The Progress of the Use of Vetiver Grass System for Erosion Control and Slope Stabilization along the Yadana Gas Pipeline Right-of-way

The Yadana Gas Pipeline Project

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Soil and water conservation is a very crucial issue at local, national and global levels. Vetiver grass has been used in the preservation of soil and water in agricultural areas and along road shoulder slopes. PTT Public Company Limited, on the other hand, has used vetiver grass in a different application in the Yadana Gas Pipeline Project along the 50-km. strip of forestry area for erosion control, slope stabilization, and water and soil conservation along the pipeline right of way (R/W). Vetiver grass was applied after the completion of pipeline laying in 1998. Vetiver grass system was integrated with the engineering erosion control structure in a total of 50 areas, classified into 44 high-risk areas and 6 very high-risk areas. Monitoring and follow-up have been continuously implemented for 5 years (1998-2003), of which result was found that vetiver grass system has played a significant role in turning engineering erosion control structure into natural permanent stabilized structure, able to naturally preserve soil and water.

Special techniques used in the areas with very high-risk of soil erosion with the 30^{o}-40^{o} slope are berms, or soil-filled jute sacks in which vetiver grass slips were planted and sacks were arranged as ladders. Vetiver grass slips have grown with root system permanently holding berms serving as soil and water conservation tools. This has enabled vegetation additionally sowed to grow and cover the areas. In addition, as soil and water have been well conserved by vetiver grass, native plants have also grown during the end of the 2nd year. Such results have confirmed the benefits and qualities of vetiver grass. Special techniques have, therefore, been extended to other erosion areas. As for agronomic technique using live stakes of 7 species, 2 species have been found to grow better. Vetiver grass growth recorded is as follows: the 1st year vetiver grass thickets had a diameter of 10-15 cm.; 2nd year 20-30 cm. and 3rd year 40 cm. Leaves in the areas together with EM fertilizer have been used as nutrients for vetiver grass slips instead of chemical fertilizer, which has proved to be equally effective. Vetiver grass, however, needs to be trimmed after the rainy season, resulting in its growth and strength. It was also found that vetiver grass from bags grew better than the slips but the cost was 2.5 times higher. Jute sacks are also more efficient but are 6 times more costly than plastic bags.

From 1998 to the present, a total of 2,013,500 vetiver slips have been used, with 20,922,315 baht of expense. The erosion control has been modified from reparation to preventive measures and there is a trend that expenses will decline annually. Jute sacks can absorb water better and are decayed into nutrients for soil. Above all, they do not create visual impact. The benefit derived is that no critical erosion was found along the gas pipeline right of way, and no critical damage was done to gas pipeline. The vetiver grass system and engineering techniques can be integrated to effectively control erosion and preserve soil and water in areas with high risk of erosion.

Keywords: natural permanent stabilized structure, soil-filled jute sacks, vetiver grass system and engineering techniques

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1. Introduction

The Yadana Gas Pipeline Project started the laying of 105-cm.-diameter gas pipeline on March 24, 1997 from the Thailand-Myanmar border to the Ratchaburi Power Plant at the distance of 238.5 kilometers. The construction/pipeline laying was completed on June 30, 1998. Presently, natural gas from the Yadana and Yetagun field at the volume of 525 and 260 million cubic feet per day (MMSCFD), respectively, is supplied to 2 power plants in Ratchaburi province i.e. Ratchaburi Power Plant and TECO Power Plant, as well as to Wang Noi Power Plant in Phra Nakhon Si Ayutthaya province. The three power plants can altogether generate the 4,500 MW of electricity or 30% of the country.

The pipeline laying in the Yadana Gas Pipeline Project was necessitated to pass a distance of 50 kilometers in the forestry area with the construction right-of-way (R/W) of 20 meters. Due to construction characteristics, strip surface clearing and construction resulted in bare soil after pipeline installation, thereby exposed to immediate soil erosion impact. The most effective application of reinstatement measures must be implemented, based on environmental evaluation, engineering design / construction, and re-vegetation / agronomic control. Vetiver grass was thus introduced in the high-risked erosion areas.

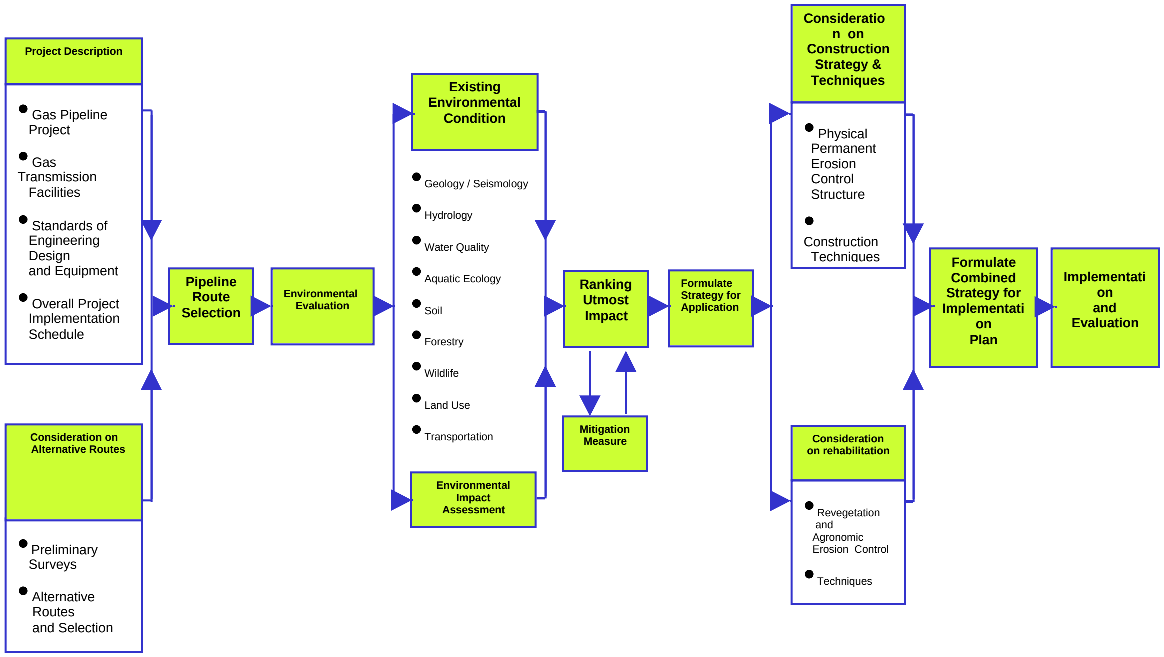
2. Procedure and Concept

The Environmental Impact Assessment (EIA) clearly analyzed that the erosion was the severe immediate soil erosion. After the backfilling, the soil was bare and erosion immediately occurred in the rainy season, especially from KP 0 to KP 50 in the high mountain area and the soil was in series of Thayang, Lat Ya, Mae Rim, and Slope Complex. With vegetation (prior to the construction), such soil series had the erosion rate of around 16-21 tons/rai/year; however, as bare soil without vegetation, high erosion would be materialized with a rise to 69-2,000 tons/rai/year. This would yield further impact i.e. the loss of soil riches, water quality affecting community and especially the pipe itself. The mitigation measures utilized the integration of agronomic methods and engineering techniques. In the high-erosion areas, vetiver grasses were planted while engineering techniques served as erosion control structure, of which formulation procedures and methods are illustrated in Flow Chart Figure 1. Details of the Flow Chart are presented in the paper of The Use of Vetiver Grass System for Erosion Control and Slope Stabilization along the Yadana Gas Pipeline Right-of-Way.

In solving soil erosion resulting from construction and implementing rehabilitation, the following philosophy was observed:

- Initial stage: Manmade Engineering Erosion Control Structure and re-vegetation were used. For high- and very-high erosion areas, vetiver grasses were grown so that their root systems could hold the manmade berms to preserve soil and water and continuously provide moisture for the areas.
- From the end of the 2nd year: Native plants or plants that were planted have grown up, and can permanently and naturally preserve soil and water as previously (before pipeline laying).

Figure 1 : Flow chart of Vetiver Grass combined with re-vegetation agronomic erosion control and construction methodology



3. Overall Performance

The implementation of Re-vegetation and Agronomic Erosion Control combined with Manmade Engineering Erosion Control Structure has been translated into the application table.

In the construction R/W along the 50-km. strip of forestry area in which the soil loss potential was classified as E_0, E_1, E_2, and E_3, as shown in table 1. The Erosion Rating Risk as classified was up to the construction map site as shown in Figure 2. Both engineering and agronomic techniques were tabulated in table 2. In the E_2, and E_3 areas, vetiver grasses were applied.

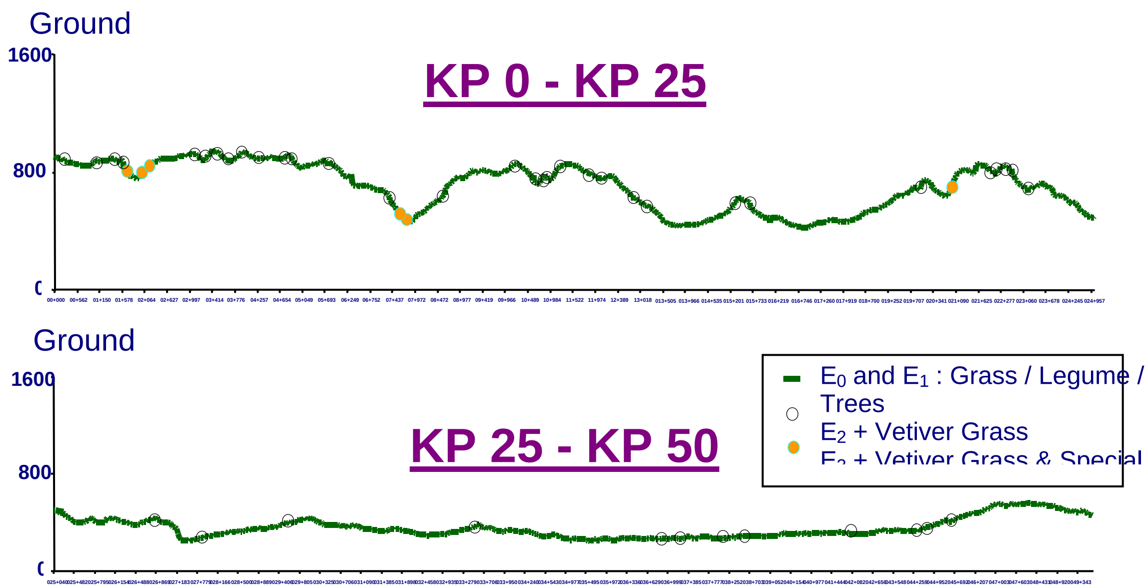
Table 1: The Classification of Rating Code according to the Soil Loss Potential

Soil Loss (ton / rai / yr.)	Rating Code	Erosion Rating Risk
0 – 16	E_0	Low Risk
17 – 64	E_1	Moderate Risk
65 – 112	E_2	High Risk
113 above	E_3	Very High Risk

Remarks: 1 Hectare = 6.25-rai

Source: Construction Procedures of the Yadana Gas Pipeline Project

Figure 2 : The Erosion Rating Risk were identified to the construction profile



Remarks : KP is Pipeline Kilo Post.

Table 2: Physical Permanent Erosion Control Structure Combined with Agronomic and Re-vegetation Erosion Control

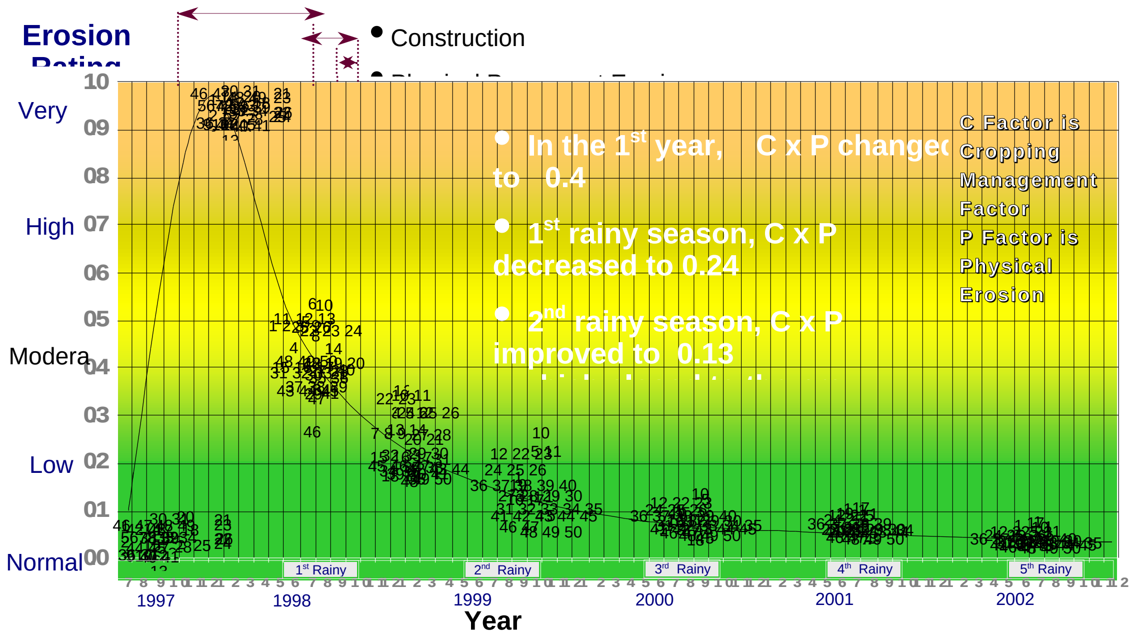
	Re-vegetation & Agronomic Erosion Control			Engineering Erosion Control Structure	
Areas / Condition	Grass + Legume	Tree	Vetiver Grass	Soft Plugs & Berm and Drainage System	Special Technique
E_0	✓	✓	-	-	-
E_1	✓	✓	-	-	-
E_2	✓	✓	✓	✓	-
E_3	✓	✓	✓	✓	✓

Remarks: In E_0 areas, trees may not be planted.

Evaluation by walking survey was implemented once a year by taking into consideration the rehabilitation performance i.e. how much and how quick the R/W in forestry areas has been recovered back to its original state. The Universal Soil Loss Equation was used in evaluating Soil Loss by considering multiplication results of Cropping Management Factor - C Factor i.e. Physical Erosion Control Structure, and Erosion Control Practice - P Factor i.e. Agronomic and Re-vegetation Erosion Control, while other parameters (Rainfall erosion index, Soil erodibility factor, Slope length factor, Slope steepness factor) are treated as constant terms. Multiplication results of C and P Factors are index of Rehabilitation Performance.

Each year, C& P Factors of each KP were evaluated. It was found that on the whole the areas were rehabilitated back to their original natural state. In the E_2, and E_3 areas, in particular, where the Project Owner have been very concerned, it was found that vetiver grasses have played a very significant part in making the Manmade Erosion Control Structure to become the Natural Permanent Erosion Control. The performance results are illustrated in Figure 3.

Figure 3 : Rehabilitation performance i.e. multiplication results of the C and P Factor for each KP.



4. The Progress of Vetiver Grass System & Lessons Learned

4.1 Vetiver Grass System:

In the high-risked (E_2) and very high-risked erosion areas (E_3), engineering techniques used were diversion berms and drainage system while for the agronomic techniques, vetiver grasses were used. Vetiver grasses were grown with a distance of 10-15 cm. between slips along the contour line and 1-meter distance between each row. The significant point for serious consideration is vetiver grasses must be planted strictly according to technical principles. In addition, seeds of legumes and grass were sowed and perennial trees were also grown as supplementary. In the areas with 35^o-40^o slope, diversion berms were made with special techniques. That is jute sacks filled with earth were arranged as ladders. Concurrently, agronomic techniques were also used by growing vetiver grasses on those sacks and live stakes were pegged onto the sacks. After 4-year monitoring, the results were found that vetiver grasses were very significant factors in making engineering erosion control environment into natural and permanent erosion control for soil and water preservation.

Vetiver Grass: From 1998 up to the present, a total of 2,013,500 slips were used. The growth of vetiver grass has been evaluated, with the following average growth:

	Diameter of Clump of Vetiver Grass (cm.)
1st Year	10-15
2nd Year	20-30
3rd Year	35-40

In using vetiver grass in high-erosion area to prevent erosion and to conserve soil and water applied in pipeline route, the following significant results were found:

- As soon as vetiver slips were (properly) planted, the row of vetiver grass would immediately serve to prevent erosion while vegetation would take time to grow.
- When grown, with continuously expanding bushes, vetiver grass enhances and reinforces the Physical Erosion Control Structure constructed in areas with high risks of erosion to become Natural Permanent Erosion Control eventually.
- Vetiver grass kept soil moisture and helped perennial trees to grow back to their original state or better in a period of two to three years onward.
- In case of erosion, the areas in which vetiver grass was grown would be easier for repair than the areas with vegetation alone.
- Growing vetiver grass slips on jute sacks by making holes on the sacks, their roots can penetrate into other layers of sacks.

Live Stake: In the areas where soil-filled jute sacks were arranged in a laddered pattern, a total of 5,000 live stakes of 7 native plants were used to peg into the jute sacks.

1. Garuga pinnata Roxb.

2. ***Choerospondias axillaris (Roxb.) B.L.Burtt & Hill***
3. ***Pterocarpus indicus Hasm.***
4. ***Lagerstroemia tomentosa Presl***
5. ***Erythrina subumbrans (Hassk.)***
6. ***Cephalanthus tetrandra (Roxb.) Ridsdale & Bakhf.***
7. ***Elaeocarpus hygrophilus Kurz***

4.2 Lessons Learned

Agronomic Aspects: Vetiver grasses cultivated in bags grew more quickly than vetiver grass slips. Vetiver grasses must be trimmed after the rainy season to enhance their growth and strength as shown in the Figure 4. EM or Bio-Fertilizer was tried on vetiver grasses and heaps of leaves in the areas were digested into nutrients for vetiver grasses instead of chemical fertilizer, of which result was found to be equally good.

Figure 4 : KP 0+050, Trimming Vetiver Grass after the rainy season

: As for live stakes pegged on jute sacks, 2 species of plants i.e. Erythrina subumbrans (Hassk.) and Pterocarpus indicus Hasm. were found to grow better than other species.

: Growing vetiver grass slips on soil-filled jute sacks should be done at the end of dry season or very early rainy season so that vetiver grass slips can have a chance to grow in the first rainy season as long as possible.

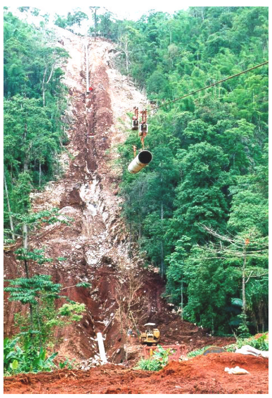
Engineering Aspect : In some areas, the laddered berms were too steep, which had to be adjusted to the level about 5^o. In few other areas, the erosion is a result of inadequate water diversion berm construction that did not convey water flow into the off - Right-of-Way well re-vegetated areas. However, this was rectified by placing soil-filled jute sacks as diversion berm extension on the downhill site of the berms. It was also found that in some cases, berms deflected water off the right-of-way in well re-vegetated area, but delivered run-off water into the same spot which, however, resulted in erosion. This was corrected by putting soil-filled jute sacks extensions of the berms to spread run-off water into different well re-vegetated areas.

5. Case Illustration

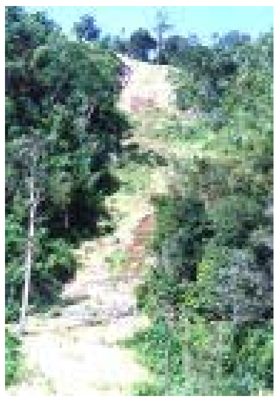
KP 19+900 was the 40^o slope area, with very high risk of erosion. Special engineering techniques were used by arranging jute sacks in a laddered pattern.

On the agronomic side, vetiver grasses were planted onto the jute sacks and pegged with live stakes. In these areas, a total of 40,000 jute sacks were used. Present condition: Manmade Erosion Control Structure as constructed was turned into Natural Permanent Erosion Control Structure, as illustrated in Figure 5.

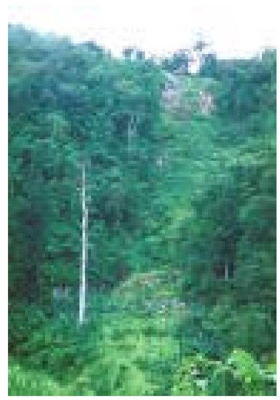
Figure 5 : **KP 19+800, in the 40° Slope area, 40,000 jute sacks were arranged in a laddered pattern.**



KP 19+900 : June 1998



KP 19+900 : March 1999



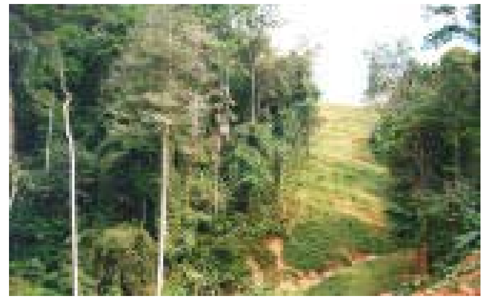
KP 19+900 : October 2000

KP 19+900 : November 2001

At KP 15 where cable crane was used as a special engineering technique in pipeline laying, laddered berms were made and vetiver grasses were planted. Present condition: Native plants had grown and covered the areas, as illustrated in Figure 6.

Figure 6 : **In KP 15, Cable Crane was used in steep slope areas, Laddered berms were made and Vetiver Grasses were growth.**

KP 15 : March 1998



KP 15 : January 1999

KP 15 : September 2001

KP 15 : July 2000

At KP 10+850, engineering techniques were not correctly applied, the too-steep laddered berms were corrected by using jute sacks combined with vetiver grasses as illustrated in Figure 7.

Figure 7 : **KP 10+850, readjust the laddered berms slope.**

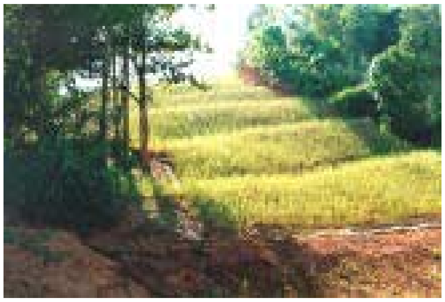
KP 10+850 : 2001

KP10+850 : 2001

KP 10+850 : 2002

KP 12+300 had right slope of laddered berms, with vetiver grasses planted. Present condition: Berms become Natural Permanent Erosion Control Structure and can preserve soil and water, shown in Figure 8.

Figure 8 : **KP 12+300, On the slope terrain where ladder berms were built and vetiver grass was planted to prevent erosion**



KP 12+300 : July 1998

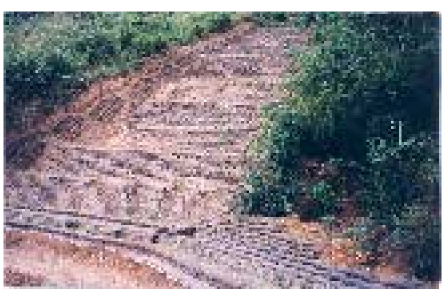
KP 12+300 : November 1999

KP 12+300 : September 2001

KP 12+300 : July 2000

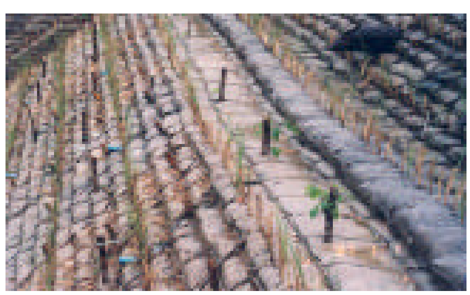
From the results of the first two years and the lessons learned, the successful application of jute sacks and vetiver grasses was used to correct KP 1+800 by building berms with jute sacks and vetiver grasses, illustrated in Figure 9.

Figure 9 : KP 1+800, The application of jute sacks and vetiver grass were used for rebuilding laddered berms.



KP 1+800 : 2001

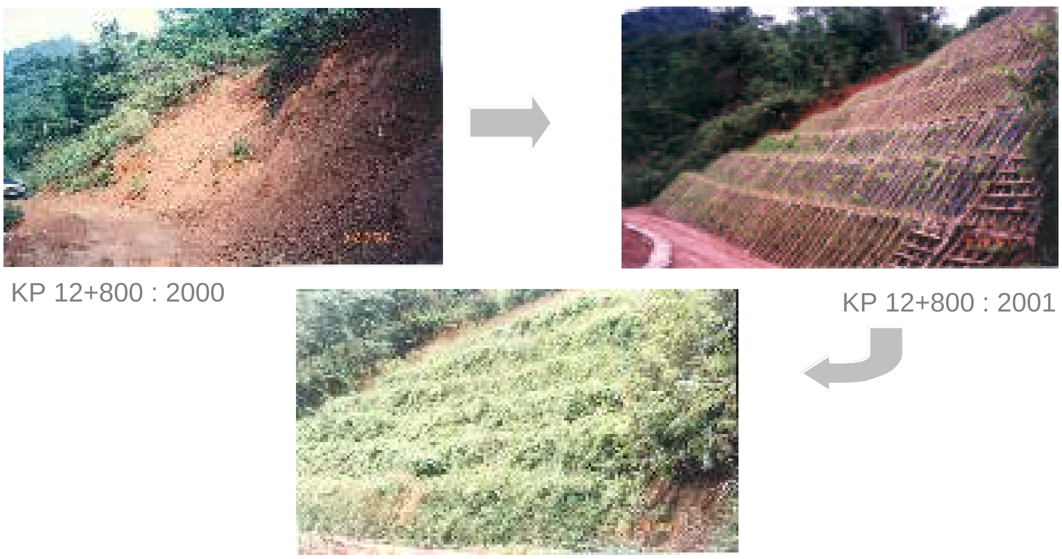
KP 1+800 : 2001



KP 1+800 : 2001

To solve the problem on stabilize steep shoulder slope, this technique also works well as shown in the figure 10.

Figure 10 : KP 12+800, The application of jute sacks and vetiver grass were used for stabilize steep shoulder slope.



KP 12+800 : 2000

KP 12+800 : 2001

KP 12+800 : 2002

6. Cost & Benefits

From 1998 to the present, expenses in repairing various points along the 50-kilometer right-of-way totaled 20,922,315 million baht. Jute sacks were 6 times more expensive than plastic bags. (A jute sack costs 18 baht while a plastic bag is 3 baht.) Expenses in cultivating vetiver grasses in bags, which grow more quickly, were 2.5 times higher than vetiver grass slips. The expenses, however, later were reduced by growing from cultivation areas near the right-of-way. The cost was lowered by 1 time, which can increase income for local workers.

The direct benefit of the application of vetiver grass system in erosion control of the Yadana Gas Pipeline Project was that no major damage was done to the pipeline transmission system with no interruption of gas supply to the 3 power plants of 785 MMSCFD. The said natural gas is used to generate 30% of electricity of the country. Another benefit derived is that the application of the construction in the forestry areas was significant. Vetiver grass is not weed, so was not expanded out of the areas and did not cause any continuing problem to the ecological system of the areas off the right-of-way. Knowledge earned has been further expanded for erosion control and soil and water preservation in Kui Buri Forest Plantation of PTT Plc. in the project of The Office of the Royal Development Projects Board. Techniques and methods have also been disseminated to communities and agriculturists to make use of vetiver grasses as soil and water conservation in their own agricultural areas.

Table 3 : R/W Repairing expenses.

Year	Total Vetiver Grass	Total areas	Budget
1998	1,000,000	38	2,000,000
1999	545,000	25	640,000
2000	165,000	61*	11,778,735
2001	68,000	13	1,366,040
2002	47,500	13	3,159,700
2003	188,000	10	1,977,840
	2,013,500	160	20,922,315

**** Remark : Readjust and using jute sacks combine with vetiver grass***

7. Conclusion

- As for Vetiver Grass System that combined engineering and agronomic techniques, engineering aspects must be correctly designed and constructed from the start. In terms of agronomy, vetiver grasses must also be planted according to the correct principles and techniques, with annual trimming at the minimum. Planting vetiver grass slips on jute sacks must be done at the end of dry season or early rainy season. This can enhance effectiveness and efficiency of erosion control of vetiver grass system to eventually become natural permanent erosion control.
- Philosophy Concept vs. Results : From the evaluation during the past 4 years, it was found that native plants could sprout and grow by the end of the second year. In the third and forth years, they covered the areas and served in agronomic terms instead of manmade ones.

KP	Native Plant
1-2	***Dodonae viscose Jacq***
2-4	***Dodonae viscose Jacq, Melastoma spp.***
4-8	***Dodonae viscose Jacq, Melastoma spp.,***
	Boea Mivea (L.) Gaubich
10-13	***Dodonae viscose Jacq, Melastoma spp.***
15-16	***Dodonae viscose Jacq,***
	Musa acuminate Colla
22-29	***Dodonae viscose Jacq,***
	Musa acuminate Colla
37-38	***Dodonae viscose Jacq***
42-47	***Boea Mivea (L.) Gaubich***

Remark : KP is abbreviation of Pipeline Kilo Post.

Native plants grew in between densely and scatteredly along the 50-km. strip. This proved that vetiver grass system can prevent the erosion and conserve soil and water, able to preserve moisture throughout the year.

Figure 11 : KP 15, Musa acuminate Colla; Native Plants, were grew cover the areas.

Figure 12 : KP 46, Boea Mivea (L.) Gaubich; Native Plants, were grew along the R/W.

8. The Royal Grace of His Majesty the King

PTT Public Company Limited used and implemented the vetiver grass system in terms of application, species selection, and request for vetiver grass slips, which is an ultimate consequence of the Royal Grace of His Majesty the King, in continuously researching and experimenting vetiver grass for the benefits of His subjects.

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