การศึกษาความเป็นไปได้เบื้องต้นการพัฒนาเหมืองหินปูนเพื่ออุตสาหกรรมซีเมนต์ในประเทศกัมพูชา

นายโซชีท เค็ม

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต
สาขาวิชาวิศวกรรมทรัพยากรธรณี ภาควิชาวิศวกรรมเหมืองแร่และปิโตรเลียม
คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2556

ลิขสิทธิ์ของจุฬาลงกรณ์มหาวิทยาลัย

บทคัดย่อและแฟ้มข้อมูลฉบับเต็มของวิทยานิพนธ์ตั้งแต่ปีการศึกษา 2554 ที่ให้บริการในคลังปัญญาจุฬาฯ (CUIR)
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A PRE-FEASIBILITY STUDY OF LIMESTONE QUARRY DEVELOPMENT FOR CEMENT INDUSTRY IN CAMBODIA

Mr. Socheat Kem

จุฬาลงกรณ์มหาวิทยาลัย
CHULALONGKORN UNIVERSITY

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering Program in Georesources Engineering
Department of Mining and Petroleum Engineering
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จุฬาลงกรณ์มหาวิทยาลัย
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โซชีท เค็ม : การศึกษาความเป็นไปได้เบื้องต้นการพัฒนาเหมืองหินปูนเพื่ออุตสาหกรรมซีเมนต์ในประเทศกัมพูชา. (A PRE-FEASIBILITY STUDY OF LIMESTONE QUARRY DEVELOPMENT FOR CEMENT INDUSTRY IN CAMBODIA) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ผู้ช่วยศาสาตราจารย์ ดร.สุนทร พุ่มจันทร์, 112 หน้า.

งานวิจัยนำเสนอการศึกษาความเป็นไปได้เบื้องต้นการพัฒนาเหมืองหินปูนเพื่ออุตสาหกรรมซีเมนต์ในประเทศกัมพูชา โดยมีพื้นที่วิจัยที่ตำบลเปรตา อำเภอบันเตีย จังหวัดกัมปอด งานวิจัยชิ้นนี้มีวัตถุประสงค์หลัก คือ 1) สร้างแบบจำลองทางธรณีวิทยาเพื่อนำไปสู่การคำณวนปริมาณสำรองทางธรณีและเป็นการเตรียมข้อมูลสำหรับการออกแบบและการทำเหมือง 2) เพื่อสร้างรูปแบบการพัฒนาเหมืองที่ดีที่สุด ซึ่งเกี่ยวข้องกับการสร้างแบบจำลองแหล่งแร่ การประเมินปริมาณสำรองการทำเหมือง การออกแบบเหมือง การดำนินการทำเหมืองและการฟื้นฟู 3) สร้างแบบวิเคราะห์ด้านการเงิน ซึ่งเกี่ยวข้องกับ การคำณวนส่วนลดจากกระแสเงินสด (DCF) มูลค่าปัจจุบันสุทธิ (NPV) อัตราผลตอบแทนภายใน (IRR) และค่าใช้จ่ายเฉลี่ยของน้ำหนัก (WACC)

ผลการศึกษาพบว่า แบบจำลองทางธรณีวิทยาสร้างจากบล๊อกโมเดล จำนวน 560,000 บล๊อก โดยขนาด 15ม.x15ม.x10ม. ในแนว(x,y,z) การประเมินปริมาณสำรองโดยใช้วิธีการ อินเวิส ดิสแต้นส์ พบว่าแหล่งหินปูนมีปริมาณสำรองทางธรณีวิทยา 204 ล้านตัน ผลการออกแบบเหมืองโดยวิธีการของ เลอ-กรอสแมนได้สร้างแบบเหมืองที่เป็นไปได้มากที่สุด คือเหมือง MP1 ซึ่งมีปริมาณสำรองที่ทำเหมืองได้ 30 ล้านตัน เหมาะสำหรับปริมาณการผลิตที่ 1 ล้านตัน/ปี ตลอด 25 ปีของอายุเหมือง ระบบการจัดการวัสดุประกอบด้วยรถบรรทุกเทท้ายจำนวน 5 คัน รถตักล้อยางจำนวน 1 คัน และรถขุดตักจำนวน 2 คัน เพื่อที่จะจัดการกับอัตราการผลิตหินปูน 550 ตัน/ชั่วโมง ผลการวิเคราะห์ทางการเงิน คำณวนค่ามูลค่าปัจจุบันสุทธิได้ 19.3 ล้านดอลล่าร์ อัตราผลตอบแทนที่ร้อยละ 45 ซึ่งมีค่าสูงกว่าค่าใช้จ่ายเฉลี่ยของน้ำหนัก คำณวนได้ที่ร้อยละ 15 นอกจากนี้ข้อแนะนำทางด้านสิ่งแวดล้อมได้นำเสนอ ระดับเสียงและการสั่นสะเทือนสูงสุดที่ 115 เดซิเบล และ 5 มม./วินาที (ความเร็วอนุภาคสูงสุด) โดยมีแผนการฟื้นฟูการทำเหมืองระยะสุดท้าย ด้วยการปรับสภาพขุมเหมืองให้เป็นอ่างเก็บน้ำซึ่งจะเป็นประโยชน์ต่อท้องถิ่นในภาพรวม กล่าวโดยสรุปแล้วการพัฒนาเหมืองนี้ มีความเป็นไปได้ทั้งในแง่ด้านเทคนิค ด้านการเงิน และด้านสิ่งแวดล้อม

ภาควิชา วิศวกรรมเหมืองแร่และปิโตรเลียม ลายมือชื่อนิสิต ....

สาขาวิชา วิศวกรรมทรัพยากรธรณี ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก ....

ปีการศึกษา 2556

5471221821 : MAJOR GEORESOURCES ENGINEERING
KEYWORDS: LIMESTONE QUARRY/ QUARRY OPERATION/ PIT DESIGN/ BLOCK MODEL/ MINE PLANING/ ENVIRONMENTAL CONCERN.

SOCHEAT KEM: A PRE-FEASIBILITY STUDY OF LIMESTONE QUARRY DEVELOPMENT FOR CEMENT INDUSTRY IN CAMBODIA. ADVISOR: ASST. PROF. SUNTHORN PUMJAN, Ph.D., 112 pp.

The research presents a pre-feasibility study of limestone quarry development for cement industry in Cambodia. The research area locates at Prey Ta Pret village, Banteay Meas district, Kampot province, Cambodia. This research focuses mainly on the technical development of limestone quarry with the following objectives; (1) to construct the geological block model to calculate the geological resource and to provide an input for quarry operation and design; (2) to formulate an optimum quarry development involving ore modeling, mineable reserve estimation, pit design, mine operation, and mine rehabilitation; (3) to develop a financial analysis involving discounted cash flow model, Net Present Value (NPV), the Internal Rate of Return (IRR), and the Weight Average Cost of Return (WACC).

The result of geological block model generates 560,000 blocks with block discretization of 15mx15mx10m in (x,y,z) dimension. The geological resource of 204 million tons is estimated by using the Inverse Distance Square Method. The pit optimization using the Lerchs-Grossmann method yields the selected ultimate pit (MP1) with 30 million tons mineable reserve. The mineable reserve is designed for 1 million tons per year limestone production covering 25 years mine life. For the material handling, it requires 5 trucks, 1 loader and 2 excavators to handle 550 tons per hour of limestone production. In terms of financial analysis, 19.3 million dollar of NPV is estimated with the IRR of 45 percent which is higher than the WACC of 15 percent. For environmental consideration, the maximum noise and ground vibration level recommend for blasting are 115 dB linear and 5 mm/s (peak particle velocity), respectively. The final rehabilitation is planned to convert the final pit into a water reservoir which are benefit the local communities. In summary, this quarry project is proven feasible taking into consideration of technical, financial and environmental aspects.

Department:	Mining and Petroleum Engineering	Student's Signature	....
		Advisor's Signature	....
Field of Study:	Georesources Engineering		
Academic Year:	2013		

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CHAPTER I

INTRODUCTION

1.1. Background

Cambodia had experienced civil war during 1960 to 1980 that crippled the country's economy in almost every aspect. Since 1980 onward, the country has resumed the economic activities especially in the area of mineral resource development.

The country's mineral resources largely remained unexplored and unexploited during the war period and even recently, the country's mineral resource still remain under developed due to the lack of capital, specialists, and technology. Development of the minerals sector in Cambodia has also been limited by limited geological information and unattractive conditions for investors in this sector. In general, Cambodia does not produce metallic minerals in any significant scale, and the mining activity in this country is mainly for construction materials.

Nowadays, most of construction materials are produced from quarry companies which most of them are small scale operation and supply aggregate for construction. In particularly, limestone is the main source of aggregate, and limestone is burnt to obtain calcium oxide for commercial uses. For cement industry, the standard calcium oxide content of limestone should be at least 45 percent. Typically, 1.4 to 1.5 tons of limestone is required to produce 1 ton of clinker.

Geologically, limestone resource of the country locates in the southern part of Cambodia in particular in Kampot Province. Kampot Province, located 130 km, south of Phnom Penh, is contains of big resource of Limestone where very high potential for cement production.

1.2. Status of Cement Industry in Cambodia

During 2009-2010, the construction and real estate sectors have taken an impact from the global crisis, resulting in reduced wealth and an increase in lay-offs. A number of multi-billion dollar construction projects have been frozen or scaled down, resulting in thousands of both semi-skilled and unskilled workers, most of who are from rural areas, lose their jobs. The country GDP contracted to 0.1 percent, resulting from poor exports of garments (volumes down by 16 percent), smaller tourism receipts (down by 2 percent with tourist air arrivals reduced by 10 percent), and weak inflows of foreign direct investment (down by 35 percent). These negative impacts were compounded by credit crunch and a severe slowdown in construction sector. This situation had a direct impacted to the construction project and unavoidability the demand of cement.

In the following year 2011, the 6.0 percent GDP growth was being driven by strong exports of goods and services, private investment, and macroeconomic. In the first half of 2011, the construction and real estate sectors remained subdued after experiencing negative growth last year. The garments, tourism, construction and agriculture had been the main engines of growth, even though; the global economic crisis was hitting these sectors hard in the past year. The real estate sector fell by 15.8 percent and construction dropped by 25.5 percent in 2011. The Cambodia's GDP during 2006 to 2013 is presented in Table 1.1. From the Table 1.1, the GDP of Cambodia posted a strong growth from 2006-2008, and drop significantly during 2009 global economic crisis, and strongly recover from the year 2010 onward.

Table 1.1 GDP grow rate from 2006-2013 in Cambodia

Year	2006	2007	2008	2009	2010	2011	2012	2013
GDP	10.77	10.2	6.7	0.1	5	6	6.5	6.5

Sources: *Cambodia economic and statistics year 2012*

In terms of population, the population of Cambodia is growing from year to year. The growth rate was 1.68 percent in 2012. In Phnom Penh alone, the capital of Cambodia has the population of 3 million compared to 14.9 million in total (Cambodia statistics, 2012). Currently, the population in Phnom Penh is on the increasing trend due to the migration of the rural people to the capital seeking job and study opportunities.

At current state, most of the people in Cambodia prefer home and apartment built from concrete instead of using wood or bamboo because wood are very expensive compared with the concrete. Many construction projects have been built especially in Phnom Penh city and nearby provinces to satisfy the demand of the population. Therefore, the demands of cement also increase in accordance with these projects.

The demand of cement had decreased during the economic crisis in 2009. During that time, most of the construction projects had been postponed and it was also effect to cement demand, and then cement production. After 2009, in 2010 and 2011, the demands of cement had picked up rapidly because of construction boom after recovery from the global economic crisis. Nowadays 2013, the demand of cement is **2.5 million ton (MT)** per year, compare to the domestic supply of cement which is only available at **1 million ton** per year leaving the shortage of **1.5 million tons on the** demand side. The demand and supply of cement in Cambodia indicated that Cambodia got an effect from global economic crisis and the demands of cement were reduced for the short period of time (2009). However, the demand for cement production is increasing immediately in the next following year 2010. In these regard, the quarry development for cement production in Cambodia is required to balance the domestic demand.

In view of the shortage supply, this shortage quantity is imported mainly from Thailand and Vietnam to make balance in construction sector. Figure 1.1 shows the supply of cement in Cambodia in year 2012.

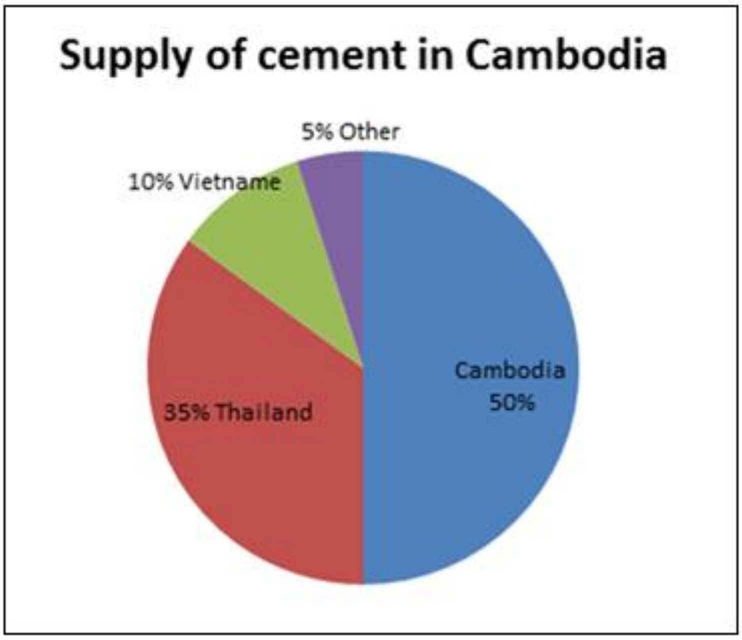

Figure 1.1 Supply cement in Cambodia in 2002

According to the Figure 1.1, Cambodia is able to supply the cement only 50 percent of domestic demand while the remaining are imported from Thailand, and Vietnam of 35 and 10 percent respectively. In this situation, Cambodia really needs to develop more quarries for cement industry to strike a balance of domestic use and reduce the import quantity.

1.3. Government Policy Frameworks

The policy and law of Minerals Management and Mining of Cambodia, for all domestic and foreign companies who invest in mining sector were promulgated by the government since July 13, 2001 by the Ministry of Industry Mines and Energy (MIME) which are tabulated in the Table 1.2 below. In Table 1.2, two stages of mineral development activities are prescribed. First, the mineral exploration which involves all the necessary exploration activities must be carried out within 2 years prior to the decision whether to continue to the development stage. Second, the mineral development, given that the mineral deposit is feasible for mining development, the mining license is valid for 5 years term, and can be renewed for another 10 years.

Table 1.2 Law and regulation for mining in Cambodia

Stage	Mining tenements	Provisions	terms
Mineral Exploration	Mineral Exploration License	Exclusive right to conduct exploration within specified area	Valid for 2 years and renewable for up to 4 years (2 years at a time). Maximum area 200 km^2.
Mineral Development	Industrial Mining License	Exclusive right to extract minerals within specified area	Valid for 5 years and renewable for another 10 years (5 years at a time).

Source: *Ministry of Industry Mines and Energy in Cambodia*

To promote local and foreign investment in Cambodia's mining sector, the government has strengthened the country's legal framework, bolstered its institutions and liberalized the relevant regulations, in ways that are positive to private sector investment and business activities in Cambodia. In mining sector, Investor can set up 100 percent foreign owned investment project and be able to employs skilled workers from overseas, only in cases these workers cannot be found in the domestic labor force. The law for **Management and Mining of Mineral**

Resources was drafted in 1996 and approved by the cabinet in 2000. The new law was promulgated by the Government on July 13, 2001

It's the fact that, the mining project relies on the available infrastructure connected to the mine site. Nowadays, the government has many infrastructures, roads, and bridges that connected from city to city, city to province and province to rural area. Most of projects have been approved by government since 2000. These infrastructures can be proved benefit for the mining project.

According to the government activity to mineral industry, government is taking a good care to all invested mining companies in Cambodia. Some laws have set on investment provides the following incentives to investment projects in Cambodia, for example;

- A corporate income tax rate of 9 percent, except for the exploration and exploitation of natural resource include timber, oil and gas, gold, and precious stones.
- Losses carried forward for up to five years.
- Non-taxation on the distribution of dividends, profits or proceeds of investments, whether transferred abroad or distributed within the country.
- A corporate tax exemption of up to eight years, depending on the characteristics of the project and the priorities of the government.
- 100 percent import duty exemption on construction materials, means of production, equipment, intermediate goods, raw materials and spare part used by:
    - An export-oriented project with a minimum of 80 percent of the production set apart for export.
    - Projects located in the designated special Promotion Zone.
- 100 percent exemption of export tax, if any.

Although the government not specifically provide incentives to quarry and cement industry, but some incentives stated above can be applied to quarry and cement industry. In addition to the current shortage of cement domestic supply, the quarry development for cement project in Cambodia would be very attractive.

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1.4. Geology and Site Investigation

Cambodia is geologically composed of three different structures: the Triassic and Liassic "Ancient Gulf" cover a large area in the East; the Jurassic-Cretaceous continental sandstone forms important highlands in the West and, between them, the Quaternary basin which occupies the whole central plain of the country.

Geological studies show series of sedimentary formation extending from Precambrian at the bottom through to Cretaceous at the top, the whole are affected by successive tectonic and volcanic activities. The Tertiary formation, of which outcrops are very limited on land, formed a thick layer in the sea bottom and seems to be an important target for the oil and gas exploration.

Geologically, limestone formation distributes in Battambang and Kampot province belongs to Permian period produced a sedimentary sequence of sandstone, shale, fossilferrous, and andesite. Such limestone suitable for the production of aggregate and lime for construction purposes and cement manufacture. Limestone is classified as rock containing at least 80 percent calcium carbonate, and the remaining small percentage of silica, and magnesium oxide. To be commercially useful, limestone must not only have a reasonable high and consistent purity, but must also occur in bedded of sufficient horizontal and vertical extent to suitable for quarrying, and locates close to the available transportation system and potential markets.

As mention earlier, in Cambodia the most limestone deposit is the Permian limestone series of the southern and western provinces such as Kampot, Battambang, Pursat, and Kampong Speu. In this study, the research area is selected at Prey Ta Pret village, Sdach Kong Khang Leach commune, Banteay Meas district, Kampot province. The research area is located 22 km northeast of Kampot town, and 130 km south of Phnom Penh. The research area is selected based on the quality and quantity of limestone deposit and the infrastructure within that area. From the survey of geological of drill holes data, it's shown that the CaO percentage gives average of 52 percent which is considered a good quality for cement production in addition to the large extent of limestone deposit. The research area is close to the national road which can connect to the main seaport. The geology map of Cambodia is presented in Figure 1.2, and the research area is presented in Figure 1.3.

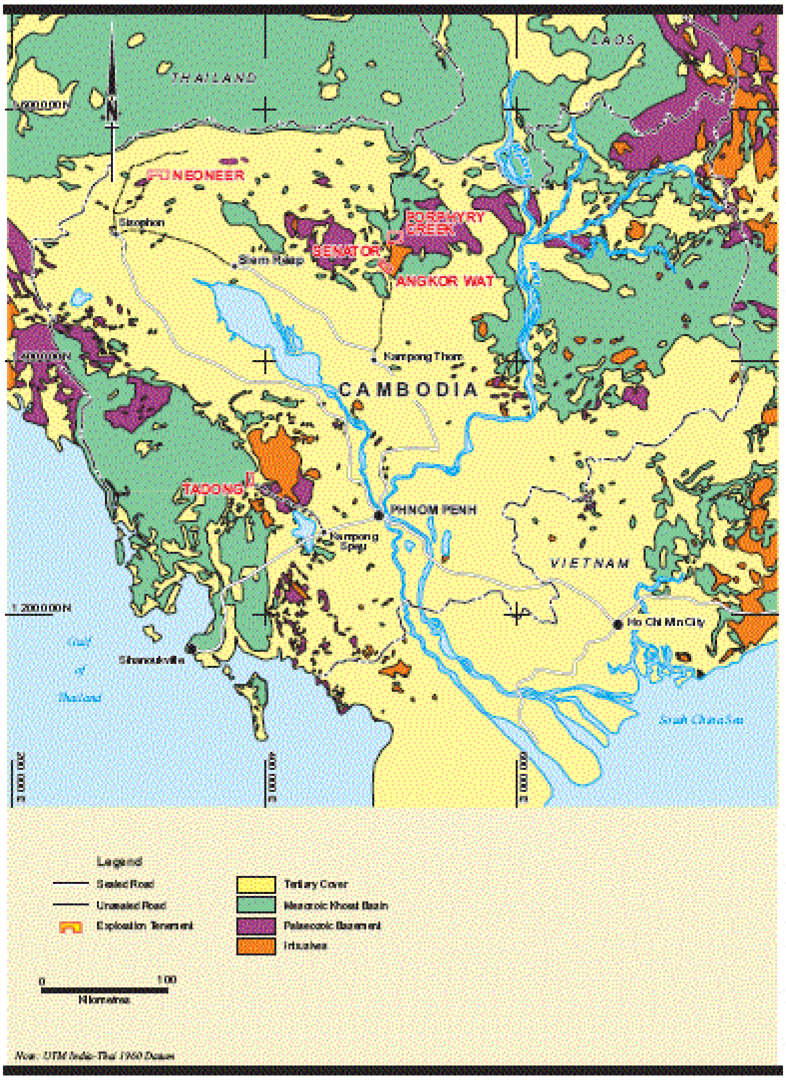

Figure 1.2 Geological map of Cambodia

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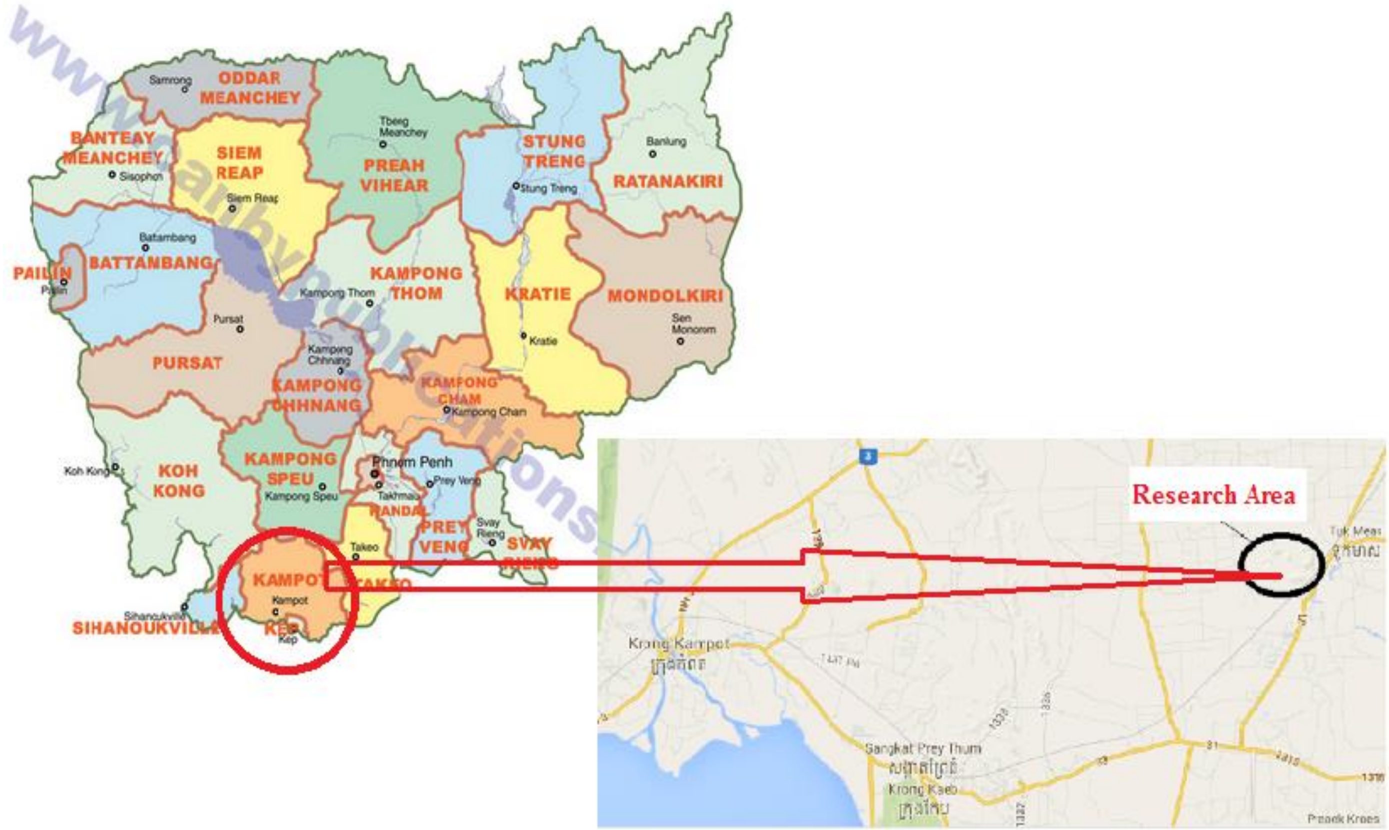

Figure 1.3 Research area at Kampot province

1.5. Formulation of the Research Problem

Cambodia is a developing country. Mining industry is very important to the country, and it is in the pre-development stage. Lacks of human resource, technique development are common in mining development especially in quarry sector. Modern human resource development in mining sector has just started in 2013 at Institute of Technology of Cambodia (ITC) when the mining curriculum has established and at the same time the mining industry starts to implement all activities (exploration, development and operation). For quarry development, it involves geological exploration, resource estimation, mine design, mine operation (drilling, blasting, loading and hauling), and environmental consideration. To effectively carry out the quarry development, the country has to develop human resource with the supporting knowledge related to all mining activities.

This research provides a framework of quarry development for cement industry in Cambodia. It emphasizes 3 stages of quarry feasibility study which are technical, financial, and environment.

1.6. Literature Review

Larry B. Smith (2005) conducted a research to technical report and qualified person review eagle rock quarry. This research focus on the development aggregate resource to be mined crushed and transport. Preliminary assessments are prepared in this researches which are equipment selection, processing, reclamation, economic, environmental, operating cost and financial model. The result of this research is given at 20 year mine life with production 6 million ton per year. There are 5 classes aggregate for sale through 4 stage crushing and screening operation. The financial analysis in 2002, result the after tax return of from 18 percent to 32 percent (Smith, 2005).

There are a few of researches about quarry in Cambodia. Nearly 10 years ago the quarries have been developed very slowly. In 2007, one quarry company has been established which located at Kampot province. Kampot Cement Company (KCC) is the first cement company and the biggest quarry mining in Cambodia, joint venture between Siam Cement Group (90 percent) and the Khaou Chuly Group (10 percent), which located in the Touk Meas District, Kampot province, 130 km south of Phnom Penh. It started production during the second quarter of 2007. Output from the Kampot plant mainly served domestic consumption. KCC produces thousand ton of cement every day from the main raw material of limestone deposit in Kampot province. Kampot Cement Company has developed the quarry in Cambodia and transferred the technology to the local people for developing quarry in Cambodia.

Do Manh Cuong (2010) present the current situation of limestone cement management in Vietnam and the new application of 3D block model for improve the quality of limestone production and the effect of quarry operation. The case study is providing with the Thanh Luong limestone deposit at Ha Tien 1 Cement Company. As the result, the quality of limestone operation is controlled by computer program 3D block model. The result are very satisfactory and positive (Cuong, 2010).

Sindh Board of Investment (2010) published the pre-feasibility study granite quarry project. The concept of the pre-feasibility study granite provides the information to investor for preparing quarry project. This study focuses on financial analysis and sustainable socio economic benefit. As a result, the initial cost of the project including the working capital is 9,200,600 Rupee with the estimate of sale cost given at 33,133,373 rupee. The annual internal rate of return of this project given at 49.7 percent with the approximately of 2 year 11 month payback period estimated (Invesment, 2010).

1.7. Objectives

Considering the above background and formulation problem, this research is conducted with the following objectives:

- To construct the geological block model to calculate the ore resource potential and to provide an input for quarry operation and design.
- To formulate an optimum quarry development involving ore modeling, reserve estimation, pit design, mine operation, and mine rehabilitation.
- To develop a financial analysis involving cash flow model, Net Present Values (NPV), and the Internal Rate of Return (IRR).

1.8. Usefulness

The final results from this research will benefit the quarry development in Cambodia in many aspects

1. It provides the framework for quarry pre-feasibility study in Cambodia by taking a full consideration of local factors (infrastructure, cost factor, environmental issue, etc.).
2. It illustrates the technical requirement and its designed parameters for resource estimation, mine optimization, mine planning and design, mine operation (drilling, blasting, loading and hauling), mine environment, and rehabilitation.

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CHAPTER 2
METHODOLOGY

The methodology employed in this study consecutively comprised of 3D block model construction, statistical analysis, mine optimization, mine design, mine economics, and environment. The content related to these techniques will be discussed.

2.1. 3D Block Model

Currently, most of activities in exploration and mining operation revolve around the 3D block model. In this model, all relevant mineral deposit characteristics are organized in a transparent and manageable way. The quality of the productivity and efficiency of activities are controlled by the 3D block model. Generally speaking, 3D block model is a simplified mathematical description of a deposit. The deposit is subdivided into small blocks that each block represents a planning unit which contains information about raw material properties such as chemical grade, rock type, geology, geological structure condition, etc. the model of 3D block is illustrated in Figure 2.1 (William Hustrulid, 1995).

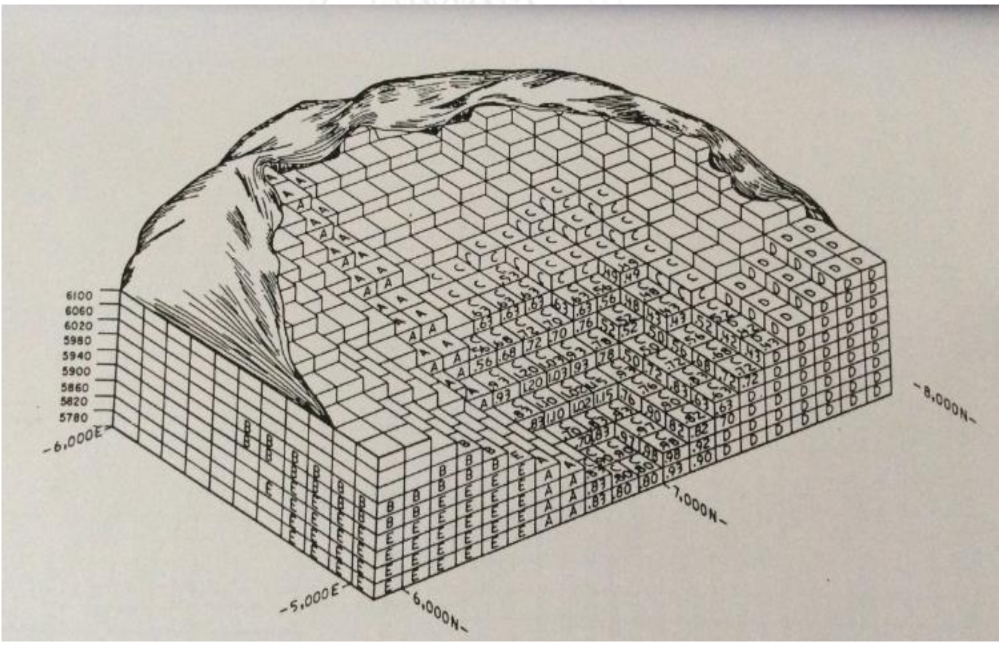

Figure 2.1 3D Block model matrix

In practice, the estimation for the grade and tonnage is carried out by interpolating the ore grades into the block where the overall statistics of the deposit can be made.

David (1977) illustrated the rule of thumb for block size consideration, the minimum size of a block should not be less than ¼ of the average drill hole interval. It's mean that 50 meter block dimension for a 200 meter drilling spacing grid. In mining practice, the bench height is designed as the height of the block (William Hustrulid, 1995).

After defining the block dimension, the tonnage and the grade of each block will be estimated. The interpolation technique is used to calculate the grade of these blocks. Many of interpolating techniques are available such as the triangular method, polygonal method, inverse distance weight method (IDWM), and geostatistic method. The principle of these interpolating techniques built on the weighting criteria and the area of influence of the surrounding data to the estimated block. The IDWM and geostatistic method are commonly used for block model estimation due to their advantage on assigning weigh factors based on data distribution. In this thesis, the IDWM will be used for block model calculation.

2.2. Inverse Distance Weighting Technique

The Inverse Distance Weighting method calculates the block values (assay grade) by weighting of values of geometric data in the neighborhood of each estimated block. The points located closer to the block center have more influence or weight in the process of weighting. It is sure that the grade of the block should be more similar to nearer point than those far away. This method assumes that influence of the variable entered on the map decreased with the increase of the distance from its sampling location. The optimization of the interpolation parameters focuses on the exponential power 'm', search radius, and maximum/minimum number of closest sample (nearest neighbors) use to interpolate grid-cell concentration. The general equation to calculate the Inverse Distance Weighting technique:

$$g = \frac{\sum_{i=1}^{n} \frac{g_i}{d_i^m}}{\sum_{i=1}^{n} \frac{1}{d_i^m}} \qquad \text{(eq. 2.1)}$$

Where g is grade of the ore

d is the distance from the center of the block to the nearby block.

m is the power function.

The power function, m, varies in response to the variation of ore grade. For limestone deposit, the limestone properties show continuous grades. Therefore, the power function of 2 (m=2) is chosen for this IDWM calculation. It's then called Inverse Distance Squared Weighting (IDSW).

The equation (eq.2.1) becomes:

$$g = \frac{\sum_{i=1}^{n} \frac{g_i}{d_i^2}}{\sum_{i=1}^{n} \frac{1}{d_i^2}} \qquad \text{(eq.2.2)}$$

Figure 2.2 illustrates the IDSW block calculation.

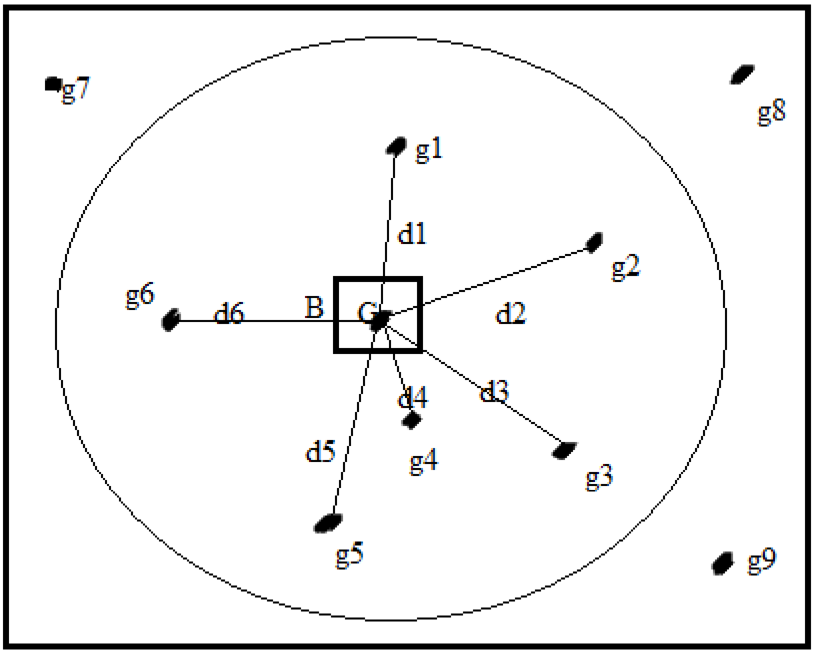

Figure 2.2 IDWS block calculation

2.3. Statistical Analysis

Inverse Distance technique is used to calculate the grade of the ore block. This application is based upon the selection of the power 'm' and the radius of influence 'R' for the sample search area. The minimum value of the radius R is determined by the sufficient number of point for the calculations. It varies with the drilling pattern. The estimated blocks values vary according to the nature of the sample data. In this step, the statistical analysis is employed to understand the distribution of the estimated data.

2.3.1. Basic Statistics

In the statistics analysis, statistical parameters are calculated for the selected variables, in this study the selected variables are the chemical grade of limestone. The variation of limestone grade will be displayed via histogram and cumulative probability distribution plots.

The histogram plot shows the limestone grade distribution with the frequency of each range. The cumulative distribution function (CDF) is other method to calculate the distribution of the grade. The plot of cumulative distribution functions illustrates how many percentage of the grade that lower or greater than the observed values. The cumulative frequencies of the grades are calculated by using:

$$C_f = \frac{100(i - 1/2)}{n} \qquad \text{(eq.2.3)}$$

Where i is the i-th observation

n is the total number of observation

C_f is the cumulative frequency (%)

Together with the histogram and CDF, other statistical parameters are calculated such as the minimum, the maximum, the average, median, variance, skewness, and the standard deviation.

2.4. Geometrical Considerations

For open pit mining operation, the ore body is mined from the top down in a series of horizontal layer called benches. Mining start from the top to bottom of the bench, and continued to the next layer. The process continues until reached the bottom bench elevation. A road or ramp is created to access to other benches. The width and steepness of the ramp depend on the type of equipment selection. Overall slope angle is an important geometric parameter that has significant impact on mine configuration. In open pit mining, the selection of mining machinery relates to the physical size and the space requirement to enhance the efficiency of operation. Drilling, loading, and hauling equipment require an amount of working space.

2.4.1. Basic Bench Geometry

The vertical distance between the highest point benches (crest) to the lowest point bench (toe) is call bench height. Figure 2.3 illustrates the part of bench geometry. The bench faces angle is the horizontal angle of line connecting bench toe to the bench crest. It varies from 55 degree to 80 degree for the most hard rock mining.

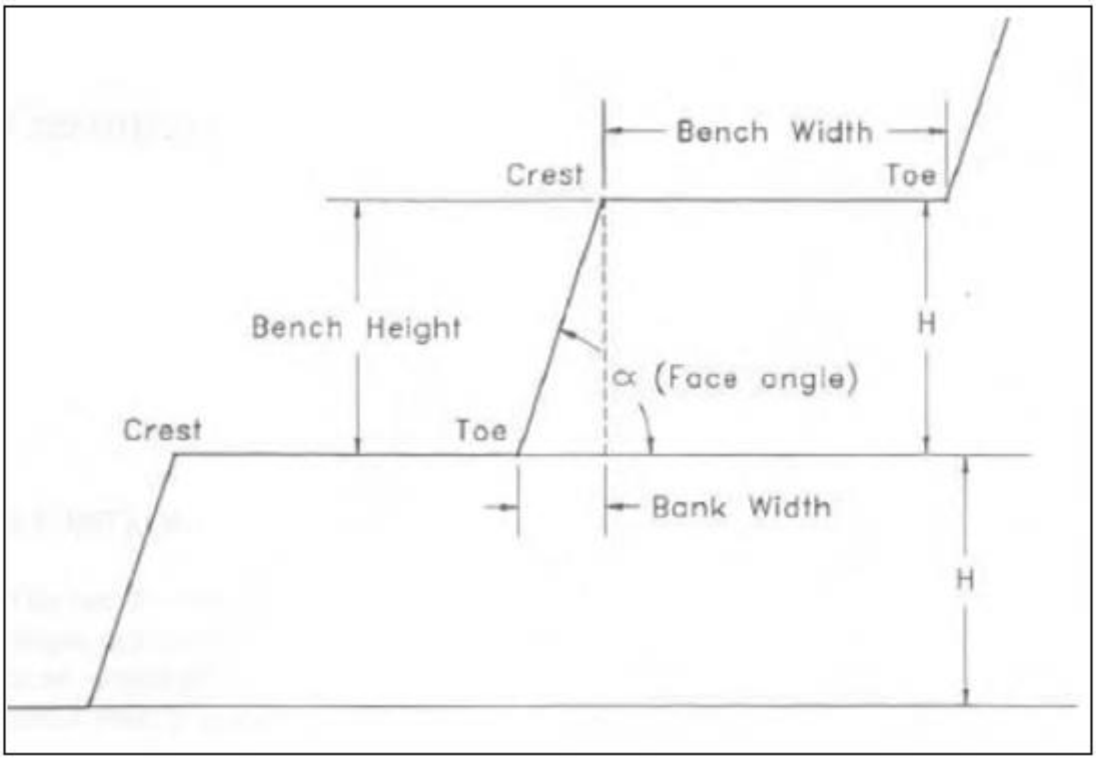

Figure 2.3 Bench configuration

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2.4.2. Pit Slope Geometry

In the pit design, there are many of slopes and benches connected from crest to toe of each bench. The angle measured from the bottom bench toe to the top bench crest is called overall pit slope angle. It's the angle that the wall of the open pit stand and it's determined by the rock strength, geologic structure and water condition. Figure 2.4 illustrates the overall pit slope angle with 5 benches and overall pit slope angle of 45 degree.

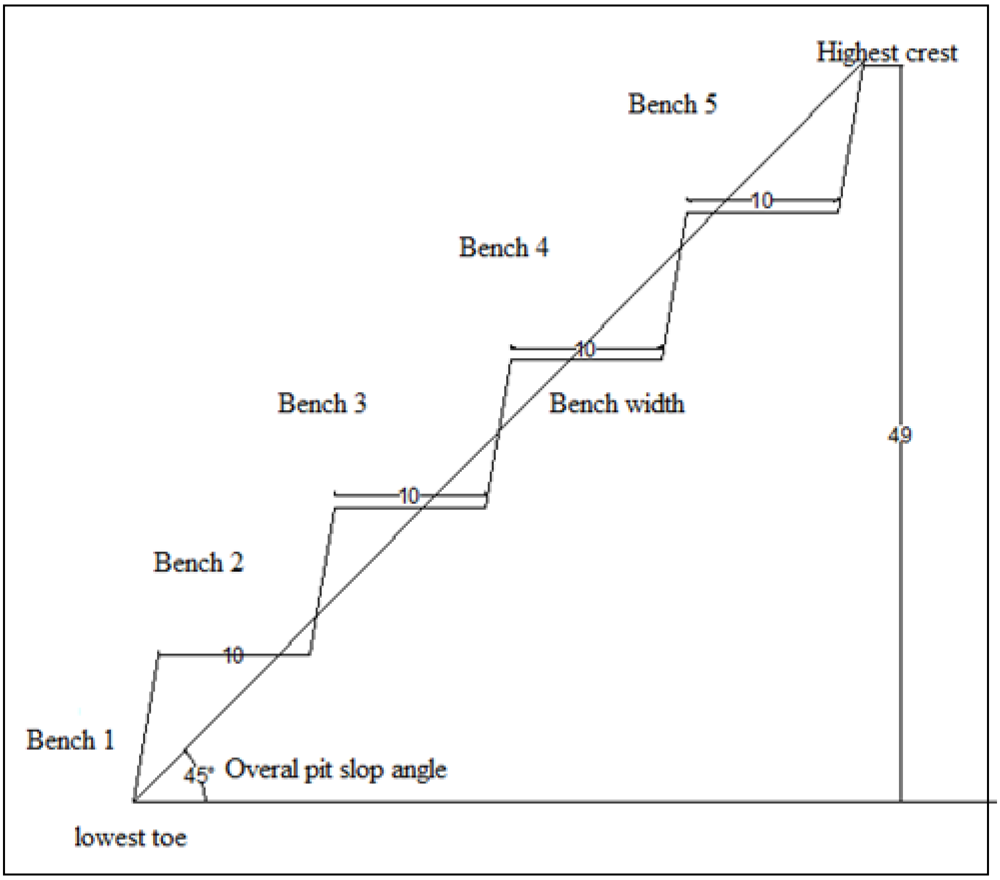

Figure 2.4 Overall slope angle with 5 benches

2.4.3. Stripping Ratios

One method to describe the geometrical efficiency of a mining operation is through the use of the term “stripping ratio”. It referred to the amount of waste that must be removed to release a given ore quantity. The ratio is most commonly expressed as

$$SR = \frac{\text{Waste (ton)}}{\text{Ore (ton)}} \qquad \text{(eq.2.3)}$$

In this study, the ore is defined based on the block model containing the grade above the cutoff grade values, and the waste is defined as the block model containing the grade below the cutoff grade values.

2.5. Economic Block Model

The block model represents ore body, and the storage of the information within the block. For the economic block model, the block values, overall slope angle, and block discretization are assigned to optimize the pit. In this study, two optimization techniques are available which are floating cone method and Larches-Grossmann method. The Larches-Grossmann method is used in this study.

Floating cone is the technique for determining the final pit configuration. In the manual process, the cone is floated from the left to right on the first row of the block to find the positive block to be removed. In the second row, start searching from the left to find the positive block and if the sum of all block falling within the cone are positive, the blocks are mined. The process continues search the block from left to right and top to bottom in floating cone process until no more blocks can be mined. After that, go back to the first row again and repeat the process for a second iteration. If no positive block can be found, the mining operation will be stop. The identification of the block to be negative or positive is depending on the economic block value or the quality of the ore block to be defined. In the process of using computer program, it is more convenient to use the net values of the block directly.

Lerchs-Grossmann is also the technique for determining the optimum design of open pit mine. This method is published in 1965 by Lerchs and Grossmann. The concept of this technique is block geometry. The block is selected based upon the slope angle and the slope is formed by moving up one block and over another block. The point important of this method is the ratio of block height per block width.

Mineral and economic data are combined to assign a net dollar value to each mineral model block. It’s similar to the block model that the block model is represent in tonnage and economic block model is represented in the dollar or other currency.

2.6. Financial Analysis

Financial analysis concerns the discounted cash flow (DCF) calculation, the Net Present Value (NPV), and Internal Rate of Return (IRR).

2.6.1. Discounted Cash Flow

The criterion most commonly employed in the minerals industry when evaluating the rate of return on an investment proposal is called the discounted cash flow rate of return (DCF-ROR) (Mian, 2002). The DCF-ROR is referred to the net inflow or out flow of money that occurs during a specific time period. The elementary cash flow calculation is:

Gross profit = Gross revenue-operating expense

Net profit = Gross profit (taxable income) - tax

Cash flow = Net profit + DD&A - Capital Cost

The discount cash flow method is widely accepted and used in the industry for all types of capital investment evaluations. The discounted cash flow method recognizes the time value of money. This is critical when assessing the profitability of long term investments. Future and past values of money can be converted into their present value equivalent by using the time value of money concept.

2.6.2. Weight Average Cost of Capital (WACC)

In financial model, the weighted average cost of capital, or WACC, is the rate that a company is expected to pay on average to all its security holders to finance the project. The WACC is the minimum acceptable return that a company must earn on an existing project base to satisfy its creditors, owners, and other providers of capital, or they will invest elsewhere.

The formula to calculate WACC is;

$$WACC=E/V \times R_e + D/V \times R_d \times (1-T_c) \qquad \text{(eq.2.4)}$$

Where:

R_e is cost of equity.

R_d is cost of debt.

E is Market value of the firm's equity.

D is Market value of the firm's debt.

V=E+D is the firm value.

T_c is Tax rate.

Weighted average cost of capital is used in discounting cash flow for calculation of NPV and other valuations for investment analysis.

WACC represents the average risk faced by the organization. It would require an upward adjustment if it has to be used to calculate NPV of project which is more risk than the company's average projects and a downward adjustment in case of less risky project.

2.6.3. Internal Rate of Return (IRR)

Internal rate of return (IRR) is another important and widely reported measure of profitability of the project. IRR is reported as a percentage rather than a dollar figure such as NPV. IRR is the discount rate at which the net present value is exactly equal to zero, or the present value of cash inflows is equal to the present value of cash outflows. Another definition of IRR is the interest rate received for an investment consisting of payment (negative value) and income (positive value) that occur at regular period. The equation for calculating IRR is:

$$\sum_{t=1}^{n} \frac{NCFt}{(1+IRR)^{t}} = 0 \qquad \text{(eq.2.5)}$$

NCFt is net cash flow.

IRR is the Internal Rate of Return.

The investment decision when using IRR is whether to accept the investment if the calculated IRR is greater than the return on the alternative use of funds or cost of capital, and to reject the investment if its calculated IRR is less than the return on the alternative use of funds or cost of capital.

2.6.4. Net Present Value (NPV)

The net present value (NPV) is the present value of cash surplus or present worth, which is obtained by subtracting the present value of periodic cash outflows from the present value of periodic cash inflow (Mian, 2002). The present value is calculated using the weighted average cost of capital of the investor, also referred to the discount rate or minimum acceptable rate of return.

When NPV of an investment at a certain discount rate is positive, it pays for the cost of financing the investment or the cost of the alternative use of funds. The investment generates revenue is equal to the positive present value. It also implies the rate of return on the investment is at least equal to the discount rate. The net present value method of evaluating the desirability of investments is mathematically represented by the following equation:

$$NPV = \frac{S_1}{(1+id)} + \frac{S_2}{(1+id)^2} \frac{S_3}{(1+id)^3} + ... + \frac{S_n}{(1+id)^n} - I_o$$

$$NPV = \sum_{t=1}^{n} \frac{S_t}{(1+id)^t} - I_o \qquad \text{(eq.2.6)}$$

$$NPV = \sum_{t=1}^{n} \frac{NCFt}{(1+id)^t}$$

Where

S_t= the expected net cash flow (gross revenue-LOE-taxes) at the end of year t

I_o is the initial investment outlay at time zero

id is the discount rate

n is the project's economic life in years.

NCF is net cash flow.

If the NPV is positive, then the project is acceptable. If the NPV is negative, then the project is rejected. If the NPV is zero, the analyst will be indifferent because the proposal is generating the same return as the alternative use of funds will generate. The NPV decision criterion follows directly from the assumption that the analyst is required to maximize the value of the project. This criterion results in optimal choice of project.

2.7. Mining Operation Development

In mining operation, technique development is the main key important and also the role to enhanced the quarry or mining successfully. In this step, it will describe the main process of mining operating which is operated on the daily basis. The mining operation revolves around the drilling, blasting, loading, and hauling sequence.

2.7.1. Drilling

Drilling operation, in the field of blasting, is the first operation to be carried out and its purpose is to drill the blast holes, with the adequate geometry and distribution within the rock mass, where the explosive charge will be placed along with their initiating devices. There are many types of drilling method such as rotary, percussion, and combined rotary and percussion method. In this research, the combined rotary and percussion drilling method will be used (Carlos Lopez, 1995).

Drilling by rotary percussion is the most classic system for drilling blast holes. The drilling principle of rotary percussion rig is based upon the impact of a steel piece (piston) that hits a utensil which transmits at the same time the energy to the bottom of the blast hole by means of the final element called the bit. In Figure 2.5, it illustrates the top hammer drill, one of the two large groups of rotary percussion. Top hammer drill are produced outside the blast hole, and transmitted by the shank adaptor and the drill steel to the drill bit. The hammer can be driven hydraulically or pneumatically (Tatiya, 2005).

Figure 2.5 Top hammer drill

2.7.2. Blasting Pattern

Fragmentation has a large impact on quarry performance at every stage of the drilling, and blasting process. Blast holes layout should be designed with respect to the collected survey data, and hence the accuracy and interpretation of this data are very important. Safety parameters, vibration limits, explosive to be used must be considered when designing the pattern. The resulting blast design plan should clearly specify the burden, spacing, drill holes diameter, type and quantity of explosives and type of delay detonator (William Hustrulid, 1999). The following list of blasting pattern dimension symbols is shown in Figure 2.6.

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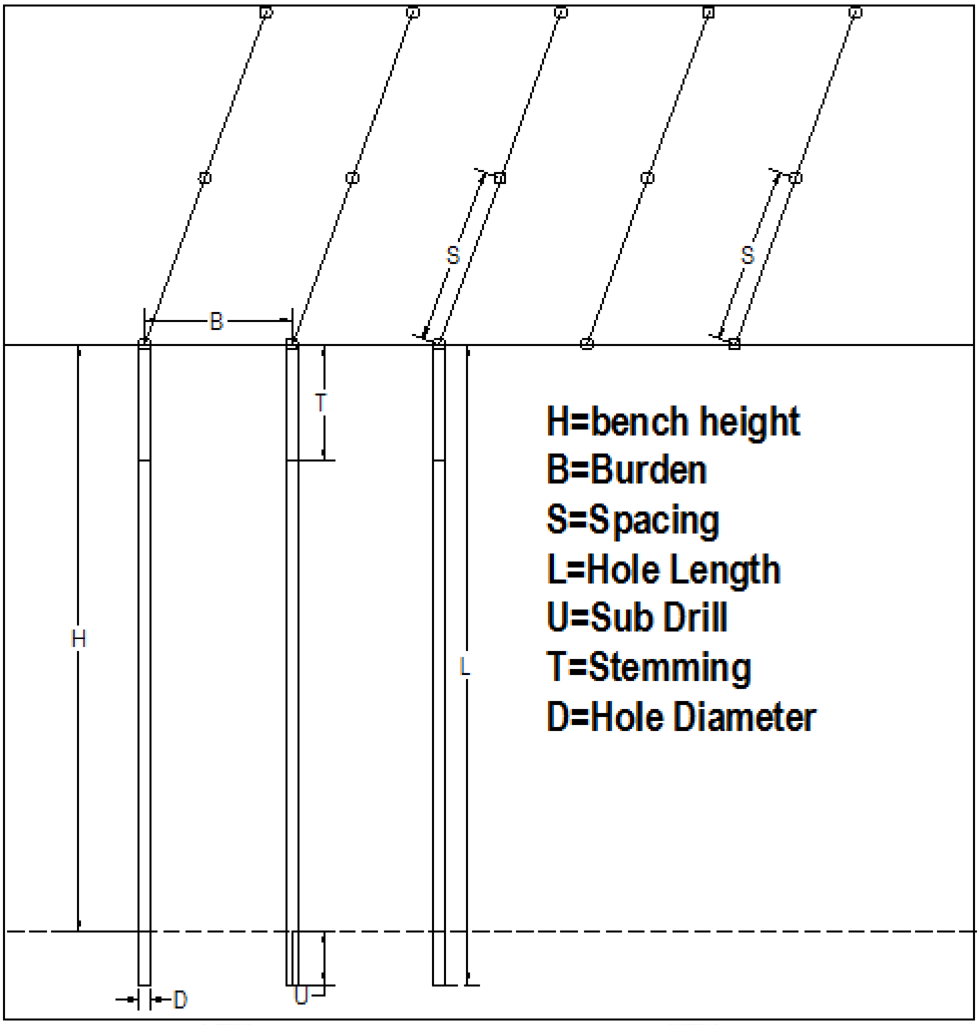

Figure 2.6 Blasting pattern

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2.7.3. Loading and Hauling

A surface mine contains pits with mineral endowed rock or ore. The surface mine extracts ore that lies within the upper layer of the mine boundary. Figure 2.7, illustrates the process for creating a pit in sequentially manner. The process starts when the explosive loosen the earth; then excavating equipment remove vertical layers (benches) of material. Over time, these benches themselves are blasted, excavated and removed, making the pit wider and deeper. Mining engineers categorize the mined material into ore and waste material, with sub categories depending upon the quality or grade of the ore. Trucks transport this material to a number of dumpsites, which can include crushing, stockpiles, and waste dumpsites.

The long-term mine plan optimizes the timing of bench development such that market demand is met and the value of the mine is maximized. The plan, alongside the optimization of the shape of the pit provides required productivity rates, bench sequences, and the shape of the mine (including bench heights). The height of the bench is varied and dictates the type of equipment that can remove it. There are alternate practices for conducting material movement in mine, however, for large-scale open pit mining, in particular, the truck and loader material movement practice is the preferred method of materials handling (*SME Mining Engineering Handbook*, 1992).

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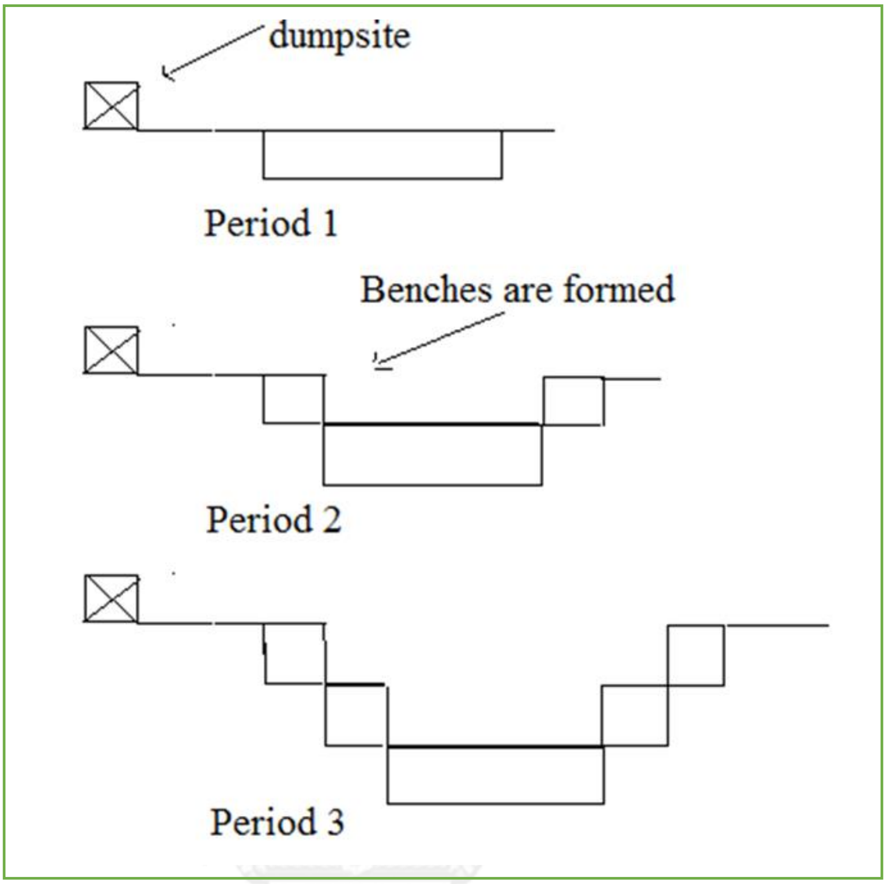

Figure 2.7 Mining sequence and planning

- **Loader**

Loader lifts the ore and waste material onto the trucks for removal from the mine. In an open-pit mine, loader types can include hydraulic excavator, backhoe excavator, and front-end loader (wheel loader). The type of loader selected for use in a surface mine depends on the type of mineral to be extracted and specifications of the mine geometry, such as the bench height. Other factors must be considered in the equipment selection process, particularly, the compatibility of the loader with selected truck fleet. For example, some loader cannot reach the top of the tray on the larger trucks. Conversely, some loader capacities exceed the capacity of the truck. If the best truck and loader set are determined, then the truck and loader type will be selected simultaneously (Christina, 2013).

The equation to estimate the production per hour of the wheel loader is;

$$O = \frac{BC \times BF \times D \times MA \times JF \times 3600\,\mathrm{sec}}{(1+SF) \times CT} \qquad \text{(eq.2.7)}$$

Where, O: Production, ton//hour.

BC: Bucket size, cubic yard (CY).

BF: Bucket Fill factor, percent.

D: Density in Place, ton/CY.

MA: Mechanical Availability, percent.

JF: Job Factor, percent.

SF: Swell Factor, percent.

CT: Average cycle time, second.

- **Cycle Time of the Truck**

The truck cycle time itself comprises load time, haul time (full), dumping time, return time (empty), queuing (and other delays) and spotting times. A cycle may begin at a loading site where the truck receives its load from the excavating equipment. The truck travels full of ore to the dumpsite via a designated route along a haul road. The dumpsite may be a stockpile, waste dumpsite. After dumping the load, the truck turns around and travels empty back to the loader. Spotting is the act of maneuvering the truck under the loader for serving. This can take several minutes. In a large mine, the truck cycle time may be 20-30 minutes in total, and can vary significantly over time if the stockpiles move and as the mine deepens. Figure 2.8 (Christina, 2013) illustrates the cycle time of the truck from the loader and dumpsite.

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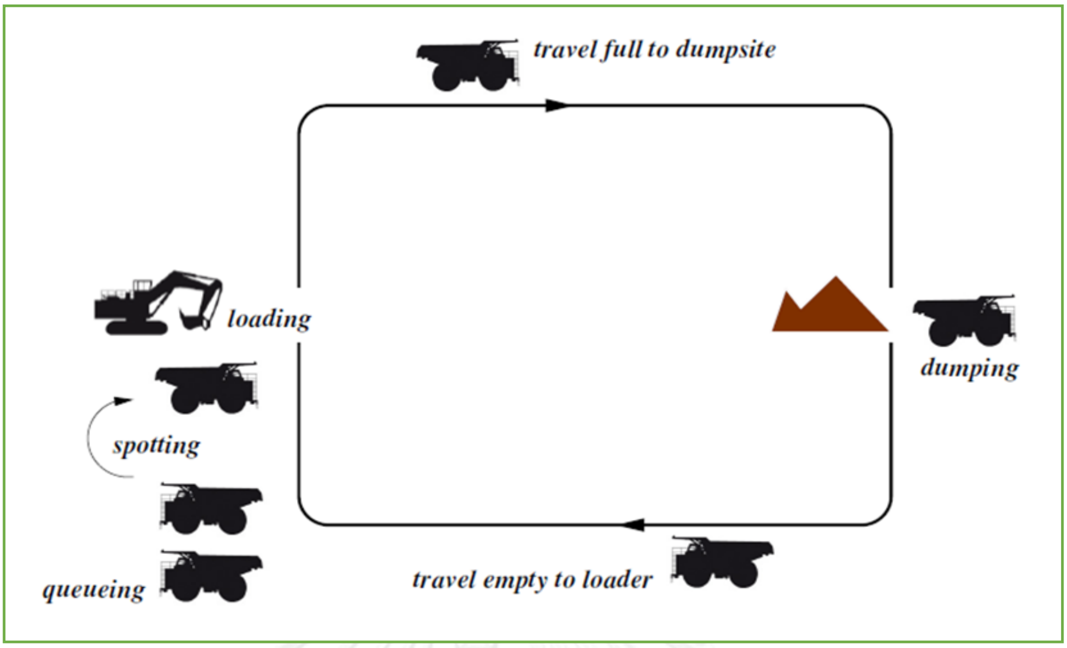

Figure 2.8 Cycle time of the truck

The average cycle time (C) is another parameter to determine the production rate in each cycle time of equipment. Table 2.1 (*Caterpillar Performance Handbook*, 1979-2004) illustrates the average of cycle time that increase with the size of the equipment.

Table 2.1 Average cycle

Loader size (cubic yard)	Cycle time (minute)
1.7-4.5	0.45-0.50
5.0-7.5	0.50-0.55
7.5-11	0.55-0.60
15-21	0.60-0.70

CHAPTER III

THE RESULTS OF THE STUDY

In parallel with the adopted methodology, this chapter displays the results of model development comprising of drill holes data input, statistical analysis of variables, geological model construction, resources estimation, pit optimization, mineable reserve estimation, and quality of limestone for cement industry. The results of mine planning and scheduling, master plan consideration and financial analysis are also displayed and discussed in detail.

3.1. 3D Block Model Development

The 3D block model is constructed on minesight software platform. The minesight work flow starts with drill holes data input, statistical analysis of variables, and geological model construction. The results of these processes will be discussed.

3.1.1. Drill Holes Data Preparation

In this project, the selected study area cover an approximate area of 1,300 x 600 sq. meters, extending from the grid coordinates 728310 to 729667 in the Easing direction and from the grid coordinates 1615254 to 1615826 in the Northing direction. There are 21 drill holes and 336 assay data. The drill hole description starts from C1-11 to C1-16, C1-20B, C1-21 to C1-29, and C1-5 to C1-8. All the drill holes data contains the coordinates of each hole and the grade of silica (SiO_2), magnesium oxide (MgO), sodium oxide (Na_2O), calcium oxide (CaO) and iron oxide (Fe_2O_3) as illustrated in Figure 3.1.

Drill hole ID	Eesting	Northing	Elevation	Interval	Azimuth	Dip
C1-11	729255	1615425	200	10	-45	65
C1-11	From	To	Interval	Sio2	MgO	Na2O
C1-11	0	5	5	8.03	0.79	0.27
C1-11	5	10	5	1.59	0.5	0.23
C1-11	10	15	5	0	0.12	0.04
C1-11	15	20	5	0.38	0.22	0.09
C1-11	20	25	5	0.84	0.25	0.11
C1-11	25	30	5	0	0.11	0.02
C1-11	30	35	5	0	0.11	0.03
C1-11	35	40	5	0	0.1	0.02
C1-11	40	45	5	0	0.13	0.02
C1-11	45	50	5	0	0.11	0.02
C1-11	50	55	5	0	0.11	0.02
C1-11	55	60	5	0	0.13	0.11
C1-11	60	65	5	0.21	0.22	0.08

Figure 3.1 Drill hole data input

Figure 3.1 illustrates a drill hole of C1-11 format. The data format for input into the Minesight program provides drill hole ID and coordinates (X,Y,Z), assay data (from, to, interval, azimuth, dip) and the geology data (from, to, interval, codes) . The first column represent the name of drill hole (C1-11) and the first row of the data also represent the name of drill hole, the drill hole coordinates (X=729255,Y=1615425, Z=200), interval, azimuth and dip respectively. The assay data locates in the third row and fifth, sixth, and seventh column which is the grade of silica (SiO_2), magnesium oxide (MgO), sodium oxide (Na_2O), calcium oxide (CaO), and iron (Fe_2O_3), respectively. Figure 3.2 illustrates the composited data of drill hole C1-13.

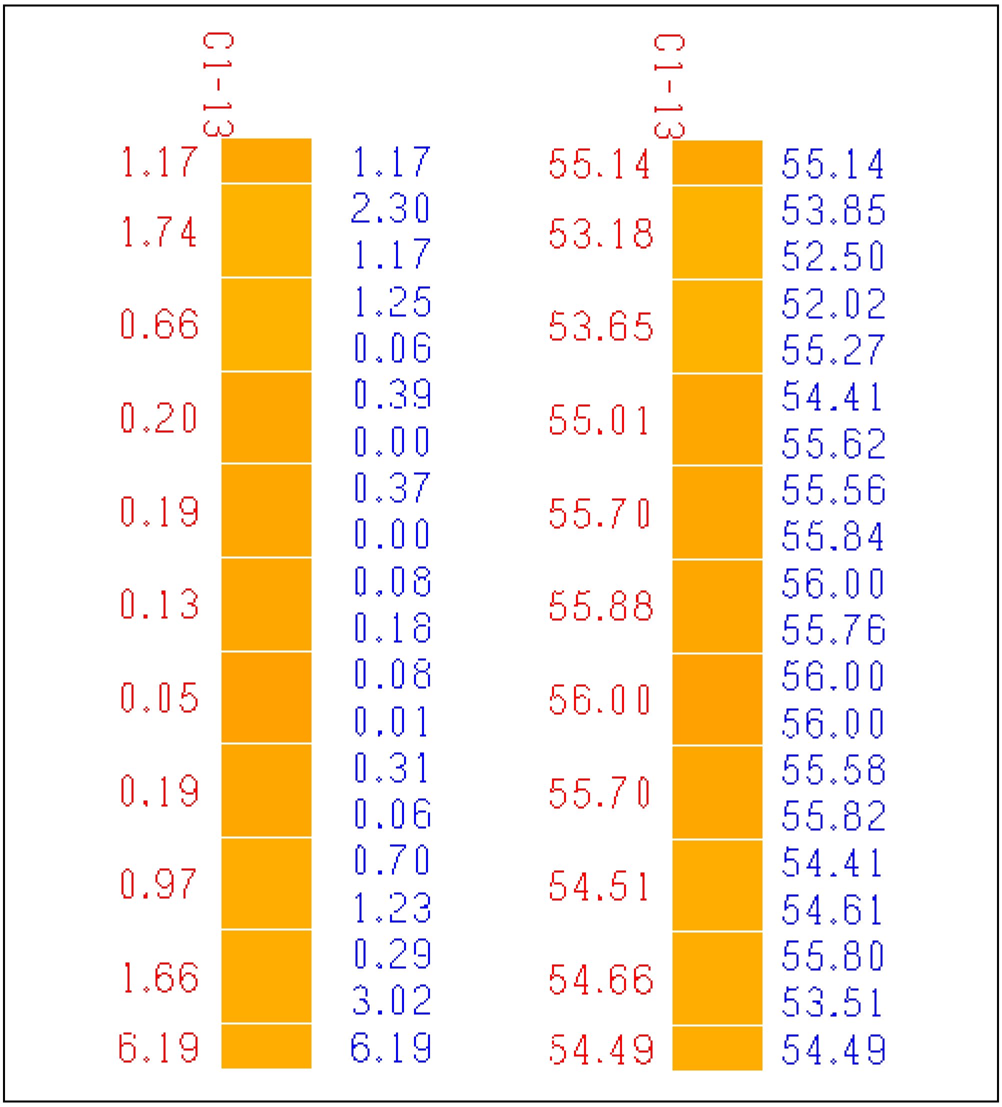

Figure 3.2 Composite data of drill hole C1-13

From Figure 3.2, the number on the left hand side of the drill hole represents the average grade of silica and calcium oxide content in terms of percent grade, also the composite of silica and calcium oxide content in terms of percent grade is represented on the right hand side of the drill hole. The full database of drill hole data is provided in Appendix C.

3.1.2. Statistical Analysis of Assay Data

The preliminary statistics of assay data are tabulated in Table 3.1. It shows the statistical values of minimum, maximum, average, median, skewness, variance, and the standard deviation values for all variables. All the drill holes data contains the drill hole coordinates and the grade of the calcium oxide (CaO), silica (SiO_2), magnesium oxide (MgO), sodium oxide (Na_2O), and iron (Fe_2O_3).

Table 3.1 Statistics data of assay values

	Min	Max	Average	Median	Skewness	Variance	S. Dev.
Easting	728310	729667	-	-	-	-	-
Northing	1615254	1615826	-	-	-	-	-
Elevation	96	314	-	-	-	-	-
SiO_2	0	66.6	4	0.92	4.44	57.86	7.61
CaO	1.08	62.89	52.24	53.81	-5.12	34.31	5.86
MgO	0	13.84	0.42	0.2	8.88	1.35	1.16
Fe_2O_3	0	7.75	0.68	0.53	5.87	0.52	0.73
Na_2O	0	8.41	0.24	0.17	10.56	0.38	0.62

From Table 3.1, the statistical data of all variables are presented. The silica content records a minimum and maximum value of 0 and 66.6 percent respectively. The silica content is averaged at 4 percent together with the median, skewness, variance, and standard deviation of 0.92, 4.44, 57.86, and 7.61, respectively.

The calcium oxide content records a minimum and maximum value of 1.08 and 62.89 percent. The calcium oxide content is averaged at 52.24 percent together with the median, skewness value and standard deviation of 53.81, -5.12, 34.31 and 5.86 percent respectively. In this study, only the silica and calcium oxide content will be used in the analysis. While the statistical analysis of the other remaining parameters such as magnesium oxide, iron oxide, and sodium oxide will also analyzed in this chapter just for the overall comparison but will not be used in the block model.

- **Histogram and cumulative distribution plots**

The construction of histogram is an important step for statistical analysis. The shape of the histogram can be used to determine the distribution characteristic of the data. Figures 3.3 and 3.4 illustrate the histogram and cumulative distribution of calcium oxide data.

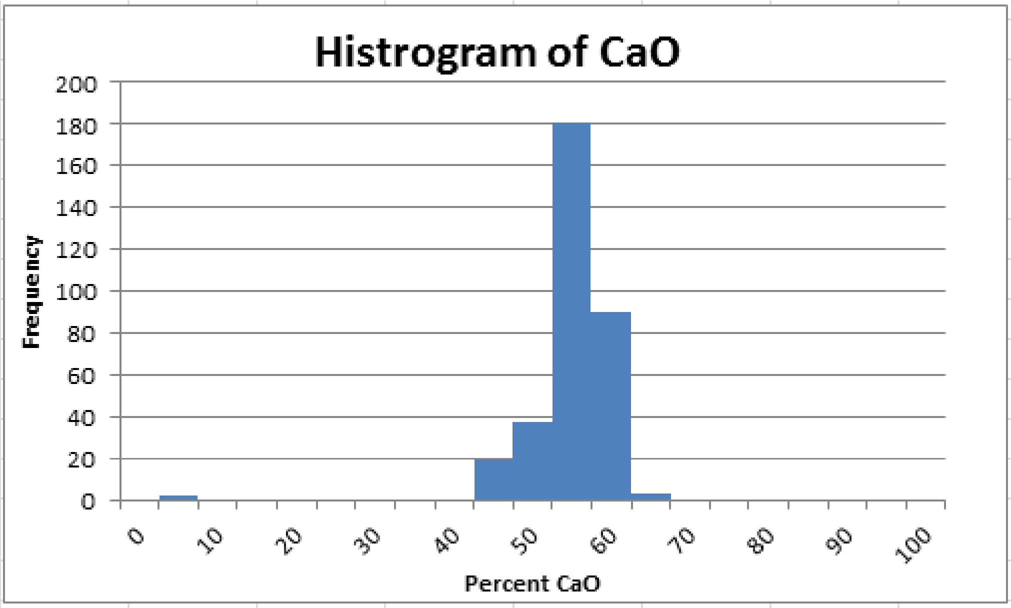

Figure 3.3 Histogram of CaO (percent)

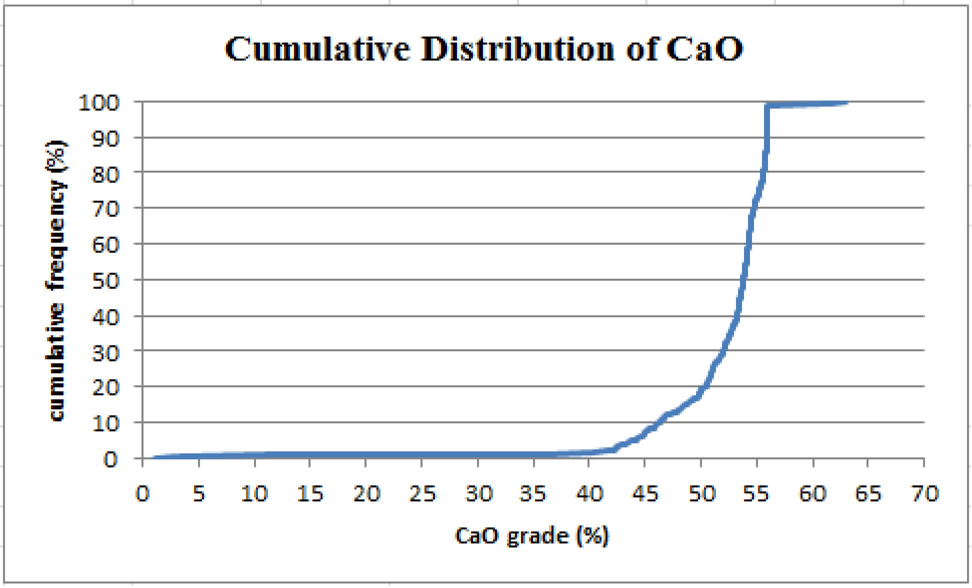

Figure 3.4 Cumulative distribution of CaO

In the Figures 3.3 and 3.4, the histogram and cumulative distribution of calcium oxide present a non-symmetrical distribution with a strong negative skewness (skewness of -5.12), the median 53.81percent) is slightly (greater than the average (52.24 percent) value. It also presents a few of lower tail values that have a strong effect by reducing the average value. The histogram and cumulative distribution of silica content are presented in Figures 3.5, and Figure 3.6.

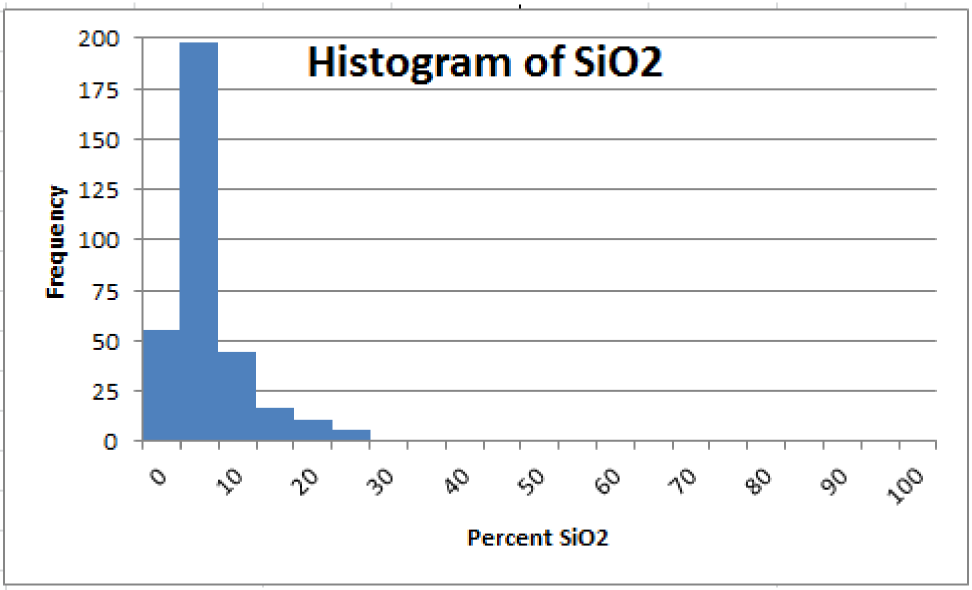

Figure 3.5 Histogram of SiO_2 (percent)

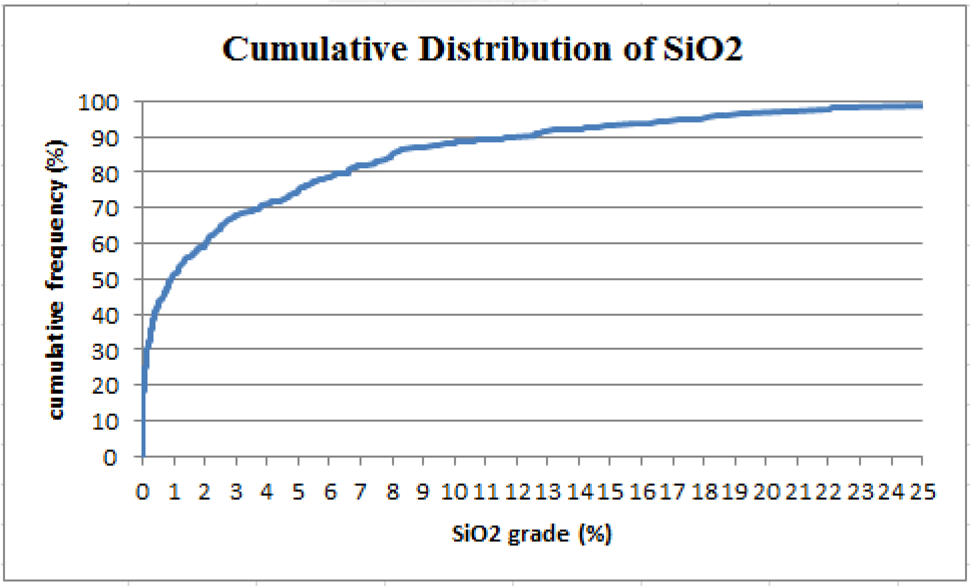

Figure 3.6 Cumulative distribution of SiO_2

In Figures 3.5 and 3.6, the histogram and cumulative distribution of silica content present a non-symmetrical distribution with two modes of data. The silica content averages at 4 percent and shows a strong positive skewness (skewness of 4), leaving more cluster of data in the lower tail area of the distribution. High variance and standard deviation are also observed in this statistical analysis results.

The histograms of magnesium oxide (MgO), iron (Fe_2O_3), and sodium oxide (Na_2O) are illustrated in Figures 3.7, 3.8, and 3.9, respectively.

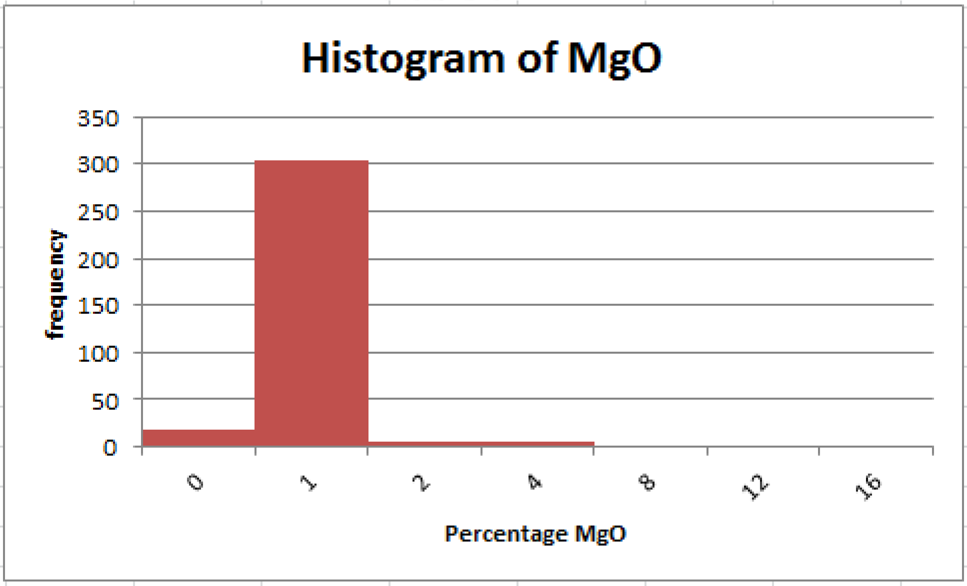

Figure 3.7 Histogram of MgO

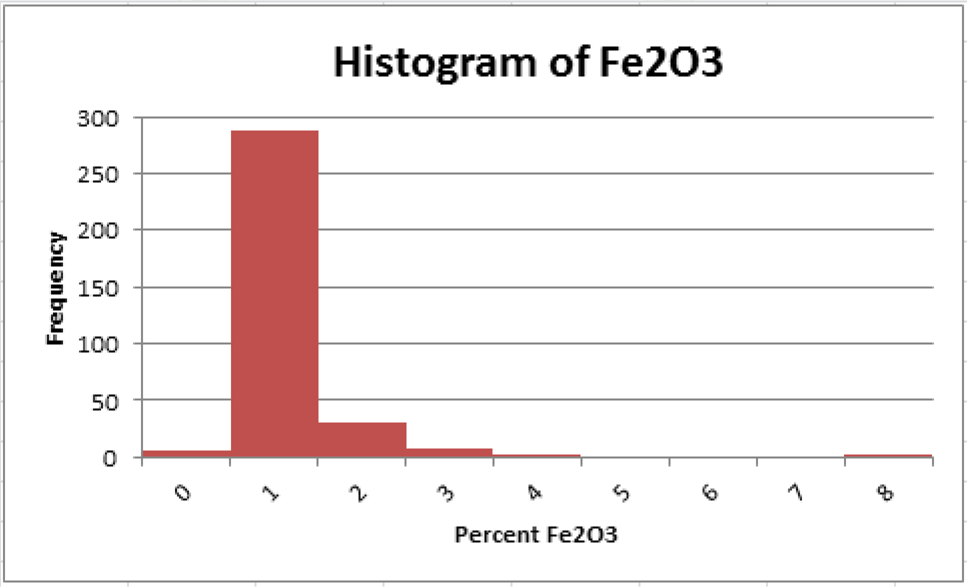

Figure 3.8 Histogram of Fe_2O_3

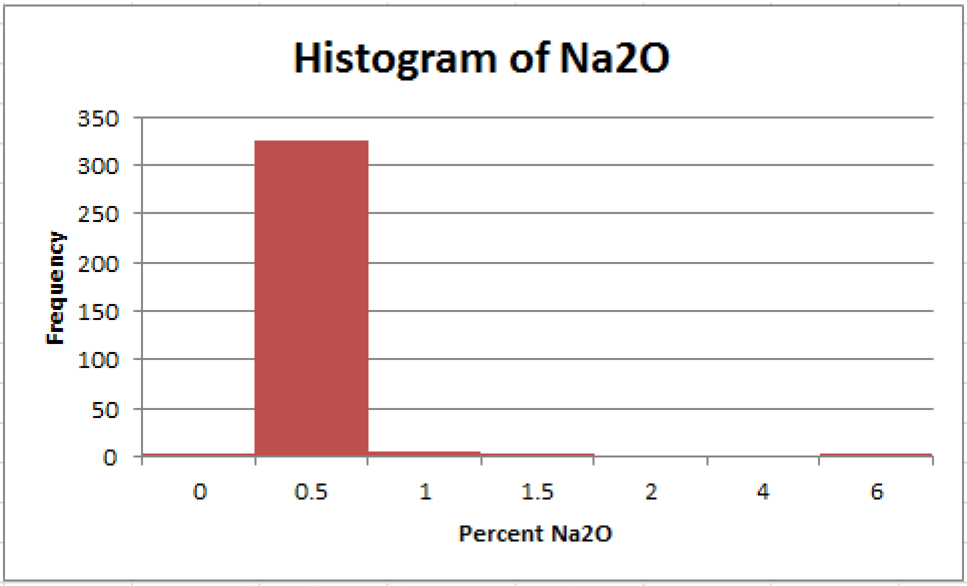

Figure 3.9 Histogram of Na_2O

From Figures 3.7-3.9, the histogram of magnesium oxide (MgO), iron (Fe_2O_3), and sodium oxide (Na_2O) show an identical pattern of a strong positive skewness meaning the data are clustered in the lower tail area. These data are less varied compared to silica and calcium oxide content data. However, as mentioned above, these data will not use in the block model. The statistics results of these data are just for the overall statistical comparison.

3.1.3.. Geological Model

In this step, the geological model boundary is delineated within the confined of studied area grid coordinates (Northing 728310 to 729667, Easting 1615254 to 1615826). Within the geological boundary comprises mainly of limestone resource which is chemically suitable for cement production. The 21 drill hole locations are superimposed with the topography represented by the contour lines and drill holes ID (red color) as seen in Figures 3.10 and 3.11. In Figure 3.10, it shows the boundary of 3D model encompassing study volume and drill holes data, the top view of topographic and drill hole data are shown in Figure 3.11. This geological volume will be subjected to resource estimation using Inverse Distance Square Method (IDSM).

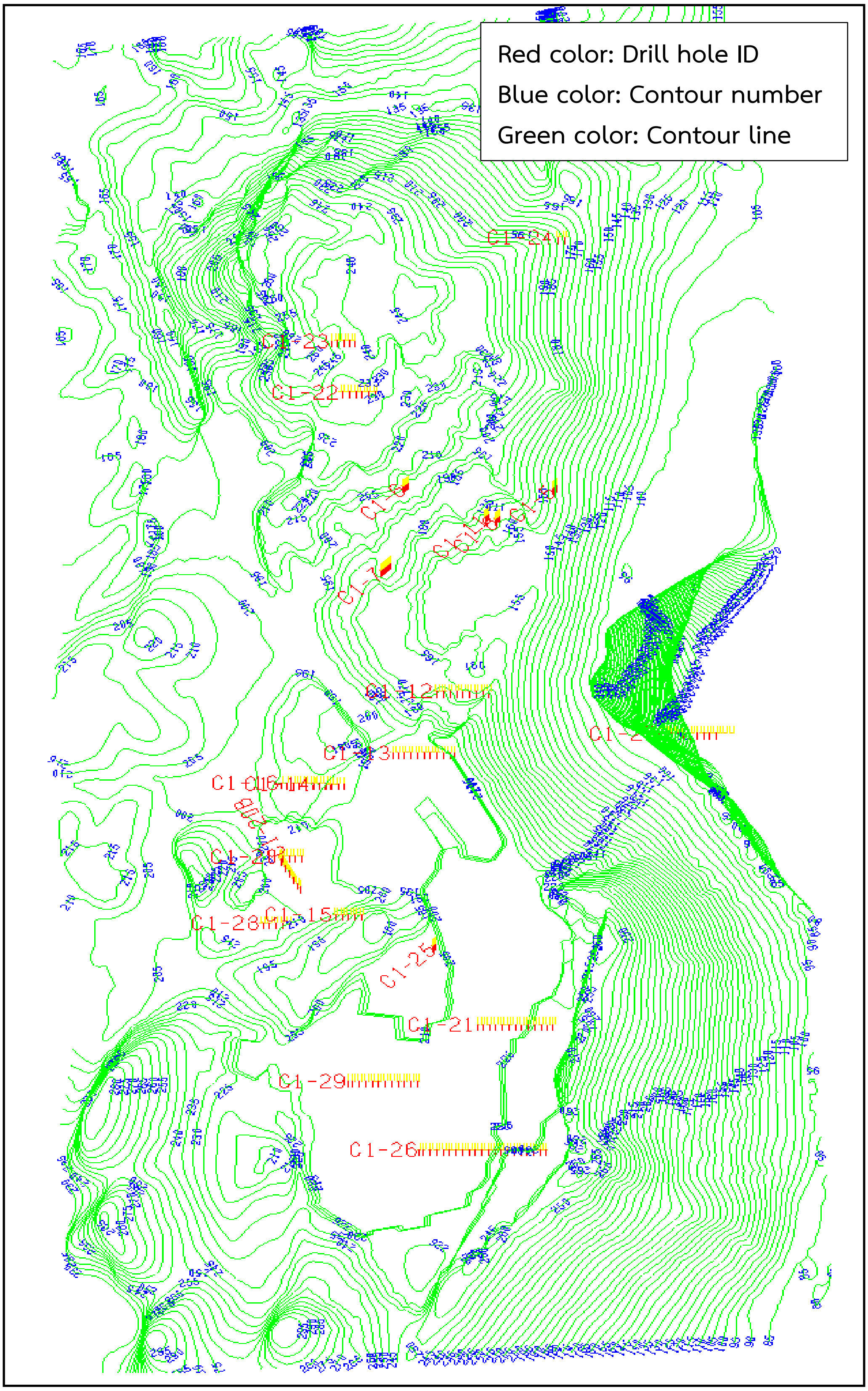

Figure 3.10 Overview of drill hole and topography in 3D model

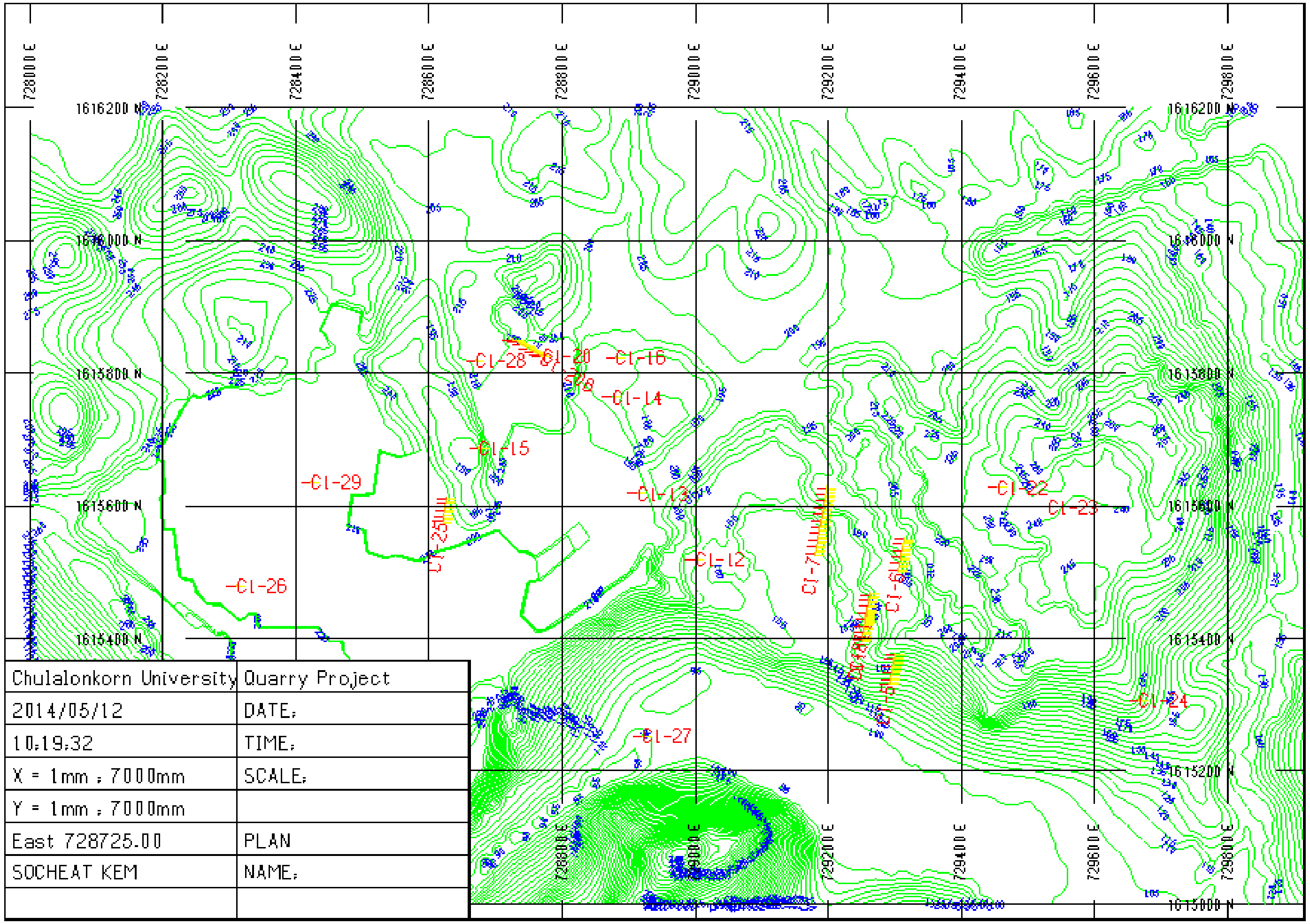

Figure 3.11 Top view of drill hole locations

3.2. Resource Estimation

Inverse Distance Squared weighting technique (IDSW) is used to calculate the block grade. The IDSM method is used to calculate the block grade by weighting the value of assay data in the neighborhood of each processed grid. The dimensions of searching distance of all block are selected at 150m, 150m, 15m in (X, Y, and Z) distance, respectively. The block discretization is set as 15mx15mx10m in (X,Y,Z) dimension, resulting a total number of 560,000 blocks. Each block contains 2,250 cubic meters which translate to 5,850 tons, given the specific gravity of limestone 2.6.

In the IDSM process, the square power function is used in the relationship (eq.2.1). In the IDSM subroutine, the block is selected systematically and the calcium oxide and silica are estimated from the surrounding data using the weighting technique. The estimate assay values are stored for all estimated blocks within the searching volume parameters.

The results of IDSM show that the total number of estimated block is 35,000 blocks. Generally, the estimated blocks are clustered around the drill hole data extending 150 meters from the drill hole center as seen in Figure 3.12. It is important to note that the number of estimated block depends on the searching volume, the more the searching volume, the more of estimated blocks. In this study, the 150x150x10m in (x, y, z dimension) searching volume is defined based on the spacing of the drill hole and the bench height configuration. With this defined parameters, the total geological resource of 204 million tons is estimated. The block grade distribution of calcium oxide and silica content are presented in Figures 3.12 and 3.13.

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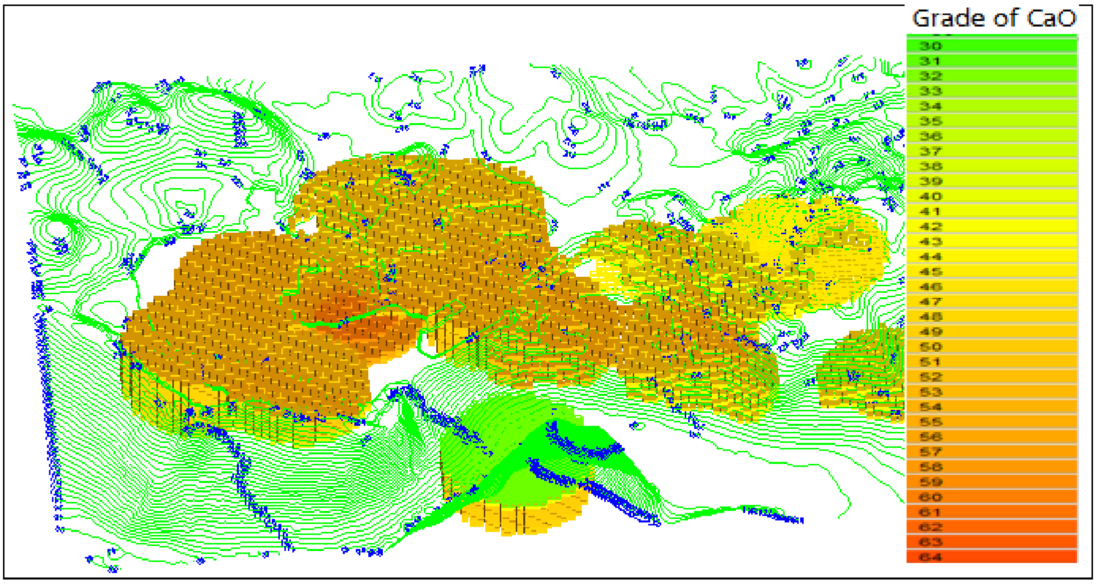

Figure 3.12 Result of estimated block from IDWM for CaO

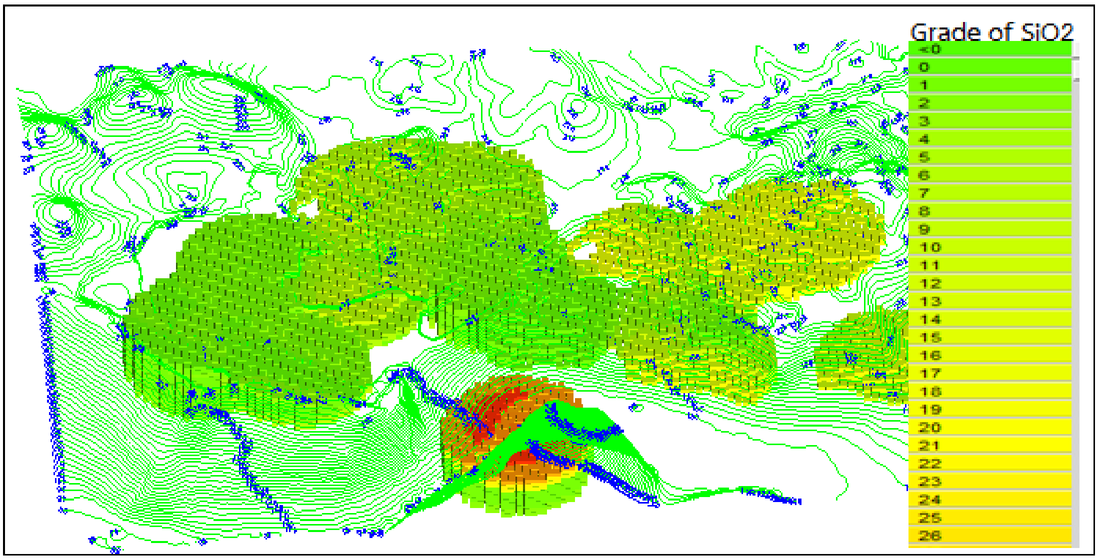

Figure 3.13 Result of estimated block from IDWM for SiO_2

3.3. Pit Optimization and Reserve Estimation

Pit optimization is the final step of pit design to determine the ultimate pit limit for planning and scheduling process. It identifies which block should be mind and which block should be left in the ground. Pit optimization is also defines the lateral and vertical extent to which a given deposit can be mined economically.

In this study, the Lerchs-Grossmann method is used to calculate the pit optimization of the ore in each block. For this calculation, some parameters are used to evaluate a final pit dimensions based upon reserves expressed in the form of grade block model. These parameters are quality of limestone, mining cost, sale cost, overall pit slope angle and the block size. The limestone quality block grade (calcium oxide and silica content) is derived from IDWM estimated block. The mining cost is given as 2 dollar per ton, the sale cost of limestone production is given as 6 dollar per ton, and the overall slop angle is defined as 45 degree angle. The block discretization is set as 15mx15mx10m in (x, y, z dimension). Tables 3.2 summarize the input for pit optimization process.

Table 3.2 Summarize of input for pit optimization

Pit Optimization method	Lerchs-Grossmann method
Block grade estimation model	IDWM block grade
Block discretization	15mx15mx10m (x, y, z dimension)
Mining cost	2 dollar per ton
Sale cost of limestone production	6 dollar per ton
Overall slope angle	45 degree

The results of running pit optimization give three main ultimate pits (MP1, MP2, MP3) and three small connected pits (SP1, SP2, SP3) as shown in Figure 3.14. The total mineable reserve of 84 million tons is estimated based on this optimized ultimate pit. However, in this study, only the main pit MP1 is selected for the first stage of mine development. The MP1 is chosen based solely on the quality of limestone grade considering higher calcium oxide and low silica content, and the quantity of limestone that suitable for the production of 1 million tons per year and 25 years mine life.

The mineable reserve of MP1 pit stands at 30 million tons of limestone which covering the 25 years mine production. The area of MP1 pit is shown in Figure 3.15 together with the designed haul road. The pit area is within the yellow color shade, the main haul road is shown in red line color.

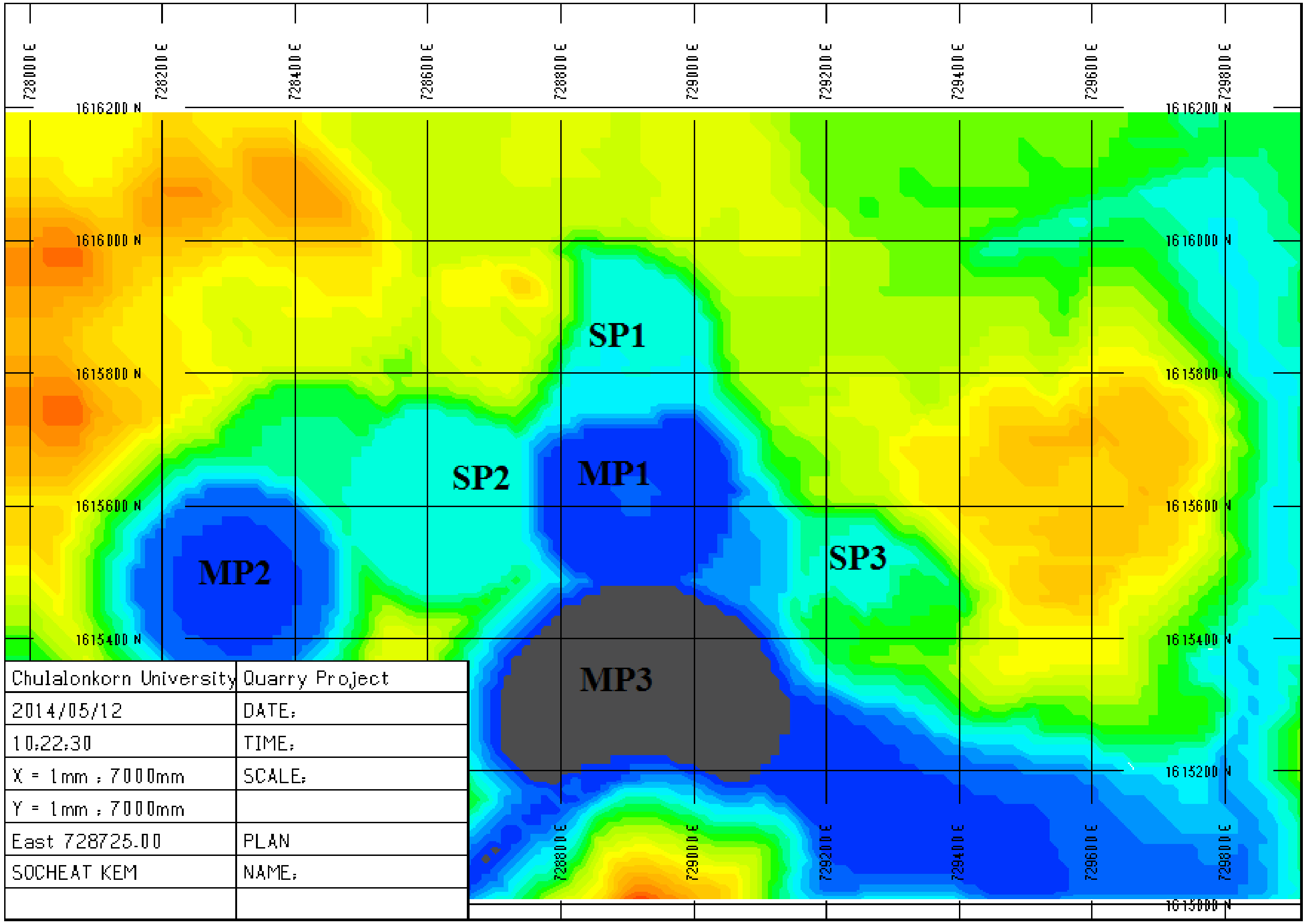

Figure 3.14 Top view of pit optimization

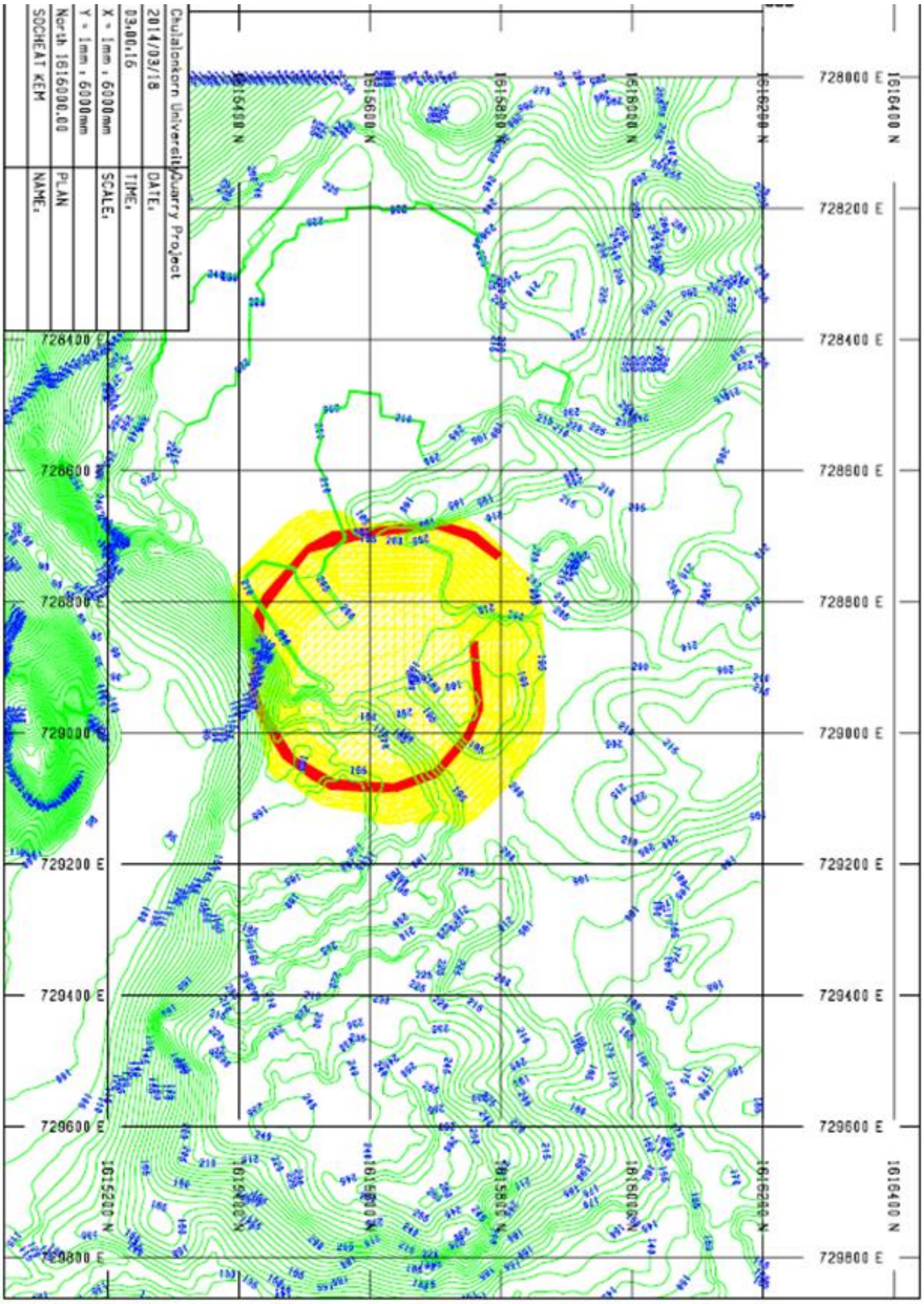

Figure 3.15 Top view of MP1 pit with haul road

The cross section of MP1 pit for different sections aligned in E-W and N-S directions are shown in Figures 3.16-3.21. The cross sections illustrate the final pit limit superimposed on the block grade in this case the calcium oxide content. The calcium oxide content varies with the yellow color shade by which the light yellow color gives low grade and the orange shade color gives the high grade zone. It's important to note that the mineable reserve is estimated within the boundary of MP1 pit, the pit limit is shown as blue color line in cross section.

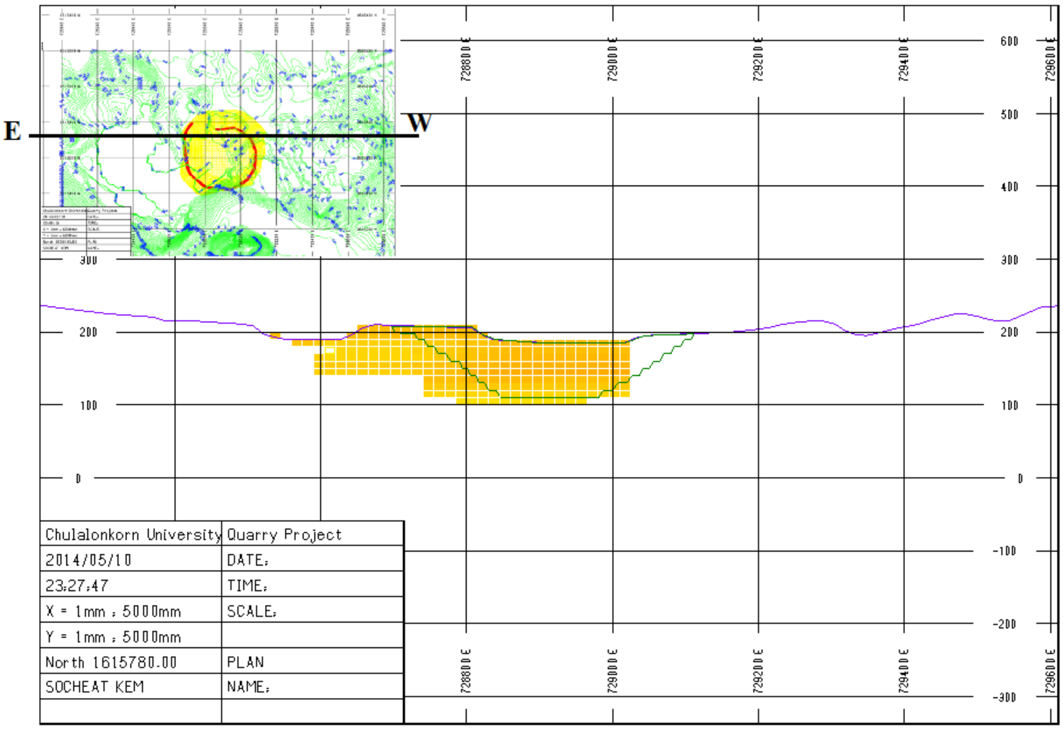

Figure 3.16 Cross section of CaO of MP1 pit at E1615780W section

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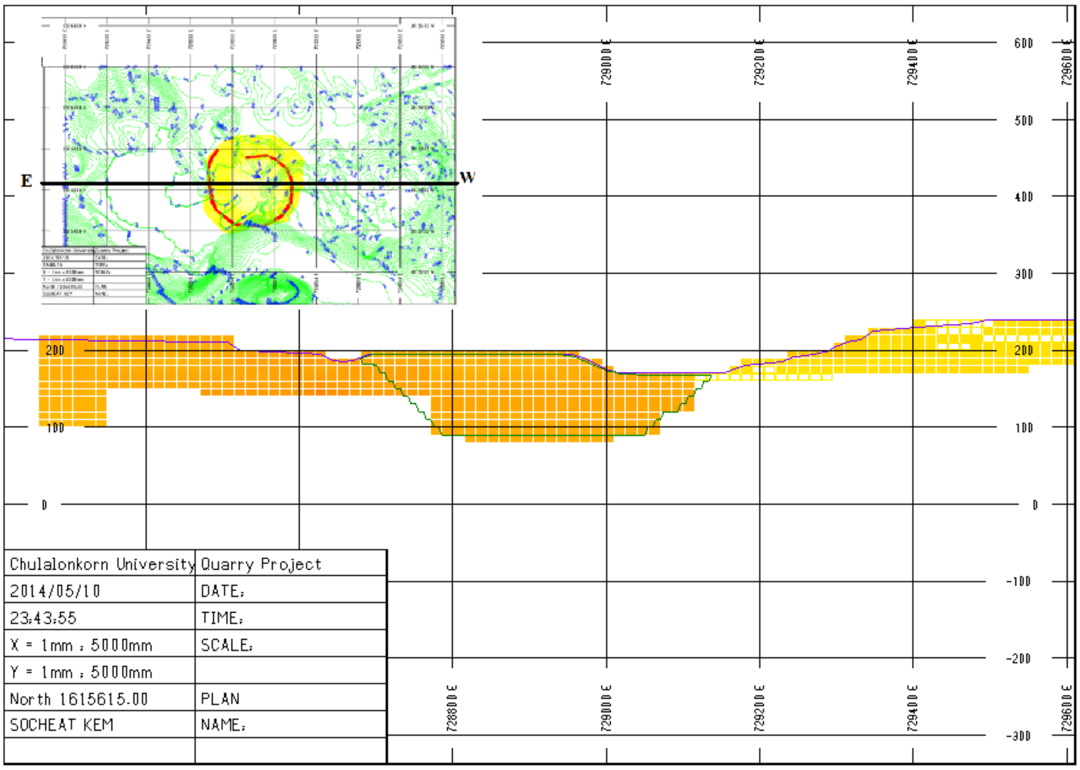

Figure 3.17 Cross section of CaO of MP1 pit at E1615615W section

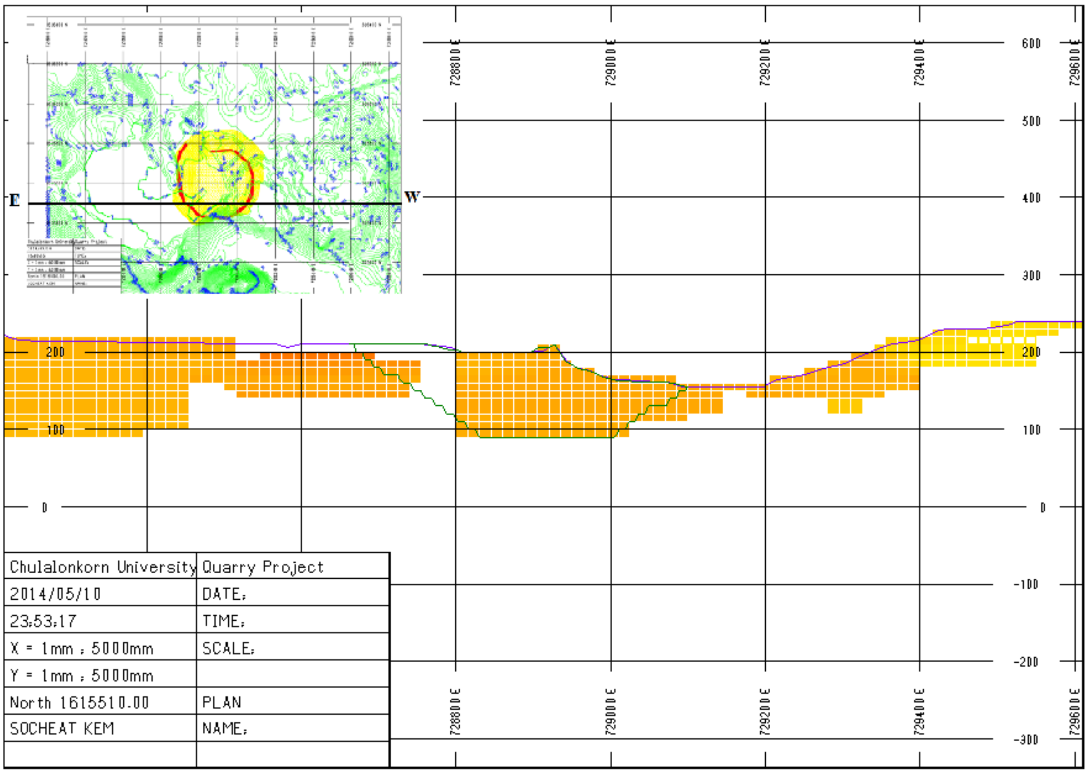

Figure 3.18 Cross section of CaO of MP1 pit at E1615510W section

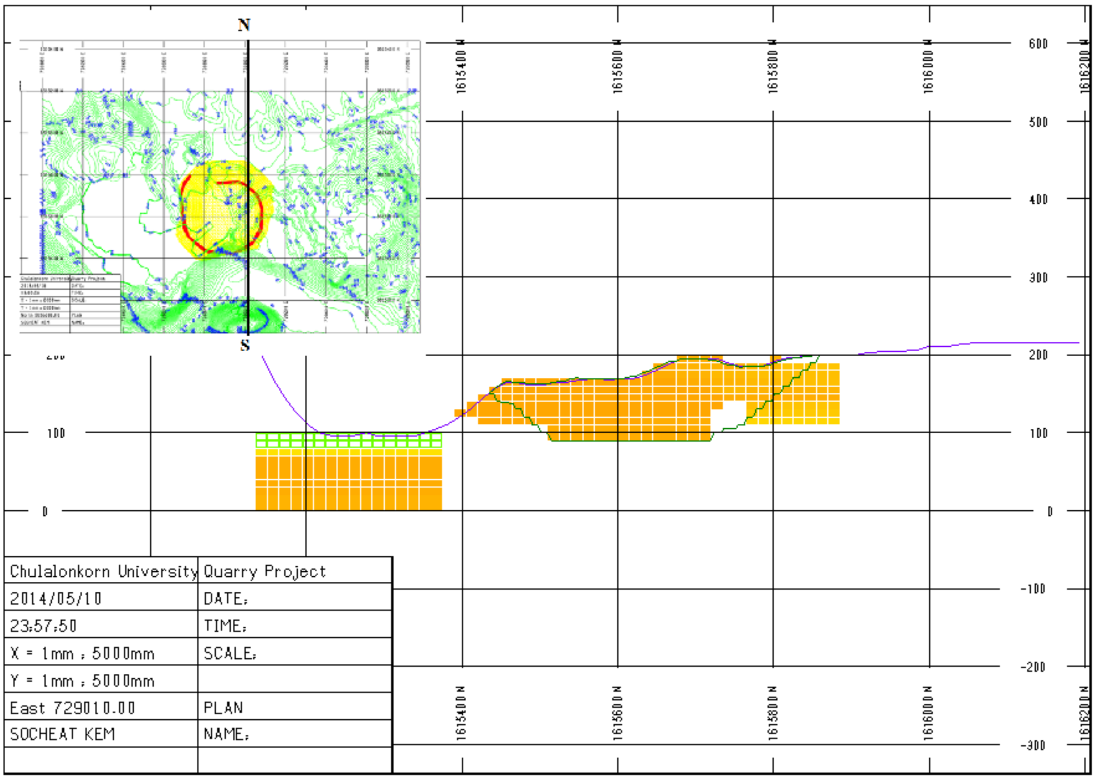

Figure 3.19 Cross section of CaO of MP1 pit at N729010S section

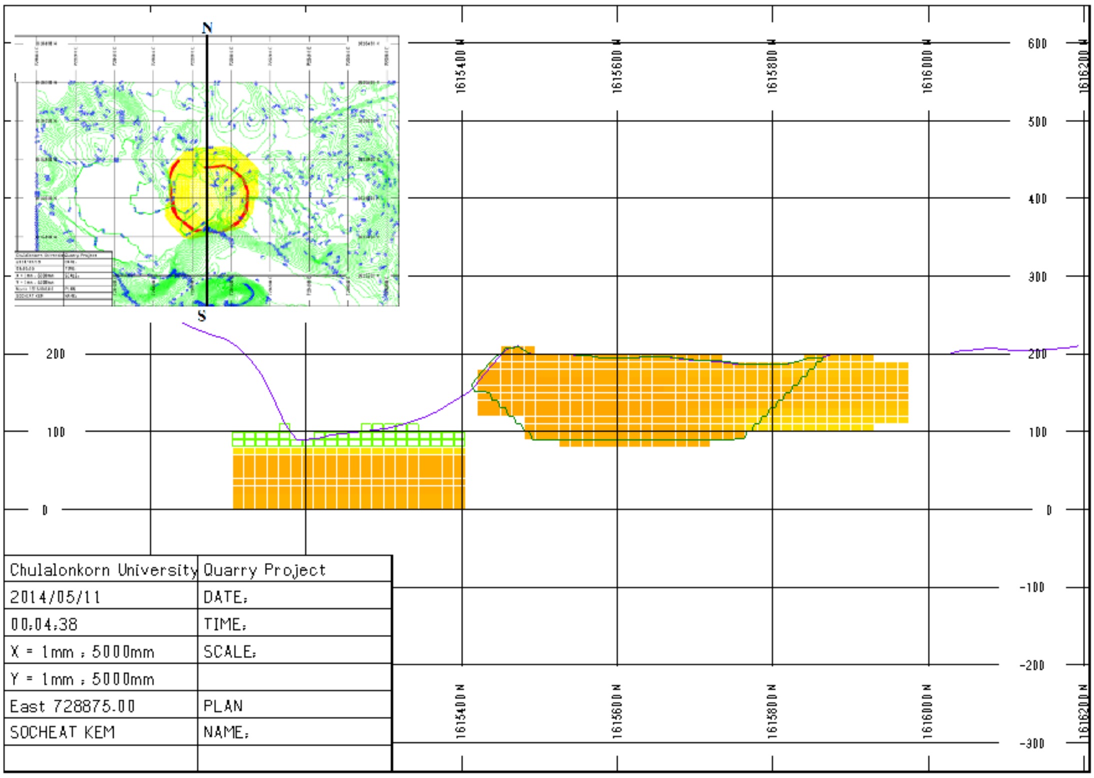

Figure 3.20 Cross section of CaO of MP1 pit at N729875S section

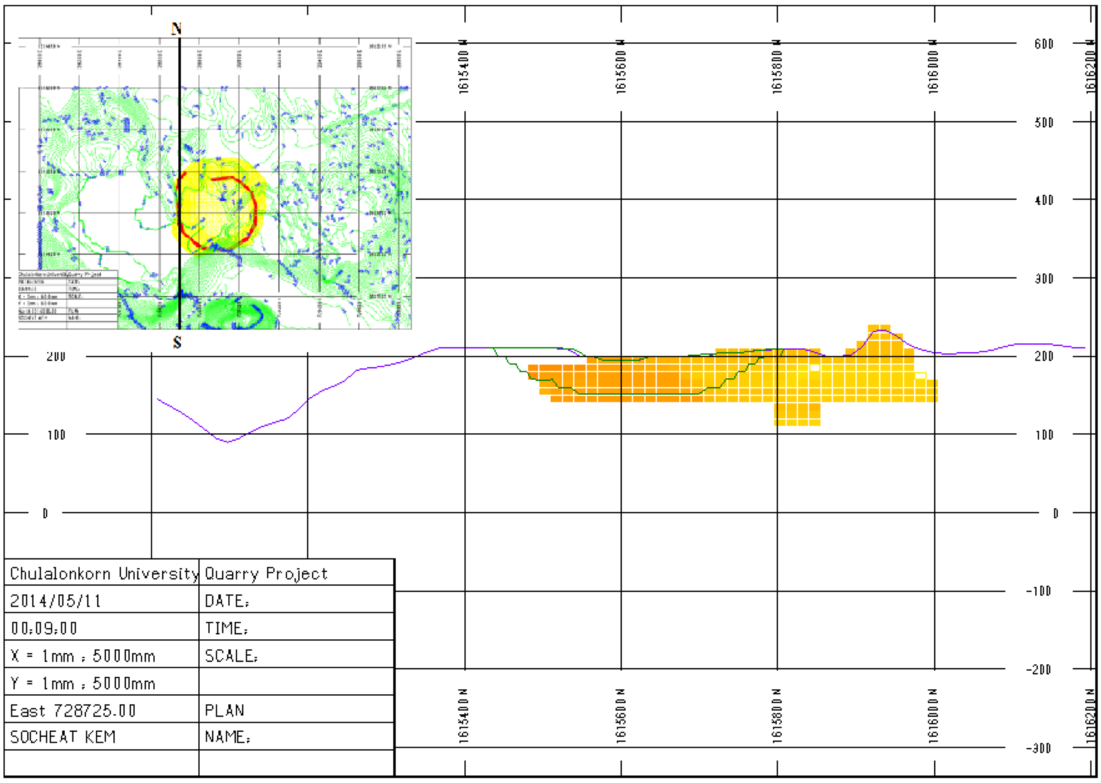

Figure 3.21 Cross section of CaO of MP1 pit at N7298725S section

3.4. Quality of Limestone for Cement Production

The chemical quality of limestone is the important parameter for quarry production. The grades which are equal or over the cutoff quality are classified as ore, and the grades which are below the cutoff quality are classified as waste. In this study, the chemical grade of calcium oxide and silica are the two main variables of interest and the cutoff grade assigned for these two variables are 52 percent and 3 percent, respectively. In practice, the mixing of limestone with different grade will also be used to meet the required quality. Mixing method is a commonly used for cement production process. Therefore, the ore with low grade (high SiO_2 or low CaO) will be mixed with high grade (low SiO_2 or high CaO) by using two method. The first method is called “mix by common”. It’s a normal mixing grade by using the high grade mix with the low grade to get the average that complete requirement. The second method is called “mix by weight” this method is more precise than the first method because this method considers about the grade and the weight of the ore. This method can be applied with the deposit of highly varied grade. Table 3.3 illustrates the assigned cutoff grades for limestone production.

Table 3.3 The assigned cutoff grade for limestone production

Ore	CaO	SiO_2
High Quality	Higher than 52 percent	Lower than 3 percent
Mix method (req. grade)	Higher than 52 percent	Between 3 to 4 percent
	Between 45 to 52 percent	Lower than 3 percent

From Table 3.3, the cutoff qualities of limestone to be treated as ore are with calcium oxide higher than 52 percent and silica lower than 3 percent. The mix-method classifies the qualities of limestone into two groups. Firsts, the calcium oxide is higher than 52 percent, and silica between 3 to 4 percent. Second, the calcium oxide between 45 to 52 percent and silica is lower than 3 percent. Other qualities which are not fit into this classification will be treated as waste.

3.5. Mine Planning and Scheduling

Based on the ultimate pit design, the annual planning and scheduling of the product are showed in Figure 3.22. The mine pit layouts from the first year to the year twenty five is provided. In year six, the production will be double from the first year production (from 1 to 2 million tones limestone production). With the assumption that within the past six years' experience the project is firm enough to increase the capacity to meet the increase domestic demand. That results in a sharp expansion of pit layout from year two to year six as shown in Figure 3.22. However, the final pit layout as of year 25 will be used as the basis for mine rehabilitation.

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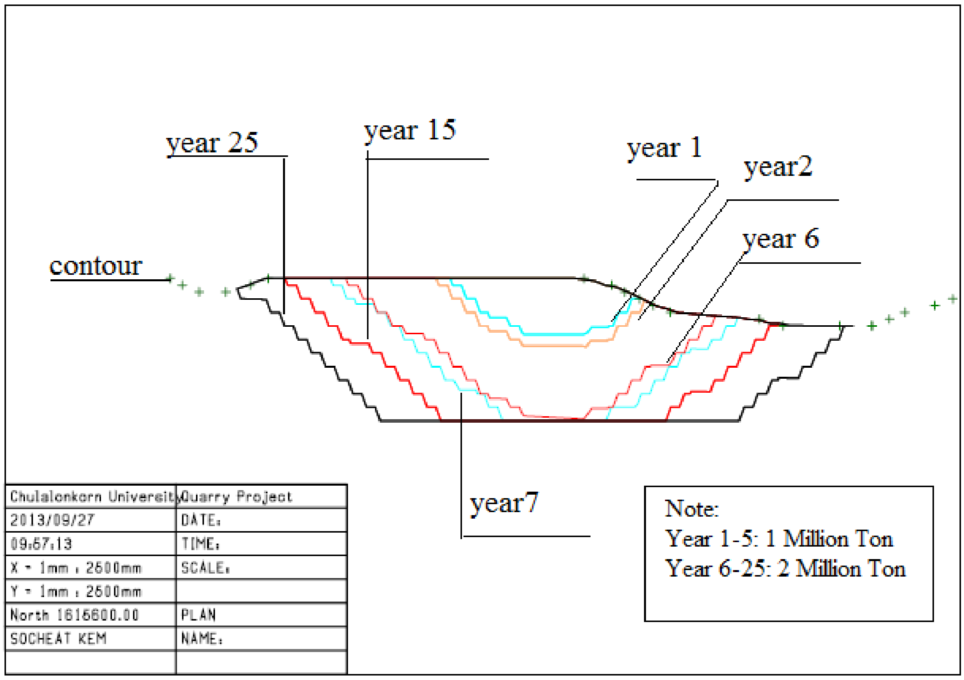
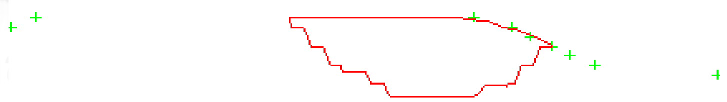
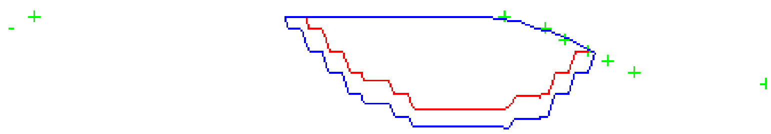


Figure 3.22 Mine planning and scheduling

The expansion of pit layout from year one to year twenty five is shown in Table 3.4

Table 3.4 The expansion of pit layout from year one to year twenty five

Year	Cumulative production (Tons)	Pit Geometry
1	1,324,800	
2	2,004,447	

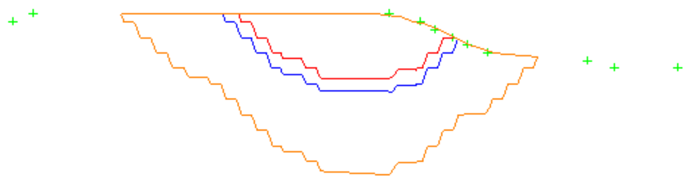
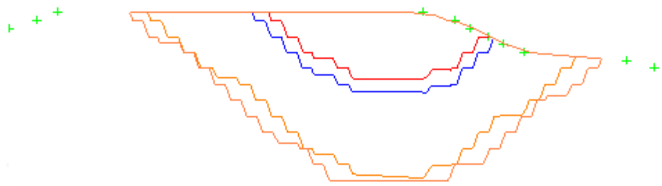
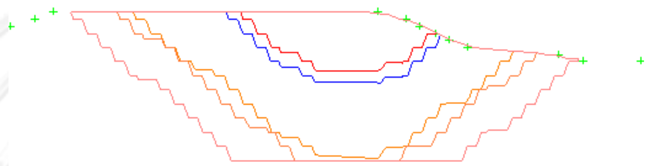
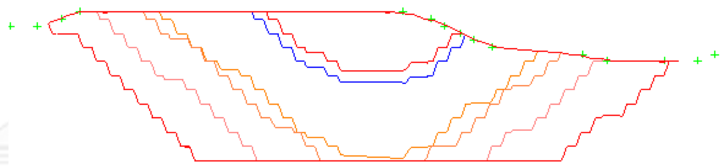
6	8,752,483	
8	10,275,331	
15	18,719,693	
25	29,525,579	

Table 3.4 illustrates the tonnage of the limestone production in the first year operation until the last planning in year 25 with their pit geometry. In the first year, the production starts with 1.3 million tons with the overall slope angle of 45 degree, in this year the level of the pit floor elevation is 150 meters above the mean sea level (msl) and the surface elevation 210 meters above msl. The second year production accumulates to 2 million tons with the same slope angel 45 degree and the floor pit elevation lower to 140 meters above msl. In the final year production, the cumulative production amounts to 29.5 million tons while maintain the 45 degree overalls slope angle and the final pit floor elevation drop to 90 meters above msl.

With this ultimate pit geometry, 12 benches of 10 meters bench height and 10 meter bench width are designed. The overall slope angle is maintained at 45 degree with the faces slope of 80 degree as shown in Figure 3.23.

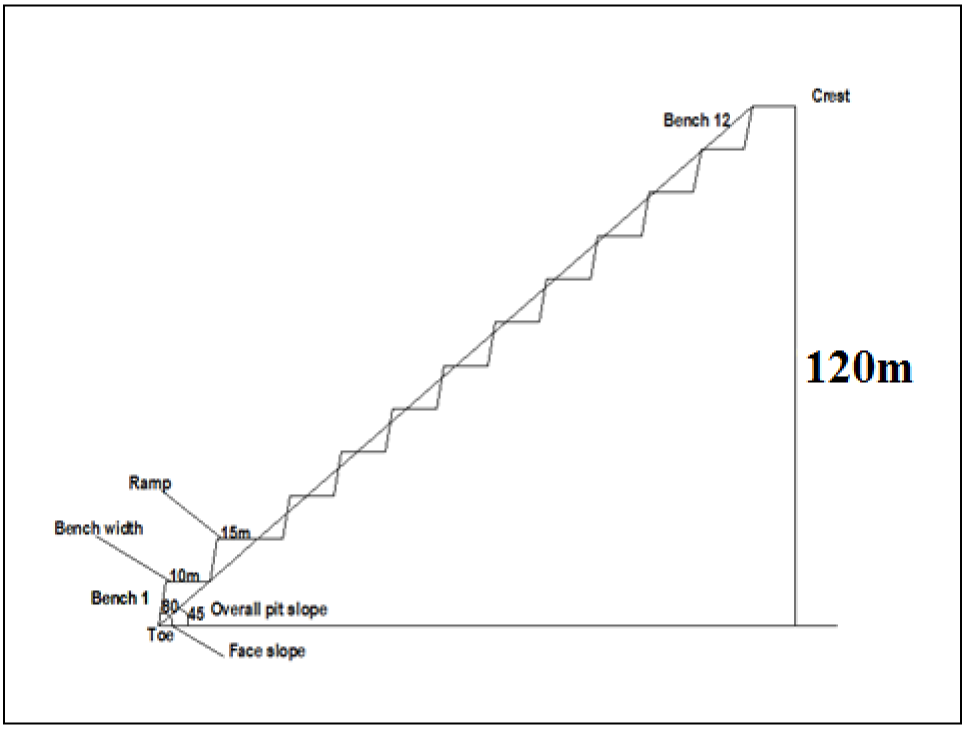


Figure 3.23 The ultimate pit geometry with bench configuration

The ramp of the haul road is designed 15 meter by width larger than the bench width (10 meters width). The overall depth of the pit is 120 meters. The minable of limestone and waste including the qualities of limestone for each bench are showed in the Table 3.5.

Table 3.5 Limestone production and its quality at bench level

Benches	Ore (ton)	Waste (ton)	S/R (ore/waste)	CaO	SiO_2
210	1,005,030	1,688,495	0.60	53.09	2.20
200	1,815,660	2,204,957	0.82	52.89	2.48
190	2,613,825	2,140,680	1.22	53.57	2.75
180	3,204,810	1,997,740	1.60	53.65	2.75
170	3,295,935	1,703,337	1.93	53.84	2.34
160	3,357,990	1,547,783	2.17	54.10	1.56
150	3,270,060	1,387,103	2.36	54.67	0.90

140	3,003,277	1,424,055	2.11	55.28	0.64
130	1,901,430	1,188,043	1.60	54.44	0.88
120	1,754,190	904,413	1.94	54.54	0.88
110	1,539,000	914,603	1.68	53.95	2.03
100	1,410,705	1,021,522	1.38	51.38	5.25
90	1,353,667	1,260,649	1.07	41.45	18.34
Total	29,525,579	19,383,382	1.52	52.83	3.31

Table 3.5 illustrates the minable of limestone and its quality for each bench from the top crest to the bottom toe of the pit level. The stripping ratio of this pit is **2:3 (waste: ore)**. However, some of the waste will be used for mixing purpose and that will changing the stripping ratio.

3.6. Master Plan Consideration

Master plan is a plan that covers overall mining activities. It describes the flow of the process interconnected from the working bench to the storage unit. The important infrastructures such as main road, office, work shop, apartment, and fix location are mentioned in the master plan. In this project, the master plan is established, and the related infrastructures located within the mine area as shown in Figure 3.24.

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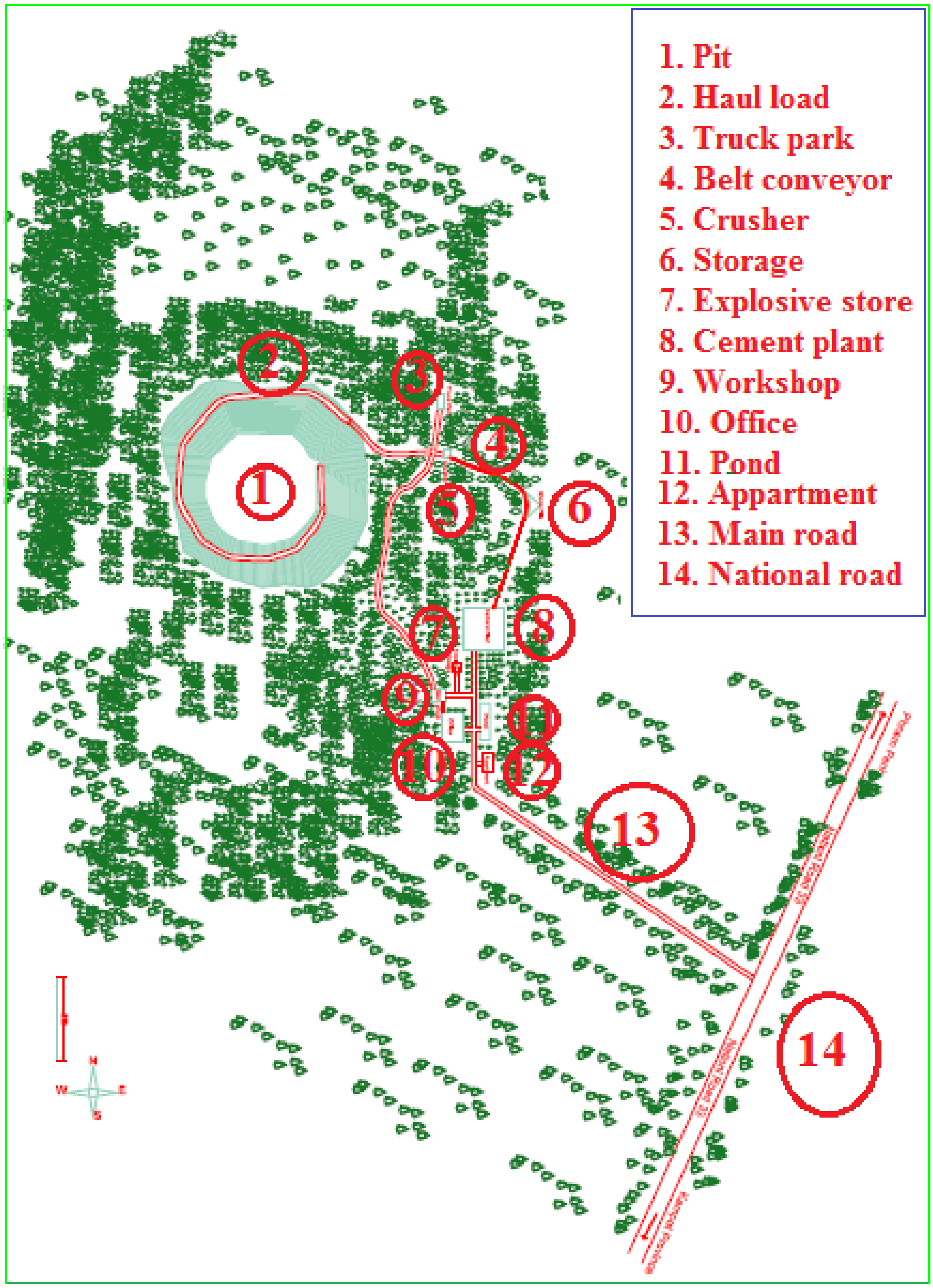

Figure 3.24 The conceptual mine master plan and its infrastructures

Figure 3.24, the main road (13) is extended from the pit boundary (1) to the crusher (5) and continued to the workshop (9). The limestone production is feed into the hammer crusher (5) with maximum diameter of 1 meter, and the output from the crusher should be less than 25 millimeter. There is belt conveyer (4) line connected from the crusher direct to stock pit (6), and limestone is homogenized in the stock pile before send to the cement plant (8) by conveyer. Truck Park (3) is designed close to the crusher zone to reduce the travel time during the operation and stand by time. Workshop for repairing and maintenance is also located close to the main road. Explosive storage (7) is also installed far away from the main building and water body (11) to avoid the risk and effect of explosive quality. The office (10), apartment (12) for the staff is also mentioned in the master plan. The whole concept of mine master plan is shown in Figure 3.24.

3.7. Financial Analysis

The financial study involves the Discount Cash Flow (DCF) analysis, weight average cost of capital (WACC), Internal Rate of Return (IRR), and Net Present Value (NPV).

For all investment projects, some important parameters for considering the project to be feasible are the DCF, IRR, and NPV. DCF is used to calculate the cash inflow and cash out flow. IRR is used to compare with the interest rate of the project. NPV is also used to validate the feasibility of the project.

3.7.1. Discount Cash Flow Calculation (DCF)

There are many steps to calculate the discount cash flow. In this step, the parameters need to determine the cash flow models are capital cost, operation cost, sale cost, depreciation cost, the tax rate, and royalty. The input parameters and calculation sheet are shown in Tables 3.6 and 3.7.

Table 3.6 The input parameters for DCF

Input parameters	Values
Capital cost	7,664,000 dollar
Operation cost	2 dollar per ton
Sale cost	6 dollar per ton
Tax rate	25 percent
Royalty	0.2 dollar per ton

Table 3.7 The discount cash flow calculation sheet

year	0	1-5	6-10	11-15
Total Production	-	5,559,840	12,355,200	12,355,200
Gross Revenue	-	33,359,040	74,131,200	74,131,200
Annual Royalty	-	-1,111,968	-2,471,040	-2,471,040
Net Revenue	-	34,471,008	76,602,240	76,602,240
Operation cost	-	-15,438,402	-33,283,895	-33,593,655
Depreciation	-	-4,620,000	-2,621,000	0
Taxable income	-	14,412,606	40,697,345	40,911,785
Tax @ 25%	-	-3,603,151	-10,174,336	-10,227,946
Net Income	-	10,809,454	30,523,009	30,683,839
Depreciation	-	4,620,000	2,621,000	0
Capital cost	-7664000	0	0	0
Present Value@15%	-7664000	10,047,631	11,070,643	9,511,225
Cash Flow	-7664000	15,429,454	33,144,009	32,780,639

3.7.2. Weight Average Cost of Capital (WACC)

In mining project, there are two types of capital budgets. The first budget is by borrowing from the bank and other budget will get from the owner of the project or from the shareholders. In this study, the assumption have been made that 30 percent of the fund will be from the bank with the interest rate of 8.5 percent, and the remaining 70 percent will be from the shareholders with some expect rate of return. As a result, the weight average cost of capital is the combination of the equity and debt. The equation (2.3) will be used to calculate the weight average of capital (WACC). Table 3.8 provides the parameters inputs for WACC calculation. The calculated WACC is 15 percent, which provide the interest rate of the project.

Table 3.8 The input parameter for WACC

Parameter	Equation	results
Capital cost		7,664,000
E (equity)	7,664,000x70%	5,364,000
D (debt)	7,664,000x30%	2,300,000
V (total debt and equity cost)	E + D	7664000
R_d (cost of debt)	8.5 percent	0.085
T_c (Tax rate)	25 percent	0.25
R_f (free risk)	4 percent	0.04
R_m (medium risk)	17 percent	0.17
β (coefficient)	10 percent high risk	1.1
R_e (cost of equity)	$R_f+\beta(R_m-R_f)$	0.18
WACC	$E/V \times R_e + D/V \times R_d \times (1-T_c)$	0.15

3.7.3. Internal Rate of Return (IRR)

IRR is the interest rate that the cash inflow equal to the cash outflow or the sum of discounted of net cash flow equal zero. IRR is very important for investment and it uses to identify the payback period or when the project will get profit. In case when the IRR is equal to the interest rate or WACC, the net present value will be zero and the project will not get any profit. The project is feasible when IRR is higher than the interest rate or WACC. The IRR has to be approximated by trial or error method. However, the IRR can be conveniently tabulated in Microsoft excel spread sheet. In this study, IRR of this project is calculated at 45 percent which is much more than the WACC interest rate (15 percent). The higher IRR results from the fact that the sell cost of limestone production (6 dollar per ton) is much higher than the operating cost (2 dollar per ton).

3.7.4. Net Present Value (NPV)

NPV is the sum of the discounted annual cash flow or the sum of present value. If NPV is positive, it considers a feasible project and if NPV is negative, it considers a non-feasible project. In this project, NPV is positive which is equal to **19.3**

million dollar. Therefore, this quarry project considers financially feasible. The calculation sheet of NPV is shown in Table 3.9.

Table 3.9 The calculation sheet of NPV

year	0	1-5	6-10	11-15
Total Production	-	5,559,840	12,355,200	12,355,200
Gross Revenue	-	33,359,040	74,131,200	74,131,200
Annual Royalty	-	-1,111,968	-2,471,040	-2,471,040
Net Revenue	-	34,471,008	76,602,240	76,602,240
Operation cost	-	-15,438,402	-33,283,895	-33,593,655
Depreciation	-	-4,620,000	-2,621,000	0
Taxable income	-	14,412,606	40,697,345	40,911,785
Tax @ 25%	-	-3,603,151	-10,174,336	-10,227,946
Net Income	-	10,809,454	30,523,009	30,683,839
Depreciation	-	4,620,000	2,621,000	0
Capital cost	-7664000	0	0	0
Present Value@15%	-7664000	10,047,631	11,070,643	9,511,225
Cash Flow	-7664000	15,429,454	33,144,009	32,780,639
NPV=∑(present value) =19.3 million dollar				

For the financial analysis, it can be summarized that the WACC is estimated at 15 percent with two sources of funding which are 30 percent from bank loan and 70 percent from shareholder. IRR is estimated at 45 percent which is considerably much more than WACC rate, and NPV is 19.3 million dollar. Taking these financial factors into account, the quarry project is proven feasible.

CHAPTER IV

MINING OPERATION

Mining operation is an important process for quarry operation. There are 4 continuous processes for doing mining operation; drilling, blasting, loading and hauling.

4.1. Drilling and Blasting

Blasting pattern is very important design to the quality of rock fragmentation and to identify the number of rock tonnage. In this study, the blasting pattern is designed as shown in Table 4.1.

Table 4.1 Blasting pattern parameters

Parameters	Relationship	Results
Drilling pattern	5 rows with 7holes	35 hole
Diameter of drill hole	-	D=3.5inch=90mm
Burden	B=25xD	B=2.5m
Spacing	S=1.15xB	S=3m
Sub-drill	U=0.3xB	U=0.9m
Stemming	T=0.8xB	T=2m
Bench Height	H=4xB	H=10m
ANFO density		800kg/m^3
Limestone density		2.60
Volume of rock	V=NxBxSxH	V=2625m^3=6956 ton
Specific Charge	SC	0.5kg/m^3
Total explosive	T_e=SCxV	T=1312kg
ANFO	95 percent of T_e	1246kg
High explosive	5 percent T_e	66kg
Charge per hole	T_e/number of hole	37.48kg
ANFO per hole	ANFO/ number of hole	35.6kg
Power Factor	PF=T_e/V	PF=0.188kg/ton

Table 4.1 illustrates the blasting design. There are 35 holes in total which contain 5 rows and 7 columns. The diameter of the drill hold is 3.5 inches with the bench height of the blast equal to 10 meter. The volume for one blast is around 2,625 m^3 which is required 1,312 kg of explosive in total. There are two type of explosive in the process of this blasting design, first of all is ANFO (Ammonium Nitrate Fuel Oil) that contain 1,246 kg and the high explosive (emulsion) contain 66kg. The power factor of the blast is 0.188 kg/ton.

According to the blasting design above, topography map and the real condition, the block size of the project is given as 15m, 15m, 10m in (x, y, z) dimension, respectively. This block shows that the total volume of each block is 2,250 cubic meter which is equal to 6,000 ton (specific gravity of limestone =2.60). As a result, one blast almost equal to one blocks tonnage. Figure 4.1 illustrates the blasting pattern design for this project.

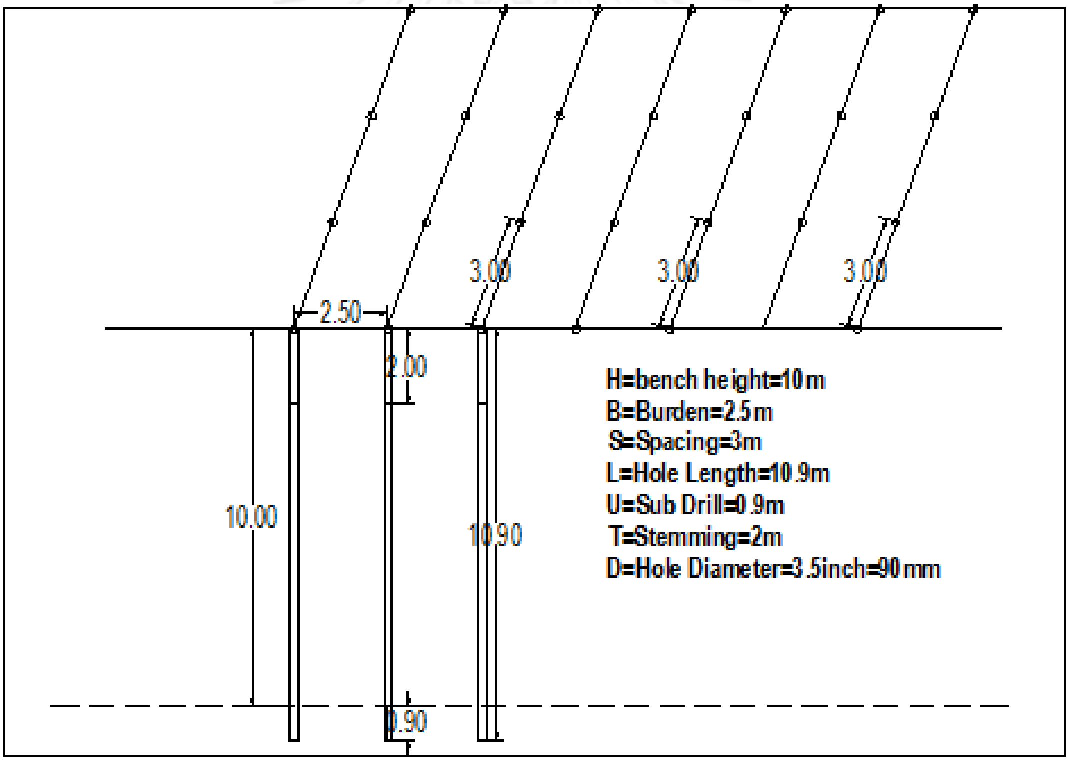

Figure 4.1 Blasting pattern design

4.2. Loading and Transportation

Typically for the limestone quarry production, wheel loader, excavator, and truck system are chosen to be a material transportation equipment because the flexibility and facilities. To ensure the selected equipment meet production requirement equipment, the design of equipment selection has been performed at the expected initial and maximum operation parameters of the facilities.

In this study, the wheel loader (model CAT 966C), excavator (model CAT 320D, and the dump truck (model 3305F OFF-HIGTWAY) are used. The equipment production calculations are illustrated in the following sections.

4.2.1. Loader Production Calculation

The loader model CAT 966C with the capacity of 2.3 cubic meter is used in this calculation. From equation (2.7), the estimation of the production per hour of the wheel loader is shown in Table 4.2 together with all input parameters.

Table 4.2 Estimation of production per hour of the wheel loader

Parameters	Equation	Result
BC (bucket size)	$2.3m^3$	3 CY
BF (bucket fill factor)	90 percent	0.9
D (density in place)	1.6 ton/m^3	1.2 ton/CY
MA (mechanical availability)	85 percent	0.85
JF (job factor)	83.3 percent (assumption)	0.833
SF (swell factor)	60 percent (limestone)	0.60
CT (average cycle time)	0.5 min	0.5
O (production)	$\frac{BC \times BF \times D \times MA \times JF \times 3600\,\text{sec}}{(1+SF) \times CT}$	172 ton/hour

From the calculation in Table 4.2, the result production of wheel loader per hour is 172 ton/hour, and it requires 3wheel loader for loading 550 ton per hour of limestone production.

4.2.2. Excavators Production Calculation

As mention earlier, the excavators model CAT 32D is used in the quarry operation with the capacity of 1.2 cubic meter. The same calculation from equation (2.7) the calculation sheet of excavator production per hour is provided in Table 4.3.

Table 4.3 Production per hour of excavator calculation

Parameters	Equation	Result
BC (bucket size)	1.2 m^3	1.57 CY
BF (bucket fill factor)	90 percent	0.9
D (density in place)	1.6 ton/m^3	1.2 ton/CY
MA (mechanical availability)	85 percent	0.85
JF (job factor)	85 percent (assumption)	0.85
SF (swell factor)	60 percent (limestone)	0.60
CT (average cycle time)	0.5 min	0.5
O (production)	$\frac{BC \times BF \times D \times MA \times JF \times 3600\,\text{sec}}{(1+SF)\times CT}$	92 ton/hour

4.2.3. Truck Production Calculation

In the quarry operation, trucks are an important equipment to transport the ore or waste material from the site to the crushing plan or waste dumps. It's necessary to understand about the number and the type of the truck to reduce the operation cost and enhance the productivity. In this research, the type and the capacity of the truck are selected to determine the number of truck to operate and the cycle time of each truck.

The main objectives of the truck production calculation have 3 folds which are; first to estimate the loading time of wheel loader; second to estimate the hauling time for truck from working bench to crusher; third to estimate the return time of truck from crusher to working bench. The assumptions have been made that the dumping time and the spotting time are 1.5 minutes and 0.8 minute based on the information of Caterpillar Handbook (*Caterpillar Performance Handbook*, 1979-2004). The detail input information is provided in Appendix C.

In this study, the cycle time are calculated based on a haul road connecting the center at the pit to the crusher. The hauling and returning distance are divided into 3 segments based on the road condition (percent grade, working condition) as shown in Table 4.3. The truck average speed and time are calculated for hauling and returning segments. The total hauling time is 3.57 minutes, while the total returning time is 3.29 minutes. The wheel loader loading time is 4.5 minutes. Therefore, taking every truck cycle time into consideration, **the total cycle time of the trucks is 13.66 minutes.** The summary of total truck's cycle time is provided in Table 4.4.

Table 4.4 Hauling and returning time

Hauling				
segments	Length (m)	Grade (%)	Avg. Speed (km/h)	Time (min)
1	200	0	19	0.6
2	670	10	17	2.36
3	220	0	21.6	0.6
Total	1090			3.57
Returning				
1	220	0	25.2	0.52
2	670	-10	18.2	2.2
3	200	0	21	0.57
Total	1090			3.29

Table 4.5 The total truck's cycle time

Load	4.5 minutes
Haul	3.57 minutes
Dump	1.5 minutes
Return	3.29 minutes
Spot	0.8 minutes
Total	13.66 minutes

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4.2.4. Unit Production

The unit production calculation aims to optimize the number of truck need for the quarry operation. Unit production is calculated by consider the truck payload, truck cycle time, hour per shift, and operation efficiency. The calculation is displayed in Table 4.5.

Table 4.6 Unit operation calculation

Parameters	Equation/ Assumptions	Results
Working time	50 min/hour (assumption)	50 min/ hour
Operation efficiency	85 percent (assumption)	0.85
Productivity	Truck/cycle*1cycle/cycle time*work time*operation efficiency	100 ton/hour
N (number of the truck)	Cycle time/ loading time	3 trucks
To reach 550 ton/ hour	550 ton/h /productivity	6 trucks

The unit operation calculation shows that 6 trucks are required to fulfill the 550 tons per hour of material handling.

To summarize the loading and transportation requirement of the quarry operation the total cycle time of truck operation is approximately 14 minutes, and it requires 1 loader, 2 excavators and 6 trucks to handle 550 tons per hour of limestone production.

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CHAPTER V

ENVIRONMENTAL AND SOCIAL CONSIDERATION

5.1. Introduction

In the quarry operation, there are problems related to environment which are noise, vibration, and air blast pollution. These problems are generated during the quarry operation such as drilling, blasting, loading and transportation.

Noise from mining is a common source of community concern because operational noise emissions frequently occur on a continuous basis. This can interfere unreasonably with day to day activities, particularly concentration, recreation and sleep, and result in an adverse impact on residential amenity.

Vibration and air blast from blasting can lead to community concern primarily due to the fear of structural damage. This fear occurs because people are able to detect vibration at levels which are well below those which result in even superficial damage to buildings and items of heritage value.

5.2. Noise Pollutions Control

Noise from the quarry operation is one of the main problems in quarry operation. It's happen any time during the mine start to operate. Most of the noise pollution is generated during blasting, transportation and in the crushing plant. There is much mitigation to control and reduce the noise during operation. However, the best policy to mitigate the noise control is to set the noise standard in the quarry operation.

In this study, the noise standards for quarry operation are recommended as following;

- The maximum noise level recommend for blasting is 115dB linear
- The level of 115 dB linear can be exceeded on up to 5 percent of the total number of blasts over a period of 12 months. However, the noise level should not exceed 120 dB linear at any time.
- Optimum placement of waste dumps, location of haul roads, location of fixed plant such as crushers and loading hoppers, waste dumps, stockpiles, can be used to shield fixed items of plant which generate noise.

- Selecting low noise plant and equipment incorporating available noise control equipment. This should be among one of the first measures chosen to minimize noise impact.

5.3. Vibration Control

Blasting can generate vibration, audible noise, fly rock and dust. In general, the levels of vibration caused by blasting are well below those which can cause structural damage to properties. Table 5.1 illustrates the level of the vibration with the degree of perception (Hudson, 1998).

Table 5.1 Vibration level with degree of perception

Approximate Vibration Level	Degree of Perception
0.10 mm/s	Not felt
0.15 mm/s	Threshold of perception
0.35 mm/s	Barely noticeable
1.0 mm/s	Noticeable
2.2 mm/s	Easily noticeable
6.0 mm/s	Strongly noticeable
14.0 mm/s	Very strongly noticeable

However, for this study, the recommended standard vibration limit is introduced as following;

- The recommended maximum level for ground vibration should be 5 mm./s (peak particle velocity).
- The peak particle velocity level of 5 mm/s may be exceeded less than up to 5percent of the total number of blasts over a period of 12 months. The level ground vibration should not exceed 10 mm/s at any time.
- Reducing the maximum instantaneous charge (MIC) by using delays, reduced hole diameter and/or deck loading.
- Changing the burden and spacing by altering the drilling pattern, and/or delay layout, or altering the hole inclination.

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- Use the minimum practicable sub-drilling which gives satisfactory toe conditions.

5.4. Air Pollution Control

The primary air emission associated with quarry operations is dust. Dust can be a nuisance to neighbors and may be a safety hazard to quarry employees. Dust from mining and quarrying operations, if allowed to enter the atmosphere creates an uncomfortable working environment, causes excessive wear on machinery, reduces visibility and increasing the risk of accidents.

In the quarry operation, the dust emission standard are introduced is following;

- Respirability silica should not more than 0.2 mg/m^3
- Inspirable particulates, containing less than 1 percent free silica 10.0 mg/m^3
- Respirability particulates, containing less than 1 percent free silica 3.0 mg/m^3
- Eliminate exposed detonating cord and secondary blasting. In the event that an explosive detonating cord is used to detonate the blast holes, it should be covered with a suitable aggregate material. However, the potential for initiation-related air blast emissions can be minimized with the use of NONEL (non-electric) initiation systems.
- Use a water spray to reduce dust from truck and any equipment during operation.

5.5. Communities Liaison

Liaison between mining company and the community is important at every point, from the beginning of the exploration stage throughout the mine operation stage and rehabilitation period. The community must be kept informed and involved in the decision-making process affecting them if a good working relationship is to develop between all involved parties. A good working relationship is the keystone to a win/win approach involving mining and the community.

This suggestion can be made are that the policies and regulations for connecting with the people around the quarry should be established. The first step consists of the people in the immediate neighborhood surrounding the operation. This is the population directly affected by the operation or its truck traffic. The second step is the larger community. These are the people beyond the immediate neighborhood, the general public, who are not directly impacted by the production facility or its trucks. The project should plan to build the school for the children around the quarry, check the health for every 3 months, and provide the skill for the people to add more jobs. In addition, the activity with the community like soccer, field trips are recommended. In every 6 months, it is advised to set up the program for discussing with the people around the quarry to hear their concerns and request for better linkage between community and quarry project.

5.6. Mine Rehabilitation

Rehabilitation should be considered as a core part of the business, and should be fully integrated with the planning of quarry operation. Similarly, the rehabilitation plan and decommission plan need to be fully integrated so that activities undertaken during operation and decommission do not impair the ability to execute the rehabilitation plan.

It is suggested that, during the mine operation, there are some activities for mine rehabilitated. Especially, along the rock slope, the mines are planted with local species and other mine area to keep the site green.

After mine life, since the project located in the rural area and the people usually have problem with water resources during dry season. As a result, the final rehabilitation scheme should convert an extraction pit into a water reservoir, which includes small ponds, and a large water reservoir. This reservoir will benefit local communities for agricultural irrigation and fish cultivation.

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CHAPTER VI
CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

From the research output, many important points can be concluded in accordance with the steps of work. These results are primary used for quarry design and management in the research area in Cambodia. These points are:

1. From the 3D block model, the 21 drill holes data with 336 assay data is prepared in minesight input format. The calcium oxide and silica content are the selected variables. These variables are composite with regular interval of 5 meters. The statistical results of calcium oxide grade show a mean average of 52.24 percent and variance of 34.31 percent, and silica grade shows a mean average of 4 percent with the variance of 57.86 percent.
2. The geological block model is constructed with the block discretization of 15 mx15mx10m in (x,y,z) block dimension, resulting a 560,000 total number of blocks. The geological block model cover all studies volume extending 1,300 meters in x-direction (Easting), 600 meters in y-direction (Northing), and 500 meters in z-direction (thickness).
3. The IDSM is used to calculate the geological resource of the deposit. The result shows that the total geological resource of 204 million tons is estimated.
4. The Lerchs-Grossmann pit optimization is used to achieve the optimum pit design. The results show three main ultimate pit (MP1, MP2, MP3) and three small connected pit (SP1, SP2, SP3). The total mineable reserve of these ultimate pits is 84 million tons. However, in this study on the main MP1 pit is selected for the first stage of mine development. The MP1 pit is chosen based solely on the quality and quantity of limestone that suitable for cement production. Therefore, the mineable reserve of 30 million tons of limestone from MP1 pit is estimated. The 30 million tons mineable reserve is produced for 1 million tons per year production, and covering the 25 year mine life.
5. In this study, the cutoff qualities of limestone to be treated as ore are with calcium oxide higher than 52 percent and silica lower than 3 percent. The mix-method classifies the qualities of limestone into two groups. Firsts, the

calcium oxide is higher than 52 percent, and silica between 3 to 4 percent. Second, the calcium oxide between 45 to 52 percent and silica is lower than 3 percent. Other qualities which are not fit into this classification will be treated as waste.

6. For mine planning and scheduling, In the first year, the production starts with 1.3 million tons with the overall slope angle of 45 degree, in this year the level of the pit floor elevation is 150 meter above the mean sea level (msl), and the surface elevation of 210 meter above msl. The second year production accumulates to 2 million tons with the same slope angel 45 degree and the floor pit elevation lower to 140 meters above msl. In the final year production, the cumulative production amounts to 29.5 million tons while maintain the 45 degree overall slope angle and the final pit floor elevation drop to 90 meter above msl.
7. For the financial analysis, it can be summarized that the WACC is estimated at 15 percent with two sources of funding which are 30 percent from bank loan and 70 percent from shareholder. IRR is estimated at 45 percent which is considerably much more than WACC rate, and NPV is 19.3 million dollar. Taking these financial factors into account, the quarry project is proven feasible.
8. The blasting pattern is designed with 35 holes in total which contain 5 rows and 7 columns. The diameter of the drill hold is 3.5 inches with the bench height of the blast equal to 10 meter. The volume for one blast is around 2,625 m^3 which is required 1,312 kg of explosive in total. There are two type of explosive in the process of this blasting design, first of all is ANFO (Ammonium Nitrate Fuel Oil) that contain 1,246 kg and the high explosive (emulsion) contain 66kg. The power factor of the blast is 0.188 kg/ton.
9. The loading and transportation requires 14 minutes for the total cycle time of truck operation. The material handling requires 5 trucks, 1 loader and 2 excavators to handle 550 tons per hour of limestone production.
10. For environmental consideration, the maximum noise level recommend for blasting is 115 dB linear. The recommended maximum level for ground vibration should be 5 mm/s. The respirability and inspirable particulate silica should be less than 0.2 mg/m^3, and less than 1 percent free silica 10 mg/m^3.

11. After mine life, the final rehabilitation scheme should convert an extraction pit into a water reservoir, which includes small ponds, and a large water reservoir. This reservoir will benefit local communities for agricultural irrigation and fish cultivation.

6.2. Recommendations

Some recommendation can be made from the results of the research and the future work:

1. The site investigation in terms of geological mapping (structural mapping) should be carried out to include the structural control parameters in the pit optimization process.
2. The geostatistcal method can be used to estimate the block values which provide the more reliable model.
3. The recommended environmental standards should take into accounted of the local specific conditions.
4. For future study, the conveyor belt can be used as an alternative of truck transportation.

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APPENDIX

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APPENDIX A
Mining License and Royalty

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ព្រះរាជាណាចក្រកម្ពុជា

ជាតិ សាសនា ព្រះមហាក្សត្រ

ក្រសួងសេដ្ឋកិច្ច និងហិរញ្ញវត្ថុ

ក្រសួងឧស្សាហកម្ម រ៉ែ និងថាមពល

លេខ: ១៣៧ សហវ.ឧរថ.ប្រក. រាជធានីភ្នំពេញ,ថ្ងៃទី ២៧ ខែ មីនា ឆ្នាំ២០០៩

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ប្រកាសអន្តរក្រសួង

ស្តីពីការកំណត់ថ្លៃ

ចុះបញ្ជី ពាក្យសុំ(អាជ្ញាប័ណ្ណ) ការពន្យារពេល ការផ្ទេរសិទ្ធិនៃអាជ្ញាប័ណ្ណធនធានរ៉ែ ឈ្នួលដីប្រចាំឆ្នាំនៃតំបន់សម្បទានសំរាប់ធ្វើការស្វែងរុករក និង/ឬធ្វើអាជីវកម្មធនធានរ៉ែ និង សួយសារធនធានរ៉ែ

ឧបនាយករដ្ឋមន្ត្រី រដ្ឋមន្ត្រីក្រសួងសេដ្ឋកិច្ច និងហិរញ្ញវត្ថុ និង រដ្ឋមន្ត្រីក្រសួងឧស្សាហកម្ម រ៉ែ និងថាមពល

- បានឃើញរដ្ឋធម្មនុញ្ញនៃព្រះរាជាណាចក្រកម្ពុជា
- បានឃើញព្រះរាជក្រឹត្យលេខ នស/រកម/០៧០៤/០០១ ចុះថ្ងៃទី ១៣ ខែ កក្កដា ឆ្នាំ ២០០៤ ដែលប្រកាសឱ្យប្រើច្បាប់ធម្មនុញ្ញបន្ថែម សំដៅធានានូវដំណើរការជាប្រក្រតីនៃស្ថាប័នជាតិ
- បានឃើញព្រះរាជក្រឹត្យលេខ នស/រកត/០៩០៨/០៥៥ ចុះថ្ងៃទី ២៥ ខែ កក្កដា ឆ្នាំ ២០០៨ ស្តីពីការតែងតាំងរាជរដ្ឋាភិបាលនៃព្រះរាជាណាចក្រកម្ពុជា
- បានឃើញព្រះរាជក្រមលេខ ០២/នស/៩៤ ចុះថ្ងៃទី ២០ ខែ កក្កដា ឆ្នាំ ១៩៩៤ ដែលប្រកាសឱ្យប្រើច្បាប់ស្តីពីការរៀបចំ និងការប្រព្រឹត្តទៅនៃគណៈរដ្ឋមន្ត្រី
- បានឃើញព្រះរាជក្រមលេខ ០១/នស/៩៣ ចុះថ្ងៃទី ២៨ ខែ ធ្នូ ឆ្នាំ ១៩៩៣ ដែលប្រកាសឱ្យប្រើច្បាប់ស្តីអំពីប្រព័ន្ធហិរញ្ញវត្ថុ និងច្បាប់ទាំងឡាយដែលធ្វើវិសោធនកម្មច្បាប់នេះ
- បានឃើញព្រះរាជក្រមលេខ នស/រកម/០១៩៦/១៨ ចុះថ្ងៃទី ២៤ ខែ មករា ឆ្នាំ ១៩៩៦ ដែលប្រកាសឱ្យប្រើច្បាប់ស្តីពីការបង្កើតក្រសួងសេដ្ឋកិច្ច និងហិរញ្ញវត្ថុ
- បានឃើញព្រះរាជក្រមលេខ នស/រកម/០១៩៦/០៥ ចុះថ្ងៃទី ២៤ ខែ មករា ឆ្នាំ ១៩៩៦ ដែលប្រកាសឱ្យប្រើច្បាប់ស្តីពីការបង្កើតក្រសួងឧស្សាហកម្ម រ៉ែ និង ថាមពល
- បានឃើញព្រះរាជក្រមលេខ នស/រកម/០៧០១/០៥ ចុះថ្ងៃទី ១៣ ខែ កក្កដា ឆ្នាំ ២០០១ ដែលប្រកាសឱ្យប្រើច្បាប់ស្តីពីការគ្រប់គ្រង និងការធ្វើអាជីវកម្មធនធានរ៉ែ
- បានឃើញអនុក្រឹត្យលេខ ០៤ អនក្រ.បក ចុះថ្ងៃទី ២០ ខែ មករា ឆ្នាំ ២០០០ ស្តីពីការរៀបចំ និងការប្រព្រឹត្តទៅរបស់ក្រសួងសេដ្ឋកិច្ច និងហិរញ្ញវត្ថុ
- បានឃើញអនុក្រឹត្យលេខ ៣៥ អនក្រ.បក ចុះថ្ងៃទី [illegible] ខែ មេសា ឆ្នាំ ១៩៩៩ ស្តីពីការរៀបចំ និងការប្រព្រឹត្តទៅរបស់ក្រសួងឧស្សាហកម្ម រ៉ែ និងថាមពល

- បានឃើញអនុក្រឹត្យលេខ ៧៨ អនក្រ.បក ចុះថ្ងៃទី ១៨ ខែ វិច្ឆិកា ឆ្នាំ ២០០៤ ស្តីពីការបំពេញបន្ថែម និងកែសម្រួលនាយកដ្ឋានមួយចំនួននៃក្រសួងសេដ្ឋកិច្ច និងហិរញ្ញវត្ថុ។

សម្រេច

ប្រការ ១.-

រូបវ័ន្តបុគ្គល នីតិបុគ្គលដែលដាក់ពាក្យសុំ ឬសម្បទានិកដែលមានអាជ្ញាប័ណ្ណធនធានរ៉ែ ត្រូវបង់ជូនរដ្ឋនូវថ្លៃតាមតារាងកំណត់ថ្លៃដូចខាងក្រោម:

១. ថ្លៃចុះបញ្ជី

១- អាជ្ញាប័ណ្ណសិប្បកម្មធនធានរ៉ែ	៤០.០០០	(សែសិបពាន់) រៀល
២- អាជ្ញាប័ណ្ណអណ្តូងរ៉ែបើកនិងការដ្ឋានវាយថ្ម សំរាប់ :		
២-១ ខ្សាច់សំណង់, ឡាតេរីត, ដីឥដ្ឋ......................	៤០០.០០០	(បួនរយពាន់) រៀល
២-២ ថ្មសំណង់, ថ្មអារ, ក្រួស, ម្នាងសិលា និងថ្មផ្សេងទៀតដែលមានលក្ខណៈប្រហាក់ប្រហែល	៨០០.០០០	(ប្រាំបីរយពាន់) រៀល
៣- អាជ្ញាប័ណ្ណអាជីវកម្មរ៉ែត្បូងថ្មមានតម្លៃ	២.០០០.០០០	(ពីរលាន) រៀល
៤- អាជ្ញាប័ណ្ណកែច្នៃធនធានរ៉ែ	៤០០.០០០	(បួនរយពាន់) រៀល
៥- អាជ្ញាប័ណ្ណស្វែងរុករក	៨០០.០០០	(ប្រាំបីរយពាន់) រៀល
៦- អាជ្ញាប័ណ្ណឧស្សាហកម្មអាជីវកម្មធនធានរ៉ែ	១.២០០.០០០	(មួយលានពីររយពាន់) រៀល

២. ថ្លៃពាក្យសុំ(តម្លៃអាជ្ញាប័ណ្ណ) licence fee

១- អាជ្ញាប័ណ្ណសិប្បកម្មធនធានរ៉ែ	៥០.០០០	(ហាសិបពាន់) រៀល
២- អាជ្ញាប័ណ្ណអណ្តូងរ៉ែបើកនិងការដ្ឋានវាយថ្ម សំរាប់ :		
២-១ ខ្សាច់សំណង់, ឡាតេរីត, ដីឥដ្ឋ......................	៦០០.០០០	(ប្រាំមួយរយពាន់) រៀល
២-២ ថ្មសំណង់, ថ្មអារ, ក្រួស, ម្នាងសិលា និងថ្មផ្សេងទៀតដែលមានលក្ខណៈប្រហាក់ប្រហែល	១.៦០០.០០០	(មួយលានប្រាំមួយរយពាន់) រៀល
៣- អាជ្ញាប័ណ្ណអាជីវកម្មរ៉ែត្បូងថ្មមានតម្លៃ	៨.០០០.០០០	(ប្រាំបីលាន) រៀល
៤- អាជ្ញាប័ណ្ណកែច្នៃធនធានរ៉ែ ដែលមាន :		
៤.១- កំលាំងពលកម្មតិចជាង៧នាក់......................	៨០០.០០០	(ប្រាំបីរយពាន់) រៀល
៤.២- កំលាំងពលកម្មពី៧នាក់ ទៅ ១៤ នាក់................	១.៦០០.០០០	(មួយលានប្រាំមួយរយពាន់) រៀល
៤.៣- កំលាំងពលកម្មលើសពី ១៤ នាក់......................	៣.២០០.០០០	(បីលានពីររយពាន់) រៀល
៥- អាជ្ញាប័ណ្ណស្វែងរុករក	៦.០០០.០០០	(ប្រាំមួយលាន) រៀល
៦- អាជ្ញាប័ណ្ណឧស្សាហកម្មអាជីវកម្មធនធានរ៉ែ	១២.០០០.០០០	(ដប់ពីរលាន) រៀល

៣. ថ្លៃពន្យារបន្ត

១- អាជ្ញាប័ណ្ណអណ្តូងរ៉ែបើកចំហនិងការដ្ឋានវាយថ្ម សំរាប់
១-១ ខ្សាច់សំណង់, ឡាតេរីត, ដីឥដ្ឋ.................... ៤២០.០០០ (បួនរយម្ភៃពាន់) រៀល
១-២ ថ្មសំណង់, ថ្មអារ, ក្រួស, ម្នាងសិលា និងថ្មផ្សេងទៀតដែលមានលក្ខណៈប្រហាក់ប្រហែល..... ១.១២០.០០០ (មួយលានមួយរយម្ភៃពាន់) រៀល
២- អាជ្ញាប័ណ្ណអាជីវកម្មរ៉ែត្បូងថ្មមានតម្លៃ .... ៥.៦០០.០០០ (ប្រាំ លានប្រាំមួយរយពាន់) រៀល
៣- អាជ្ញាប័ណ្ណកែច្នៃធនធានរ៉ែ ដែលមាន :
៣.១- កំលាំងពលកម្មតិចជាង៧នាក់................. ៥៦០.០០០ (ប្រាំរយហុកសិបពាន់) រៀល
៣.២- កំលាំងពលកម្ម ពី៧ នាក់ ទៅ ១៤ នាក់..... ១.១២០.០០០ (មួយលានមួយរយម្ភៃពាន់) រៀល
៣.៣- កំលាំងពលកម្មលើសពី ១៤ នាក់............ ២.២៤០.០០០ (ពីរលានពីររយសែសិបពាន់) រៀល
៤- អាជ្ញាប័ណ្ណស្វែងរុករក.. ៤.២០០.០០០ (បួនលានពីររយពាន់) រៀល
៥- អាជ្ញាប័ណ្ណឧស្សាហកម្មអាជីវកម្មធនធានរ៉ែ .... ៨.៤០០.០០០ (ប្រាំបីលានបួនរយពាន់) រៀល

៤. ថ្លៃផ្ទេរសិទ្ធិនៃអាជ្ញាប័ណ្ណធនធានរ៉ែ

១-អាជ្ញាប័ណ្ណអណ្តូងរ៉ែបើកចំហនិងការដ្ឋានវាយថ្មសំរាប់ :
១-១ ខ្សាច់សំណង់, ឡាតេរីត, ដីឥដ្ឋ.................... ២.០០០.០០០ (ពីរលាន) រៀល
១-២ ថ្មសំណង់, ថ្មអារ, ក្រួស, ម្នាងសិលា និងថ្មផ្សេងទៀតដែលមានលក្ខណៈប្រហាក់ប្រហែលគ្នា .. ៨.០០០.០០០ (ប្រាំបីលាន) រៀល
២-អាជ្ញាប័ណ្ណអាជីវកម្មរ៉ែត្បូងថ្មមានតម្លៃ .... ១៦.០០០.០០០ (ដប់ប្រាំមួយលាន) រៀល
៣-អាជ្ញាប័ណ្ណកែច្នៃធនធានរ៉ែ ដែលមាន :
៣.១- កំលាំងពលកម្មតិចជាង៧នាក់ .... ២.០០០.០០០ (ពីរលាន) រៀល
៣.២- កំលាំងពលកម្មពី៧នាក់ ទៅ ១៤ នាក់..... ៤.០០០.០០០ (បួនលាន) រៀល
៣.៣- កំលាំងពលកម្មលើសពី ១៤ នាក់........... ៦.០០០.០០០ (ប្រាំមួយលាន) រៀល
៤- អាជ្ញាប័ណ្ណស្វែងរុករក..................................... ២០.០០០.០០០ (ម្ភៃលាន) រៀល
៥- អាជ្ញាប័ណ្ណឧស្សាហកម្មអាជីវកម្មធនធានរ៉ែ ...... ២៤.០០០.០០០ (ម្ភៃបួនលាន) រៀល

៥. ថ្លៃឈ្នួលដីប្រចាំឆ្នាំនៃតំបន់សម្បទានសំរាប់ធ្វើការស្វែងរុករក និង/ឬធ្វើអាជីវកម្មធនធានរ៉ែ

ប្រភេទអាជ្ញាប័ណ្ណធនធានរ៉ែ	ថ្លៃឈ្នួលដីប្រចាំឆ្នាំ
១- អាជ្ញាប័ណ្ណសិប្បកម្មធនធានរ៉ែ	
-ប្រភេទ ក (សំរាប់រ៉ែរបេះដាច់ ខ្សាច់ ក្រួស ឡាតេរីត)	១០ (ដប់) ដុល្លារអាមេរិក/ហិកតា/ឆ្នាំ
-ប្រភេទ ខ (សំរាប់រ៉ែមាស)	១៥ (ដប់ប្រាំ) ដុល្លារអាមេរិក/ហិកតា/ឆ្នាំ
-ប្រភេទ គ (សំរាប់រ៉ែត្បូងថ្មមានតម្លៃ-ពាក់កណ្តាលមានតម្លៃ)	៣០ (សាមសិប) ដុល្លារអាមេរិក/ហិកតា/ឆ្នាំ

ទំព័រទី ៣

២- អាជ្ញាប័ណ្ណអណ្តូងរ៉ែបើកនិងការដ្ឋានវាយថ្ម	
-ប្រភេទ ក (សំរាប់ថ្មអារ និងថ្មបំបែក)	៤០ (សែសិប) ដុល្លារអាមេរិក/ហិកតា/ឆ្នាំ
-ប្រភេទ ខ (សំរាប់រ៉ែរបេះដាច់ ខ្សាច់ ក្រួស ឡាតេរីត)	២០ (ម្ភៃ) ដុល្លារអាមេរិក/ហិកតា/ឆ្នាំ
-ប្រភេទ គ (សំរាប់ថ្មកំបោរ)	១០ (ដប់) ដុល្លារអាមេរិក/ហិកតា/ឆ្នាំ
៣- អាជ្ញាប័ណ្ណអាជីវកម្មរ៉ែត្បូងថ្មមានតម្លៃ	
-ប្រភេទ ក (សំរាប់រ៉ែត្បូងថ្មមានតម្លៃ-ពាក់កណ្តាលមានតម្លៃ)	១២ (ដប់ពីរ) ដុល្លារអាមេរិក/ហិកតា/ឆ្នាំ
-ប្រភេទ ខ (សំរាប់ថ្មសំណង់)	៤០ (សែសិប) ដុល្លារអាមេរិក/ហិកតា/ឆ្នាំ
៤- អាជ្ញាប័ណ្ណកែច្នៃធនធានរ៉ែ	ថ្លៃឈ្នួលដីឬទីតាំងអនុវត្តតាមច្បាប់សារពើពន្ធ
៥- អាជ្ញាប័ណ្ណស្វែងរុករក	
- ពីឆ្នាំទី១ ដល់ឆ្នាំទី២	០.១៥ (ដប់ប្រាំសេន)ដុល្លារអាមេរិក /ហិកតា/ឆ្នាំ
- ពីឆ្នាំទី៣ ដល់ឆ្នាំទី៤	០.៣០ (សាមសិបសេន) ដុល្លារអាមេរិក /ហិកតា/ឆ្នាំ
- ចាប់ពីឆ្នាំទី៥ឡើងទៅ	០.៥០ (ហាសិបសេន)ដុល្លារអាមេរិក /ហិកតា/ឆ្នាំ
៦- អាជ្ញាប័ណ្ណឧស្សាហកម្មអាជីវកម្មធនធានរ៉ែ	
- ពីឆ្នាំទី១ ដល់ឆ្នាំទី៣	៤ (បួន) ដុល្លារអាមេរិក/ហិកតា/ឆ្នាំ
- ពីឆ្នាំទី៤ ដល់ឆ្នាំទី៥	៨ (ប្រាំបី) ដុល្លារអាមេរិក/ហិកតា/ឆ្នាំ
- ពីឆ្នាំទី៦ ឡើងទៅ	១០ (ដប់) ដុល្លារអាមេរិក/ហិកតា/ឆ្នាំ

៦. សួយសារលើតម្លៃធនធានរ៉ែ

គ. ធនធានរ៉ែលោហៈ	អត្រាសួយសារ	
	សំរាប់ផ្គត់ផ្គង់ដល់រោងចក្រហើយដែលរោងចក្រនោះស្ថិតនៅក្រោមការគ្រប់គ្រងរបស់សម្បទានិកដែលមានអាជ្ញាប័ណ្ណធនធានរ៉ែ	សំរាប់គោលបំណងពាណិជ្ជកម្ម
- អង់ទីម៉ូនី (Sb)	២.៥ % - ៣.៥% នៃតម្លៃលក់ផលិតផល ដោយផ្អែកតាមតម្លៃនៅលើទីផ្សារអន្តរជាតិ	៤% - ៥%
- ក្រូម (Cr)		
- ដែក (Fe)		
- ម៉ង់កាណែស (Mn)		
- ម៉ូលីបដែន (Mo)		
- តង់ស្តែន (W)		
- ទីតាន/អាលុយមីញ៉ូម		
- ទង់ដែង (Cu)		
- ស័ង្កសី (Zn)		
- សំណប៉ាហាំង (Sn)		

 ß

- សំណ (Pb)		
- មាស (Au)		
- ប្លាទីនញ៉ូម (Pt)	២.៥ % - ៣.៥% នៃតម្លៃលក់ផលិតផល ដោយផ្អែកតាមតម្លៃនៅលើទីផ្សារអន្តរជាតិ	៤% - ៥%
- ប្រាក់ (Ag)		
- អ៊ីមីនីត (Ti) និង		
-ធនធានរ៉ែលោហៈផ្សេងទៀត ដែលមានលក្ខណៈប្រហាក់ប្រហែលគ្នា		
ខ. ធនធានរ៉ែអលោហៈ (ធនធានរ៉ែឧស្សាហកម្ម)		
- ដីឥដ្ឋធ្វើស៊ីម៉ងត៍	០.១០ ដុល្លារអាមេរិក/តោនស៊ីម៉ងត៍ដែលផលិតបាន	០.១០ ដុល្លារអាមេរិក/តោន
- កៅឡាំង	១.២០ ដុល្លារអាមេរិក/តោននៃផលិតផលសំរេច	១.២០ ដុល្លារអាមេរិក/តោន
- ថ្មកំបោរ	០.២០ ដុល្លារអាមេរិក/តោនស៊ីម៉ងត៍ដែលផលិតបាន	១.៥០ ដុល្លារអាមេរិក/តោន
- ថ្មហ្វូស្វ៊ីត	១.២០ ដុល្លារអាមេរិក/តោនជីហ្វូស្វាតដែលផលិតបាន	១.២០ ដុល្លារអាមេរិក/តោន
- ខ្សាច់ស៊ីលីស	១.៥០ ដុល្លារអាមេរិក/តោនខ្សាច់ឆៅ (មិនទាន់កែច្នៃ)	១.៥០ ដុល្លារអាមេរិក/តោន
- អំបិល	០.៥០ ដុល្លារអាមេរិក/តោនអំបិល	០.៥០ ដុល្លារអាមេរិក/តោន
គ. ត្បូងថ្មមានតម្លៃ ពាក់កណ្ដាលមានតម្លៃ ថ្មសំណង់		
គ.១. ត្បូងថ្មមានតម្លៃ		
- ពេជ្រ		
- ត្បូងទទឹម		
- ត្បូងកណ្ដៀង	១៥ % នៃតំលៃលក់ផលិតផល នៅលើទីផ្សារអន្តរជាតិ	
- មរកត និង		
- រ៉ែត្បូងថ្មទាំងឡាយដែលមានគុណភាពប្រហាក់ប្រហែលគ្នា		
គ.២. ត្បូងថ្មពាក់កណ្ដាលមានតម្លៃ		
-ត្បូងសេកុន (Zircon)		
-អាមេទីស (Amethyst)	១៥ % នៃតំលៃលក់ផលិតផល នៅលើទីផ្សារអន្តរជាតិ	
- តូប៉ាស		
- រ៉ែត្បូងថ្មទាំងឡាយដែលមានគុណភាពប្រហាក់ប្រហែលគ្នា		
គ.៣. ថ្មសំណង់		
ហ្សេត. ថ្មម៉ាប. ចាំហ្សេទីត. ក្រានីត កាល់សេដូន. អាស្ទីត. អូប៉ាល់ធម្មតា. អាហ្គាត. មាឡាស៊ីត. ឈើថ្ម . ថ្មថ្មើមអណ្ដើក និងថ្មទាំងឡាយដែលមានគុណភាពប្រហាក់ប្រហែល ។	១៥ % នៃតំលៃលក់ផលិតផល នៅលើទីផ្សារអន្តរជាតិ	

ឃ. ធនធានរ៉ែឥន្ធនៈរឹង		
- ធ្យូងថ្ម	៧ % នៃតំលៃលក់ផលិតផល នៅលើទីផ្សារអន្តរជាតិ	
- ធ្យូងភក់		

ប្រការ ២.-

អង្គភាពពាក់ព័ន្ធក្រោមចំណុះក្រសួងសេដ្ឋកិច្ច និងហិរញ្ញវត្ថុ និងក្រសួងឧស្សាហកម្ម រ៉ែ និងថាមពល ព្រមទាំងរូបវន្តបុគ្គល នីតិបុគ្គល ឬសម្បទានិកដូចក្នុងប្រការ១ ដែលមានអាជ្ញាប័ណ្ណធនធានរ៉ែ ត្រូវទទួលបន្ទុកអនុវត្ត តាមប្រកាសនេះ ។

ប្រការ ៣.-

ប្រកាសនេះមានប្រសិទ្ធភាព និងចូលជាធរមាន ចាប់ពីថ្ងៃចុះហត្ថលេខានេះតទៅ ។

ឧបនាយករដ្ឋមន្ត្រី
រដ្ឋមន្ត្រីក្រសួងសេដ្ឋកិច្ច និង ហិរញ្ញវត្ថុ

គាត ឈន់

រដ្ឋមន្ត្រីក្រសួងឧស្សាហកម្ម រ៉ែ និង ថាមពល

ស៊ុយ_សែម

ចម្លងជូន :
- ខុទ្ទកាល័យព្រះបរមរាជវាំង
- អគ្គលេខាធិការដ្ឋានព្រឹទ្ធសភា
- អគ្គលេខាធិការដ្ឋានរដ្ឋសភា
- អគ្គលេខាធិការរាជរដ្ឋាភិបាល
- ទីស្តីការគណៈរដ្ឋមន្ត្រី
- ខុទ្ទកាល័យសម្តេចអគ្គមហាសេនាបតីតេជោ **ហ៊ុន សែន** នាយករដ្ឋមន្ត្រីនៃព្រះរាជាណាចក្រកម្ពុជា
- គ្រប់ក្រសួង រដ្ឋលេខាធិការដ្ឋាន
- គ្រប់ខេត្ត-ក្រុង (ដើម្បីជូនជ្រាប)
- ដូចប្រការ ២ (ដើម្បីអនុវត្ត)
- ឯកសារ-កាលប្បវត្តិ

APPENDIX B
Financials Evaluation

จุฬาลงกรณ์มหาวิทยาลัย
Chulalongkorn University

INVESTMENT COST

No	Item	USD
1	**Land**	**210,000**
	Area (ha)	35
	Pricing (USD/Ha)	6,000
2	**Land Improvement (Access road)**	**200,000**
3	**Construction**	**44,000**
	Area (sqm)	200
	Cost (USD/sqm)	220
4	**Machinery**	**5,362,000**
	Hyd. Drilling Machine 2 units	840,000
	Crushing Plant 550 t/h 1 unit	4,200,000
	Head banging	180,000
	Measurement	22,000
	Electrics system and network	120,000
5	**Vehicles**	**1,835,000**
	Truck wheel 10@5unit	600,000
	Excavator (CAT 330)@2 unit	600,000
	Excavator (CAT 966 C)	450,000
	Back Hoe (CAT 320)	100,000
	small truck	85,000
6	**Office Equipment**	**10,000**
7	**License Fee**	**3,000**
	Total	**7,664,000**

Chulalongkorn University

ASSUMPTION

1. Investment

	USD
Land	210,000
Land Improvement (Access road)	200,000
Construction	44,000
Machinery	5,362,000
Vehicles	1,835,000
Office Equipment	10,000
License Fee	3,000
Total	7,664,000

2. Operation

Reserved Raw Material	30,000,000	Tons
Loss from Blasting	20%	
Net R/M	24,000,000	Tons
Production Capacity	1,372,800	Tons/Year
- M/C Capacity	550	Tons/Hr
- Working hour	8	Hours/Day
- Working day	26	Days/Month
Proportion of Products		
1. Limestone	100%	
2. Aggregate	0%	
3. Dust	0%	
4. Soil	0%	

Production	Year1	Year2	Year3	Year4	Year5	Year6	Year7	Year8	Year9	Year10	Year11-15	
Capacity (MioTons)	1,372,800	1,372,800	1,372,800	1,372,800	1,372,800	1,372,800	1,372,800	1,372,800	1,372,800	1,372,800	1,372,800	
Utilization	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	
Working period (จำนวนกะ)	1	1	1	1	1	2	2	2	2	2	2	
1. Limestone	1,235,520	1,235,520	1,235,520	1,235,520	1,235,520	2,471,040	2,471,040	2,471,040	2,471,040	2,471,040	2,471,040	
2. Aggregate	-	-	-	-	-	-	-	-	-	-	-	
3. Dust	-	-	-	-	-	-	-	-	-	-	-	
4. Soil	-	-	-	-	-	-	-	-	-	-	-	
Total	1,235,520	1,235,520	1,235,520	1,235,520	1,235,520	2,471,040	2,471,040	2,471,040	2,471,040	2,471,040	2,471,040	
3. Revenue & Cost												
Selling Price				8,648,640								
1.Lime stone	6	USD/ton										
2.Aggregate	-	USD/ton										
License Fee (ประทานบัตร)	**0.2**	USD/ton										
Royalty-Limestone	0.2	USD/ton										
Royalty-Aggregate	-	USD/ton										
Maintenace Cost	0%											
Insurance Premium	2%											
Depreciation			Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10-15
- Construction	5	Years	8,800	8,800	8,800	8,800	8,800					
- Machinery	10	Years	536,200	536,200	536,200	536,200	536,200	536,200	536,200	536,200	536,200	536,200
- Vehicle	5	Years	367,000	367,000	367,000	367,000	367,000					

R/W Price													
Fuel	**1.02**	USD/Liter											
Drilling Expense													
Drilling cost	0.350	USD/Ton											
Blasting expense	0.880	USD/Ton											
Transport (Truck)													
Transport cost	0.256	USD/Ton											
Loading													
Loading Cost	0.413	USD/Ton											
Crushing Plant													
Crushing cost	0.477	USD/Ton											
Direct Labour (Mining Plant)			Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11-15
	No of employee	Rate (USD/day)											
Drilling Workers	4	4	4,992	4,992	4,992	4,992	4,992	9,984	9,984	9,984	9,984	9,984	9,984
Blasting Workers													
Truck Drivers	7	6	13,104	13,104	13,104	13,104	13,104	26,208	26,208	26,208	26,208	26,208	26,208
Excavator Drivers (CAT 330)	2	6	3,744	3,744	3,744	3,744	3,744	7,488	7,488	7,488	7,488	7,488	7,488
Total			**21,840**	**21,840**	**21,840**	**21,840**	**21,840**	**43,680**	**43,680**	**43,680**	**43,680**	**43,680**	**43,680**
Direct Labour (Crushing Plant)			Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11-25
Enginees	2	15	9,360	9,360	9,360	9,360	9,360	9,360	9,360	9,360	9,360	9,360	9,360
Foreman	4	10	12,480	12,480	12,480	12,480	12,480	12,480	12,480	12,480	12,480	12,480	12,480
Machanic	5	10	15,600	15,600	15,600	15,600	15,600	15,600	15,600	15,600	15,600	15,600	15,600
Electrician	2	10	6,240	6,240	6,240	6,240	6,240	6,240	6,240	6,240	6,240	6,240	6,240
Labour - Blasting	3	4	3,744	3,744	3,744	3,744	3,744	3,744	3,744	3,744	3,744	3,744	3,744
Labour	10	4	12,480	12,480	12,480	12,480	12,480	24,960	24,960	24,960	24,960	24,960	24,960
Excavator Driver (CAT 966 C)	1	6	1,872	1,872	1,872	1,872	1,872	3,744	3,744	3,744	3,744	3,744	3,744
Back Hoe Driver (CAT 320)	1	6	1,872	1,872	1,872	1,872	1,872	3,744	3,744	3,744	3,744	3,744	3,744
Water Truck Driver			-	-	-	-	-	-	-	-	-	-	-
Total	41		63,648	63,648	63,648	63,648	63,648	79,872	79,872	79,872	79,872	79,872	79,872
Total (mining plant+crushing Plant)			85,488	85,488	85,488	85,488	85,488	123,552	123,552	123,552	123,552	123,552	123,552

1. Drilling

Hole Dia.		90	mm	Hole depth	10.9	m
Bench height		10	m	row	5	
Burden		2.5	m	collum	7	
Spacing		3	m	S.G	2.65	
Blasting Volum =		2625	m3			
		6956	ton			
Blasting per hole=		198.75	m3/hole			
		18.23	ton/m			
operation (drilling)		7	h/day			
		994	ton/h			
Drilling machine		2	unit			
Maintenance		5.5	USD/hour			
		0.011	USD/ton			
Repaire		0.02	USD/ton			
Feul consumption		21	litre/h, @		1.02	USD/Litre
		1.02	USD/Litre			
		0.006	USD/ton			
Total		0.0374	USD/ton			
Drill Bit dia. 90 mm		350.00	USD	Life =	2,000.00	m.
	Drill Bit =	0.18	USD/m.	0.025	USD/Ton	
Drill Rod 4 pcs/set		1,400.00	USD/set	Life =	2,500.00	m.
	Drill Rod =	0.56	USD/m.	0.081	USD/Ton	
Shank adaptor		400.00	USD	Life =	2,000.00	m.
	Shank adaptor =	0.20	บาท/m.	0.029	USD/Ton	
Cost of drilling		0.173	USD/Ton			
over head charge 100%		0.173	USD/Ton			
total cost of drilling		**0.346**	**USD/Ton**			

2. Blasting

Description	Unit	Used/hole	Unit price	cost	USD/Ton
Emulsion(d=50mm)	kg.	2	2.28	0.06	USD/Ton
NH_4NO_3	kg.	35.60	1.18	0.56	USD/Ton
Fuel Oil 6%	Litre	2	1	0.03	USD/Ton
MS Detonator	Nos.	1	1	0.01	USD/Ton
Copper Wire	m.	13	1	0.17	USD/Ton
			Total	0.83	USD/Ton

Cost of explosive	0.83	USD/ton
labor and package	0.05	USD/ton
Total of Blasting	**0.88**	**USD/ton**

3. Transport

production	113	ton/hour		
maintenance			2.000	USD/hour
			0.018	
fuel consumption	2.5	km/liter	12.00	liter/hour
Oil			0.108	USD/ton
truck	3000	USD	0.002	USD/ton
Total		0.128	USD/ton	
Service Charge 100 %		0.128	USD/ton	
Total cost of transport		0.256	USD/ton	

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4. Loading			
production	172	ton/hour	
Maintenance costs	8	USD/hour	
	0.047	USD/Ton	
fuel consumption	27	Litre/hour	
oil	0.160	USD/Ton	
total	0.207	USD/Ton	
service charge 100%	0.207	USD/Ton	
Total of Loading cos	**0.413**	**USD/Ton**	
5. crushing plant			
Milling machine	0.117	USD/Ton	
mill machinary	0.167	USD/Ton	
other	0.033	USD/Ton	
electricity charge	0.160	USD/Ton	
Crushing plant cost	**0.477**	**USD/Ton**	

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SALES

	Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11-15
Products												
1. Limestone	-	617,760	1,235,520	1,235,520	1,235,520	1,235,520	2,471,040	2,471,040	2,471,040	2,471,040	2,471,040	2,471,040
2. Aggregate	-	1	-	-	-	-	-	-	-	-	-	-
3. Dust	-	-	-	-	-	-	-	-	-	-	-	-
4. Soil	-	-	-	-	-	-	-	-	-	-	-	-
Total	-	**617,761**	**1,235,520**	**1,235,520**	**1,235,520**	**1,235,520**	**2,471,040**	**2,471,040**	**2,471,040**	**2,471,040**	**2,471,040**	**2,471,040**
Total R/W	-	**772,201**	**1,544,400**	**1,544,400**	**1,544,400**	**1,544,400**	**3,088,800**	**3,088,800**	**3,088,800**	**3,088,800**	**3,088,800**	**3,088,800**
Acc R/W	-	772,201	2,316,601	3,861,001	5,405,401	6,949,801	10,038,601	13,127,401	16,216,201	19,305,001	22,393,801	25,482,601
Sales												
1. Limestone	-	3,706,560	7,413,120	7,413,120	7,413,120	7,413,120	14,826,240	14,826,240	14,826,240	14,826,240	14,826,240	14,826,240
2. Aggregate	-	-	-	-	-	-	-	-	-	-	-	-
Total	-	**3,706,560**	**7,413,120**	**7,413,120**	**7,413,120**	**7,413,120**	**14,826,240**	**14,826,240**	**14,826,240**	**14,826,240**	**14,826,240**	**14,826,240**

OPEX

	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11-15
Total Products	617,761	1,235,520	1,235,520	1,235,520	1,235,520	2,471,040	2,471,040	2,471,040	2,471,040	2,471,040	2,471,040
Total R/W Blasting	-	772,201	1,544,400	1,544,400	1,544,400	1,544,400	3,088,800	3,088,800	3,088,800	3,088,800	3,088,800
License (ประทานบัตร)											
Licence Fee	-	154,440	308,880	308,880	308,880	308,880	617,760	617,760	617,760	617,760	617,760
Drilling											
Hole Deep (Metres)											
Feul Charge	216,216	432,432	432,432	432,432	432,432	864,864	864,864	864,864	864,864	864,864	864,864
Blasting											
Costing	543,630	1,087,258	1,087,258	1,087,258	1,087,258	2,174,515	2,174,515	2,174,515	2,174,515	2,174,515	2,174,515
Transport (Truck)											
Costing	158,147	316,293	316,293	316,293	316,293	632,586	632,586	632,586	632,586	632,586	632,586
Loading (Excavator)											
Costing	255,135	510,270	510,270	510,270	510,270	1,020,540	1,020,540	1,020,540	1,020,540	1,020,540	1,020,540
Crushing Plant	294,672	589,343	589,343	589,343	589,343	1,178,686	1,178,686	1,178,686	1,178,686	1,178,686	1,178,686
Direct Labour											
Mining Plant	21,840	21,840	21,840	21,840	21,840	21,840	21,840	21,840	21,840	21,840	21,840
Crushing Plant	63,648	63,648	63,648	63,648	63,648	63,648	63,648	63,648	63,648	63,648	63,648
Other Expenses											
Maintenance	-	-	-	-	-	-	-	-	-	-	-
Insurance	143,940	143,940	143,940	143,940	143,940	143,940	143,940	143,940	143,940	144,820	144,820
Equipment Expense											
Total	**1,697,228**	**3,319,464**	**3,473,904**	**3,473,904**	**3,473,904**	**6,409,499**	**6,718,379**	**6,718,379**	**6,718,379**	**6,719,259**	**6,719,259**

DEPRECIATION

Item	Value (Bht)	D. Years	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11-15
Construction	44,000	5	8,800	8,800	8,800	8,800	8,800	-	-	-	-	-	-
			8,800	17,600	26,400	35,200	44,000	44,000	44,000	44,000	44,000	44,000	44,000
Machinery	5,362,000		548,200	548,200	548,200	548,200	548,200	524,200	524,200	524,200	524,200	524,200	-
Hyd. Drilling Machine 2 units	840,000	10	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	-
Acc. Depre			84,000	168,000	252,000	336,000	420,000	504,000	588,000	672,000	756,000	840,000	840,000
crushing plant 550 t/h 1 unit	4,200,000	10	420,000	420,000	420,000	420,000	420,000	420,000	420,000	420,000	420,000	420,000	-
Acc. Depre			420,000	840,000	1,260,000	1,680,000	2,100,000	2,520,000	2,940,000	3,360,000	3,780,000	4,200,000	4,200,000
Head banging	180,000	10	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	-
Acc. Depre			18,000	36,000	54,000	72,000	90,000	108,000	126,000	144,000	162,000	180,000	180,000
Measurement	22,000	10	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	-
Acc. Depre			2,200	4,400	6,600	8,800	11,000	13,200	15,400	17,600	19,800	22,000	22,000
Electrics system& network	120,000	5	24,000	24,000	24,000	24,000	24,000	-	-	-	-	-	-
Acc. Depre			24,000	48,000	72,000	96,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000
Vehicles	1,835,000	5	367,000	367,000	367,000	367,000	367,000	-	-	-	-	-	-
Truck wheel 10@5unit	600,000	5	120,000	120,000	120,000	120,000	120,000	-	-	-	-	-	-
Acc. Depre			120,000	240,000	360,000	480,000	600,000	600,000	600,000	600,000	600,000	600,000	600,000
Excavator (CAT 330)@ 2unit	600,000	5	120,000	120,000	120,000	120,000	120,000	-	-	-	-	-	-
Acc. Depre			120,000	240,000	360,000	480,000	600,000	600,000	600,000	600,000	600,000	600,000	600,000
Excavator (CAT 966 C)	450,000	5	90,000	90,000	90,000	90,000	90,000	-	-	-	-	-	-
Acc. Depre			90,000	180,000	270,000	360,000	450,000	450,000	450,000	450,000	450,000	450,000	450,000
Back hoe (CAT 320)	100,000	5	20,000	20,000	20,000	20,000	20,000	-	-	-	-	-	-
Acc. Depre			20,000	40,000	60,000	80,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
Small truck	85,000	5	17,000	17,000	17,000	17,000	17,000	-	-	-	-	-	-
Acc. Depre			17,000	34,000	51,000	68,000	85,000	85,000	85,000	85,000	85,000	85,000	85,000
Total	**7,241,000**		**924,000**	**924,000**	**924,000**	**924,000**	**924,000**	**524,200**	**524,200**	**524,200**	**524,200**	**524,200**	-

year	0	1	2	3	4	5	6	7	8	9	10	11-15
Total Production	-	617,760	1,235,520	1,235,520	1,235,520	1,235,520	2,471,040	2,471,040	2,471,040	2,471,040	2,471,040	2,471,040
Gross Revenue	-	3706560	7413120	7413120	7413120	7413120	14826240	14826240	14826240	14826240	14826240	14826240
Annual Royalty	-	-123552	-247104	-247104	-247104	-247104	-494208	-494208	-494208	-494208	-494208	-494208
Net Revenue	-	3830112	7660224	7660224	7660224	7660224	15320448	15320448	15320448	15320448	15320448	15320448
Operation cost	-	-1697228	-3319463.77	-3473904	-3473904	-3473904	-6409499	-6718379	-6718379	-6718379	-6719259	-6719259
Depreciation	-	-924000	-924000	-924000	-924000	-924000	-524200	-524200	-524200	-524200	-524200	0
Taxible income	-	1208884	3416760.23	3262320	3262320	3262320	8386749	8077869	8077869	8077869	8076989	8601189
Tax @ 25%	-	-302221	-854190.058	-815580	-815580	-815580	-2096687	-2019467	-2019467	-2019467	-2019247	-2150297
Net Income	-	906663	2562570.173	2446740	2446740	2446740	6290062	6058402	6058402	6058402	6057742	6450892
Depreciation	-	924000	924000	924000	924000	924000	524200	524200	524200	524200	524200	0
Capital cost	-7664000	-	-	-	-	-	-	-	-	-	-	-
Present Value@15	-7664000	1591881	2636348	2216317	1927232	1675854	2945993	2474644	2151864	1871186	1626955	1386575
Cash Flow	-7664000	1830663	3486570	3370740	3370740	3370740	6814262	6582602	6582602	6582602	6581942	6450892

$$\sum_{t=1}^{n} \frac{NCFt}{(1+IRR)^t} = 0$$

WACC	**15.0%**
NPV	$19,224,835
DCF-ROR	45%

APPENDIX C
Serial and Model of Machine Quarry

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SERIAL AND MODEL MACHINE QUARRY

DUMP TRUCK 3305F OFF-HIGTWAY TRUCK (ENGINE MODEL CUMMINES M11 C)

NO	DESCRIPTION	NO	DESCRIPTION	Remark
1	Machine Type (Dump Truck)	1	Engine Oil Use Type =15w 40 =	40 Liters
2	Machine Brande (Terex)	2	Transmission Oil UseType SAE 10w =	26.5 Liters
3	Machine Model (3305F)	3	Hydraulic Oil System UseType SAE 10w =	121 Liters
4	Engine Model (Cummines M11-C350)	4	Differential Use Oil Type SAE 80w90=	57 Liters
5	Engine Power = 216 Kw =350hP. 2100 rpm	5	Steering Hydraulic Oil System Use Type SAE 10w=	47 Liters
6	Engine Number=(3588973)	6	Engine Coolant =	98 Liters
7	Machine Sarail Number T6651450	7	Wheel Planetaries Use Oil Type SAE 80W90=	30 Liters
8	Battery (24 V DC)	8	Fuel Tank Deisel Oil =	371 Liters
9	Use Water Coolant = 6 Cylinder		Receiver Date =10 01 2007	
10	Capacity =(32 Tone)			
11	Net Weight =(24 Tone)			
12	Max Pay Load =(32 Tone)			
13	Gross Weight = (56 Tone)			

EXCAVATOR SOLAR 340LC-V(ENGINE MODEL DE12TIS .340LC-V,)

NO	DESCRIPTION	NO	DESCRIPTION	Remark
1	Machine Type (Hydraulic Excavator)	1	Engine Oil Use Type =15w 40 =	28 Liters
2	Machine Brande (DAEWOO DOOSAN)	2	Hydraulic Oil System UseType =NUTO H =46	210 Liters
3	Machine Model (340lc-v)	3	Traveling (L &R)Use Oil Type SAE 80w90=	11 Liters
4	Engine Model (DE12TIS	4	Engine Coolant =	58 Liters
5	Engine Power = 247 Hp = 1900 rpm	5	Swing Gear Use Oil Type SAE 80W90=	6 Liters
6	Engine Number	6	Fuel Tank Deisel Oil =	550 Liters
7	Machine Sarail Number >DHKHELWOK50001782L<		Receiver Date =13 06 2006	
8	Battery (24 V DC) Use Battery 12 v150 AH			
9	Use Water Coolant = 6 Cylinder			
10	Fuel Consumption Use =26 L - 28 L/h			
11	Travel Speed High =4.6 Km/h			

12	Travel Speed Low =3.1 Km/h			
13	Swing Speed =8.9 rpm			
14	Gross Weight = (37004 Kg =37.4Tone)			
15	Bucket Capacity =1.3 m3			
16	Hyd Pump type Axial Piston Pressure =(350 kg/cm2			
EXCAVATOR CAT 320 D(ENGINE MODEL CAT 320D)				
NO	DESCRIPTION	NO	DESCRIPTION	Remark
1	Machine Type (Hydraulic Excavator)	1	Engine Oil Use Type =15w 40 =	23 Liters
2	Machine Brande (CAT 320D)	2	Hydraulic Oil System UseType =NUTO H CAT30	138 Liters
3	Engine Power =	3	Traveling (L & R)Use Oil Type SAE 80w90=	16 Liters
4	Engine Number=(G32FO-031)	4	Engine Coolant =	25 Liters
5	Machine Sarail Number (CAT320D VFAL02093)	5	Swing Gear Use Oil Type SAE 80W90=	8 Liters
6	Battery (24 V DC) Use Battery 12 v 70 AH	6	Splitter Box Use Oil Type SAE 80w 90	2 Liters
7	Use Water Coolant = 6 Cylinder	7	Fuel Tank Deisel Oil =	410 Liters
8	Fuel Consumption Use =20 L - 22 L/h			
9	Travel Speed =Km/h			
10	Swing Speed = rpm			
11	Gross Weight = (20.2Tone)			
12	Bucket Capacity =1.2 m3			
13	Hyd Pump type Axial Piston Pressure =(350 kg/cm2			
DRILLING MACHINE FURUKAWA HCR 1200- DS(ENGINE MODEL BEJ1 3126 B)				
NO	DESCRIPTION	NO	DESCRIPTION	Remark
1	Machine Type (Drilling Machine)	1	Engine Oil Use Type =15w 40 =	28Liters
2	Machine Brande (Furukawa)	2	Hydraulic Oil System UseType =NUTO H VG 46	190 Liters
3	Machine Model (HCR 1200-DS)	3	Traveling (L & R)Use Oil Type SAE 80w90=	5 Liters
4	Engine Model (CATEPILLAR 3126 B)	4	Engine Coolant =	20 Liters
5	Engine Power = 168 kw 2.200 rpm	5	Fuel Tank Deisel Oil =	350 Liters
6	Engine Number=(BEJ1- UP 3126 B)	6	Compressor Model AIR MAN PDS265-S35C Use Oil 32	18 Liters
7	Machine Sarail Number 2311171	7	Discharge Air Flow =7.1m3/min	
8	Battery (24 V DC) Use Battery 12 v120 AH	8	Discharge Pressure =1.3MPA	
9	Use Water Coolant = 6 Cylinder		Receiver Date = 10/01/2007	
10	Fuel Consumption Use =20 L - 23 L/h			
11	Travel Speed =3.4 Km/h			

NO	DESCRIPTION	NO	DESCRIPTION	Remark
12	Gross Weight = (13. 5Tone)			
13	Hyd Pump type Axial Piston Pressure			
14	Drifter Model HD712			

DRILLING MACHINE ROC 742HC-11(ENGINE MODEL DEUTZ B/F 6L913C/T)

NO	DESCRIPTION	NO	DESCRIPTION	Remark
1	Machine Type (Drilling Machine)	1	Engine Oil Use Type =15w 40 =	16Liters
2	Machine Brande (DEUTZ)	2	Hydraulic Oil System UseType =NUTO H VG 68	215 Liters
3	Machine Model (ROC HC -11)	3	Traveling (L & R)Use Oil Type SAE 80w90=	6 Liters
4	Engine Model (Deutz B/f 6l913c/t)	4	Fuel Tank Deisel Oil =	300 Liters
5	Engine Power = 125 kw 2000 rpm	5	Compressor Use Oil 68	17.5 Liters
6	Engine Number=(BF 6L913/C/T)			
7	Machine Sarail Number			
8	Battery (24 V DC) Use Battery 12 v100 AH			
9	6 Cylinder			
10	Fuel Consumption Use =18L - 20 L/ h			
11	Travel Speed =3.4 Km/h			
14	Gross Weight = (11. 5Tone)			
16	Hyd Pump type Axial Piston Pressure			
17	Drifter Model cop			

BULLDOZER SD22 SHANTUI(ENGINE MODEL CUMMINES NT855-C280 BCC III)

NO	DESCRIPTION	NO	DESCRIPTION	Remark
1	Machine Type (BULLDOZER)	1	Engine Oil Use Type =15w 40 =	45 Liters
2	Machine Brande (CUMMINES NT855-C280BCCIII	2	Hydraulic Oil System UseType 15w 40	82 Liters
3	Machine Model (BULLDOZER SD22)	3	Final driver Use Oil Type SAE 80w90=	122 Liters
4	Engine Model (CUMMI)NES NT855-C280 BCCIII	4	Fuel Tank Deisel Oil =	450 Liters
5	Engine Power =162Kw =220Hp 1800 rpm	6	Coolent Water	79 Liters
6	Machine Sarail Number			
7	Battery (24 V DC) Use Battery 12 v200 AH			
8	Use Water Coolant = 6 Cylinder			
9	Fuel Consumption Use =20 L/h			

NO	DESCRIPTION	NO	DESCRIPTION	Remark
10	Travel Speed L1=3.6 Km/h L3 =11.2Km/h			
11	Gross Weight = (28 Tone)			
WHEEL LOADER (CAT 966C) (ENGINE MODEL CUMMINES M11 -C 310)				
NO	DESCRIPTION	NO	DESCRIPTION	Remark
1	Machine Type (Wheel loader)	1	Engine Oil Use Type =15w 40 =	33 Liters
2	Machine Brande (XCMG)	2	Transmission Oil UseType 15W40	64 Liters
3	Machine Model (LW820G)	3	Hydraulic Oil System UseType V G 46	340 Liters
4	Engine Model (Cummines M11-C310)	4	Main TransmissionmAnd Rim Reducer	54 Liters
5	Engine Power=216Kw. 350Hp=2100 rpm	5	Engine Coolant =	
6	Engine Number=(35130345)	6	Fuel Tank Deisel Oil =	350 Liters
7	Machine Sarail Number 10609003			
8	Battery (24 V DC) 12 V =100AH			
9	Use Water Coolant = 6 Cylinder			
10	Gross Weight = (38 Tone)			
11	Bucket Capacity =2.2 m3			
WHEEL LOADER ZL50G (ENGINE MODEL CUMMINES M11)				
NO	DESCRIPTION	NO	DESCRIPTION	Remark
1	Machine Type (Wheel loader)	1	Engine Oil Use Type =15w 40 =	22 Liters
2	Machine Brande (XCMG)	2	Transmission Oil UseType 15W40	45 Liters
3	Machine Model (ZL50G)	3	Hydraulic Oil System UseType V G 46	200 Liters
4	Engine Model (Cummines CTA A8.3-C)	4	Differentiol Use Oil Type SAE 80w90=	38 Liters
5	Engine Power= 153Kw. 220 Hp= 2200 rpm	5	Engine Coolant =	
6	Engine Number=(45550699)	6	Fuel Tank Deisel Oil =	230 Liters
7	Battery (24 V DC) 12 V =70 AH			
8	Use Water Coolant = 6 Cylinder			
9	Gross Weight = (18 Tone)			Remark
FORKLIFT CATERPILLAR (ENGINE MODEL CAT DP30L)				
NO	DESCRIPTION	NO	DESCRIPTION	
1	Machine Type (FOKLIFT)	1	Engine Oil Use Type =15w 40 =	
2	Machine Brande)	2	Transmission Oil UseType 15W40	
3	Machine Model	3	Hydraulic Oil System UseType V G 46	

4	Engine Model	4	Differentiol Use Oil Type SAE 80w90=	
5	Engine Power=	5	Engine Coolant =	
6	Engine Number=	6	Fuel Tank Deisel Oil =	
7	Machine Sarail Number			
8	Battery (12 V DC) 12 V =70AH			
9	Use Water Coolant = 4 Cylinder			

ATLASCOPCO AIRCOMPRESSOR (ENGINE MODEL ATLASCOPCO XAS97DD)

NO	DESCRIPTION	NO	DESCRIPTION	Remark
1	Machine Type (AIR COMPRESSOR)	1	Engine Oil Use Type =15w 40 =	8 Liters
2	Machine Model (XA S97DD)	2	Fuel Tank Deisel Oil =	80 Liters
3	Engine Power= 36 KW	3	COMPRESSOR OIL Use Type H 68	9 Liters
4	Engine Number=	4	Fuel Consumption Use =7.2/h	
5	Battery (12V DC) 70 AH			
6	4 CYLINDER			

BROKK MACHINE (ENGINE MODEL 180 REV-E2)

NO	DESCRIPTION	NO	DESCRIPTION	Remark
1	Machine Type (BROKK MACHINE)			
2	Machine Model (180REV-E2)			
3	Engine Power=30KW 400V			
4	Engine Number=(941441)			
5	POWER A C V 380 V			
6	Gross Weight = (1.5 TONE)			

MOTOR GRADER MACHINE (ENGINE MODEL JONHDEER 772BH)

NO	DESCRIPTION	NO	DESCRIPTION	Remark
1	Machine Type (MOTOR GRADER)	1	Engine Oil Use Type =15w 40 =	24 Liters
2	Machine Model (JOHDER)	2	Hydraulic Oil System UseType V G 46	87 Liters
3	Engine Model (JONHDER 772 BH)	3	Fuel Tank Deisel Oil =	340 Liters
4	Engine Power= 116 KW			

5	Engine Number=(35130345)			
6	Battery (24 V DC) 12 V =100AH			
7	Use Water Coolant = 6 Cylinder			

MOBILE CRANE (ENGINE MODEL NISSAN RD 10-01528)

NO	DESCRIPTION	NO	DESCRIPTION	Remark
1	Machine Type (MOBILE CRANE)	1	Engine Oil Use Type =15w 40 =	1400 Liters
2	Machine Model (NISSAN)	2	Hydraulic Oil System UseType V G 46	1400 Liters
3	Engine Model (NISSAN RD 10-01528)	3	Fuel Tank Deisel Oil =	300 Liters
4	Engine Power= 350 HP			
5	Engine Number=(RD 10-015028)			
6	Battery (24 V DC) 12 V =150AH			
7	Use Water Coolant = 10 Cylinder			

WATER TRUCK (ENGINE MODEL IZUZU)

NO	DESCRIPTION	NO	DESCRIPTION	Remark
1	Machine Type ()	1	Engine Oil Use Type =15w 40 =	
2	Machine Model ()	2	Fuel Tank Deisel Oil =	
3	Engine Model)			
4	Engine Power =			
5	Engine Number=( )			
6	Battery (24 V DC)			
7	Use Water Coolant =			

APPENDIX D

Drill Hole Logs of CaO and SiO_2

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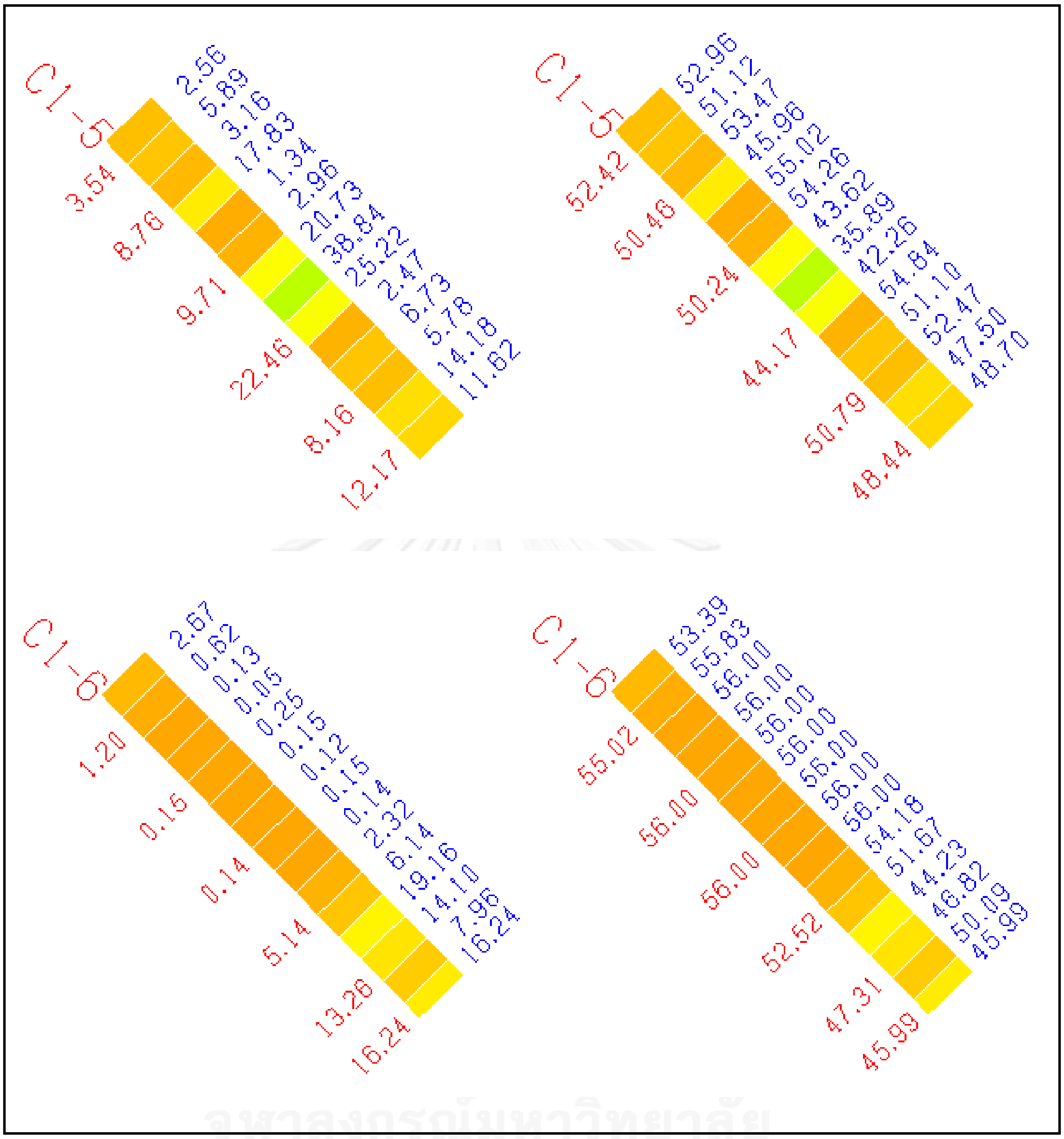

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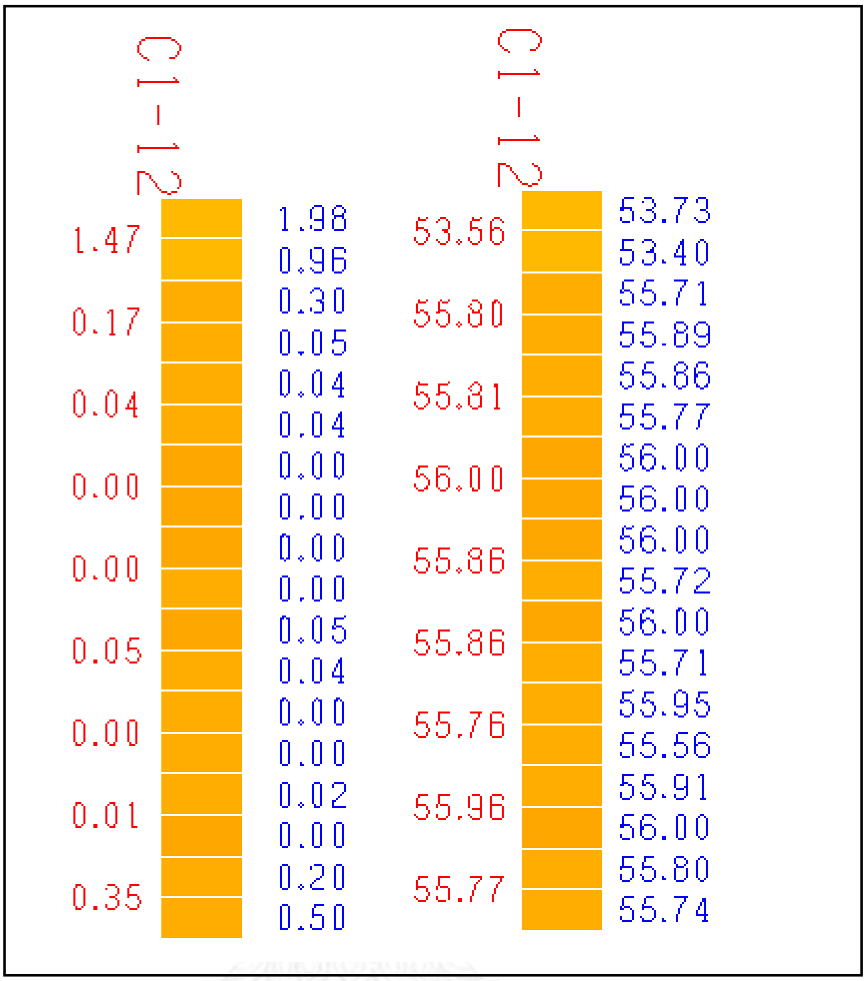
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0.00
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0.00
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0.30
0.05
0.04
0.04
0.00
0.00
0.00
0.00
0.05
0.04
0.00
0.00
0.02
0.00
0.20
0.50
C1-12
53.56
55.80
55.81
56.00
55.86
55.86
55.76
55.96
55.77
53.73
53.40
55.71
55.89
55.86
55.77
56.00
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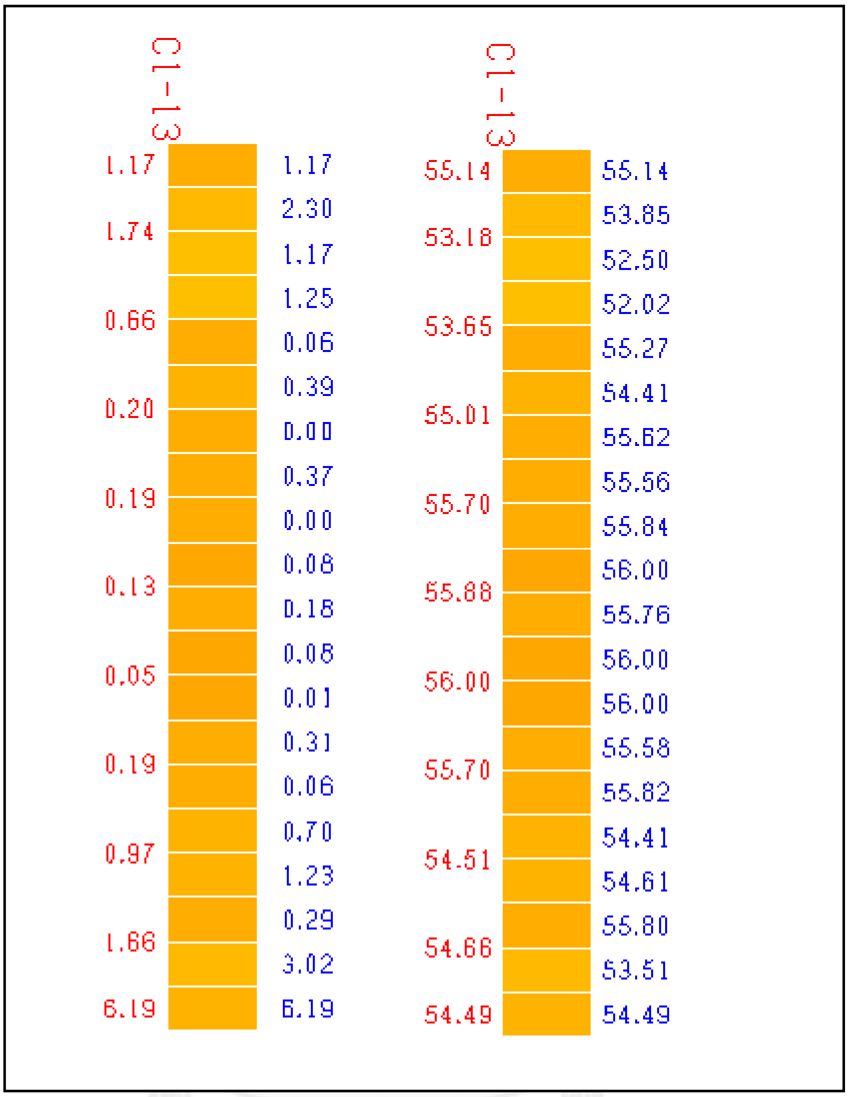
56.00
55.80
55.74



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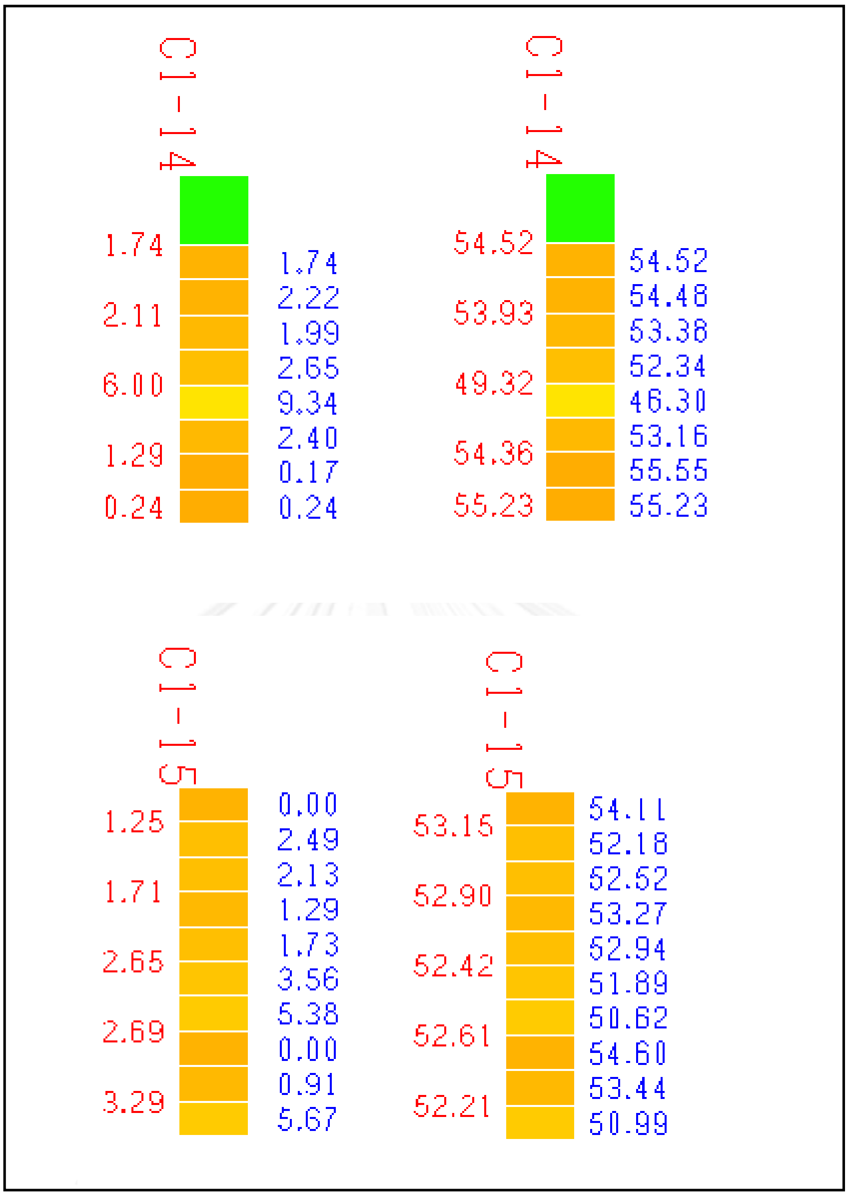
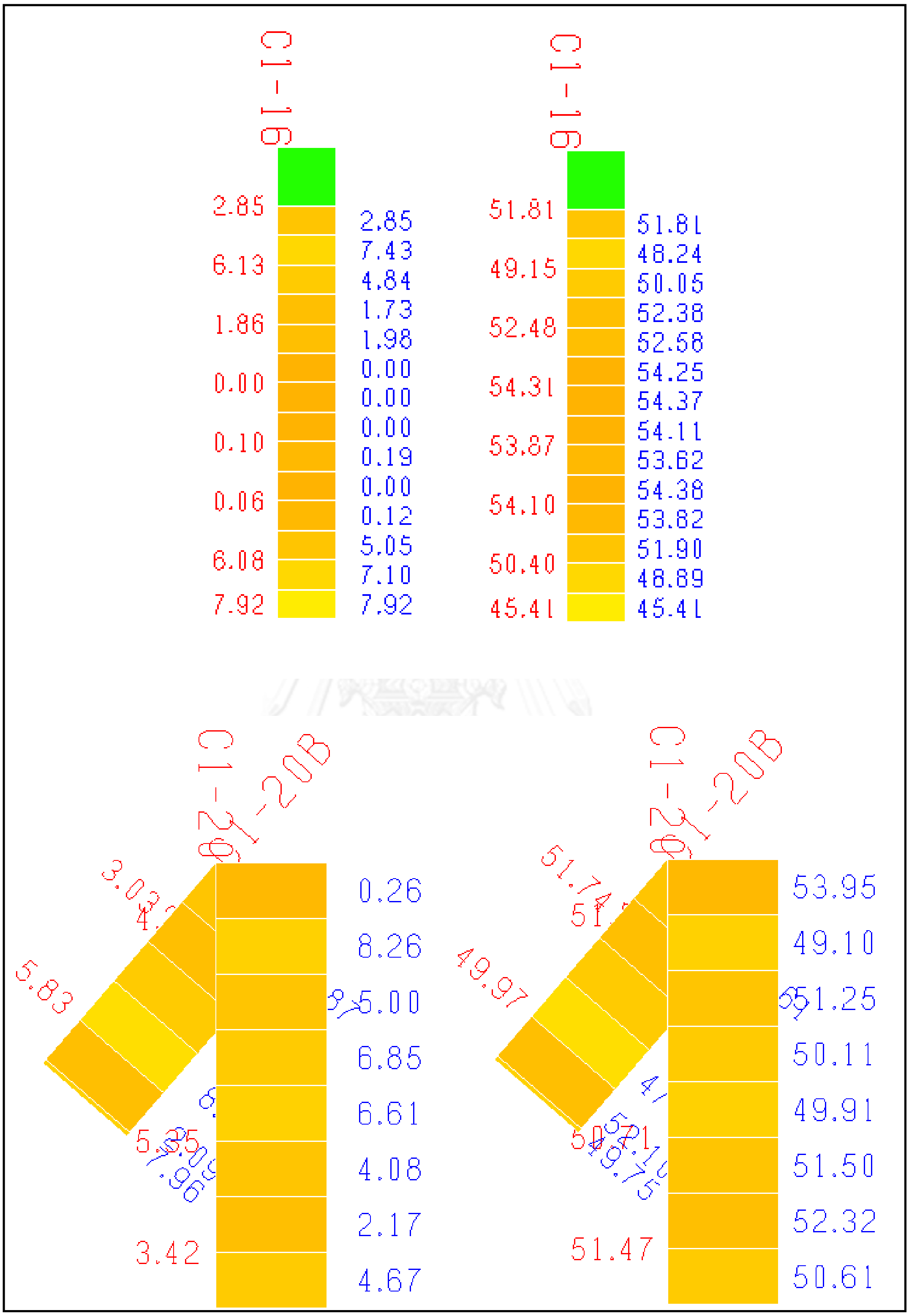


Chulalongkorn University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6.13
1.86
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0.06
6.08
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1.73
1.98
0.00
0.00
0.00
0.19
0.00
0.12
5.05
7.10
7.92
C1-16
51.81
49.15
52.48
54.31
53.87
54.10
50.40
45.41
51.81
48.24
50.05
52.38
52.58
54.25
54.37
54.11
53.62
54.38
53.82
51.90
48.89
45.41
C1-20B
5.83
3.42
0.26
8.26
5.00
6.85
6.61
4.08
2.17
4.67
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51.47
53.95
49.10
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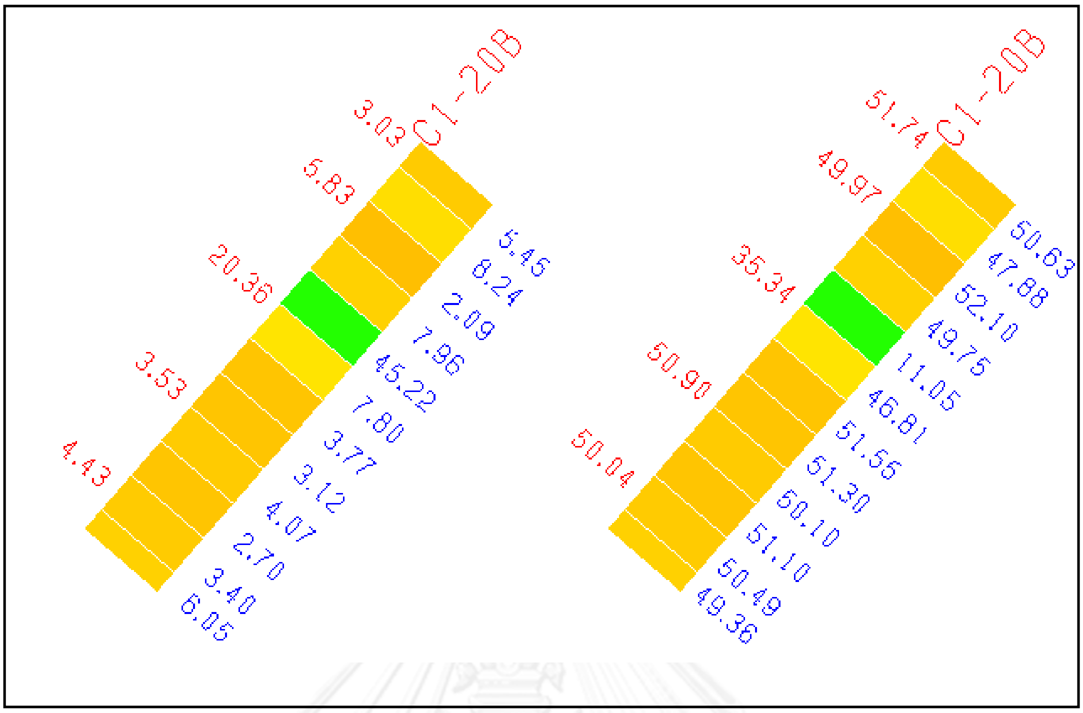
50.11
49.91
51.50
52.32
50.61



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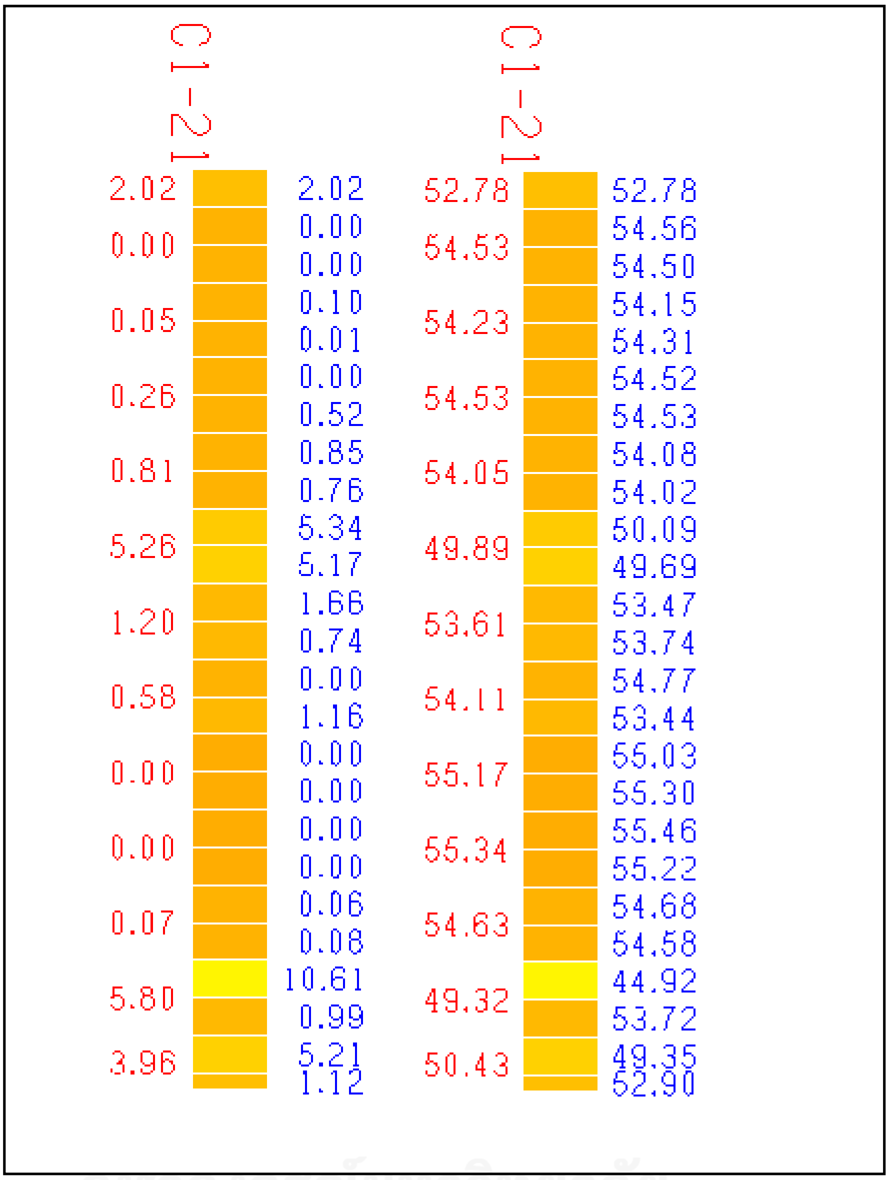

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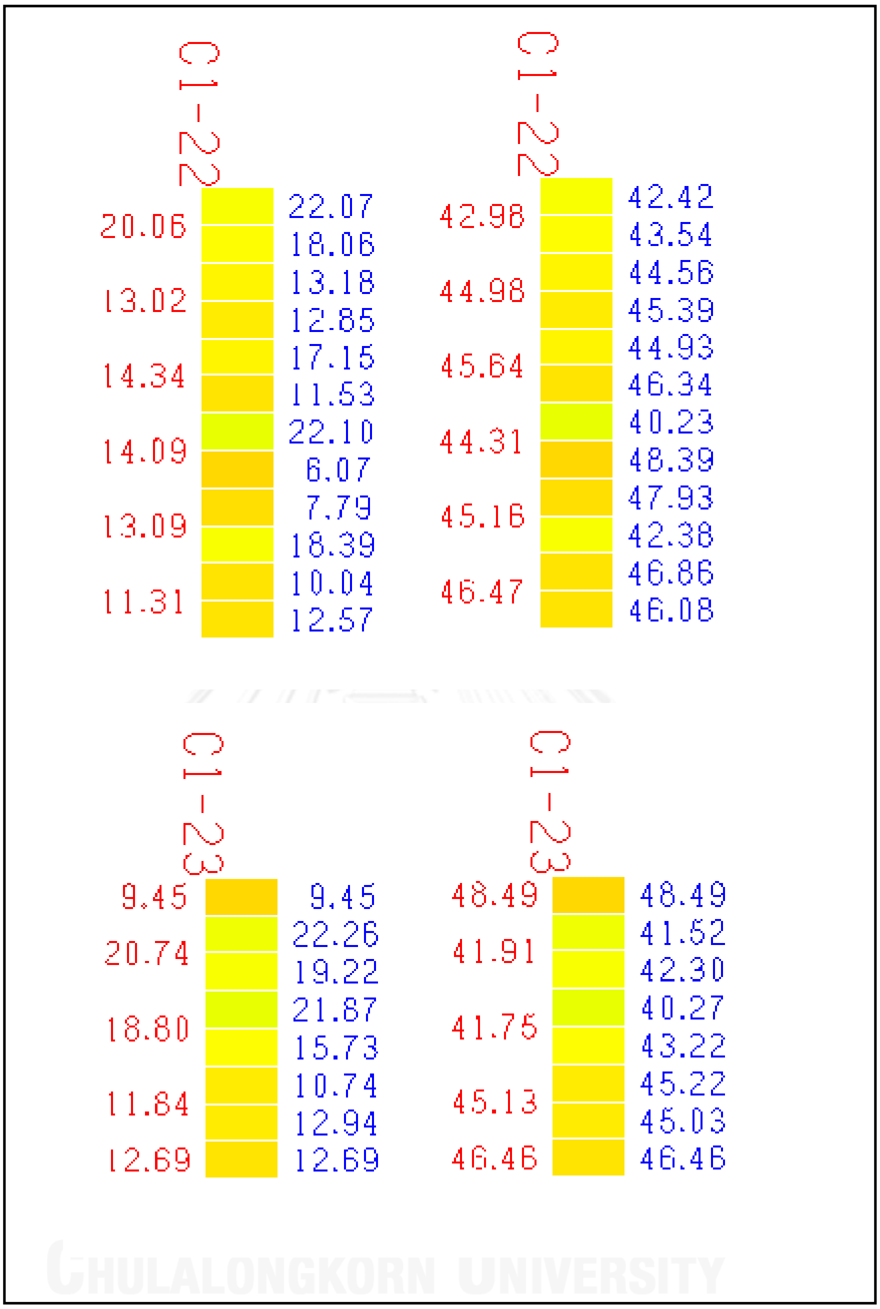
Chulalongkorn University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13.18
12.85
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11.53
22.10
6.07
7.79
18.39
10.04
12.57
C1-22
42.98
44.98
45.64
44.31
45.16
46.47
42.42
43.54
44.56
45.39
44.93
46.34
40.23
48.39
47.93
42.38
46.86
46.08
C1-23
9.45
20.74
18.80
11.84
12.69
9.45
22.26
19.22
21.87
15.73
10.74
12.94
12.69
C1-23
48.49
41.91
41.75
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46.46
48.49
41.52
42.30
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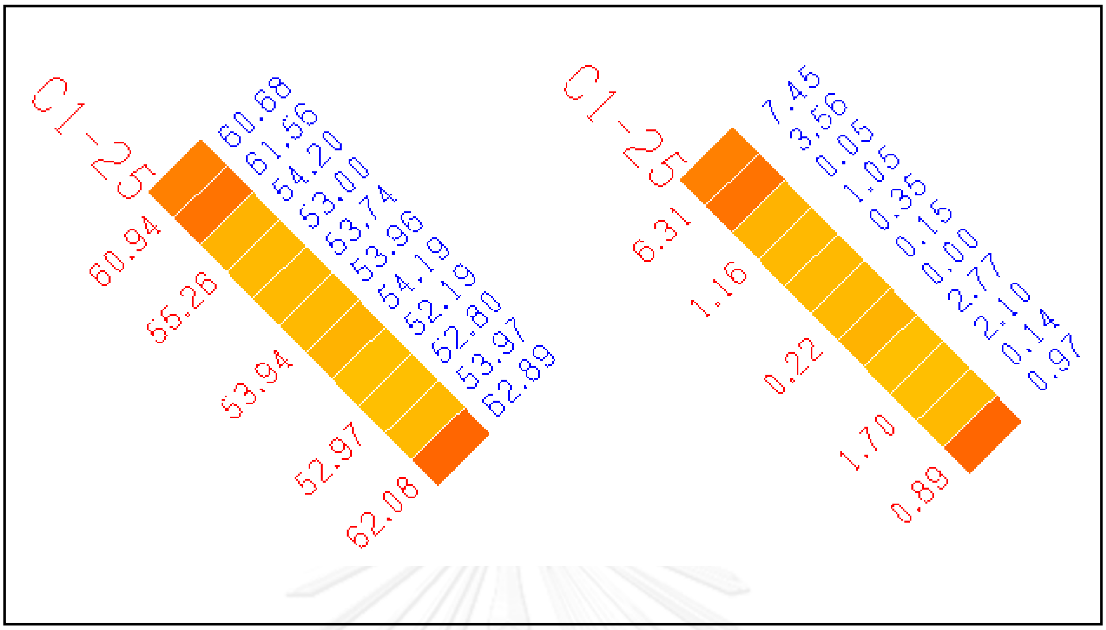
43.22
45.22
45.03
46.46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52.19
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60.94
55.26
53.94
52.97
62.08
C1-25
7.45
3.56
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1.05
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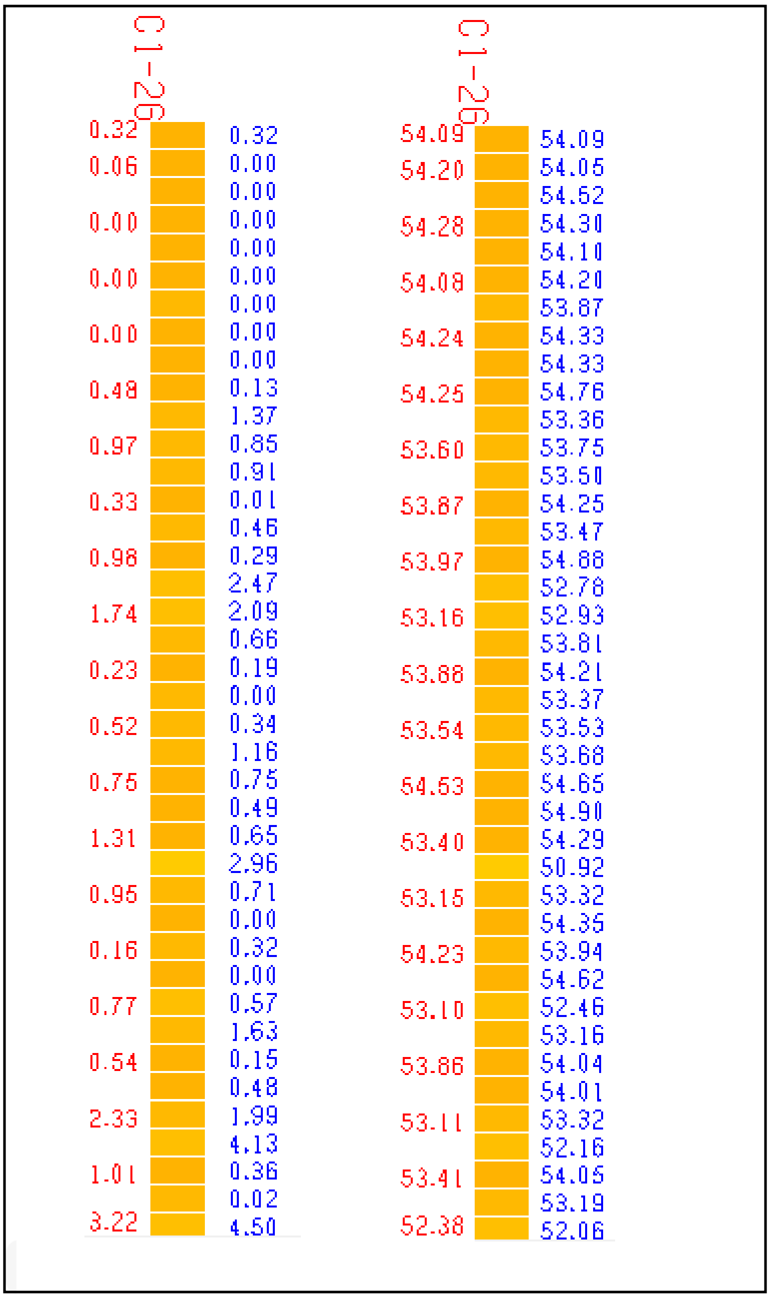
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0.00
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0.33
0.98
1.74
0.23
0.52
0.75
1.31
0.95
0.16
0.77
0.54
2.33
1.01
3.22
0.32
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.13
1.37
0.85
0.91
0.01
0.46
0.29
2.47
2.09
0.66
0.19
0.00
0.34
1.16
0.75
0.49
0.65
2.96
0.71
0.00
0.32
0.00
0.57
1.63
0.15
0.48
1.99
4.13
0.36
0.02
4.50
C1-26
54.09
54.20
54.28
54.08
54.24
54.25
53.60
53.87
53.97
53.16
53.88
53.54
54.53
53.40
53.15
54.23
53.10
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53.11
53.41
52.38
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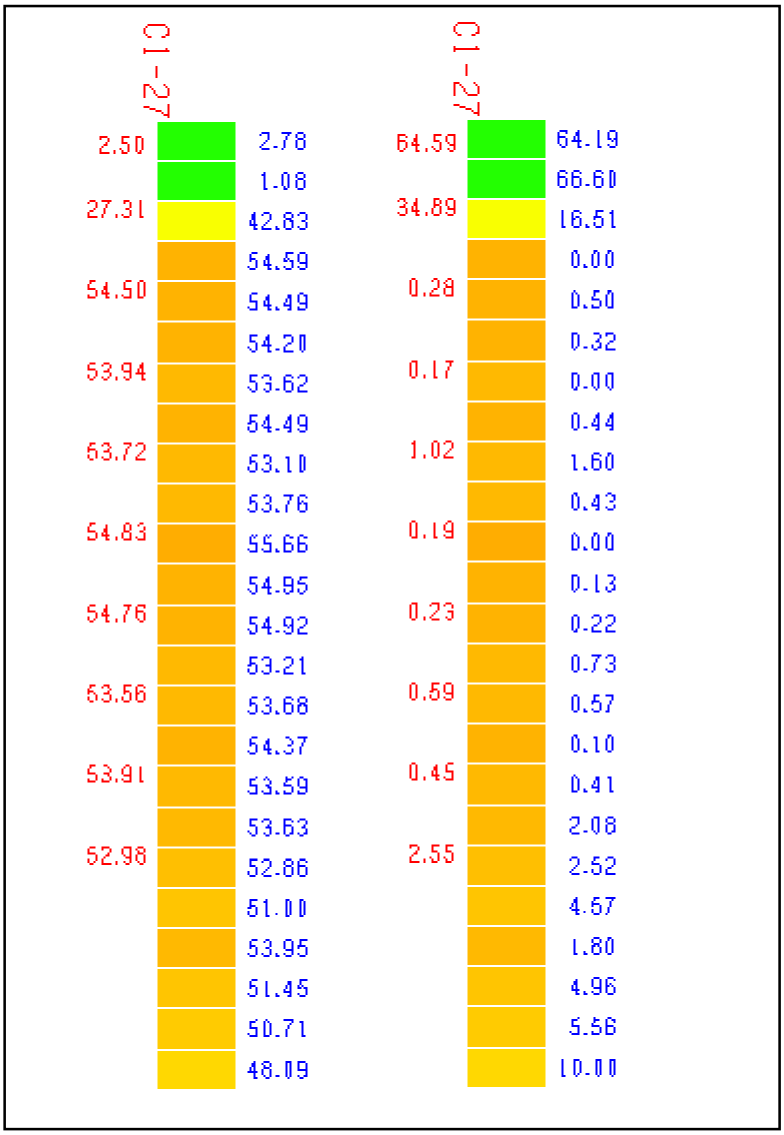

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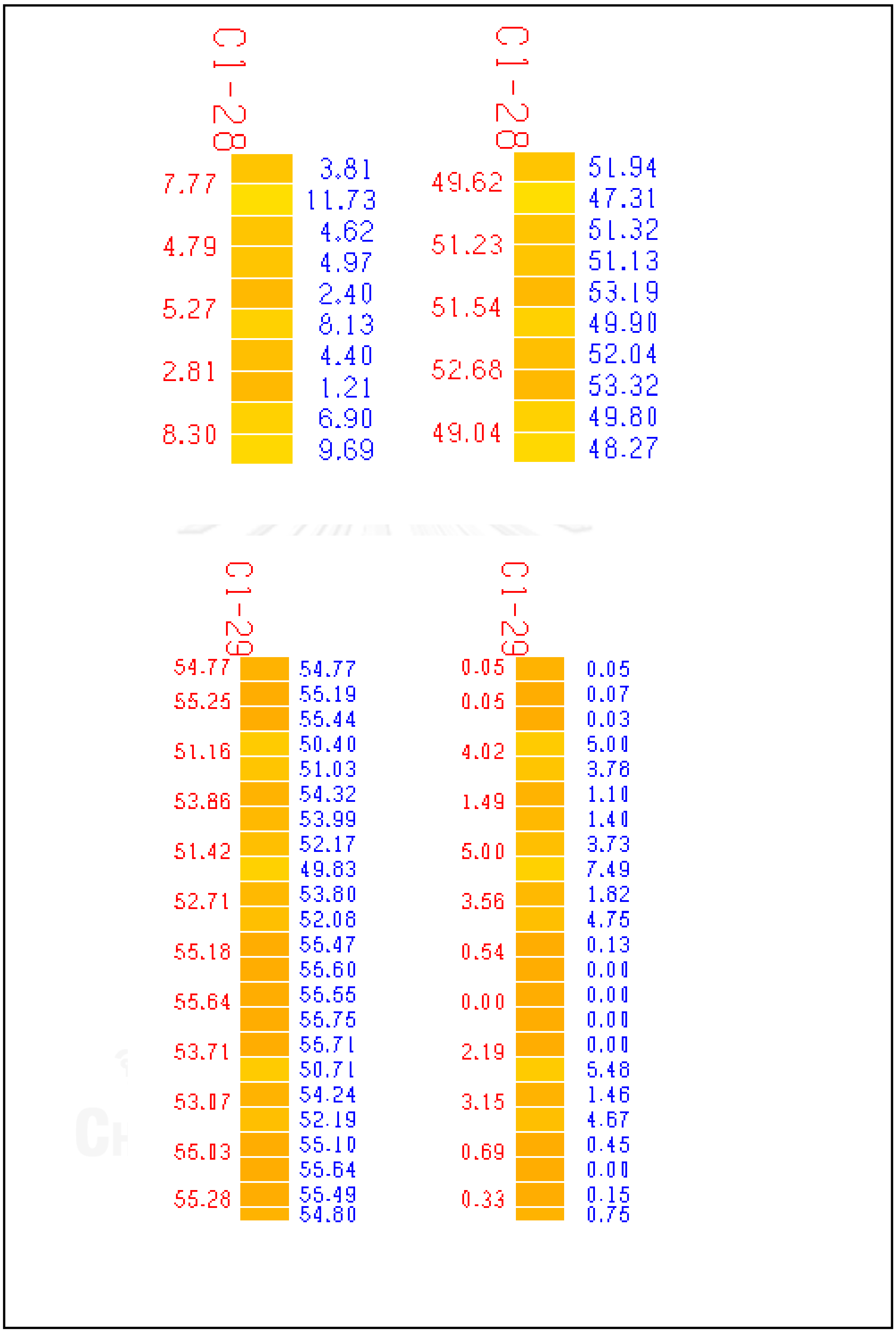
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1.21
6.90
9.69
C1-28
49.62
51.23
51.54
52.68
49.04
51.94
47.31
51.32
51.13
53.19
49.90
52.04
53.32
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48.27
C1-29
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53.86
51.42
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55.18
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53.07
56.03
55.28
54.77
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54.32
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52.17
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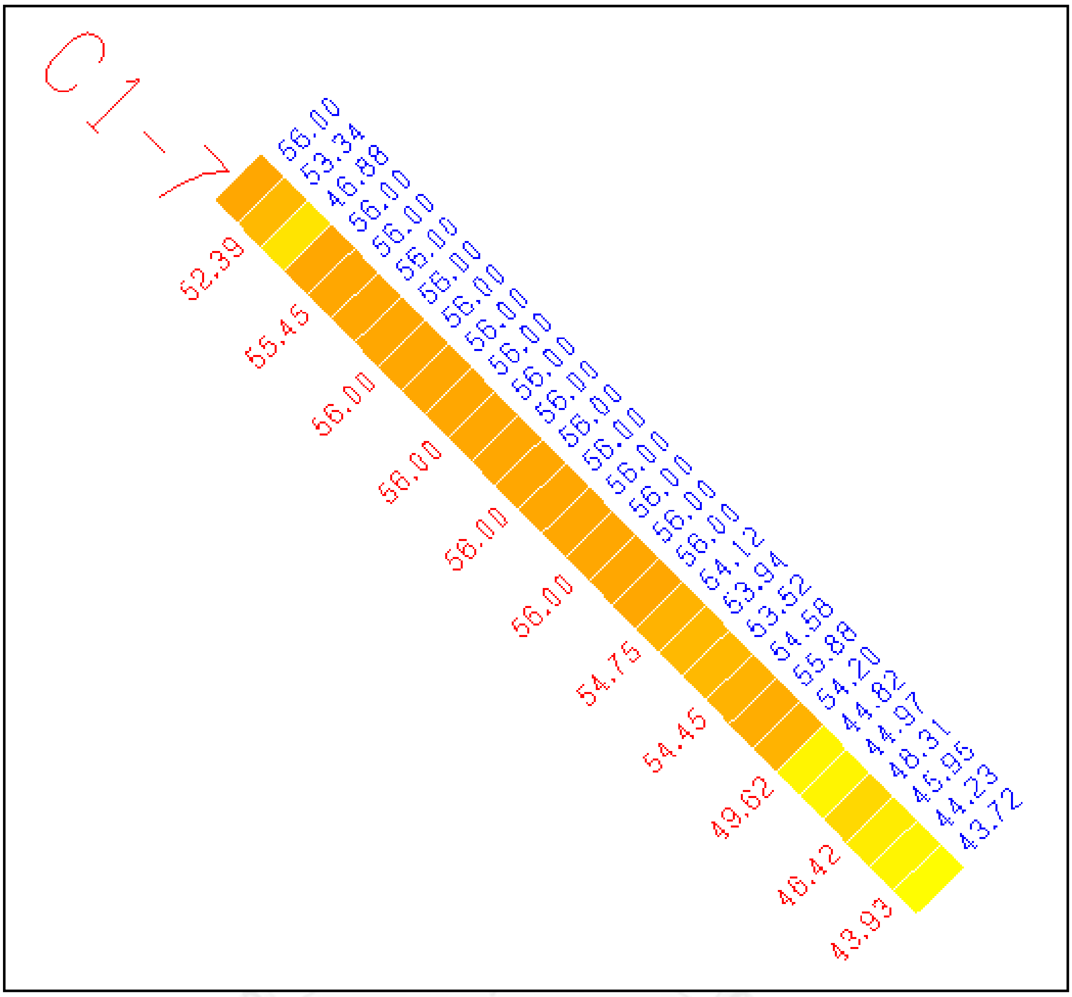

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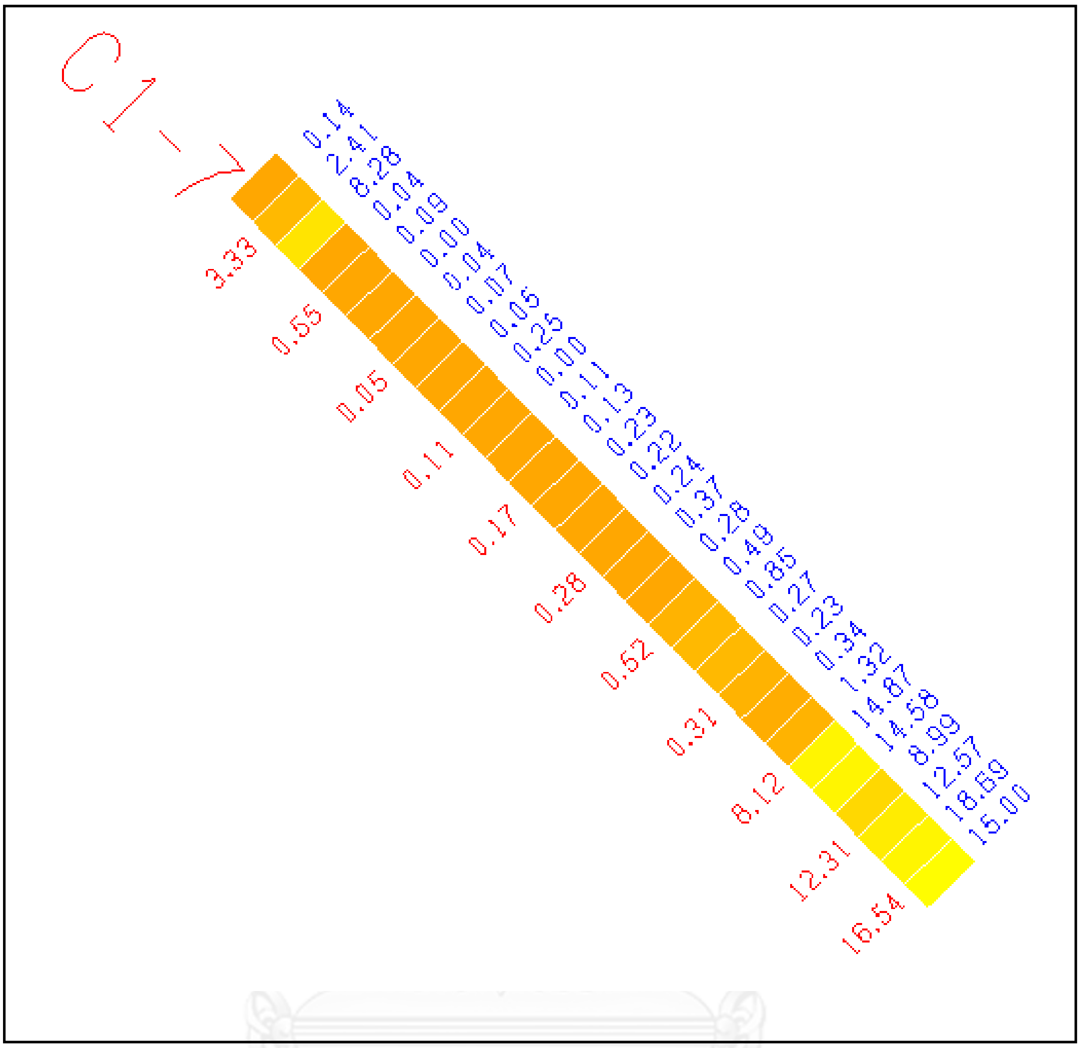
Chulalongkorn University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0.34
1.32
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14.58
8.99
12.57
18.59
15.00
3.33
0.55
0.05
0.11
0.17
0.28
0.52
0.31
8.12
12.31
16.54

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