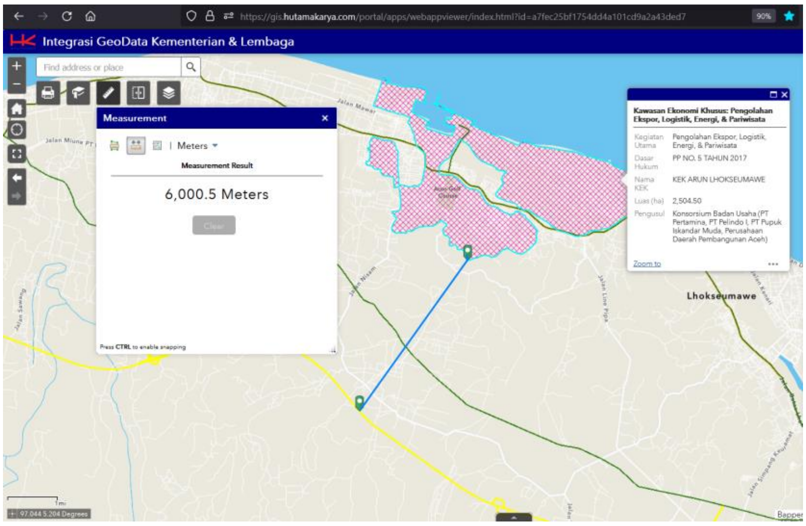

Figure 7. Special Economic Zone Analysis Through Lhokseumawe – Sigli Toll Section.

Through the thematic geoportal, Hutama Karya will have more valuable information i.e. the specific location of Arun SEZ to determine the distance of SEZ from the toll road alignment and the nearest access from the toll road segment. The benefit for Hutama Karya is to convinced that the toll road alignment designed does not intersect the access route to SEZ, if it couldn't be avoided, Hutama Karya will be re-designed to assure less intervention of SEZ access road to minimize the construction cost. The benefit for SEZ authority is knowing where their position towards the toll road alignment plan, to maximize the potential and the business development of SEZ area. Because the nearest road access to SEZ, the more interesting for future business development. And also for risk mitigation if there is no way to avoid the toll road intersecting the access road.

3.3 Geological Data for The Toll Road Alignment Design Process

Geological data plays an important role in the planning stage of the alignment design. Based on the slip rate modelling of Sumatra Island, which was compiled based on Geological and Geodetic data, it is estimated that the slip rate value of the Sumatran fault from the Sunda Strait to Aceh does not experience significant changes, but is around 14-15 mm/year (Pusgen, 2017). The geological data becomes a parameter in the process of generating the initial alignment design, to avoid the location of faults or folds.

One of the analysis carried out is on the Pekanbaru - Padang toll road, Bukittinggi - Sicincin section, where at that location is crossed by the Semangko Fault which is an active fault in the Sumatra Region (McCaffrey, 2009). As a form of risk mitigation at the design planning stage, spatial data on fault locations are defined as areas that must be avoided at the generate alignment stage using automation alignment software.

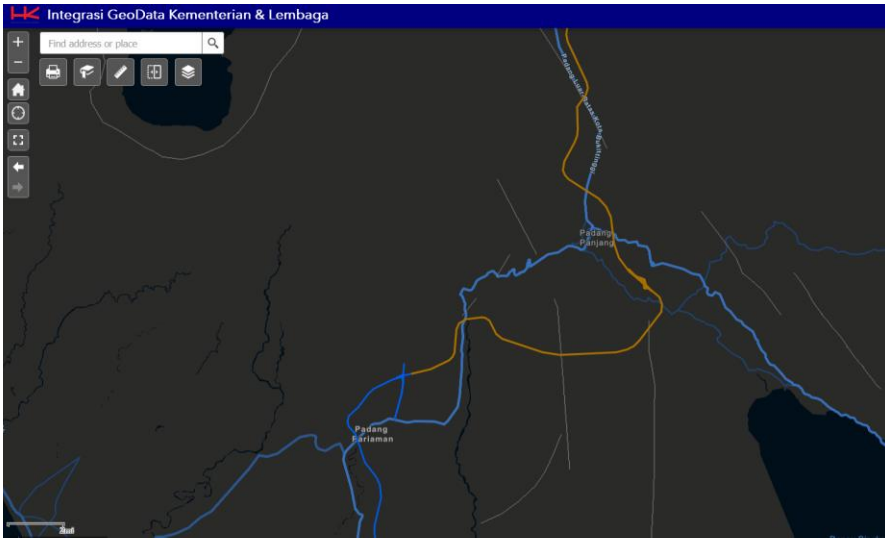

Figure 8. Example of Fault Data that crosses the Sincincin - Bukittinggi segment

Moreover, the geological data needed by Hutama Karya and also the design consultants to identify the structure design in the feasibility study or basic design phase, before the Geotechnical team made justification for the geotechnical approach and method for a soil test. The early identification will decrease operational costs because of the incorrect soil test method.

3.4 Obtaining Secondary Data for Hydrological and Drainage Studies in Trans Sumatera Toll Road

Hydrological and drainage studies were carried out at the stage of basic design and detailed engineering design. Through the thematic geoportal, Hutama Karya could obtain data from National Geospatial Agency to identify topographic data from topographical map and land use land cover map scale 1:50.000. Initial identification acquired by Hutama Karya is defining the location of the river, dam, lake, terrain, and contour, to identify the flow stream, river width, and river classification of large, medium, and a small rivers.

From these data, Hutama Karya could determine the bathymetric survey location to obtain topographic data underwater purpose to complete terrain data topography. Moreover, the completed topographic data, combined with soil investigation will be used as a base map to design appropriate bridge structures related to the existing conditions.

3.5 Initial Survey to Determine the Potential Distribution and Depth of Peat as well as Geological Conditions about Geotechnical Survey Planning

On the Rengat – Pekanbaru section, there is a crossing location with peatland. Peat soil is soil formed from weathered organic matter, especially from the past's remaining piles of plant tissue (Suriadikarta and Sutriadi, 2007).

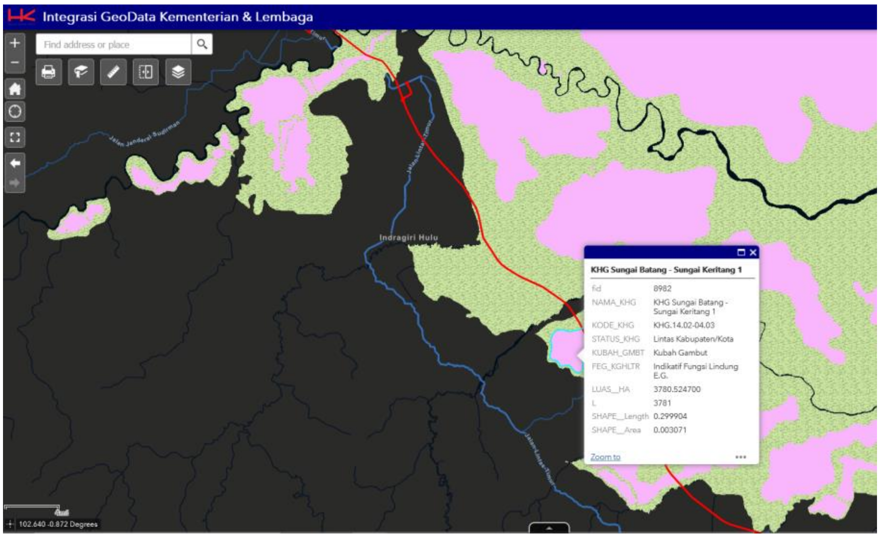

Figure 9. Distribution of Superimposed Peatlands with Jambi - Rengat Toll Road Section

The morphology of the peatland itself changes annually, with the in-situ peat material absorbing water and thereby swelling during the wintertime and then releasing water (usually through evapotranspiration) during the summertime, producing typical ground surface elevation changes of 30–50cm. Many peatlands are experiencing accelerated degradation due to the effects of large-scale drainage and oxidation, causing their subsidence. Numerous case studies report that the bulk of the subsidence for drained peatland is attributed to the decomposition of organics (O'Kelly and Johnston, 2019). Through the integration between Hutama Karya data and Peatland Restoration Agency, Hutama Karya could determine initial identification for the geotechnical approach, which is selected based on the distribution of peatland data and depth information data, then it is overlaid with geological and geo structural maps to determine the potential faults/folds and the type of rock in the location. The early identification will decrease the operational cost because of the number of attempts while determining the peatland location for a further geotechnical survey.

4. CONCLUSION & RECOMMENDATION

4.1 Conclusion

1. Integrated and updated data from Ministries and Agencies will be beneficial for Hutama Karya's in-depth analysis and decision-making process.
2. Spatial information from thematic geoportal can be used as data for preliminary analysis to design an optimum toll alignment by examining the toll design plan with the existing object and masterplan design from ministry/agencies to avoid the restricted area, overlaid with land use land cover and topographical map for hydrological study, and also as an initial data for geotechnical study using peatland and geological data.

4.2 Recommendations

1. There is still a need for further development to add various features such as spatial data analysis on the cloud, export and download data, as well as marking features.
2. There needs to be an additional connection with the Web Feature Service (WFS) and also the data security related to the usage of various data sources.

5. ACKNOWLEDGEMENTS

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