Application of GIS to improve accuracy and save time in Cut and Fill Calculation, A case study of Bunga Club Project PT. Tanjung Pura Resorts Balikpapan

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Sari: SIG (Sistem Informasi Geografis) adalah suatu perangkat lunak yang banyak digunakan untuk mengelola data spasial dan digunakan untuk perencanaan wilayah. Fitur-fitur perangkat lunak ini disamping kemampuan pengelolaan database spasial, juga fasilitas pembuatan berbagai lay-out peta tematik. Konsep layering pada perangkat lunak ini memungkinkan pengguna dalam menyelesaikan tugas pemetaan serta membantu pengguna membuat sintesa dari berbagai macam data spasial. Pemanfaatan perangkat lunak ini masih sangat terbatas pada tumpang tindih layer dan pembuatan peta tematik, serta pembuatan layout peta. Penggabungan dengan perangkat lunak lain memungkingkan penggunaan memanfatkan untuk kepentingan perhitungan volume cadangan minyak bumi dan gas, perhitungan cadangan batubara serta perhitungan volume cut and fill dan lainya. Dengan Menggunakan metode isopach, perangkat ini dapat digunakan untuk mengitung volume cut and fill pada topografi yang komplek dengan akurasi tinggi. Hasil dari perhitungan ini jauh lebih teliti dibandingkan metode sayatan karena dengan metode ini hamper semua titik ketebalan dapat terwakili. Perhitungan volume cut and fill dengan GIS memberikan hasil dengan akurasi tinggi dikarenakan Aplikasi ini dapat menentukan luasan poligon berdasarkan koordinat dengan cepat dan tepat dibandingkan menggunakan planimeter. Didalam menyelesaikan project ini alat berat harus memotong topografi sebesar 33201.82323 m3 dan material yang dibutuhkan untuk ditimbun sebesar 46748.02674 m^3 sehingga dibutuhkan tambahan material untuk menimbun 13546,20351 m^3.

Kata kunci : GIS, cadangan, cut and fill

Abstract: GIS (Geographic Information Systems) is computer software that's widely used for spatial data management and spatial planning. Features of this software are spatial database management and perform many thematic maps. Layering concept on this software enables the user to do a mapping job and helps the user make a synthesis of any kind of spatial data. The usages of this software are still limited on layer overlying and thematic map making. Combination of this software with others software enable user use this software in other interest such as oil & gas reserves calculation, coal reserves calculation, and earth moving volume calculation, etc. Using the Isopach method this software calculation of cut and fill's volume in the complex topographic area with great accuracy could be handled. The results of calculation have greater accuracy because software ability in determining polygon width quickly and precisely based on coordinates compared using planimeter. To accomplish this project the heavy equipment need to cut 33201.82323 m^3 of soil and need 46748.02674 m3 as filling materials means this project needs an additional filling volume of 13546,20351 m^3. Application of GIS to improve accuracy and save time in Cut and Fill Calculation: A case study of Bunga Club Project PT. Tanjung Pura Resorts Balikpapan.

Keywords: SIG, reserves, cut and fill

LOCATION MAP OF BUNGA CLUB PROJECT
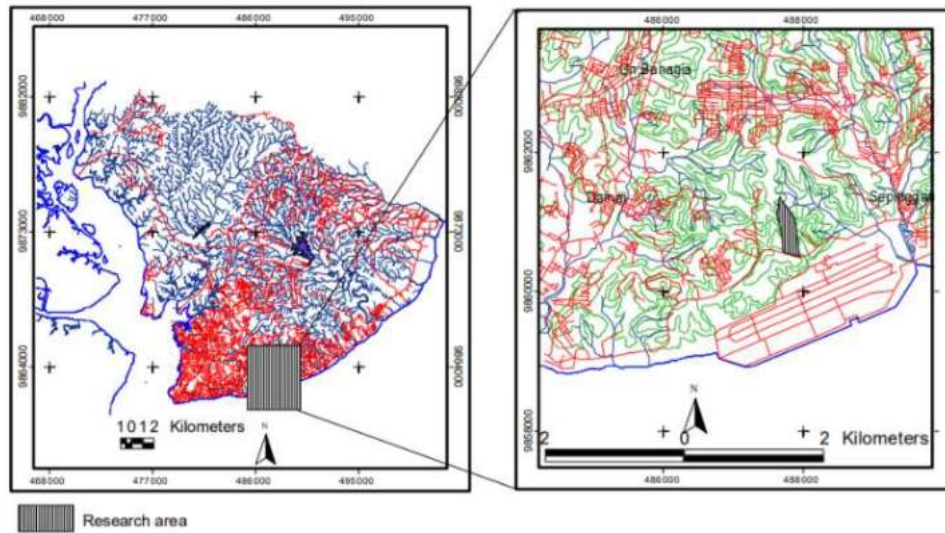PT. TANJUNG PURA RESORTS

Research area

Figure 1. Location map of the research area

I. Introduction

In mechanical earthmoving, needs of tools for reserves and complex geometric volume calculation are necessary. There are many software's in the market which is dedicated for such kind of job. Geographical Information System has not dedicated software for cut and fill calculation which is able to handle that task. A geographic information system (GIS) is a system for capturing, storing, analyzing, and managing data and associated attributes which are spatially referenced to the earth. In the strictest sense, it is a computer system capable of integrating, storing, editing, analyzing, sharing, and displaying geographically referenced information. In a more generic sense, GIS is a tool that allows users to create interactive queries (user-created searches), analyze the spatial information, edit data, maps, and present the results of all these operations. So far GIS or Geographical Information Systems is known as powerful software designated for spatial database management. It's widely used for spatial planning and decision-making/policymaking. The author would explain and demonstrate how this tool can be used for calculating the volume of cut and fill projects precisely and how this method can increase the speed of work with greater accuracy rather than conventional fashion. Basically, GIS software such as Map Info, Arc Info, and Arc View has no feature to solve such kinds of problems. But with additional software such as Spreadsheet, Surfer, and a little bit of user creativity, GIS could cope to solve cut and fill calculation. This paper is written based on both simulation and real Cut & Fill Project at Bunga Club of Tanjung Pura Resort (see figure. 1) that's located in Marsma R Iswahyudi Street, 1 Km north of Sepinggan Airport. This project was carried out from August until October 2004 involving serial activities such as topographic mapping, map digitizing, and cut and fill volume calculation. The objective is aimed to explore the possible application of GIS software to calculate cut and fill volume, make the

simulation of cut and fill volume calculation and give consideration in cost and plan of earth moving project.

Statements of the problem: This paper would like to answer these questions how could the GIS calculate efficiently and accurately the volume of cut and fill in complex terrain. The second problem is, How precise are the results compared to another method such as cross-section.

II. Methodology

There are many reserve calculation methods such as finite element, cross-section, isopach and influenced area. Most civil engineers or mine engineers use the cross-section method to make volume cut and fill estimation. Most of them use dedicated hardware and software to handle such kinds of jobs. Indeed complex volume calculation can be solve using certain methods with tool aids such as planimeter and ruler but it needs experience, many times of trial, and very time-consuming. In this case, the author adopts the isopach method which is a popular reserve calculation method that uses in calculating oil and gas reserves and another reserve such as coal. Isopach is a contour that connects points of equal thickness. Commonly, the isopachs, or contours that make up an isopachs map, display the stratigraphic thickness of a rock unit as opposed to the true vertical thickness. Isopachs are true stratigraphic thicknesses. Method determination is based on software ability, software out put and compatibility with field condition. Because the software has the ability to generate contour from the longitude, latitude, and elevation data, the isopach method is adopted. On this calculation, at least require 1) Map Info, 2) Surfer, 3) Spread Sheet (Excel , Calc etc), 4) MySQL (as tool to convert SQL from map

info to MS Excel or Calc), 5). Initial Topographic map 1: 5000 – 1:1000 with interval contour 1m, an 6) Proposed Topographic map/ Topographic after cut & fill.

User idea to use the above tool and data is beyond just merely the powerfulness of the tool itself, because the software is not addressed to handle reserve calculation. This following step can be modified by the user depend on the need of the user and case compatibility. The steps to calculate the volume of the cut and fill project as follow:

1) make an overlay between the initial topographic layer and the proposed topographic layer.
2) mark with point in every intersection of contour and give value of value proposed contour subtracted by initial contour as attribute of that point mark in new layer.
3) generate coordinate of point mark with coordinate extractor.
4) export sql data into spreadsheet or excel (use mySQL to convert become spreadsheet file).
5) use the data of intersection coordinate and value as x, y and z data in surfer.
6) generate a contour of those data.
7) export contour (Isopach map) to DXF or MIF File,
8) overlay with area boundary /Polygon layer.
9) erase outside of area boundary
10) close every contour adjust with the area boundary layer.
11) determine the breadth of closed contour (change from polyline to polygon)
12) positive contour means the level that needs cutting and a negative contour needs filling.
In order to get the precise results, we should calculate each level which has an imaginer

boundary as an isopach line. Geometric approaches should be taken into account to calculate volume each level of isopach. The following formula is used to solve oil and gas reserve and proven to give the precise result is also applicable to calculate the volume of cut and fill materials. Truncated prism: In this case, we can use the formula that usually used in the oil and gas reserves calculation like the following: If A/B > ½ then we assume that the geometric form close to trapezoidal form or truncated prism, the formula that should be used is: V = ½ h x (A + B)

where:

V = Volume

h = Height between surface A and B

A = extent of the top contour surface
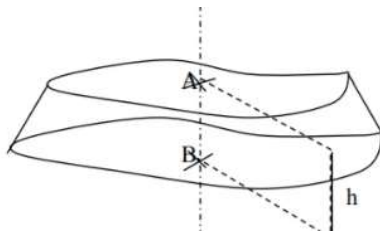
B = extent of the bottom contour surface

Figure 2. trapezoidal /truncated cone

if A/B < ½ then the formula that should be used as follows :

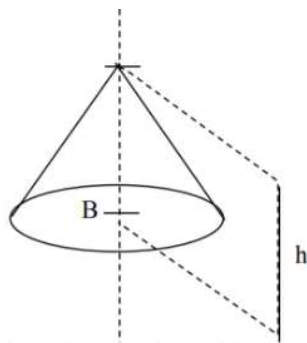$$v = \frac{1}{3}h(A+B) + \sqrt{A+B}$$

Cone or pyramid:

V = 1/3 h x B

Figure 3. Cone/pyramid

According to field conditions sometimes other geometric approaches are needed, such as triangle prism, sphere, and tube.

III. Data, Calculation, and Results

This project area is 2.62 hectares in width, maximum cutting thickness is 7 meters and maximum filling thickness is 10 m. To simplify the calculation process this area is divided become 4 blocks. Block division of the area is based on isopach value (negative or positive). Each area width in each block that's bordered by isopach line determined (see the attachment). The volume of each block calculated using one of three formulas base on the top and bottom ratio of isopach width.

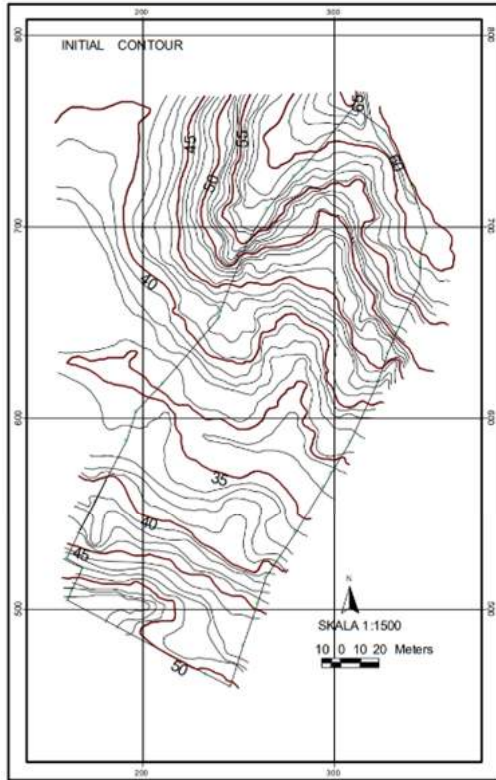Figure 4. Site Plan of Bunga Club PT. Tanjung Pura Resorts.

Figure 5. Initial Contour of Bunga Club
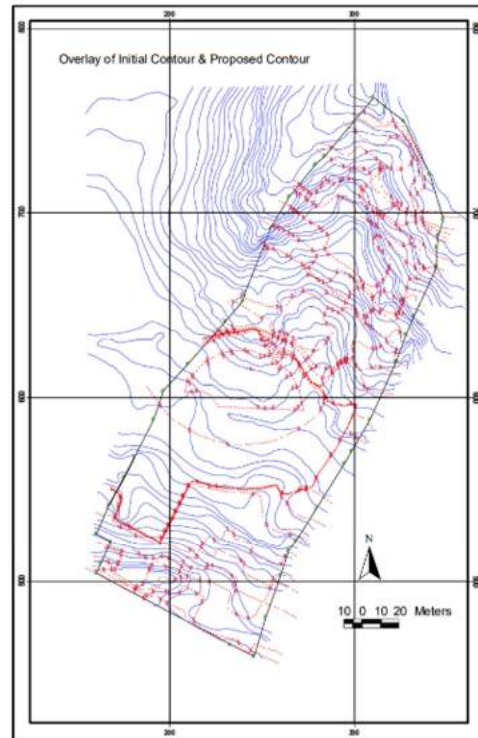PT. Tanjung Pura Resorts

Figure 6. Proposed Contour of Bunga Club PT.
Tanjung Pura Resorts

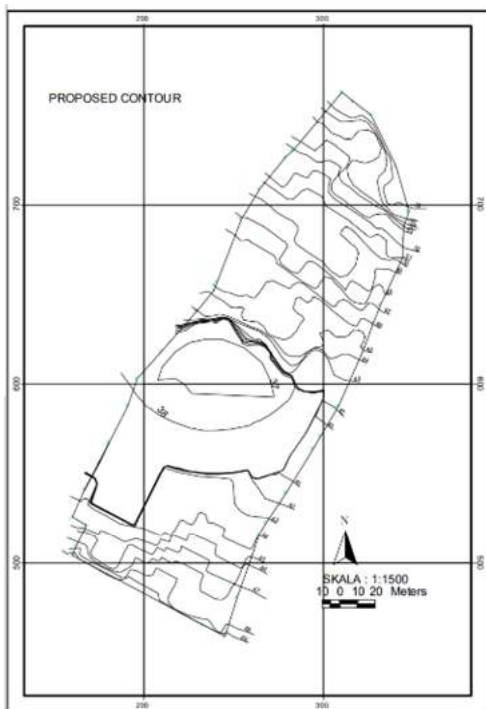Figure 7. Overlay of Initial contour and
Proposed Contour

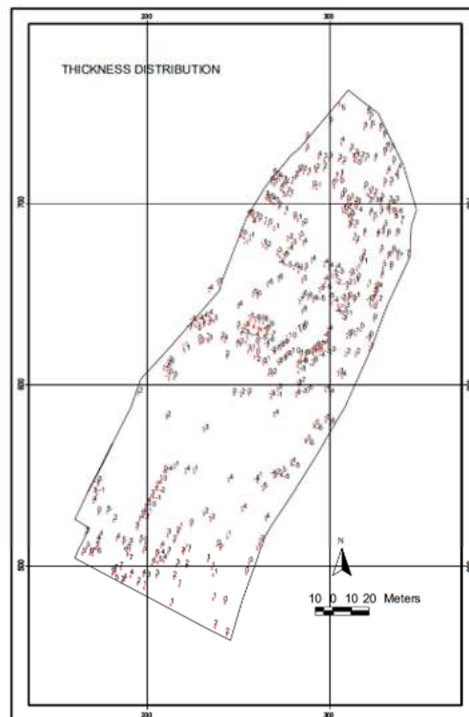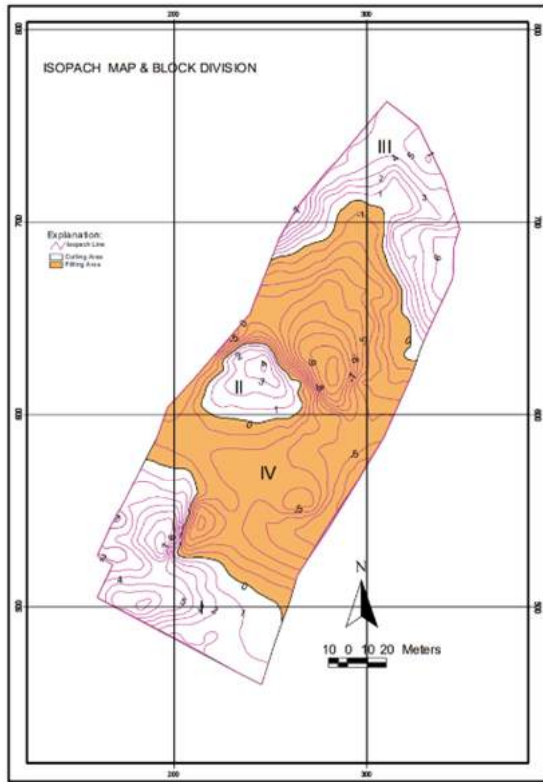
Figure 8. Thickness Distribution Map

Figure 9. Isopach Map and Block Division

The results of the calculation as follow:
Block I   = 14538.92 m^3
Block II   = 2365.309 m^3
Block III = 16297.59 m^3
Total Cutting Volume = 33201.82323 m^3
Block IV = 46748.02674 m^3
Total Filling Volume = 46748.02674 m^3
Detailed calculations are attached.

IV. Discussion

Although GIS software such as MapInfo v.7 is not designated as a tool to calculate the above job, base on professional judgment and certain principles of reserve calculation, this software can solve volume calculation with great precision. Besides give great precision and result, using this software will save time significantly. Calculation using a similar method using manual or digital planimeter is very time-consuming and has a greater error. Having has automatic information of polygonal width, GIS will save time and reduce error in planimetric calculation. When we use a manual or digital planimeter to determine the breadth of a certain area at least we have to do it three times and we will get three different results. With little additional steps and ideas, this software is also possible to solve much more complex cut and fill volume calculations. Adoption Isopach method to solve cut & fill volume calculation is also much more accurate than the cross-section method, because the isopach method base on distributed representative point, we can imagine how many cross-sections should be made in order give represent thickness in the complex topographic surface. In flat terrain or in flat slope cross-section method could be used, but in terrain with irregular which forms tongue like, irregular valley and hills the cross-section method will give a result with a great error.

V. Conclusions and Recommendations

This study gives the following conclusions:
1) GIS with additional software and Technique can improve the accuracy of cut and fill complex geometric volume calculation.
2) In order to accomplish this project, the heavy equipment need to cut 33201.82323 m^3 of soil and need 46748.02674 m^3 as filling materials means this project needs an additional filling volume of 13546,20351 m^3

Recommendation
1) We can reduce using other software by searching map basics program. If there is an available tool (map basics) to generate contour from x, y, z data we can do this job without surfer.
2) Autocad as additional software could be used to solve a similar job when a cross section is adopted. Autocad is used to draw topographic cross-sections then the breadth of cross-section determines by GIS software.

VI. Acknowledgment

VII. Bibliography

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Attachment

Table 1: Cut & Fill Volume Calculation
Result

Block	Isopach	Total Area m²	A/B	Formula	Volume	subtotal	Total Volume (m3)
I	0	5348.24					
	1	4344.81	0.81	Trapezoidal I	4846.5235		
	2	2827.32	0.65	Trapezoidal I	3586.0636		
	3	2047.27	0.72	Trapezoidal I	2437.29335		
	4	1484.28	0.73	Trapezoidal I	1765.77195		
	5	913.99	0.62	Trapezoidal I	1199.13317		
	6	432.14	0.47	Trapezoidal II	485.40014		
	7	78.15	0.18	Trapezoidal II	192.687441		
	8	0.00		Cone	26.0504387		
						14538.92359	
II	0	1502.10					
	1	998.57	0.66	Trapezoidal I	1250.33617		
	2	543.66	0.54	Trapezoidal I	771.118035		
	3	172.84	0.32	Trapezoidal II	265.602206		
	4	10.64	0.06	Trapezoidal II	74.7057829		
	5	0.00		Cone	3.54730033		
						2365.309494	
III	0	4950.69					
	1	4188.33	0.85	Trapezoidal I	4569.51135		
	2	3663.20	0.87	Trapezoidal I	3925.7652		
	3	3116.23	0.85	Trapezoidal I	3389.7152		
	4	2333.17	0.75	Trapezoidal I	2724.699		
	5	1047.81	0.45	Trapezoidal II	1185.14018		
	6	348.37	0.33	Trapezoidal II	502.759221		
	7	0.00		Cone	116.12298		Cutting Volume :
						16297.59015	33201.82323 m³
IV	0	14407.21					
	-1	12421.34	0.86	Trapezoidal I	13414.2745		
	-2	9942.99	0.80	Trapezoidal I	11182.1644		
	-3	6770.11	0.68	Trapezoidal I	8356.5482		
	-4	4601.60	0.68	Trapezoidal I	5685.85725		
	-5	2546.45	0.55	Trapezoidal I	3574.02725		
	-6	1437.30	0.56	Trapezoidal I	1991.87685		
	-7	894.92	0.62	Trapezoidal I	1166.11307		
	-8	601.06	0.67	Trapezoidal I	747.990425		
	-9	308.00	0.51	Trapezoidal I	454.52909		
	-10	78.48	0.25	Trapezoidal II	148.485839		
	-11	0.00		Cone	26.1599157		Filling Volume :
						46748.02674	46748.02674 m³