CHAPTER 6

FUTURE SOCIO-ECONOMIC FRAMEWORK

6.1 APPROACH

6.1.1 Objectives of Framework Setting

The road rehabilitation project shall be formulated and evaluated in consideration of the future traffic demand that is based on the regional development plans. Establishment of the future socio-economic framework aims at preparation of basic data required for the future traffic demand forecast with target years of 2000, 2010 and 2020.

6.1.2 Forecast Method

1) Socio-economic Indicators

A methodology of future traffic forecast taken in the Study requires the following socio-economic indicators as a framework:

- Future population

- Future gross regional domestic product (GRDP)

- Future gross value added (GVA) by industrial sector/product, and

- Future family income and expenditure

2) Forecast Methods

A demographic framework is formulated on the basis of the 1990 Population Census conducted by the National Statistics Office (NSO) and the population projection prepared by the National Census and Statistics Office (NCSO). As for an economic framework, major references are the GRDP growth target set up by the Medium-Term Philippine Development Plan, 1993-1998 (MTPDP), past GRDP data and economic parameters collected from the National Statistical Coordination Board (NSCB), and agricultural and industrial production data obtained from Bureau of Agricultural Statistics, Mines and Geo-Sciences Bureau, etc. Most of the economic data cover only up to 1992. The future economic indicators, therefore, are estimated on the basis of the data in 1992.

The population and GRDP growth targets are formulated at first, and then utilized for preparation of other economic indicators. The forecast methods and assumed conditions are discussed in the sections 6.3 and 6.4 in detail.

6.2 OUTLINE OF MEDIUM-TERM PHILIPPINE DEVELOPMENT PLAN, 1993-1998

6.2.1 Macro-economy and Development Financing

The Medium-Term Philippine Development Plan (MTPDP) for 1987-92 was formulated aiming at four development goals, i.e. the alleviation of poverty, the generation of productive employment, the promotion of equity and social justice, and the attainment of sustainable economic growth. In the MTPDP for 1993-98, the country's economic performance during the previous Plan period is assessed, and it is concluded that unexpected external factors such as the Gulf crises in August 1991 and economic recession of the industrialized countries and weakness in the internal economy prevented the attainment of sustained high economic growth. The economy has suffered from import-dependent structure, infrastructure bottlenecks especially in energy, underdeveloped monetary and capital markets, and unbalanced regional development. Based on this assessment, the Plan sets forth the following macro-economics goals, objectives and targets:

1) Goals and Objectives

The long-term goals of poverty alleviation and improved income and wealth distribution, as well as the major macro-economic objectives in the medium-term, i.e. (a) a sustained and broad-based growth of output and employment, (b) price stability, and (c) a sound balance of payments position shall be supported by the following policies:

a) Fiscal policy shall shape a revenue and expenditure program that yields a manageable consolidated public sector deficit; accords with sound public debt management, and adheres to the principles of transparency and accountability.
b) Monetary policy shall emphasize price stability without unduly sacrificing output and employment; improve the efficiency of financial intermediation; and develop the capital market to improve domestic resource mobilization.
c) External policy shall ensure a sustainable balance of payments position; continue the liberalization of the trade and capital accounts; and reduce the burden of external debt.
d) Macro-economic policies shall be consistent with the vision of attaining international competitiveness by accommodating, continued trade liberalization and tariff reform, increased investments in infrastructure, and increased investments in human capital.
e) Regional development policies shall ensure the maximization of production potentials and geographic advantages by eliminating the policy and investment bias for the National Capital Region, reducing socio-economic disparities within and among the regions, providing the regions and localities with opportunities to develop on the basis of their potentials and advantages, and widening the access of the population to productive resources and social services.

The achievement of the above goals shall be complemented by strategies pertaining to population growth, preservation of the environment, political stability, peace and order, and an efficient bureaucracy.

2) Targets

Economic Growth

The Plan sets forth the macro-economic targets for 1998. The gross national product (GNP) growth rate should be in the double digits, i.e. at least 10 percent by 1998. The gross domestic product (GDP) is to increase from a rate of 3.0-4.5% in 1994 to about 10.0% in 1998. Region X (Northern Mindanao) and Region XI (Southern Mindanao) are expected to post the second and third highest average annual GDP growth of 5.2-6.7 and 7.2-8.7% percents, respectively (Table 6.2-1).

TABLE 6.2-1 REAL GRDP GROWTH TARGET, 1993-98

(in percent per year)

	Target Annual Growth Rates						Average
	1993	1994 Low High	1995 Low High	1996 Low High	1997 Low High	1998 Low High	1993-98 Low High
Region IX	0.7%	2.4-3.3%	4.1-5.6%	5.5-7.2%	7.0-8.0%	7.7-9.2%	5.3-6.7%
Region X	3.7%	2.6-3.6%	3.3-5.0%	5.0-6.9%	6.8-7.9%	8.4-9.9%	5.2-6.7%
Region XI	1.4%	4.1-5.0%	5.7-7.5%	7.2-9.1%	9.2-10.3%	9.8-11.4%	7.2-8.7%
Region XII	0.4%	3.0-4.0%	3.9-5.6%	4.8-6.7%	6.9-8.0%	7.8-9.4%	5.3-6.7%
Philippines	1.7%	3.4-4.4%	4.1-6.2%	5.0-7.2%	7.4-8.5%	8.1-9.8%	5.6-7.2%

Source: Medium-Term Philippine Development Plan, 1993-1998

The sectorial targets are set up as follows:

a. Gross value-added (GVA) in the agriculture, fishery and forestry sector will grow annually at an average of 2.7-3.4% over the Plan period, with a rising trend. The share in GDP is expected to decline from 22.1 percent in 1993 to 19.0-19.8% in 1998 as the economy gradually shifts to greater agri-industrialization.

b. Industrial GVA shall grow at an average of 6.6-8.8% per annum over the Plan period, rising from 1.8% in 1993 to 8.9-11.4% in 1998. Industry's share in GDP is expected to increase from 33.4% in 1993 to 36.0-36.9% in 1998.

c. The growth of GVA in services will average 6.2-7.6% annually. The share of services in GDP will increase slightly from 41.7% in 1993 to 44.1-44.2% in 1998. Regions X (North Mindanao), XI (South Mindanao), IX (Western Mindanao), XII (Central Mindanao) and I (Northern Luzon) will register the highest growth rates in services GVA.

Fiscal Program

The consolidated public sector deficit will decline from 2.6% of GNP in 1993 to less than 0.1% in 1998. The ratio of the national government's budget deficit to GNP will average 0.8% with a declining trend. The national government revenue effort will improve from 17.3% of GNP in 1993 to 17.8% by 1998, while the expenditure will keep pace with GNP (Table 6.2-2).

TABLE 6.2-2 NATIONAL GOVERNMENT FISCAL PROGRAM

(in billion pesos)

	1993	1994	1995	1996	1997	1998
Total Revenues	260.3	325.6	350.2	385.1	430.6	493.6
(% of GNP)	(17.3)	(19.0)	(18.2)	(17.9)	(17.8)	(17.8)
-Tax Revenue	229.7	273.0	304.7	352.6	401.3	454.8
-Nontax Revenue	30.6	52.6	45.6	32.5	35.2	38.8
Total Disbursements	280.9	330.4	334.7	368.5	411.3	483.6
(% of GNP)	(18.0)	(19.2)	(17.4)	(17.1)	(16.8)	(17.4)
-Current Operating Expenditures	223.3	266.8	268.7	285.8	315.5	359.5
-Capital Outlays	55.4	62.3	65.6	82.1	97.4	123.8
-Net Lending	2.2	1.2	0.5	0.5	0.4	0.3
Deficit Financing	20.6	4.8	-15.5	-16.6	-25.3	-10.0
-Net External Financing	11.2	1.1	2.4	2.1	6.3	12.7
-Net Domestic Financing	9.4	3.7	-17.9	-18.7	-31.6	-22.7

SOURCE: Medium-Term Philippine Development Plan, 1993-98

Investment Program

The total Medium-Term Public Investment Program resources consisting of public resources to be generated from domestic and external sources will total to 643.8 billion pesos for the period 1994-1998. The bulk of investments is allocated for infrastructure development as shown in Table 6.2-3.

TABLE 6.2-3 SECTORAL ALLOCATION OF MEDIUM-TERM PUBLIC INVESTMENT PROGRAM, 1993-1998

	1993	1994	1995	1996	1997	1998
Public Investment Program (in billion pesos)	83.3	98.6	110.2	123.3	151.0	160.7
Sectorial Distribution (%)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
-Agri-Industrial Development	13.7%	8.9%	11.5%	12.7%	14.8%	15.6%
-Human Development	9.2%	13.8%	15.2%	19.4%	19.6%	18.7%
-Infrastructure Development	75.7%	75.5%	69.0%	65.6%	62.6%	62.3%
-Development Administration	2.9%	1.5%	3.7%	1.2%	1.6%	1.9%
-Disaster Mitigation	0.3%	0.3%	0.6%	1.1%	1.4%	1.6%

SOURCE: Medium-Term Philippine Development Plan,1993-1998

6.2.2 Regional Development Plan

1) National Goals and Objectives

The national goal for regional development is to minimize regional socio-economic disparities by providing all regions, on the basis of their comparative advantages, with opportunities to enhance their contribution to equitable growth and to widen the access of the population to productive resources, social services and physical facilities that would enable them to exploit and benefit from emerging economic opportunities.

The countryside agro-industrial development to guide the effort to promote regional development. The strategy emphasizes the strengthening of complementary linkages between agriculture and industry, between urban centers and rural areas and their integration into a mutually reinforcing national system of production, distribution and exchange. The following are the specific interrelated elements of the broad strategy:

a. Focus on rural development
b. Promoting industrial dispersal
c. Harnessing the potentials of the urban center
d. Tourism development in the regions
e. Human development
f. Strengthening infrastructure support
g. Institutional support

2) Mindanao Development Framework

The primary objective in the development of Mindanao is to reduce and eventually eradicate poverty and to achieve a functionally integrated island economy. Mindanao will be developed into a conglomerate body through a strategy anchored on the development of its comparative advantages that will allow the major growth centers to develop along specialized growth directions to enhance greater agro-industrial complementation rather than competition among its five regions.

6.2.3 Infrastructure Development Plan

1) National Goals and Objectives

The goals and objectives of the infrastructure development are (a) to provide the primary needs of the population such as reliable and adequate water, health facilities and transportation: and (b) to provide support facilities for the productive sectors and act as catalyst of development in selected areas, while those of transport sector are as follows:

a. To strengthen inter-regional and urban-rural linkages to ensure people's mobility and continuous flow of goods; and
b. To ensure the safety and efficiency of transport services to meet the needs of an increasing population and dynamic market demands.

2) DPWH Medium-Term Infrastructure Program for Mindanao

The Program has a "bias" for the following infrastructure sector:

a. Pro-poor infrastructure; which includes basic transport, sanitation, and other essential facilities that will help especially those in the bottom 30 percent of the population, particularly those in the "survival" and "subsistence" levels.
b. Rural-based and production supportive infrastructure; such as countryside highways, and flood control and drainage, to link rural production and consumption areas with the national and international economies.
c. Basic urban infrastructure; like roads, flood control and drainage, to help the poor and make the center viable markets or service areas for their rural hinterlands.

Likewise, the Program includes the following special concerns:

a. Establishing a well built and maintained arterial road network comprising the north-south backbone, east-west laterals and other roads of strategic importance to ensure continuous and efficient flow of people, goods, and services among regions and between major production and consumption areas.
b. Providing sufficient secondary roads to compliment the arterial road network to link resource areas to the main-stream.
c. Providing adequate infrastructure support to tourism and agro-industrial areas to harmonize with the government's goal to increase productivity in the countryside.
d. Addressing the infrastructure needs of the designated regional industrial centers.
e. Providing alternate access in case of regional emergencies through the development of strategic roads.
f. Mitigating flooding to induce intensive production, especially in the major river basins.

g. Providing essential infrastructure to the fast growing urban centers.
h. Adopting the following general order of project priorities: maintenance, rehabilitation, improvement, and construction.
i. Involving women and cultural minorities in relevant infrastructure development activities.

6.3 DEMOGRAPHIC FRAMEWORK

6.3.1 Philippine Population Projection, 1980-2030

The National Census Statistics Office (NCSO) , in collaboration with the Inter-Agency Committee, made a long term population projection which has been used as the basis framework for policy making and formulating the development plans. The Philippine Population Projection (PPP) projected future population by each five years, which were broken down into administrative units, ie. Regions, Provinces and Cities/Municipalities, on the following three alternative assumptions :

- Low Growth Case : (Rapid Fertility Decline) Fertility will decline from its 1980 level such that a net production rate (NRR) of 1.0 will be achieved by the year 2000.
- Medium Growth Case : (Moderate Fertility Decline) will decline from its 1980 level such that an NRR of 1.0 will be achieved by the year 2010.
- High Growth Case : (Slow Fertility Decline) Fertility will decline from its 1980 level such that an NRR of 1.0 will be achieved by the year 2020.

In the Study, the PPP is used as the demographic framework, after reviewing and modifying where necessary.

6.3.2 Projected Population

The population in the year 1990 forecasted by PPP in three cases are compared with actual population as shown in Table 6.3-1. The population of Mindanao was well forecasted as a whole in the high growth case with only 0.8 percent difference between the forecast and the actual population. If comparing them region by region or province by province, however, it is found that the high growth case does not always give accurate figures and there are several projections with bigger errors. Therefore, the assumptions in the PPP forecast were reviewed at every province and city in the project influence area, and the forecast for each province and city was modified on the basis of the 1990 census results.

TABLE 6.3-1 CENSUS POPULATION AND PPP FORECAST

	Census Population		Projected Population in 1990		
	1980	1990	Low	Medium	High
Region IX	2,546,820	3,159,197	3,150,046	3,194,803	3,217,751
Region X	2,773,021	3,509,821	3,567,433	3,615,614	3,640,314
Region XI	3,368,371	4,457,076	4,274,624	4,333,696	4,364,314
Region XII	10,966,468	14,297,462	13,894,475	14,086,372	14,185,072

Table 6.3-2 presents modified population of the Study area. Population growth trend of the regions/provinces in the Study area will be generally faster than the national average. Annual growth rates for the period 1994-2000 of the Regions X and XI will be 1.76 and 2.31 percent, and will decrease to 1.28 and 1.54 percent for the period 2010-2020, respectively.

TABLE 6.3-2 PROJECTED POPULATION

		Population					Annual Growth Rate		
Region	Province/City	Actual	Projected				1994	2000	2010
		1990	1994	2000	2010	2020	2000	2010	2020
IX	ALL	3,159,197	3,376,905	3,668,470	4,115,838	4,554,327	1.39%	1.16%	1.02%
X	Surigao del Norte	425,458	461,635	511,640	592,398	674,713	1.73%	1.48%	1.31%
	Agusan del Norte	465,458	504,815	559,957	646,633	733,056	1.74%	1.45%	1.26%
	Agusan del Sur	420,763	473,205	561,173	716,098	859,057	2.88%	2.47%	1.84%
	Rest of Region	2,197,622	2,369,928	2,598,292	2,946,404	3,296,995	1.55%	1.27%	1.13%
	Total	3,509,821	3,809,583	4,231,062	4,901,534	5,563,822	1.76%	1.48%	1.28%
XI	Davao del Norte	1,055,061	1,146,468	1,291,569	1,535,732	1,754,837	2.01%	1.75%	1.34%
	Davao City	849,947	946,263	1,093,048	1,315,710	1,520,523	2.43%	1.87%	1.46%
	Rest of Region	2,552,113	2,815,537	3,245,772	4,006,707	4,711,452	2.40%	2.13%	1.63%
	Total	4,457,076	4,908,269	5,630,389	6,858,149	7,986,812	2.31%	1.99%	1.54%
XII	All	3,171,368	3,503,330	4,042,282	4,975,712	5,856,135	2.41%	2.10%	1.64%
Rest of the Philippines		57,513,519	61,747,122	67,294,183	75,696,813	84,152,998	1.44%	1.18%	1.06%
The Philippines		60,684,887	65,250,452	71,336,465	80,672,525	90,009,133	1.50%	1.24%	1.10%

6.4 ECONOMIC FRAMEWORK

6.4.1 Future Gross Regional Domestic Product (GRDP)

The Medium-Term Philippine Development Plan (MTPDP) presents a target of the GRDP growth up to the year of 1988 only. There is no official forecast or target beyond this target year. For the study purposes, the Study Team estimated the future GRDP of the regions in Mindanao up to the year of 2020 on the following assumptions:

a. The MTPDP sets up a target of real per capita income in 1998 at US$1,000 or more as the first milestone on the way to becoming a newly industrializing country (NIC) in the next century. It is assumed that the US$2,000 level that is usually considered as the threshold for NIC will be achieved by 2010.

b. Based on the balanced regional socio-economic development concept emphasized in the MTPDP, imbalanced productions and incomes between the National Capital Region (NCR) and other regions will be improved. In 1994, the per capita income of the NCR is about 3.0 and 2.7 times as much as those of the Region X and Region XI, respectively. They are assumed to be about 2.0 times in 2020.

Taking the population growth of the regions into consideration, the GRDP is estimated as shown in Table 6.4-1.

TABLE 6.4-1 FUTURE GROSS REGIONAL DOMESTIC PRODUCT

(in million pesos at 1992 price)

Region		Year				Annual Average Growth Rate		
		1994	2000	2010	2020	1994-2000	2000-2010	2010-2020
IX	GRDP in million	38,759	59,262	108,454	192,038	7.33%	6.23%	5.88%
	Per capita GRDP	11,477	16,155	26,350	42,166	5.86%	5.01%	4.81%
X	GRDP in million	68,419	105,393	211,231	372,612	7.47%	7.20%	5.84%
	Per capita GRDP	17,438	24,910	43,095	66,970	6.12%	5.63%	4.51%
XI	GRDP in million	95,809	164,006	344,043	613,229	9.37%	7.69%	5.95%
	Per capita GRDP	19,520	29,128	50,166	76,780	6.90%	5.59%	4.35%
XII	GRDP in million	46,838	71,405	137,861	250,877	7.28%	6.80%	6.17%
	Per capita GRDP	13,369	17,665	27,706	42,840	4.75%	4.60%	4.45%

6.4.2 Agriculture and Industrial Development Framework

Under the MTPDP, the agriculture and industrial sectors will be geared toward the attainment of the following major goals: (a) industrial restructuring for worldwide competitiveness and expanded production of goods and services for the domestic and export markets; (b) stronger productive and ecologically sound links between agriculture and industry; and (c) increasing incomes, productivity and access to resources among small entrepreneurs, farmers, fisher folks and workers. Production growth targets of each sector and major products re set up in the MTPDP as shown in Table 6.4-2.

TABLE 6.4-2 ANNUAL AVERAGE GROWTH RATE BY SECTOR/PRODUCT

Sector/Product	Annual Average Growth Rate (%) Low High
Agriculture, Fishery & Forestry	2.7 - 3.4 %
- Palay	3.4 %
- Corn	5.6 %
- Livestock	4.3 - 5.4 %
- Poultry	4.6 - 5.8 %
Industry	6.6 - 8.8 %
- Manufacturing	6.5 - 9.0 %
- Mining	5.9 - 7.0 %
- Construction	7.3 - 9.0 %
- Utilities	6.5 - 7.1 %
Services	6.2 - 7.6 %

Source: MTPDP, 1993-1998

Considering the future GRDP as a basic framework, the future GVA by sector and major products are estimated on the basis of the above target growth rates and the past performance. Table 6.4-3 presents the future GVA by sector and major products up to 2020.

TABLE 6.4-3 FUTURE GVA BY SECTOR AND MAJOR PRODUCT

	Gross Value Added				Annual Average Growth Rate		
	1994	2000	2010	2020	1994-2000	2000-2010	2010-2020
1. AGRICULTURE	312,219	379,062	485,348	601,678	3.29%	2.50%	2.17%
Crop	180,384	219,197	259,899	287,587	3.30%	1.72%	1.02%
- Palay	38,234	46,728	57,409	64,746	3.40%	2.08%	1.21%
- Corn	20,332	28,195	38,186	46,140	5.60%	3.08%	1.91%
- Other Crop	121,818	144,275	164,301	176,701	2.86%	2.19%	1.22%
Livestock & Poultry	75,213	100,765	159,353	241,854	5.00%	4.69%	4.26%
- Livestock	44,175	58,693	91,149	134,404	4.85%	4.50%	3.96%
- Poultry	31,038	42,072	68,204	107,450	5.20%	5.22%	4.65%
Fishery	53,237	58,384	65,716	71,947	1.55%	1.19%	0.91%
Forestry	3,385	717	382	290	-22.80%	-6.09%	-2.71%
2. INDUSTRY	493,634	770,370	1,536,813	2,909,281	7.70%	7.15%	6.59%
3. SERVICES	669,710	999,431	1,773,016	2,787,885	6.90%	5.90%	4.63%
G D P	1,475,564	2,148,863	3,795,176	6,298,844	6.47%	5.05%	5.20%

When estimating the regional GDP by sector, the nationwide growth rates shown in Table 6.4-2 are assumed to the Study Area. It may be needed to examine if this assumption is reasonable or not, especially for the agriculture sector, because this sector is more severely restricted to grow than other sectors, by the natural conditions such as land area, water supply and climate.

Summing up Table 6.4-3, the total GVA in the agriculture sector is forecasted to grow 1.92 times in the year 2020, while rice production is estimated to increase by 1.54 times, corn by 1.69 times and other crops by 2.26 times. The plausibility of these forecasts are checked, referring to "Crop Development and Soil Conservation Framework for Mindanao Island" studied by the Agricultural Land Management and Evaluation Division (ALMED) of the Department of Agriculture in 1989.

Agricultural production is basically grown by the increases in cultivated land and yields. According to the above study, the arable land in the Study Area is estimated as shown in Table 6.4-4, where the expansion area is defined as a land currently idle and less utilized that have potential for various forms of agricultural uses. The table shows that both of Region X and XI have rooms to increase agriculture land over 1.6 times of the present. Furthermore, the provinces directly affected by the Study Road have the same expansion rate of the present agricultural area.

The said ALMED's study also worked out the data on potential yields of major crops as shown in Table 6.4-5, based on experimental yields in the various experimental stations in Mindanao. These potential yields suggest that the forecast production in 2020 would be realized only by the crop intensification and improved irrigation system, without increases of agricultural land.

In conclusion, the forecast will be realized by cultivating half of the expansion lands and achieving half of possible rises in yields. Twenty-five years are seemingly long enough to attain these. Thus, the future framework of agricultural production is considered possible, even without changing the present cropping pattern in the Study Area.

TABLE 6.4-4 ARABLE LAND OF THE STUDY AREA (Unit : hectar)

Region/Province	Total Area (A)	Arable Area			(D)/(B)
		Agricultural Area (B)	Expansion Area (C)	Total Arable Area (D)	
Region X	2,832,770	863,796	568,880	1,432,676	1.66
Agusan del Norte	188,230	41,218	31,527	72,454	1.76
Agusan del Sur	896,550	209,451	209,391	418,842	2.00
Butuan City	70,800	29,378	18,459	47,837	1.63
Surigao City	26,263	9,427	1,594	11,021	1.17
Surigao del Norte	247,673	16,611	66,817	83,428	5.02
Other Provinces	1,403,254	557,711	241,092	798,803	1.43
Region XI	3,169,290	1,103,000	766,393	1,869,393	1.69
Davao del Norte	810,354	241,780	247,233	491,013	2.03
Davao City	244,000	64,556	44,255	108,811	1.69
Other Provinces	2,114,936	796,664	472,905	1,269,569	1.59

Source: Crop Development and Soil Conservation Framework for Mindanao Island, ALMED, Department of Agriculture, 1989

TABLE 6.4-5 PRESENT AND POTENTIAL YIELDS OF MAJOR CROPS IN MINDANAO

Crops	Annual Average Yield (Kg/ha)		(B)/(A)
	(A) Present	(B) Potential	
Paddy rice irrigated	6,227	10,959	1.76
Paddy rice non-irrigated	3,484	5,945	1.71
Upland rice	1,557	1,786	1.15
Corn	2,635	5,771	2.19
Coconut	1,548	2,239	1.45
Banana	3,278	3,278	1.00
Coffee	105	964	9.18
Pineapple	8,004	9,926	1.24
Cacao	221	814	3.68
Sugarcone	2,400	12,547	5.23
Sweet potato	3,789	15,000	3.96
Cabbage	3,710	3,714	1.00
Rubber	1,716	8,080	4.71
Fishpond	1,000	1,500	1.50

Source: Crop Development and Soil Conservation Framework for Mindanao Island, ALMED, Department of Agriculture, 1989

6.4.3 Future Family Income and Expenditure

Future family income and expenditure in the respective regions are estimated on the assumption that those will be increased at the same rate of GRDP growth. The future family income and expenditure estimated by region are shown in Table 6.4-6.

TABLE 6.4-6 FUTURE FAMILY INCOME AND EXPENDITURE ESTIMATES

(In million pesos; at constant 1992 prices)

	Annual Family Income				Annual Family Expenditure			
	1994	2000	2010	2020	1994	2000	2010	2020
Region IX	30,822	47,118	86,230	152,686	25,076	38,334	70,155	124,227
Region X	35,764	55,102	110,438	194,812	30,306	46,693	93,584	165,081
Region XI	50,729	86,825	182,137	324,645	40,426	69,191	145,146	258,710
Region XII	27,400	41,770	80,645	146,755	22,374	34,108	65,852	119,836

CHAPTER 7

TRAFFIC FORECAST

7.1 APPROACH

7.1.1 Procedure of Traffic Demand Forecast

Since the Study Road is the only arterial road linking Regions X and XI with no alternative routes, notable traffic diverted from other routes will not be expected even if the rehabilitation project is completed. And furthermore, a road rehabilitation project generally creates little generated traffic. Therefore, the traffic growth rate method that is based on the current OD traffic volume estimated in Chapter 5 and the future socio-economic framework stated in the previous chapter is applied to forecast the future traffic demand on the Study Road. General procedure undertaken to forecast the future traffic is shown in Figre 7.1-1 .

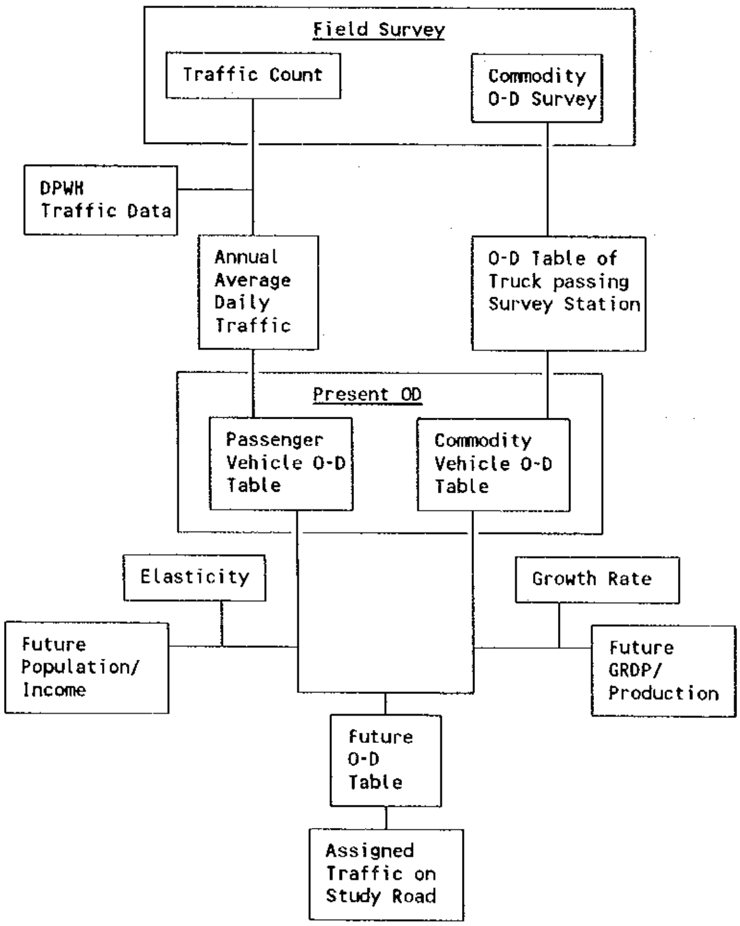


FIGURE 7.1-1 TRAFFIC FORECAST PROCEDURE

Demand of cars, jeepneys, buses, trucks and other vehicles (tricycle and motorcycle) are indivisually forecasted by using respective growth rate models. The future traffic volume of passenger vehicles are directly projected by multiplying the average growth rates of generated traffic and attracted traffic to OD traffic volume, while the future cargo truck volume is estimated in accordance with the following procedure:

Step 1 : to convert the existing truck volume into commodity O-D survey results;

Step 2 : to estimate the future commodity volume by item; and

Step 3 : to convert the future commodity volume into truck volume using the loading factor.

7.1.2 Growth Rate Models

1) Passenger Traffic and Basic Consumption Commodities

The transport demand of passenger and basic consumption commodities for daily use, generated from or attracted to each zone may increase in proportion to the trip-makers ability to pay traffic costs or the consumer's ability to buy commodities. Hence, it is assumed that such transport demand will increase in proportion to the personal income growth and population growth. The forecast model that is recommended in "Highway Planning Manual" of Department of Public Works and Highway, Philippines is applied in this Study. The model is expressed by the following formula:

$$TGR = \left[\left(\frac{I \times E}{100} + 1.0 \right) \times \left(\frac{CP}{100} + 1.0 \right) - 1.0 \right] \times 100$$

Where:

TGR: traffic (or commodity) growth rate in percent per annum
E : transport demand (or goods consumption) - income elasticity
I : per capita income growth rate in percent
CP : population growth rate in percent per annum

A per capita income growth rate and a population growth rate of the project area are discussed in the preceding chapter. A transport demand-income elasticity is in principle defined as follows:

$$E = \frac{\frac{dT}{T}}{\frac{dI}{I}} = \frac{dT \cdot I}{T \cdot dI}$$

Where:

dT : change in transport demand
T : the present level of transport demand
dI : change in per capita income
I : the present level of per capita income

The Highway Planning Manual indicates values of the elasticity by mode and by income class that were estimated on the basis of the "Family income and Expenditure Survey, 1970-1971, NCSO". The values of elasticity for private transport range from 0.7 to 1.7, while those for public transport range from 0.8 to 1.1. As to values for goods consumption-income elasticity, the Manual does not give any actual value. The previous studies estimated the elasticity for basic consumption commodities at 0.8 based on the results of the 1975 household income statistics.

The Study Team reviewed the analysis of the elasticity presented in the Manual based on the results of the "1991 Family Income and Expenditure Survey, NSO" and then conducted that rather lower values than those indicated in the Manual should be applied to the current traffic in the rural area of Regions X and XI. In addition, it is generally known that the transport demand-income elasticity for inter-regional/provincial traffic is lower than that for local/intra-urban traffic. Taking such facts and findings into consideration, 0.8 of the elasticity is established for passenger vehicles as well as basic consumption commodities.

Using the elasticity above, the future household income and the future population estimated in the previous chapter, the growth rate of each zone is calculated and each OD traffic volume is increased by multiplying the logarithmic average of the growth rates of the origin zone and the destination zone.

$$T_{ijk}^{t} = (1 + TGR_{ij}^{t-1}) * T_{ijk}^{t-1}$$

$$TGR_{ijk}^{t-1} = \sqrt{(1+TGR_{ik}^{t-1}) * (1+TGR_{jk}^{t-1})} - 1$$

where: T_{ijk}^{t} : OD traffic volume of vehicle type k, in year t, from zone i to zone j

TGR_{ijk}^{t}: TGR of T_{ijk}^{t}

TGR_{ik}^{t}: TGR of vehicle type k in Zone i, in year t

2) Other Commodities

Commodities other than the basic consumption commodities are classified into two groups,i.e. agricultural products and producers goods. Transportation demand of the former increase in proportion to the agricultural productivity, and that of the latter is assumed to increase in proportion to the regional economic growth.

Among the commodities transported by trucks passing the Study Road, cerealso, uprocessed agricultural foodstuffs, cash crops, processed cereal products, forest products belong to the former. In the latter group, there are mineral oil products, building and construction materials, and manufactured producers goods as well.

Future volumes of commodity flow are converted into truck traffic volume using the loading factors determined by commodity types on the basis of the commodity O-D survey results. Volume of empty trucks is assumed to increase in proportion to the average growth rate of all loaded trucks.

3.) Cargo Trucks

Future volumes of commodity flow are converted into truck traffic volume using the loading factors determined by commodity types on the basis of the commodity O-D Survey results. Volume of empty trucks is assumed to increase in proportion to the average growth rate of all loaded trucks.

7.2 FUTURE TRAFFIC DEMAND

7.2.1 Future Traffic Generation and Attraction

Future traffic generated from or attracted to each zone is summarized in Table 7.2-1. In most zones, vehicle trips which will use the Study Road are forecasted to increase at the annual rate in the range of 5.7 to 6.1%, and the total number of trips will increase 4.6 times of the present trips in the year 2020.

TABLE 7.2-1 FUTURE GENERATED/ATTRACTED TRAFFIC BY ZONE

(Vehicles/Day)

Zone	Generated/Attracted Traffic				Annual Growth Rate(%)
	1994	2000	2010	2020	1994-2020
1 Surigao del Norte	1,573	2,385	4,504	7,573	6.23
2 Agusan del Norte	1,483	2,234	4,143	6,830	6.05
3 Misamis Oriental	124	187	353	580	6.11
4 Bayugon	706	1,061	1,978	3,266	6.07
5 San Francisco	527	795	1,488	2,460	6.10
6 La Paz	290	443	827	1,362	6.13
7 Trento	140	209	378	600	5.76
8 Tandag	13	22	40	65	6.39
9 Bislig	1	3	8	12	10.03
10 Cateel	2	4	8	12	7.13
11 Monkayo	130	196	353	555	5.74
12 Monte Vista	176	268	485	765	5.81
13 Nabunturan	713	1,083	1,942	3,056	5.76
14 Tagum	1,100	1,722	3,169	5,076	6.06
15 New Corella	168	255	461	727	5.80
16 New Bataan	85	132	248	395	6.09
17 Sto. Tomas	3,239	5,089	9,372	15,031	6.08
18 Mati,Davao Oriental	36	56	105	169	6.13
19 Davao	7,223	11,353	20,904	33,581	6.09
20 Davao del Sur	197	307	566	902	6.03
21 South Cotabato	124	193	354	565	6.01
22 Bukidnon, N.Cotabato	13	19	34	58	5.92
Total	18,063	28,016	51,720	83,640	6.07

7.2.2 Future Traffic Volume

Forecasted traffic volumes on each section of the Study Road for the years 2000,2010 and 2020 are shown in Figure 7.2-1. Forecasted traffic volumes by vehicle type, together with the average growth rates, are presented in Table 7.2-2. Although there is a sligth difference in the average annual traffic growth rates among sections, the average rate will be over eigth percent during the period of 1994-2000, around six percent during the period of 2000-2010, and five percent more or less after 2010. Reflecting high rate of economic growth anticiapted in the Medium Term Philippine Development Plan, it is expected that the traffic on the Study Road will rapidly grow.

7.2.3 Future Commodity Volume

Volume of commodities transported crossing the provincial boundaries of Surigao del Norte and Agusan del Norte, Agusan del Norte and Agusan del Sur, Agusan del Sur and Davao del Norte and Davao del Norte and Davao City are presented in Appendix 7.1 to 7.4, respectively. Average annual growth rates of inter-provincial commodity flow are summarized as shown in Table 7.2-3. Sustained growth of commodity volumes is generally forecasted with average annual growth rates of over five percent. The commodity volumes in the sections between Surigao City and Butuan City are expected to grow faster than other sections.

TABLE 7.2-3 ANNUAL GROWTH RATES OF COMMODITY

	Average Annual Growth Rate			
	1994-2000	2000-2010	2010-2020	1994-2020
Surigao City - Butuan City	8.1%	5.2%	5.1%	5.8%
Butuan City - San Francisco	6.2%	5.5%	4.7%	5.3%
San Francisco - Tagum	5.9%	5.3%	4.6%	5.2%
Tagum - Davao City	7.1%	6.0%	4.9%	5.8%

TABLE 7.2-2(1/2) FUTURE TRAFFIC VOLUME BY SECTION

Section	Year	Vehicles with 4 or more wheels					Others		Total
		Car	Jeepney	Bus	Truck	Subtotal	Tricycle	M'cycle	
1	1994	251	115	41	238	645	449	199	1,293
	2000	383	179	67	364	993	663	308	1,964
	2010	686	323	119	739	1,867	1,192	538	3,597
	2020	1,098	514	186	1,271	3,069	1,933	864	5,866
2	1994	372	595	61	596	1,624	16	134	1,774
	2000	571	898	103	922	2,494	24	218	2,736
	2010	1,024	1,617	177	1,863	4,681	44	371	5,096
	2020	1,635	2,601	282	3,239	7,757	70	588	8,415
3	1994	236	241	68	153	698	5	82	785
	2000	383	384	120	222	1,109	8	144	1,261
	2010	674	687	201	443	2,005	15	235	2,255
	2020	1,061	1,092	318	720	3,191	23	368	3,582
4	1994	200	194	61	186	641	7	49	697
	2000	339	320	113	274	1,046	9	95	1,150
	2010	588	569	183	533	1,873	21	147	2,041
	2020	914	899	290	863	2,966	30	229	3,225
5	1994	252	312	73	206	843	4	91	938
	2000	428	508	140	304	1,380	8	168	1,556
	2010	739	904	219	586	2,448	12	270	2,730
	2020	1,154	1,448	351	942	3,895	20	420	4,335
6	1994	612	673	70	440	1,795	73	238	2,106
	2000	985	1,067	137	649	2,838	110	396	3,344
	2010	1,753	1,907	210	1,252	5,122	199	676	5,997
	2020	2,801	3,085	339	2,047	8,272	327	1,067	9,666
7	1994	771	636	74	475	1,956	40	186	2,182
	2000	1,237	1,024	145	692	3,098	63	331	3,492
	2010	2,216	1,836	222	1,315	5,589	116	551	6,256
	2020	3,568	2,986	359	2,117	9,030	190	858	10,078
8	1994	712	782	164	462	2,120	39	250	2,409
	2000	1,157	1,258	308	667	3,390	61	435	3,886
	2010	2,076	2,295	492	1,252	6,115	115	744	6,974
	2020	3,350	3,763	801	2,005	9,919	191	1,180	11,290
9	1994	547	495	189	491	1,722	134	195	2,051
	2000	905	817	349	696	2,767	211	348	3,326
	2010	1,598	1,460	567	1,296	4,921	412	581	5,914
	2020	2,558	2,373	931	2,058	7,920	701	914	9,535
10	1994	459	225	184	343	1,211	6	156	1,373
	2000	770	394	343	491	1,998	9	287	2,294
	2010	1,342	668	553	931	3,494	18	465	3,977
	2020	2,143	1,053	907	1,486	5,589	31	726	6,346
11	1994	554	293	175	421	1,443	33	291	1,767
	2000	924	501	327	594	2,346	53	507	2,906
	2010	1,640	881	525	1,094	4,140	102	882	5,124
	2020	2,651	1,416	857	1,724	6,648	175	1,427	8,250
12	1994	386	264	115	295	1,060	72	794	1,926
	2000	658	456	215	422	1,751	113	1,306	3,170
	2010	1,131	797	345	794	3,067	225	2,447	5,739
	2020	1,794	1,283	561	1,267	4,905	385	4,090	9,380

TABLE 7.2-2(2/2) FUTURE TRAFFIC VOLUME BY SECTION

Section	Year	Vehicles with 4 or more Wheels					Others		Total
		Car	Jeepney	Bus	Truck	Subtotal	Tricycle	M'cycle	
13	1994	334	101	119	191	745	8	178	931
	2000	572	191	219	278	1,260	13	322	1,595
	2010	981	303	357	530	2,171	25	531	2,727
	2020	1,547	462	580	860	3,449	43	837	4,329
14	1994	371	151	120	252	894	20	549	1,463
	2000	632	273	218	368	1,491	34	911	2,436
	2010	1,090	455	360	684	2,589	60	1,652	4,301
	2020	1,724	707	586	1,110	4,127	100	2,697	6,924
15	1994	405	113	153	355	1,026	202	633	1,861
	2000	679	208	274	516	1,677	315	1,041	3,033
	2010	1,190	339	459	924	2,912	588	1,889	5,389
	2020	1,888	516	748	1,478	4,630	964	3,059	8,653
16	1994	489	126	183	358	1,156	11	450	1,617
	2000	809	227	323	527	1,886	22	753	2,661
	2010	1,434	377	549	934	3,294	33	1,349	4,676
	2020	2,292	583	891	1,508	5,274	55	2,170	7,499
17	1994	649	157	305	500	1,611	80	511	2,202
	2000	1,061	274	529	733	2,597	128	847	3,572
	2010	1,900	467	910	1,284	4,561	232	1,523	6,316
	2020	3,055	733	1,474	2,047	7,309	370	2,457	10,136
18	1994	855	157	318	673	2,003	20	605	2,628
	2000	1,380	271	542	990	3,183	36	989	4,208
	2010	2,500	466	944	1,713	5,623	60	1,797	7,480
	2020	4,030	743	1,528	2,704	9,005	96	2,899	12,000
19	1994	1,029	332	488	1,137	2,986	1,050	1,110	5,146
	2000	1,644	548	811	1,674	4,677	1,640	1,777	8,094
	2010	3,005	980	1,442	2,862	8,289	3,020	3,255	14,564
	2020	4,854	1,568	2,326	4,458	13,206	4,827	5,242	23,275
20	1994	2,368	515	905	1,526	5,314	153	947	6,414
	2000	3,739	833	1,469	2,281	8,322	243	1,522	10,087
	2010	6,901	1,516	2,658	3,971	15,046	450	2,791	18,287
	2020	11,134	2,431	4,289	6,214	24,068	719	4,507	29,294
21	1994	2,807	957	1,043	2,122	6,929	1,016	1,596	9,541
	2000	4,425	1,527	1,675	3,215	10,842	1,603	2,538	14,983
	2010	8,205	2,805	3,060	5,666	19,736	2,973	4,689	27,398
	2020	13,238	4,513	4,947	8,901	31,599	4,770	7,566	43,935
22	1994	3,284	1,733	940	2,110	8,067	147	651	8,865
	2000	5,188	2,759	1,502	3,208	12,657	236	1,045	13,938
	2010	9,639	5,117	2,768	5,680	23,204	433	1,922	25,559
	2020	15,581	8,263	4,479	8,931	37,254	694	3,113	41,061
23	1994	2,666	2,237	442	1,568	6,913	15	858	7,786
	2000	4,217	3,558	706	2,388	10,869	28	1,368	12,265
	2010	7,841	6,628	1,302	4,228	19,999	45	2,537	22,581
	2020	12,675	10,725	2,107	6,641	32,148	73	4,114	36,335
24	1994	2,475	0	291	2,146	4,912	265	806	5,983
	2000	3,923	0	460	3,310	7,693	424	1,281	9,398
	2010	7,309	0	860	5,917	14,086	790	2,387	17,263
	2020	11,827	0	1,391	9,339	22,557	1,279	3,870	27,706

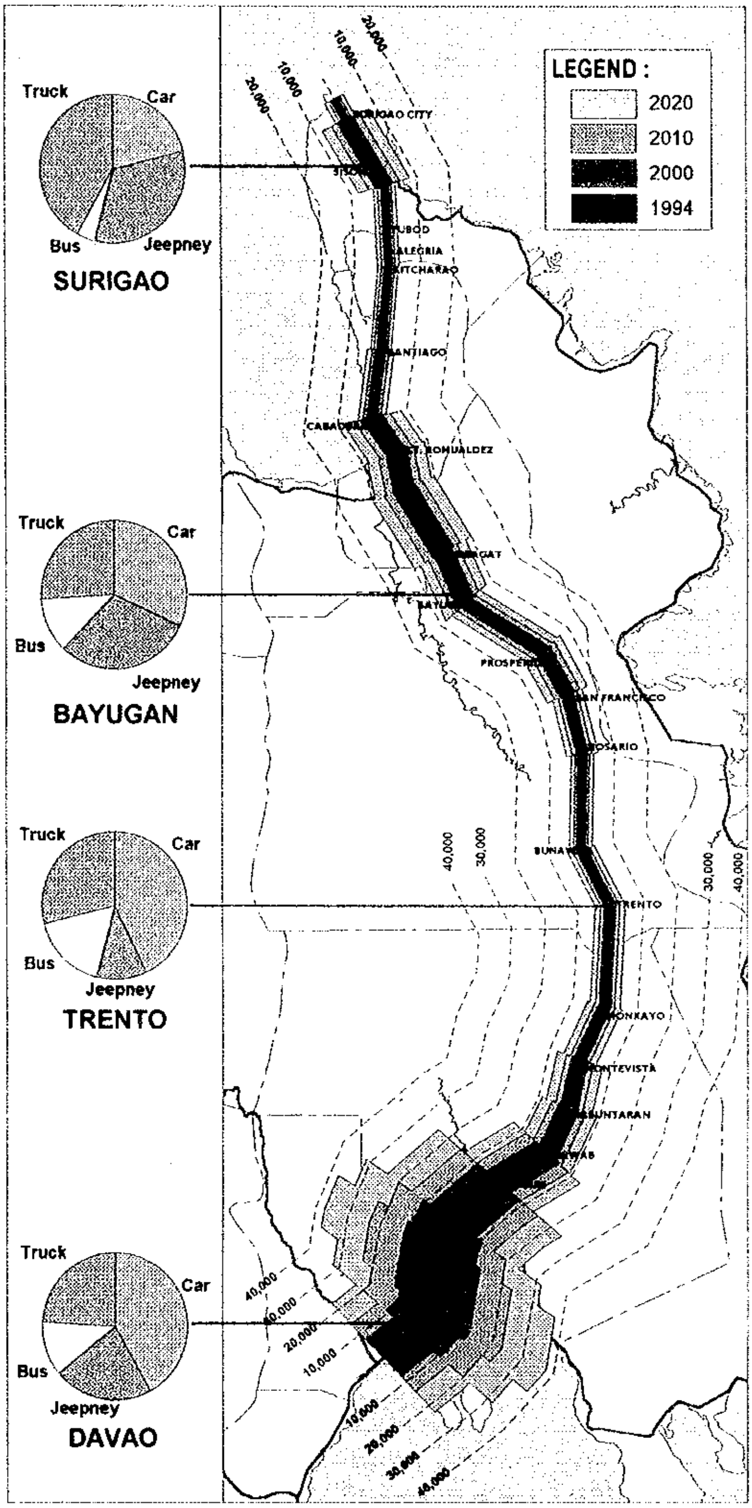


FIGURE 7.2-1 FUTURE TRAFFIC VOLUME AND VEHICLE TYPE COMPOSITION

PART II

REHABILITATION PLAN

CHAPTER 8

DEVELOPMENT OF DATABASE

8.1 ROAD INVENTORY

8.1.1 Field Surveys

A comprehensive database was developed based on the following field surveys:

- Road Referencing System Survey
- General Road Condition Survey
- Pavement Surveys
  - Pavement Distress Survey
  - Nondestructive Testing (NDT)
  - Roughness Survey
  - Present Serviceability Rating (PSR)
  - Rehabilitation Requirement Rating (RRR)
- Drainage Condition Survey
  - Pipe/Box Culvert Survey
  - Flood Section Survey

1) Road Referencing System Survey

The survey was conducted to measure the exact distance between defined reference points. Provincial/city boundary posts, kilometer posts, beginning and end of bridges, major intersections and other permanent structures were selected for reference points. The survey results were used as the common basis in terms of location and distance for the general road condition survey, the pavement surveys, and other surveys. Distance between reference points was measured by a vehicle equipped with a DIGITRIP odometer which can read distance to a level of one meter digit. The survey format is presented in Appendix 8.1.

The Study Road was divided into 18 road links (see Figure 8.1-1). Boundaries of provinces/ cities, major intersections or major bridges were selected for the start/end of each road link. Distance of each road link was established not to exceed 50 kilometers in order to minimize accumulation of odometer errors.

2) General Road Condition Survey

General road conditions such as topography, cross section type, horizontal and vertical alignments, shoulder conditions, surface drainage conditions and roadside land use were surveyed by visual inspection. Above information was recorded for every 100-meter section. The survey format used is presented in Appendix 8.1.

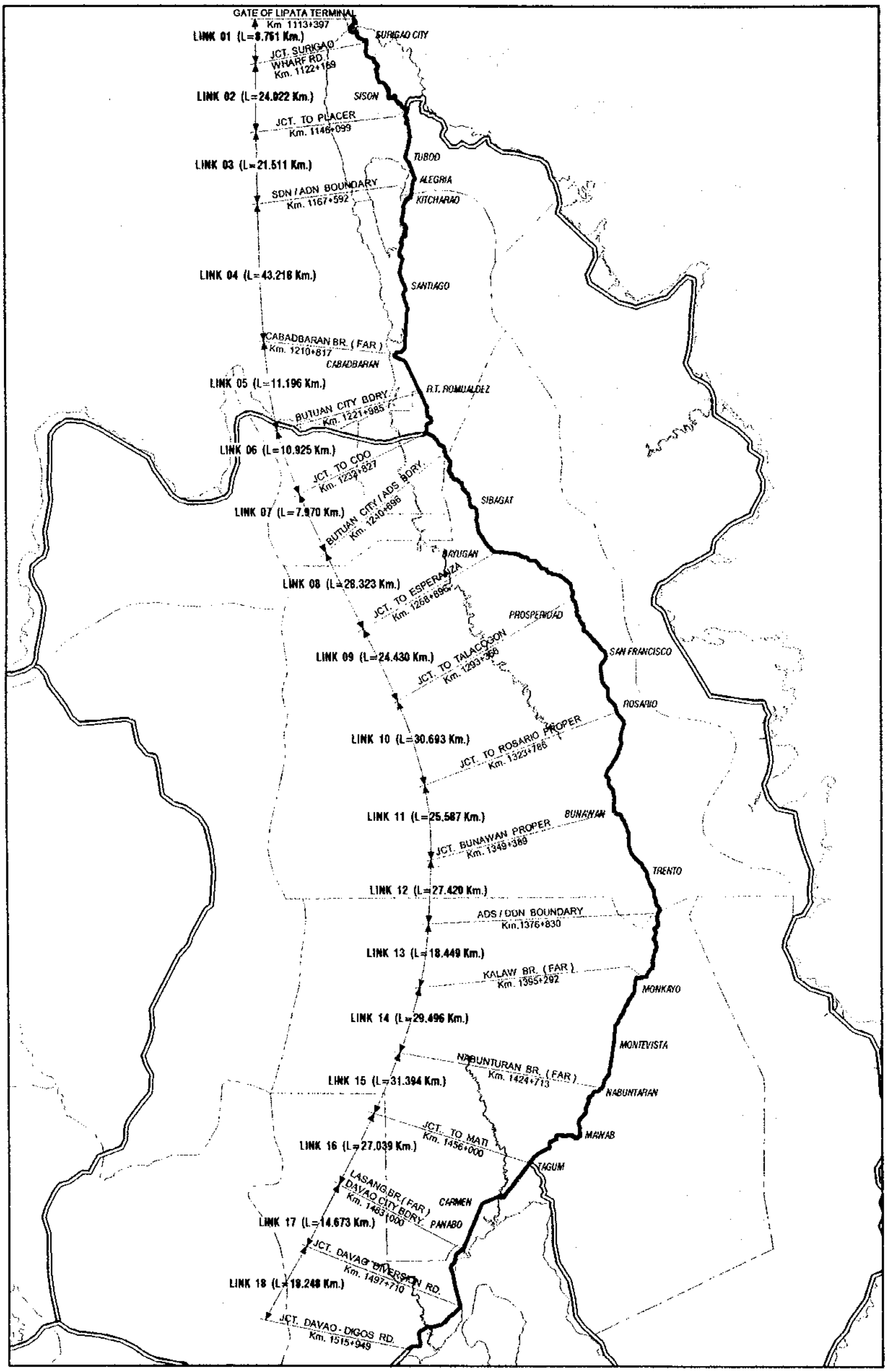


FIGURE 8.1 - 1 ROAD LINK

3) Pavement Surveys

<u>Pavement distress survey</u>

Pavement distresses were surveyed by visual inspection to evaluate level of pavement deterioration and to correlate with present serviceability rating (PSR) and rehabilitation requirement rating (RRR).

Preliminary field reconnaissance was undertaken to identify pavement types and pavement distress types. Majority sections are PCC pavement. AC overlaid PCC pavement and gravel surface were observed at several short sections. The survey format was designed based on the above findings (refer to Appendix 8.1).

Following pavement distresses were recorded for each 100-m section:

- Cracks (in meters)
  - Transverse cracks
  - Longitudinal cracks
  - Corner cracks
  - Block/Alligator cracks
- Patching (in square meters)
- Scaling (in square meters)
- Depression (in numbers)
- Pumping/water bleeding (in numbers)
- AC overlay removed (in square meters)
- Potholes (in number)
- Uneven surface (in meters)

<u>Nondestructive Testing (NDT)</u>

NDT was carried out to measure the present strength of pavement structure including PCC slab and subbase/subgrade.

NDT was carried out at every 500 meters by using the Dynatest Falling Weight Deflectometer (FWD). Test results were automatically recorded in a computer diskette in the field.

<u>Roughness Survey</u>

Roughness of pavement surface was measured using NAASRA roughness meter equipped to a Lite Ace vehicle. Roughness was measured for every 100-meter section and recorded in a computer diskette in the field which was converted to the international roughness index (IRI) in the office. Roughness is one of the dominant factors affecting riding comfort or riding quality, therefore, will be correlated with PSR and RRR to develop rehabilitation criteria.

Present Serviceability Rating (PSR)

The present serviceability of a pavement is defined as the ability at time of observation how well the pavement serves the user. Riding comfort or ride quality is the dominant characteristics. The present serviceability is expressed in terms of the mean value of individual road user's rating.

It is understood that the basis of judgment on present serviceability may be swayed by the tolerableness of road users, national characteristics as well as economic conditions of the country, since riding comfort or ride quality is a matter of subjective response or the opinion of the users.

Present serviceability rating (PSR) was undertaken by a rating panel in May 1994.

Rating Panel (7 members)

- Highway Engineer
- Construction Engineer
- Transport Economist
- Traffic Engineer
- University Student
- Private Car Driver
- PUJ Driver

Rating Method

Each member of the rating panel was asked to rate the serviceability/ comfort based on their own judgment for every 200-m section of the road using the format presented in Appendix 8.1, while riding in the vehicle driving at the speed of about 60 km/hour. The range of rating was from 5 to 0 as follows:

Rating Point	Surface Condition	
5.0 - 4.0	Very Good	- Very Comfortable
4.0 - 3.0	Good	- Comfortable
3.0 - 2.0	Fair	- Satisfactory
2.0 - 1.0	Poor	- Uncomfortable
1.0 - 0.0	Very Poor	- Very Uncomfortable

Acceptability

Each member of the rating panel was further asked to record his opinion whether the serviceability of 200-m section was acceptable or not.

Rehabilitation Requirement Rating (RRR)

Since the present serviceability rating is a subjective assessment by the road users based on their own guideline and judgment, the rating does not necessarily identify the sections where the rehabilitation works are needed, when judged from the engineering point of view.

The rehabilitation requirement rating is exercised only by the experienced engineers who assess pavement conditions paying attentions on the pavement distresses and judge requirement or necessity of rehabilitation.

The rehabilitation requirement rating was undertaken by a rating panel in May 1994.

Rating Panel (6 members)

- 2 - Highway Engineers
- 1 - Highway Planning Engineer
- 2 - Maintenance Engineers
- 1 - Construction Engineer

Rating Method

Each engineer was asked to rate his engineering judgment on rehabilitation requirement for every 200-meter section of the road using the format presented in Appendix 8.1, while riding in the vehicle driving at the speed of about 20 km/hour. The range of rating was from 5 to 0 and criteria of judgment were as follows:

Rating Point	Surface Condition
5.0 - 4.0	No deficiency
4.0 - 3.0	Slight deficiency
3.0 - 2.0	Considerable deficiency but immediate treatment is not required
2.0 - 1.0	Considerable deficiency and immediate treatment is required
1.0 - 0.0	Reconstruction is immediately required.

Acceptability

Each member of the rating panel was further asked to record whether each 200-meter section was acceptable or not from the viewpoint of engineering judgment.

4) Drainage Condition Survey

Pipe/Box Culvert Survey

Location of pipe/box culvert is a point of water concentration. Inadequate design and/or lack of maintenance of culverts are frequently causing overflow of water, resulting in deterioration of pavement, scouring of shoulders, slope failures, etc.

All existing culverts were surveyed on their locations, sizes and conditions as well as whether they are causing problems to the road. The survey format used is presented in Appendix 8.1.

As difficulties to locate locations of culverts were expected, the survey team requested assistance from respective District Offices to expedite the survey. Maintenance engineer and/or maintenance foreman accompanied the survey team to locate culverts.

Flood Section Survey

The survey was undertaken to identify flood sections. No particular field survey format was prepared. The survey was undertaken by interviewing DPWH Regional/District Offices officials and nearby residents, gathering information from relevant agencies and field reconnaissance.

River sections which are damaging or would damage road sections were also surveyed.

8.1.2 Development of Equations For Pavement Condition Evaluation

There are various indices which express pavement conditions and, at the same time, are used for pavement condition evaluation. In this Study, two indices, namely present serviceability index (PSI) and rehabilitation requirement index (RRI) were selected for pavement condition evaluation.

Present serviceability rating (PSR) is an indicator to express the serviceability of a pavement as described in 8.1.1. The conduct of the rating each time when required for the pavement management is, however, time consuming and therefore unpractical. It is a practical way to develop an equation to predict the PSR from measurements of roughness and distresses such as crack, patching, scaling, etc. and to use the value obtained by the equation in lieu of the PSR. Thus obtained value is called the present serviceability index (PSI).

Likewise, the value obtained from physical measurements using the equation so formulated as to predict the rehabilitation requirement rating (RRR) is called the rehabilitation requirement index (RRI).

This section discusses the development of the PSI/RRI equations by a multiple regression analysis using the data obtained by the pavement surveys.

1) Correlation between PSR/RRR and Physical Measurements

Table 8.1.1 shows the correlation coefficients of each two variables among ratings and physical measurements.

TABLE 8.1-1 CORRELATION COEFFICIENTS BETWEEN TWO VARIABLES AMONG RATINGS AND PHYSICAL MEASUREMENTS

	Ratings		Physical Measurements								
	PSR	RRR	Roughness	Crack	Patching	Scaling	Depression	Pumping/ Water Bleeding	AC Overlay Removed	Pothole	Uneven Surface
PSR	1.000	.845	-.740	-.639	-.293	-.548	-.326	-.016	-.103	-.452	-.009
RRR	.845	1.000	-.628	-.661	-.248	-.539	-.338	-.014	-.079	-.380	.001
Roughness	-.740	-.628	1.000	.609	.275	.470	.289	.021	.185	.484	.002
Crack	-.639	-.661	.609	1.000	.124	.368	.436	-.005	-.020	.407	-.028
Patching	-.293	-.248	.275	.124	1.000	.151	.022	-.009	-.002	.224	.080
Scaling	-.548	-.539	.470	.368	.151	1.000	.147	.020	-.017	.418	-.029
Depression	-.326	-.338	.289	.436	.022	.147	1.000	.007	-.002	.186	-.035
Pumping/ Water Bleeding	-.016	-.014	.021	-.005	-.009	.020	.007	1.000	.023	-.016	.027
AC Overlay Removed	-.103	-.079	.185	-.020	-.002	-.017	-.002	.023	1.000	.113	-.012
Pothole	-.452	-.380	.484	.407	.224	.418	.186	-.016	.113	1.000	-.012
Uneven Surface	-.009	.001	.002	-.028	.080	-.029	-.035	.027	-.012	-.012	1.000

Among the physical measurements, three variables, i.e., pumping/water bleeding, AC overlay removed and uneven surface were omitted from the analysis because of their low correlations to the ratings. Accordingly, the variables to be used as predictors in the PSI/RRI equations are as follows:

- Roughness
- Pavement distress:crack, patching, scaling, depression, pothole

Figure 8.1-1 shows the connection between corresponding PSR/RRR values and the physical measurements, where pavement distress is expressed in a combined value of five kinds of distress as defined in 2) below.

2) Establishment of PSI/RRI Equations

The general mathematical form of the PSI/RRI was assumed to be:

$$PSI/RRI = C + A \cdot f(R) + B \cdot f(S1,S2,...)$$

where f(R) and f(S1,S2,...) are functions of roughness and pavement distress respectively and C, A and B are the coeficients to be determined by a least squares regression analysis. Based on a preliminary analysis, the following forms were selected:

$$f(R) = \log R$$
$$f(S1,S2,...) = \sqrt{\alpha S1 + \beta S2 + ...}$$

By a least squares regression analysis, the following equations were derived:

$$PSI = 5.64\text{-}3.2 \log R\text{-}0.044\sqrt{D1} \quad (r=0.848) \quad \cdots\cdots\cdots(1)$$
$$D1 = C+1.4P+0.25S+8D+11H$$
$$RRI = 5.12\text{-}2.1 \log R\text{-}0.087\sqrt{D2} \quad (r=0.841) \quad \cdots\cdots\cdots(2)$$
$$D2 = C+0.63P+0.18S+6D+2H$$

where

R = roughness (IRI)
D_1 = distress factor-1 (for PSI)
D_2 = distress factor-2 (for RRI)
C = crack ($m/1,000m^2$)
P = patching ($m^2/1,000m^2$)
S = scaling ($m^2/1,000m^2$)
D = depression ($no./1,000m^2$)
H = pothole ($no./1,000m^2$)
r = correlation coefficient

The PSI/RRI equations based on one factor, either roughness or distress, are as shown in Figure 8.1.2. The PSI/RRI values calculated by the above equations are plotted against corresponding PSR/RRR in Figure 8.1-3. The equations have a tendency to give slightly undervalued PSI/RRI in the range of PSR/RRR above 2.5 and slightly overvalued in the range of about 2.5 to 1.0. Although the equations have such a tendency mentioned above, they can be practically used for pavement condition evaluation.

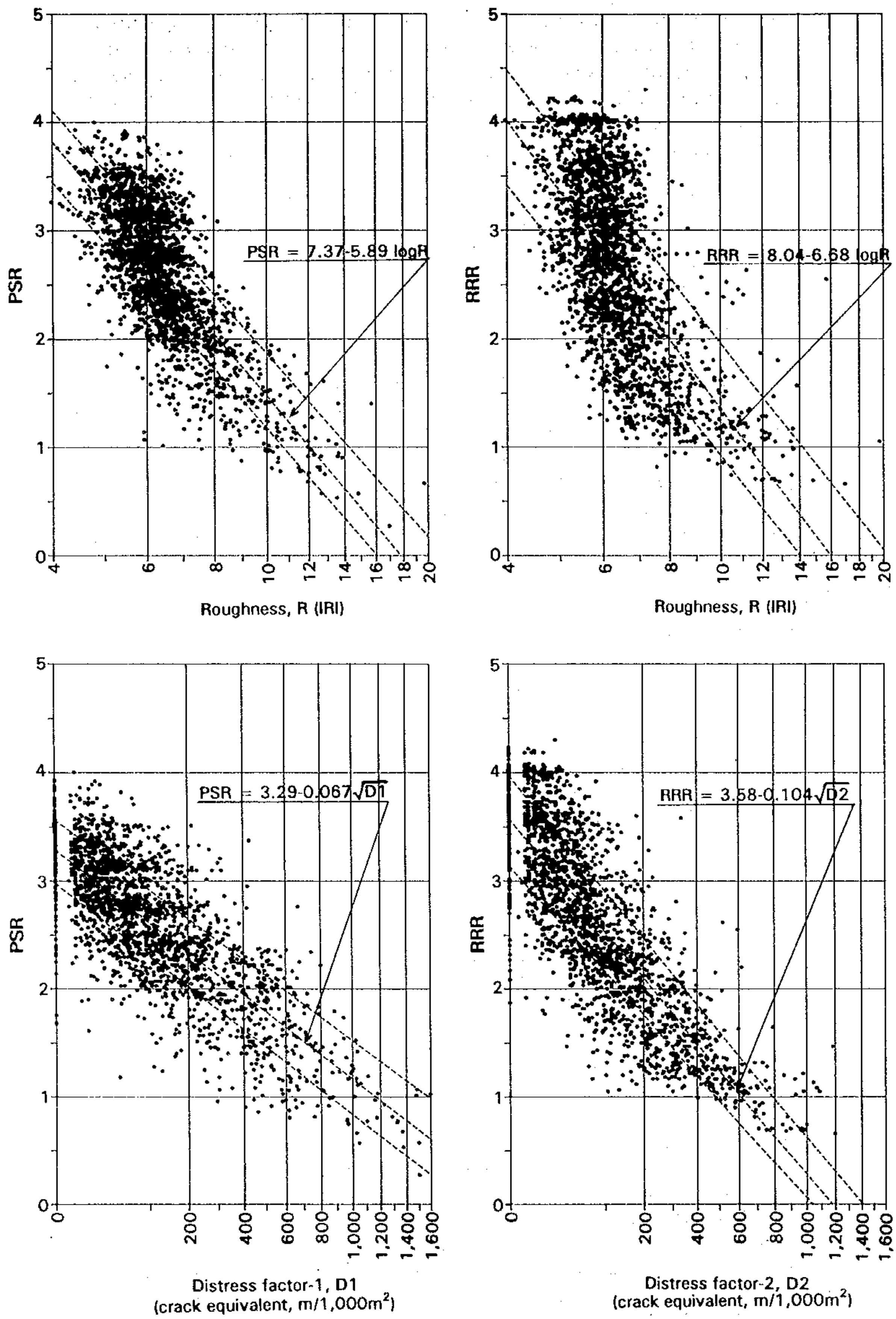


FIGURE 8.1-2 PRESENT SERVICEABILITY RATING (PSR)/REHABILITATION REQUIREMENT RATING (RRR) VS PHYSICAL MEASUREMENT OF PAVEMENT

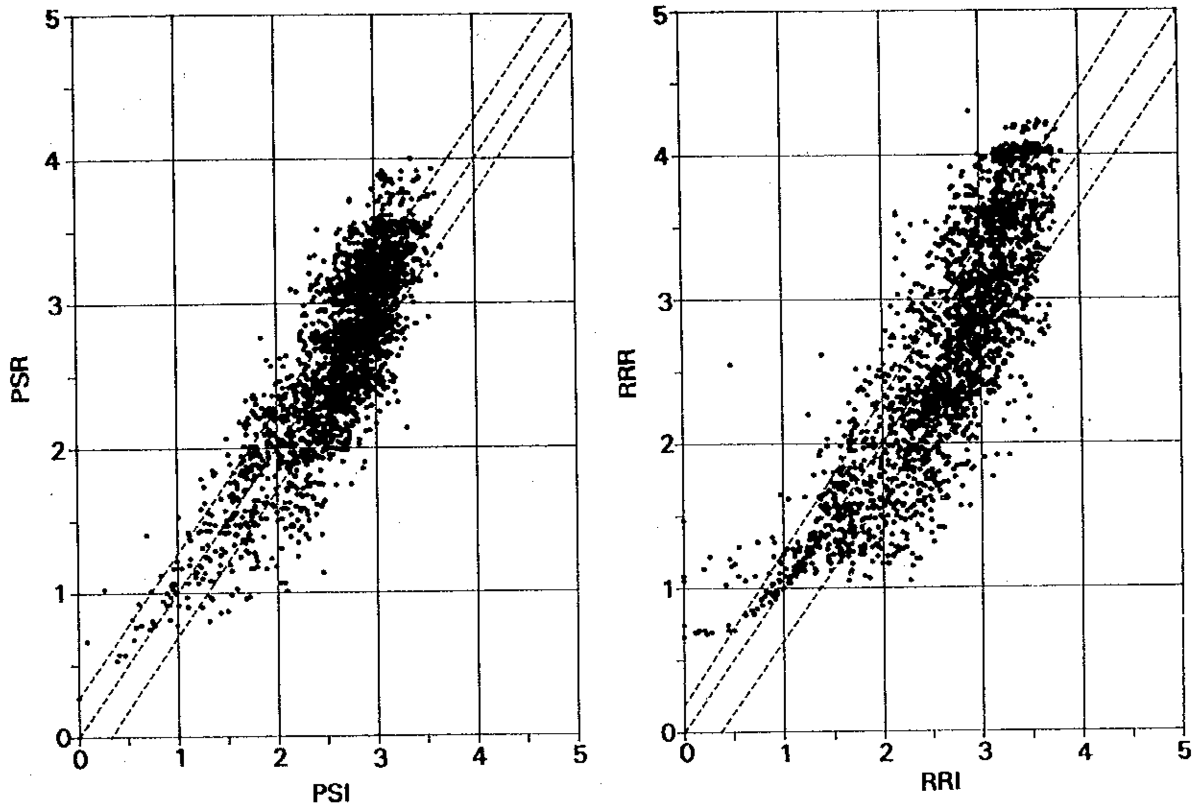


FIGURE 8.1-3 PRESENT SERVICEABILITY RATING (PSR) VS PRESENT SERVICEABILITY INDEX (PSI) AND REHABILITATION REQUIREMENT RATING (RRR) VS REHABILITATION REQUIREMENT INDEX (RRI)

3) PSI/RRI of Surveyed Pavement

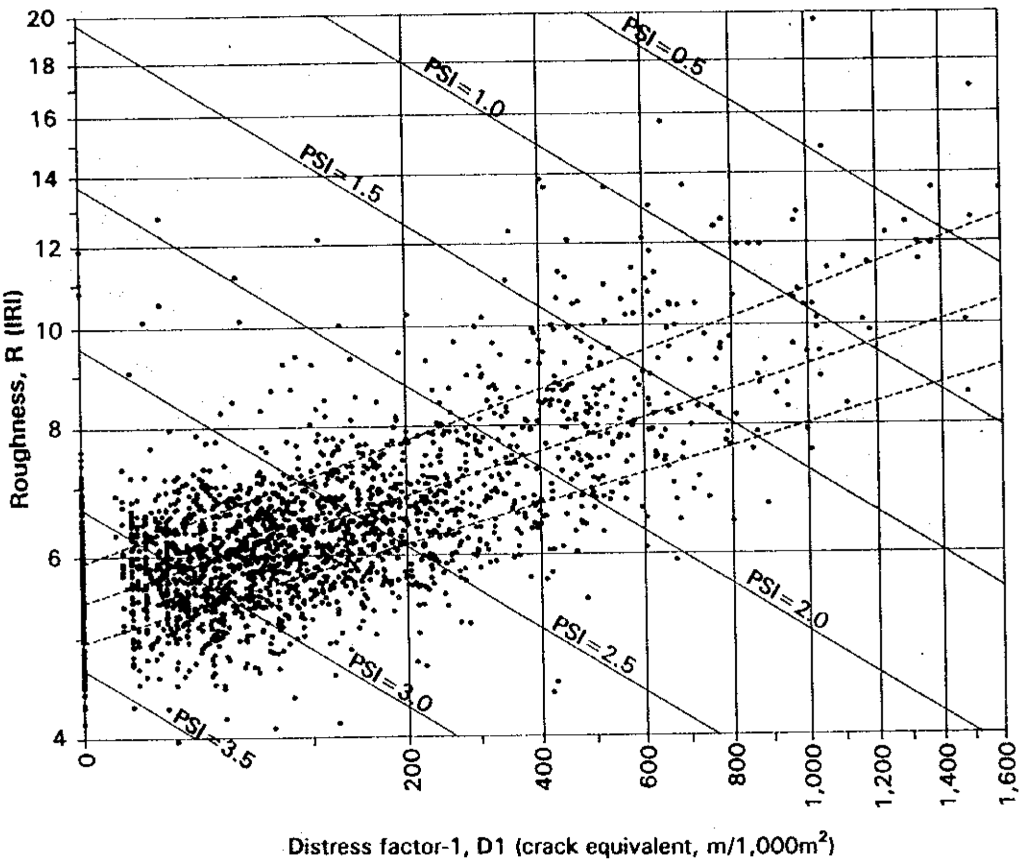
Figure 8.1-4 shows roughness-distress values of the surveyed pavement plotted on the roughness-distress plane with PSI/RRI contours. As shown in this figure, roughness is more dominant in PSI, while distress in RRI.

4) Acceptability

Each member of the rating panel was asked to indicate whether the pavement being rated is acceptable or not. The relationship between acceptability opinions and PSI/RRI is graphically shown in Figure 8.1-5.

The results are summarized as follows:

- Pavement of PSI = 2.6 is acceptable for 50 percent of raters.
- Pavement of PSI = 2.1 os unacceptable for 50 percent of raters.
- Pavement of RRI = 3.0 is acceptable for 50 percent of raters.
- Pavement of RRI = 2.6 is unacceptable for 50 percent of raters.



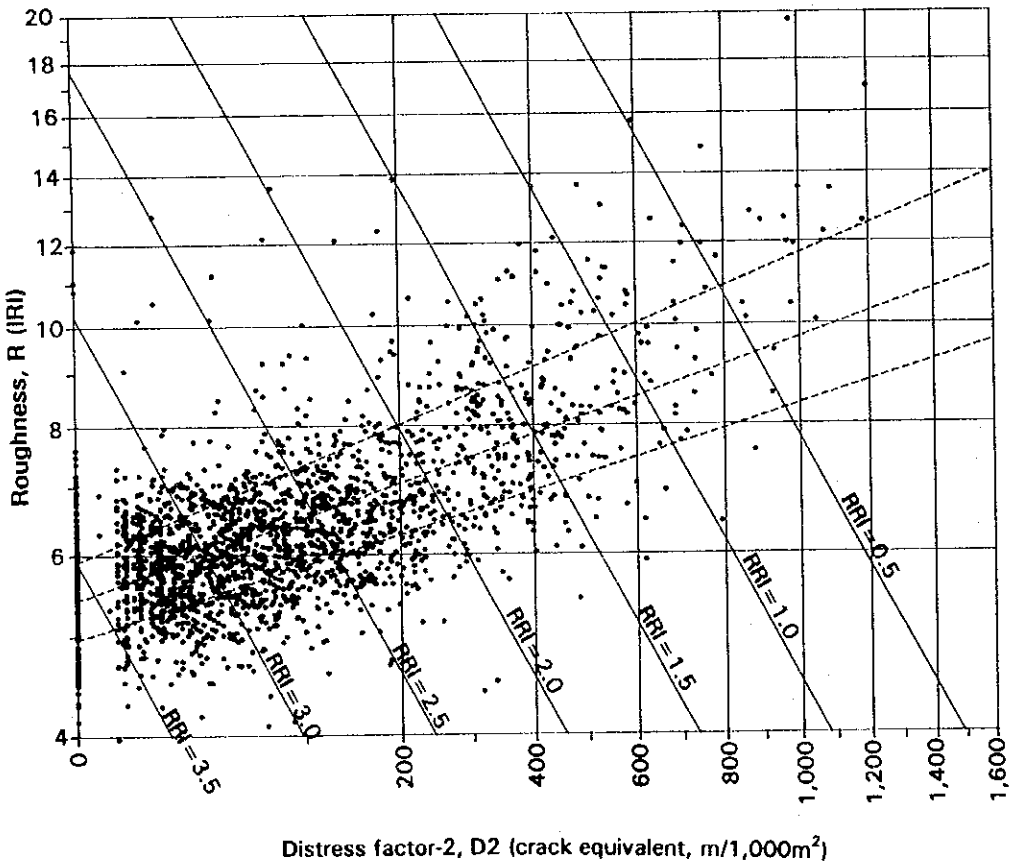
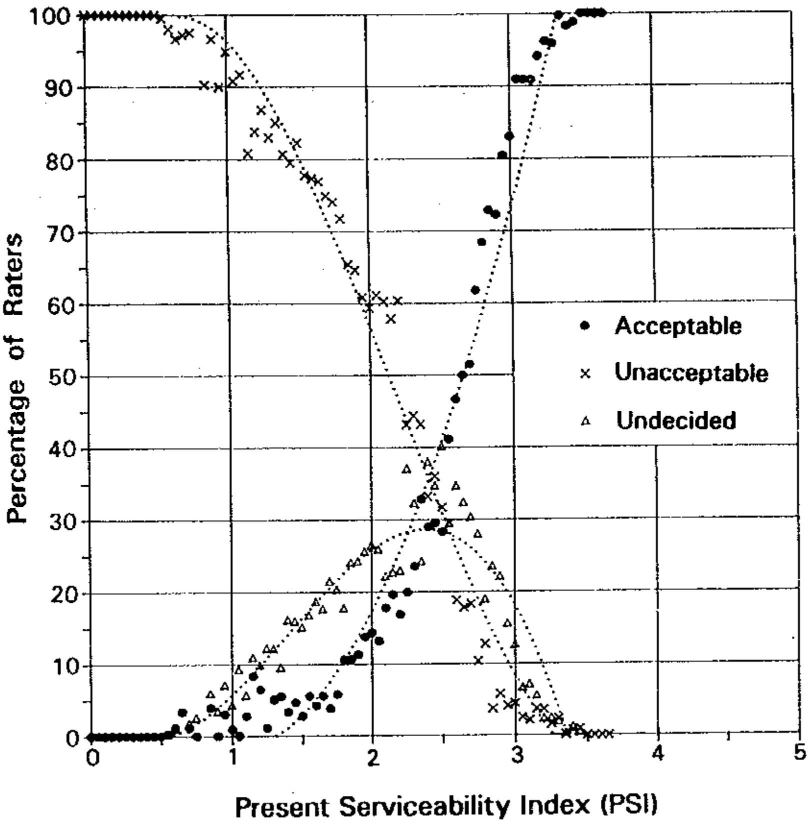


FIGURE 8.1-4 CONDITION OF SURVEYED PAVEMENT



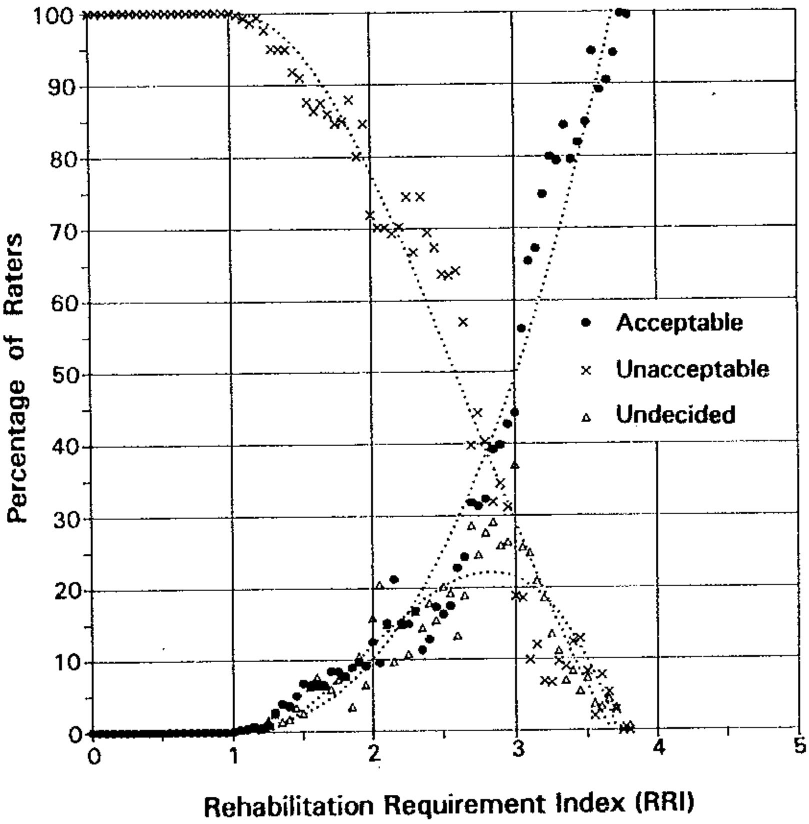


FIGURE 8.1-5 ACCEPTABILITY VS PSI/RRI

8.1.3 Road Inventory Database

All data collected by the field surveys were stored in the computer to prepare the computerized road inventory database. Following files were prepared:

File Name	Contents	Sample Printout
REFER	• Road referencing system survey data	Table 8.1-2
ROAD-1B	• General road condition survey data • Flood section	Table 8.1-3
ROAD-2B	• Pavement distress survey data • Nondestructive survey data • Roughness data • PSI and RRI	Table 8.1-4
PSR	• Present Serviceability rating data	
RRR	• Rehabilitation Requirement Rating data	
PIPE	• Pipe/Box Culvert survey data	Table 8.1-5

REFER, ROAD-1B and ROAD-2B were interfaced with the graphical presentation software.

TABLE 8.1-2 SAMPLE PRINT-OUT: FILE "REFER"

Pan-Philippine Highway - Mindanao
Road Referencing System

Road Link No. : 03
Inventory Date : May, 1994

Reference Marker Number	Refer. Marker Type 1)	Reference Marker Description	Odometer Reading (km)	Remarks 2)	Distance between Ref.Markers (km)
03-01	S		.000		-
03-02	B	Payao Bridge (near)	.301		.301
03-03	B	Payao Bridge (far)	.331		.030
03-04	K	KM 1147	.880		.549
03-05	K	KM 1148	1.886		1.006
03-06	K	KM 1149	2.884		.998
03-07	K	KM 1150	3.888	PRP	1.004
03-08	K	KM 1151 (fell down)	4.888		1.000
03-09	B	Timamana Bridge (near)	4.977		.089
03-10	B	Timamana Bridge (far)	4.993		.016
03-11	B	Motorpool Bridge (near)	5.596		.603
03-12	B	Motorpool Bridge (far)	5.604		.008
03-13	K	KM 1152	5.887		.283
03-14	B	Pingaping Bridge (near)	5.993		.106
03-15	B	Pingaping Bridge (far)	6.008		.015
03-16	K	KM 1153	6.889	PRP	.881
03-17	B	Marga Bridge (near)	7.484		.595
03-18	B	Marga Bridge (far)	7.498		.014
03-19	K	KM 1154	7.891		.393
03-20	K	KM 1155	8.894		1.003
03-21	B	Tubod Bridge (near)	9.677		.783
03-22	B	Tubod Bridge (far)	9.702		.025
03-23	K	KM 1156	9.895	PRP	.193
03-24	K	KM 1157	10.898		1.003
03-25	B	Siana Bridge (near)	11.059		.161
03-26	B	Siana Bridge (far)	11.074		.015
03-27	B	Magpayang Bridge I (near)	11.664		.590
03-28	B	Magpayang Bridge I (far)	11.689		.025
03-29	I	Jct. to Mainit	11.807		.118
03-30	K	KM 1158	11.896		.089
03-31	B	Magpayang Bridge II (near)	12.118		.222
03-32	B	Magpayang Bridge II (far)	12.124		.006
03-33	B	Pongtud Bridge (near)	12.439		.315
03-34	B	Pongtud Bridge (far)	12.475		.036
03-35	K	KM 1159	12.904	PRP	.429
03-36	K	KM 1160	13.903		.999
03-37	K	KM 1161	14.904		1.001
03-38	K	KM 1162 (missing)	15.902		.998
03-39	B	Alimpatayan Bridge (near)	16.194		.292
03-40	B	Alimpatayan Bridge (far)	16.216		.022
03-41	B	Alipao Bridge (near)	16.278		.062
03-42	B	Alipao Bridge (far)	16.292		.014
03-43	K	KM 1163 (fell down)	16.908		.616
03-44	B	Baluran Bridge (near)	17.050		.142
03-45	B	Baluran Bridge (far)	17.063		.013
03-46	B	Candiis Bridge (near)	17.217		.154
03-47	B	Candiis Bridge (far)	17.233		.016
03-48	B	Tugbongon Bridge (near)	17.409		.176
03-49	B	Tugbongon Bridge (far)	17.419		.010
03-50	K	KM 1164	17.960	PRP	.541
03-51	B	Magtiaco Bridge (near)	18.412		.452
03-52	B	Magtiaco Bridge (far)	18.598		.186
03-53	K	KM 1165	18.914		.316
03-54	B	San Pedro Bridge (near)	19.614		.700
03-55	B	San Pedro Bridge (far)	19.658		.044
03-56	K	KM 1166	19.917		.259
03-57	K	KM 1167	20.919	PRP	1.002
03-58	E	Surigao del Norte/Agusan del Norte	21.511		.592

1)Reference Marker Type
S:Start Road Link
E:End Road Link
O:Others
K:Kilometer Post
I:Road Intersection
B:Bridge
R:Regional Boundary
P:Provincial Boundary
D:District Boundary

2)Remarks
PRP:Recommended Permanent Reference Point
SB :Survey Breaks
Z :Obstruction to Line of Drive

TABLE 8.1-3 SAMPLE PRINT-OUT: FILE "ROAD - 1B"

Pan−Philippine Highway − Mindanao
Road Inventory No. 1

Road Link Number : 01
Sheet Number : 01
Inventory Date : May, 1994

KM	From to (m)		Topo- graphy 1)	Cross Sec- tion Type 2)	Sharp Curve (No)	Ver- tical Gra- dient 3)	South Bound Shoulder, Side Ditch, Roadside Land Use: Shoulder: Width (m)	Mat'l 4)	Dropoff (m)	Heave (m)	Scoured (m)	Side Ditch 5): N (m)	E (m)	R (m)	C (m)	Land Use 6)	North Bound Shoulder, Side Ditch, Roadside Land Use: Shoulder: Width (m)	Mat'l 4)	Dropoff (m)	Heave (m)	Scoured (m)	Side Ditch 5): N (m)	E (m)	R (m)	C (m)	Land Use 6)	Flood prone Sec- tion (m)
1113	397 −	400	2	2		1	1.50	1				3				5	1.50	1				3				5	
	400 −	500	2	2		1	1.50	1				100				5	1.50	1				100				5	
	500 −	600	2	4		1	1.50	1		30			100			7	1.50	2		50		100				7	
	600 −	700	2	4		2	1.50	1					100			5	1.50	1		50		100				7	
	700 −	800	2	4		2	1.50	1					100			5	1.50	1				100				5	
	800 −	900	2	4		2	1.50	1						100		5	1.50	1				100				5	
	900 −	1000	2	4		2	1.50	1						100		5	1.50	1				100				3	
1114	0 −	100	2	4		1	1.50	1						100		5	1.50	1				100				5	
	100 −	200	2	4	1	2	1.50	1						100		5	1.50	1				100				5	
	200 −	300	2	4		2	1.50	1			30			100		5	1.50	1				100				5	
	300 −	400	2	4		2	1.50	1						100		5	1.50	1				100				5	
	400 −	500	2	4		2	1.50	1						100		5	1.50	1				100				5	
	500 −	600	2	4	1	2	1.50	1	100				100			5	1.50	1				100				7	
	600 −	700	2	4		2	1.50	1	100				100			5	1.50	1				100				7	
	700 −	800	2	4		1	1.50	1					100			5	1.50	1				100				3	
	800 −	900	2	4		−2	1.50	1				100				5	1.50	1				100				3	
	900 −	1004	2	4		−2	1.50	1					104			5	1.50	1				104				5	
1115	0 −	100	2	4	1	−2	2.00	1	100				100			5	1.50	1				100				5	
	100 −	200	2	2	1	−2	2.00	1					100			3	1.50	1				100				5	
	200 −	300	2	2	1	−2	2.00	1						100		5	1.50	1				100				5	
	300 −	400	2	2		−2	2.00	1						100		5	1.50	1					100			5	
	400 −	463	2	4		2	1.50	1						63		5	1.00	1					63			5	
	463 −	479	Lipata Bridge																								
	479 −	500	2	4	1	2	1.50	1						21		5	1.50	1					21			5	
	500 −	600	2	1		1	1.50	1							100	3	1.50	1					100			5	
	600 −	700	2	4		1	1.50	1			50				100	3	1.50	1					100			5	50
	700 −	800	2	4		1	1.50	1				100				3	1.50	1				100				3	100
	800 −	900	2	4	1	2	1.50	1			100	100				3	1.50	1					100			3	
	900 −	995	2	4	1	2	1.50	1					95			3	1.50	1				95				3	

1)Topography
1:Flat
2:Rolling
3:Mountainous

2)Cross Section Type
1:Flat
2:Cut
3:Embankment
4:Cut/Embankment
5:Embankment/Cut
(Facing South)

3)Vertical Gradient
1:Below 3%
2:3−5%
3:Above 5%
+:Upgrade
−:Downgrade
(Facing South)

4)Shoulder Material
1:Earth
2:Gravel
3:Concrete

5)Side Ditch
N:None
E:Earth
R:Riprap
C:Concrete

6)Roadside Land Use
1:Rice Field
2:Plowed Field
3:Coconut Field
4:Forest
5:Waste Land
6:Swampy Area
7:Built−up Area

TABLE 8.1-4 SAMPLE PRINT-OUT: FILE "ROAD - 2B"

Road Link Number : 01
Sheet Number : 01
Inventory Number : May,1994

Pan–Philippine Highway – Mindanao
Road Inventory No.2

South Bound Lane

KM	From–to (m)	Pave-ment Type 1)	Pave-ment Width (m)	Under Reconst-ruction (m)	Crack 2) Trn (m)	Lng (m)	Crn (m)	Blk (m)	T (m)	Other Distress 3) Pt (m²)	Sc (m²)	Dp (No)	Pp (No)	Rm (m²)	Ph (No)	Rough-ness (IRI)	Modulus Conc. (GPa)	Subgr. (MPa)	Evalua-tion 4) PSI	RRI
1113	397 – 400	1	6.70													5.00			3.4	3.7
	400 – 500	1	6.70													5.01			3.4	3.7
	500 – 600	1	6.70													5.23			3.3	3.6
	600 – 700	1	6.70													6.02	33.8	223	3.1	3.5
	700 – 800	1	6.70													6.56			3.0	3.4
	800 – 900	1	6.70			14			14							6.34			2.6	2.9
	900 – 1000	1	6.70													5.84			3.2	3.5
1114	0 – 100	1	6.70													5.56			3.3	3.6
	100 – 200	1	6.70													5.59	22.4	120	3.2	3.6
	200 – 300	1	6.70													5.85			3.2	3.5
	300 – 400	1	6.70													6.00			3.1	3.5
	400 – 500	1	6.70													6.22			3.1	3.5
	500 – 600	1	6.70		3				3							6.21			3.0	3.2
	600 – 700	1	6.70													5.78	35.2	213	3.2	3.5
	700 – 800	1	6.70													4.79			3.5	3.7
	800 – 900	1	6.70													5.05			3.4	3.6
	900 – 1004	1	6.70													5.80			3.2	3.5
1115	0 – 100	1	6.70													6.11			3.1	3.5
	100 – 200	1	6.70													6.38	35.5	198	3.1	3.4
	200 – 300	1	6.70													6.84			3.0	3.4
	300 – 400	1	6.70													6.01			3.1	3.5
	400 – 463	1	6.70							30						5.54			2.6	2.7
	463 – 479	Lipata Bridge																		
	479 – 500	1	6.70							30						5.46			2.2	2.1
	500 – 600	1	6.70													5.21			3.3	3.6
	600 – 700	1	6.70													5.17	27.8	131	3.4	3.6
	700 – 800	1	6.70													4.87			3.4	3.7
	800 – 900	1	6.70													5.00			3.4	3.7
	900 – 995	1	6.70													5.63			3.2	3.5

North Bound Lane

KM	From–to (m)	Under Reconst-ruction (m)	Crack 2) Trn (m)	Lng (m)	Crn (m)	Blk (m)	T (m)	Other Distress 3) Pt (m²)	Sc (m²)	Dp (No)	Pp (No)	Rm (m²)	Ph (No)	Rough-ness (IRI)	Modulus Conc. (GPa)	Subgr. (MPa)	Evalua-tion 4) PSI	RRI	Un-even Sur-face (m)
1113	397 – 400													4.92			3.4	3.7	
	400 – 500													4.92			3.4	3.7	
	500 – 600		3				3							5.36			3.2	3.3	
	600 – 700													6.17			3.1	3.5	
	700 – 800													6.30			3.1	3.4	
	800 – 900		3				3							6.27	21.7	194	3.0	3.2	10
	900 – 1000													6.26			3.1	3.4	
1114	0 – 100													6.11			3.1	3.5	
	100 – 200													6.10			3.1	3.5	
	200 – 300		2				2							6.26			3.0	3.2	
	300 – 400													6.37	25.2	192	3.1	3.4	
	400 – 500		3				3							6.22			3.0	3.2	
	500 – 600													5.66			3.2	3.5	
	600 – 700													5.29			3.3	3.6	
	700 – 800													5.24			3.3	3.6	
	800 – 900													5.10	22.7	136	3.4	3.6	
	900 – 1004													5.50			3.3	3.6	
1115	0 – 100													6.24			3.1	3.5	
	100 – 200													6.72			3.0	3.4	
	200 – 300										1			6.69			3.0	3.4	
	300 – 400													6.40	46.5	371	3.1	3.4	
	400 – 463							30						6.10			2.5	2.6	
	463 – 479																		
	479 – 500							30						4.97			2.3	2.2	
	500 – 600													5.06			3.4	3.6	
	600 – 700													4.91			3.4	3.7	
	700 – 800													4.55			3.5	3.7	
	800 – 900													4.64			3.5	3.7	
	900 – 995													5.31	23.4	121	3.3	3.6	

1)Pavement Type
1:PCC
2:PCC Overlaid with AC
3:Gravel

2)Crack
Trn :Transverse
Lng:Longitudinal
Crn:Corner
Blk :Block/Alligator
T :Total

3)Other Distress
Pt :Patching
Sc :Scaling
Dp :Depression
Pp :Pumping/Water Bleeding
Rm:AC Overlay Removed
Ph :Pothole

4)Evaluation
PSI:Present Serviceability Index
RRI:Rehabilitation Requirement Index

TABLE 8.1-5 SAMPLE PRINT-OUT: FILE "PIPE"

Pan–Philippine Highway–Mindanao
Culvert Inventory

Sheet Number : 01
Inventory Date : May, 1994

Culvert No. 1)	Location	Type/Size of Culvert: Type 2)	No. of Barrel (No)	Diameter/ Size(WxH) (m)	Road Location 3)	Culvert Condition: Capacity 4)	Damage 5)	Clogging 6)	Inlet Cond.: Damage 7)	Clogging 6)	Outlet Cond.: Damage 7)	Clogging 6)	Over-Flow 8)	Slope Condition at Outlet 9)	Remarks
1 –001	1113.550	BC	1	2.00x2.00	1	1	2	1/2	2	1/2	2	1/4	2	4	
1 –002	1113.595	BC	1	2.50x2.00	1	1	2	1/2	2	1/2	2	1/2	2	4	
1 –003	1113.823	PC	1	0.90 dia.	2	1	2	0	2	0	2	0	2	4	
1 –004	1113.930	PC	1	0.60 dia.	2	2	2	0	2	0	2	0	2	4	
1 –005	1114.130	PC	1	0.90 dia.	2	1	2	0	2	0	2	0	2	4	
1 –006	1114.510	PC	1	0.90 dia.	2	1	2	0	2	0	2	0	2	4	
1 –007	1114.850	PC	1	0.60 dia.	2	2	2	0	1	0	2	0	2	4	
1 –008	1115.240	PC	1	0.90 dia.	2	1	2	0	0	0	2	0	2	4	
1 –009	1115.750	PC	1	0.90 dia.	2	1	2	1/4	3	1/4	2	0	2	3	
1 –010	1116.000	PC	1	0.90 dia.	2	1	2	0	0	0	0	0	2	4	
1 –011	1116.130	PC	1	0.60 dia.	2	1	2	1/4	3	1/4	3	0	2	4	
1 –012	1116.310	BC	1	3.05x3.05	2	1	2	0	2	0	2	0	2	4	provide slope protection at inlet
1 –013	1116.670	PC	1	0.60 dia.	2	1	2	1/4	2	1/4	0	3/4	2	4	
1 –014	1116.750	PC	1	0.60 dia.	2	2	2	0	0	1/4	0	0	2	4	
1 –015	1116.900	PC	1	0.90 dia.	2	1	2	0	0	0	0	1/4	2	4	
1 –016	1117.000	PC	1	0.60 dia.	2	2	2	0	0	0	0	0	2	4	
1 –017	1117.100	PC	1	0.60 dia	2	2	2	0	0	0	1	0	2	4	
1 –018	1117.160	PC	1	0.60 dia.	2	2	2	0	2	0	0	0	2	4	
1 –019	1117.210	PC	1	0.60 dia.	2	2	2	0	2	0	0	0	2	4	
1 –020	1117.390	PC	2	0.90 dia.	2	1	2	1/2	2	1/2	2	0	2	4	
1 –021	1117.480	PC	1	0.60 dia.	2	2	2	3/4	2	3/4	2	3/4	2	4	
1 –022	1117.550	PC	1	0.90 dia.	2	2	2	0	0	0	0	0	1	4	damage 2 pipes at outlet
1 –023	1117.750	PC	2	0.90 dia.	2	1	2	1/2	2	1/2	2	0	1	4	flooded section
1 –023	1117.750	PC	1	0.60 dia.	2	1	2	1/2	2	1/2	2	0	1	4	flooded section
1 –024	1117.900	PC	1	0.90 dia.	2	1	2	1/4	0	1/4	0	1/4	1	4	flooded section

1)Culvert No.
A:Abandoned
C:Cannot Locate

2)Type of Culvert
PC:Pipe Culvert
BC:Box Culvert

3)Road Location
1:Embankment
2:Hillside

4)Capacity of Culvert
1:Sufficient
2:Insufficient
3:Unknown

5)Damage of Culvert
1:Damaged
2:Not Damaged
3:Unknown

6)Clogging/Silting
0:Not Clogged/Silted
1/4,1/3,1/2,2/3,3/4,1
:Proportion of Clogged/Silted Portion

7)Damage of Inlet/Outlet Facility
0:No Facility
1:Existing,Damaged
2:Exsisting,Not Damaged
3:Existing,Condition Unknown

8)Overflow
1:Overflowed
2:Not Overflowed
3:Unknown

9)Slope condition at Outlet
1:Failed
2:May Fail
3:Unknown
4:Stable

8.2 BRIDGE INVENTORY

8.2.1 Field Survey

Detailed bridge inventories of the existing 125 bridges along the Study Road were prepared based on the field survey. The purpose of the survey included the assessment of the present conditions of the bridges. The field survey sheets used for the survey are presented in Appendix 8.1

The present conditions of the bridge and its components are classified into three classes as follows:

Class A

Urgent repair/replacement to the superstructure, substructure or river protection is necessary to restore the existing bridge to a safe operational condition. A Class A bridge is to be totally or partially replaced or urgently repaired and has at least one critical component (i.e. girder, slab, abutment/pier, foundation, river, river bank and approach road) categorized as Class A.

Class B

Repair to the superstructure, substructure or river protection to extend the life of the bridge is required, but restoration of the bridge to a safe operational condition is basically unnecessary. A Class B bridge has at least one component categorized as Class B.

Class C

Only maintenance of the superstructure, substructure or river protection is required to be undertaken under the normal bridge maintenance program performed by DPWH.

8.2.2 Bridge Inventory Database

The field data obtained by the field survey were recorded in a computer database. The data for each bridge is available on a display monitor as well as a print-out form with the same form as the field survey sheets.

8.3 SLOPE INVENTORY

8.3.1 Field Survey

1) Classification of Road Slope Disasters

Prior to the detailed field survey, road slope disasters were classified into five main types and each type was further sub-classified into sub-types as follows:

Main Type	Sub-type
Cut slope failures	: Surface failures Deep failures
Embankment slope failures	: Surface failures Deep failures
Debris flows	: Debris flows Mud flows
Falls	: Rock falls Debris falls
Landslides	: Bedrock (or rock) type Colluvial (or talus) type Cohesive (or soil) type

Definitions of respective types are as follows:

Cut Slope Failures (including failures of mountainside natural slopes)

A surface failure is a shallow failure occurs on slope surfaces due to erosion, weathering and structural weakness, and is generally induced by surface water flow during intensive rainfalls.

A deep failure on the other hand, is a failure that originates or extends deep within a slope, and is sub-classified into three types, i.e. scouring, rotational failures and translational failures. Scouring generally appears on slopes composed of soil, soft rock or highly weathered rock, and are induced by concentrated flow of surface water down the slope.

A rotational failure appears in slopes composed of thick soil or highly weathered soft rock, and it has a circular sliding plane in general. This type of failure is mainly induced by decrease of shear strength or increase of pore water pressure resulting from rising of the groundwater level. A translational failure appears on a structurally weak plane such as fault, bedding plane, border plane between rock and soil, etc.. It is mainly caused by rising of the groundwater level.

Embankment Slope Failures (including valley side natural slopes)

A surface failure is a shallow failure which occurs on slope surface and is caused by erosion resulting from surface water flow. This type of failure oftenly appears in slopes that are composed of soil eroded easily, that are not sufficiently compacted, and/or that have no or poor drainage facilities.

A deep failure is a failure that originates or extends deep within a slope. This failure is oftenly caused by pore water pressure in embankments that are located on the sharply inclined ground or the ground containing rich groundwater. The failure is also seen in embankments constructed on talus or the ground suffered from a landslide.

Embankment slope failures are apt to occur at the following locations; (1) inner edge of curve in a road passing mountainous area, (2) semi-cut and filled road sections on the inclined ground, (3) the either side of road crossing a valley, (4) bridge approaches, and (5) the side of a road hugging a river.

Debris Flows

A debris flow is defined as a flow of riverbed deposits whose velocity distribution resembles the movement of viscous fluid. It is induced by the force of flow caused by floods when there is a large quantity of deposits on the riverbed. It is also seen that soil and sand which have been supplied by slope failures and deposited on the side of a hill are carried down by floods.

Debris flows are sub-classified into debris flows and mud flows, depending on the size of the flowed deposits. Debris flows contain large size stones, whereas mud flows mainly contain soils and sand with no large size stones.

Falls

A falls is classified into a rock fall and a debris fall. The former is a fall of rocks detached from slopes composed of highly cracked rocks. The latter is a fall of supportless stones from slopes of debris or talus.

Landslides

A landslide is defined as a movement of materials forming the slope caused by loss of balance between shear strength and movement force along the specific slide plane. Landslides are classified into three types, namely bedrock (or rock) type, colluvial (or talus) type and cohesive (or soil) type, depending on slope composition. The bedrock type mainly occurs along structurally weak planes such as planes of faults, bedding planes, etc. inside a bedrock. The colluvial type occurs inside colluvial soil. Tiered slopes slide continuously and recurrently. As for the cohesive type, a mass of soil composed of mainly cohesive soil with gravel that is divided into some blocks moves continuously.

2) Field Survey

The field survey was undertaken in May 1994 for slopes along the Study Road. Major purpose of the survey was to prepare detailed inventories of road slopes that were not restored/protected by sufficient measures after occurrence of disaster or that were evaluated to have disaster potential. The dimensional, geological and draining conditions of slopes were visually inspected by experienced slope engineers. Based on their findings, disaster potential, conceivable causes of disaster and possible countermeasures were assessed for each slope. The findings in the visual inspection at each slope were recorded in the Slope Inventory Sheets prepared by type of disaster as presented in Appendix 8.1. Major items recorded are an outline of disaster occurred or presupposed, condition of original slope, geological condition, water condition and engineering judgment. Sketches and photographs of the slopes were attached to the sheets.

3) Evaluation of Disaster Potential

The rating method is devised to evaluate the disaster potential. In this method, an indicator is calculated as a combination of some selected factors which are rated in accordance with an appropriate criteria, and the indicator is used for evaluation of disaster potential. Although the rating method has advantages that rich experience and knowledge on disaster prevention works are not always required and that personal difference in evaluation is avoided, reliability of the method depends on the appropriateness of the rating criteria, and furthermore the criteria depends on geological and meteorological conditions of the area under consideration.

The rating methods proposed in the previous studies as well as those used in Japan were reviewed on their applicability to the slopes in the Study Area. It was concluded, however, that the existing rating methods are not always applicable to the Study and number of data collected in the Study is not enough to establish the modified rating method with adequate reliability. Consequently, the disaster potential was evaluated on the basis of observations of experienced engineers.

Slopes were categorized into: (a) slopes not protected by sufficient measures after occurrence of disasters, (b) slopes with low disaster potential, and (c) slopes with high disaster potential, taking the following factors into considerations:

a. slope gradient and height,
b. type of rock,
c. condition of weathering, crack, alterations, fractures and faults,
d. thickness and compactness of top soil,
e. possibility of surface water concentrating and quantity of groundwater,
f. deformation of the slope and evidence of past disaster, and
g. influence of river flow.

8.3.2 Slope Inventory Database

The field data entered in the Slope Inventory Sheets were recorded into a computer database. The data for each slope is available on a display monitor as well as prints with same forms as the inventory sheets.

CHAPTER 9

ROADWAY REHABILITATION

9.1 PRESENT CONDITION OF ROADWAY

9.1.1 General Conditions

Various field surveys were extensively undertaken in April and May, 1994 and a road database was prepared. Mindanao Section of the Pan - Philippine Highway (the Study Road) has a total extension of 403.355 km, composing of the following pavement types as shown in Table 9.1 - 1.

TABLE 9.1-1 PAVEMENT TYPE OF THE STUDY ROAD

Road Length	398.075 km
Bridge Length	5.280 km
Total	403.355 km
Surface type	
PCC	395.902 km
AC Overlay	1.022 km
Gravel	1.151 km
Total	398.075 km

Present conditions of the Study Road are summarized in Table 9.1-2. Conditions of each roadway component are described hereunder:

9.1.2 Pavement Condition

Pavement condition in terms of cracks (in meters per 1,000 square meters), roughness (in International Roughness Index: IRI), and the rehabilitation requirement index (RRI) is graphically shown in Figures 9.1-1, 9.1-2 and 9.1-3, respectively. In terms of RRI, pavement condition of the Study Road is summarized in Table 9.1-3.

TABLE 9.1-3 PAVEMENT CONDITION OF THE ROAD

RRI Range	South Bound		North Bound	
	km	(%)	km	(%)
Gravel Section	1.15		1.15	
Paved Section				
1.5 and below	16.25	(4.1)	23.63	(6.0)
1.5 < RRI ≤ 2.0	28.38	(7.2)	23.61	(6.0)
2.0 < RRI ≤ 2.5	40.97	(10.3)	42.94	(10.8)
2.5 < RRI ≤ 3.0	78.26	(19.8)	81.13	(20.5)
3.0 < RRI ≤ 3.5	165.49	(41.8)	164.00	(41.4)
3.5 < RRI ≤ 4.0	66.43	(16.8)	60.37	(15.3)
Above 4.0	0	(0.0)	0	(0.0)
Sub-total	395.78	(100.0)	395.68	(100.0)
Under Construction	1.15		1.25	
Total	398.08		398.08	

TABLE 9.1-2 SUMMARY OF ROAD CONDITION (1/2)

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
Road Link Number			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
City/Province			Surigao del Norte			Agusan del Norte		Butuan City		Agusan del Sur					Davao del Norte				Davao City		
Start KM			1113.397	1122.169	1146.099	1167.592	1210.817	1221.985	1232.827	1240.696	1268.896	1293.356	1323.786	1349.389	1376.830	1395.292	1424.713	1456.000	1482.1013	1497.710	1113.397
End KM			1122.169	1146.099	1167.592	1210.817	1221.985	1232.827	1240.696	1268.896	1293.356	1323.786	1349.389	1376.830	1395.292	1424.713	1455.1010	1482.1013	31497.710	1515.949	1515.949
Actual Length	Road	(km)	8.579	23.925	21.013	42.137	11.084	10.599	7.970	27.778	24.100	30.351	25.352	27.120	18.125	29.310	31.287	26.731	14.589	18.025	398.075
	Bridge	(km)	0.182	0.097	0.498	1.081	0.112	0.326	-	0.545	0.330	0.342	0.235	0.300	0.324	0.186	0.107	0.308	0.084	0.223	5.280
	Total	(km)	8.761	24.022	21.511	43.218	11.196	10.925	7.970	28.323	24.430	30.693	25.587	27.420	18.449	29.496	31.394	27.039	14.673	18.248	403.355
Topography	Flat	(km)	4.993	20.621	20.407	31.546	11.084	10.599	5.091	13.850	7.602	24.588	22.349	20.554	2.178	11.333	14.187	26.731	14.589	3.631	265.933
	Rolling	(km)	3.586	3.304	0.606	2.954	-	-	1.021	0.799	16.498	5.763	3.003	6.566	3.740	17.977	7.787	-	-	10.387	83.991
	Mountainous	(km)	-	-	-	7.637	-	-	1.858	13.129	-	-	-	-	12.207	-	9.313	-	-	4.007	48.151
Average Width	S - Shoulder	(m)	1.530	1.510	1.510	1.510	1.620	1.440	1.690	1.620	1.940	1.980	2.000	2.050	2.090	2.020	2.200	3.010	3.040	2.420	1.970
	Pavement	(m)	6.700	6.690	6.700	6.700	6.570	6.700	6.700	6.700	6.700	6.680	6.700	6.700	6.700	6.700	6.700	6.700	6.700	6.700	6.700
	N - Shoulder	(m)	1.470	1.490	1.500	1.480	1.660	1.420	1.540	1.250	1.840	1.990	1.970	2.010	2.110	2.050	2.260	3.050	2.920	2.770	1.950
Length by Type	PCC	(km)	8.579	23.925	21.013	42.137	11.084	10.599	7.970	27.468	22.848	29.941	25.151	27.120	18.125	29.310	31.287	26.731	14.589	18.025	395.902
	AC Overlay	(km)	-	-	-	-	-	-	-	0.160	0.452	0.410	-	-	-	-	-	-	-	-	1.022
	Gravel	(km)	-	-	-	-	-	-	-	0.150	0.800	-	0.201	-	-	-	-	-	-	-	1.151
South Bound	Length (km) by Range of Crack (m/1000m²)	Below 25	8.379	20.608	19.864	35.242	8.719	9.592	6.574	12.474	9.722	16.533	14.300	10.655	5.918	19.445	17.366	16.228	12.894	15.726	260.239
		25 - 50	0.200	0.751	0.462	2.387	1.454	0.400	0.200	2.703	1.953	3.447	3.483	3.296	3.565	4.170	3.556	3.335	0.979	0.695	37.036
		50 - 100	-	1.300	0.287	2.563	0.285	0.404	0.696	3.684	3.782	3.971	2.638	3.149	3.779	2.917	6.150	2.003	0.396	1.004	39.008
		100 - 200	-	1.066	0.100	1.500	0.498	-	0.500	5.935	5.098	3.207	3.228	5.815	3.066	1.896	3.212	3.750	0.300	0.600	39.771
		200 - 300	-	0.200	0.100	0.437	0.100	0.100	-	1.400	1.108	1.650	0.977	3.048	1.097	0.200	0.700	0.496	0.020	-	11.633
		300 - 400	-	-	-	-	0.028	0.100	-	0.564	0.828	0.644	0.525	1.021	0.300	0.482	0.303	0.500	-	-	5.295
		400 - 500	-	-	-	0.008	-	-	-	0.468	0.100	0.360	-	0.100	0.200	0.100	-	0.300	-	-	1.636
		Above 500	-	-	0.200	-	-	0.003	-	0.400	0.709	0.539	-	0.036	0.200	0.100	-	0.119	-	-	2.306
	Length (km) by Range of Roughness (IRI)	Below 5.0	0.506	-	0.994	4.202	0.800	0.400	3.226	1.106	-	1.889	-	5.888	1.267	0.701	1.110	5.546	2.145	0.200	29.980
		5.0 - 5.5	2.719	1.941	3.296	6.867	3.213	1.824	2.438	1.499	1.210	2.986	1.667	5.211	1.795	5.967	7.310	9.514	4.392	1.713	65.562
		5.5 - 6.0	2.716	7.583	6.655	8.823	3.592	3.982	1.448	3.706	2.121	7.808	6.008	5.350	2.808	9.810	7.924	5.755	3.318	4.549	93.956
		6.0 - 6.5	1.763	6.178	5.403	9.356	1.861	3.078	0.858	4.309	2.279	7.863	7.981	3.683	3.985	6.180	9.027	3.622	2.384	5.012	84.822
		6.5 - 7.0	0.459	5.678	3.132	7.758	0.994	1.312	-	4.313	1.872	3.883	6.212	2.247	3.229	3.979	4.120	1.476	1.740	3.032	55.436
		7.0 - 7.5	0.216	1.842	0.952	3.462	0.452	-	-	3.986	2.492	2.072	1.992	1.959	1.838	1.499	1.200	0.485	0.400	1.863	26.710
		7.5 - 8.0	0.200	0.703	0.392	1.036	0.090	0.003	-	2.171	2.692	0.782	0.893	1.300	1.118	0.300	0.596	0.149	0.100	1.045	13.570
		Above 8.0	-	-	0.189	0.633	0.082	-	-	6.538	10.634	3.068	0.398	1.482	2.085	0.874 -		0.184	0.110	0.611	26.888
	Scaling	(km)	-	-	0.358	-	-	-	0.318	11.256	9.567	1.479	1.277	7.148	3.862	1.509	1.088	1.548	0.080	0.304	39.794
South Bound Lane	Length (km) by Range of PSI	Below 1.5	-	-	0.200	0.024 -		0.003	-	2.684	3.647	1.291	0.005	0.436	1.285	0.300 -		0.355	0.018	-	10.248
		1.5 - 2.0	0.027	-	0.106	0.233	0.057	-	-	6.964	7.210	2.100	0.850	4.394	1.100	0.782	0.100	0.543	0.093	0.200	24.759
		2.0 - 2.5	0.164	1.306	0.838	1.888	0.856	0.573	0.100	5.158	4.979	5.871	5.047	5.264	6.714	2.407	3.975	2.431	0.100	1.296	48.967
		2.5 - 3.0	1.499	9.883	6.136	16.744	1.905	4.807	2.258	7.288	5.827	11.783	13.049	6.236	6.709	14.480	15.429	9.310	4.904	9.071	147.318
		3.0 - 3.5	6.889	12.736	13.733	22.648	8.166	5.216	5.261	5.534	1.637	9.306	6.200	9.990	2.317	11.341	11.763	13.758	9.374	7.458	163.347
		3.5 - 4.0	-	-	-	0.600	0.100	-	0.351	-	-	-	-	0.800	-	-	-	0.334	0.100	-	2.285
		Above 4.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Length (km) by Range of RRI	Below 1.5	0.001	0.000	0.200	0.024	0.000	0.003	0.000	4.936	4.612	1.300	0.094	3.016	1.200	0.682	0.000	0.173	0.008	0.000	16.249
		1.5 - 2.0	0.010	0.100	0.106	0.253	0.128	0.103	0.000	6.392	6.545	2.266	2.209	4.701	1.997	0.807	0.703	1.770	0.093	0.200	28.383
		2.0 - 2.5	0.037	1.609	0.562	2.333	0.595	0.219	0.500	3.848	3.519	5.391	3.613	3.380	5.314	2.206	4.084	2.553	0.020	1.191	40.974
		2.5 - 3.0	0.542	2.323	1.234	5.745	1.331	1.370	1.296	3.594	5.068	8.553	7.474	4.810	5.804	8.868	10.158	5.607	1.875	2.605	78.257
		3.0 - 3.5	4.387	16.457	13.719	23.188	5.425	6.841	2.610	7.053	2.846	9.940	10.862	5.924	2.624	12.736	11.735	9.665	7.336	12.137	165.485
		3.5 - 4.0	3.602	3.436	5.192	10.594	3.605	2.063	3.564	1.805	0.710	2.901	0.899	5.289	0.401	4.011	4.607	6.613	5.247	1.892	66.431
		Above 4.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
North Bound	Length (km) by Range of Crack (m/1000m²)	Below 25	8.379	21.345	18.475	32.959	9.711	9.980	5.368	6.869	4.441	15.456	13.215	10.960	4.234	20.070	22.780	19.018	12.332	15.404	250.996
		25 - 50	0.200	0.967	0.989	4.502	0.300	0.300	1.033	2.664	1.585	3.044	2.382	3.432	2.679	4.380	3.504	3.448	1.575	0.902	37.886
		50 - 100	-	0.813	1.179	3.232	0.666	0.200	0.500	3.726	3.171	3.719	3.301	5.796	5.351	2.866	3.208	2.156	0.462	1.419	41.765
		100 - 200	-	0.500	0.270	1.225	0.292	0.119	0.773	5.699	4.966	3.178	3.484	3.793	3.960	1.501	1.695	1.102	0.220	0.300	33.077
		200 - 300	-	-	-	0.100	0.025	-	0.096	3.067	3.152	1.064	1.571	2.483	1.601	0.311	0.100	0.702	-	-	14.272
		300 - 400	-	0.100	0.100	0.111	0.090	-	0.100	2.239	1.344	1.480	0.798	0.400	0.200	0.182	-	0.200	-	-	7.344
		400 - 500	-	0.100	-	0.008	-	-	0.100	1.299	1.689	0.727	0.300	0.220	0.100	-	-	0.005	-	-	4.548
		Above 500	-	0.100	-	-	-	-	-	2.065	2.952	1.683	0.100	0.036	-	-	-	0.100	-	-	7.036
	Length (km) by Range of Roughness (IRI)	Below 5.0	1.421	0.100	1.092	2.800	0.907	0.300	1.304	1.006 -		0.600	-	5.571	0.768	0.603	1.110	6.119	1.100	-	24.801
		5.0 - 5.5	2.803	2.706	3.659	7.350	3.806	3.296	3.246	2.507	0.431	4.431	0.695	6.758	1.697	4.914	5.713	10.318	3.862	1.173	69.365
		5.5 - 6.0	1.576	7.281	7.053	8.665	4.643	3.132	2.189	1.904	2.707	6.994	3.292	3.856	3.079	10.059	9.117	5.941	5.521	4.380	91.389
		6.0 - 6.5	2.218	5.251	5.801	10.198	1.246	2.655	0.969	2.745	1.521	7.777	8.749	3.172	2.406	7.553	8.428	3.097	3.241	4.208	81.235
		6.5 - 7.0	0.461	5.463	2.575	8.463	0.344	0.989	0.262	5.331	2.852	3.161	5.534	3.118	3.441	4.091	5.910	0.906	0.755	4.096	57.752
		7.0 - 7.5	0.100	2.120	0.641	3.127	0.056	0.227	-	3.482	2.636	2.258	3.930	2.476	2.903	1.115	0.909	0.100	-	2.207	28.287
		7.5 - 8.0	-	0.904	0.192	0.762	-	-	-	1.263	1.521	1.370	1.592	1.212	1.336	0.500	0.100	0.092	-	1.101	11.945
		Above 8.0	-	0.100 -		0.772	0.082	-	-	9.390	11.632	3.760	1.359	0.957	2.495	0.475	-	0.158	0.110	0.860	32.150
	Scaling	(km)	-	-	0.400	-	-	-	0.269	9.732	8.136	1.179	0.716	6.831	3.720	1.780	1.677	1.456	0.143	0.278	36.317
North Bound Lane	Length (km) by Range of PSI	Below 1.5	-	0.031	-	-	0.025	0.003	-	6.297	6.491	2.337	0.005	0.320	1.085	0.082	-	0.350	0.011	-	17.037
		1.5 - 2.0	0.011	-	0.110	0.047	-	0.116	0.100	4.600	6.092	2.688	1.902	3.480	1.746	0.418	0.070	0.141	0.003	0.200	21.724
		2.0 - 2.5	0.145	0.747	1.029	2.936	0.239	0.774	0.831	6.689	5.605	5.946	6.810	5.186	7.466	2.570	3.794	1.478	0.100	0.956	53.301
		2.5 - 3.0	1.567	11.532	6.918	18.364	1.742	4.879	2.700	6.525	4.112	11.062	12.629	10.423	6.548	16.338	14.116	7.399	4.708	11.464	153.027
		3.0 - 3.5	6.856	11.615	12.856	20.790	9.078	4.826	4.339	3.517	1.000	8.218	3.805	6.709	1.280	9.902	13.207	16.963	9.767	5.405	150.133
		3.5 - 4.0	-	-	0.100	-	-	-	-	-	-	0.100	-	1.002	-	-	0.100	0.400	-	-	1.702
		Above 4.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Length (km) by Range of RRI	Below 1.5	0.001	0.031	0.100	0.011	0.115	0.003	0.100	8.332	8.544	3.196	0.553	1.556	0.904	0.082	0.000	0.100	0.004	0.000	23.632
		1.5 - 2.0	0.010	0.300	0.010	0.220	0.000	0.003	0.196	4.414	5.337	2.660	2.533	4.101	2.208	0.611	0.357	0.448	0.000	0.200	23.608
		2.0 - 2.5	0.037	0.143	0.985	1.849	0.309	0.161	0.673	4.368	4.156	4.986	4.960	4.235	6.500	3.120	3.732	2.272	0.100	0.349	42.935
		2.5 - 3.0	0.406	2.380	2.715	7.717	0.906	2.032	1.762	4.892	3.103	7.321	6.947	8.180	5.956	10.121	7.083	3.792	2.554	3.267	81.134
		3.0 - 3.5	3.922	17.765	12.444	23.262	4.508	6.169	3.445	3.309	1.960	9.163	9.663	5.360	1.273	12.666	16.405	11.038	8.142	13.509	164.003
		3.5 - 4.0	4.203	3.306	4.759	9.078	5.246	2.231	1.794	2.313	0.200	2.925	0.495	3.688	0.499	2.710	3.710	8.731	3.779	0.700	60.367
		Above 4.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Uneven Surface		(km)	0.010	0.015	0.015	0.542	-	-	0.030	0.208	0.680	2.809	2.639	0.150	-	0.080	0.285	0.140	-	-	7.603
Flood Section		(km)	0.547	1.753	1.914	15.181	0.970	2.445	0.221	-	-	3.071	3.006	9.762	1.678	0.650	-	9.807	0.988	-	51.993

TABLE 9.1-2 SUMMARY OF ROAD CONDITION (2/2)

Link Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
South Bound																			
Shoulder																			
Earth	8379	10069	11781	23757	100	800	896	15519	17558	27430	22295	17040	4508	8867	2663	1001	0	2101	174764
Gravel	200	10517	1444	18170	9292	9799	6774	12259	6542	2577	3057	9819	12917	19839	27214	22299	14107	15924	202750
Concrete	0	3339	7788	210	1692	0	300	0	0	344	0	261	700	604	1410	3431	482	0	20561
Dropoff	380	1825	805	2190	2092	1937	3751	12111	12367	14550	9736	7874	6450	7383	13674	8255	7059	6522	118961
Heave	150	44	20	1560	215	50	210	490	140	80	240	90	110	20	10	0	0	0	3429
Scoured	310	100	0	195	120	120	80	1806	220	250	70	100	80	60	80	0	30	0	3621
Side Ditch																			
None	5346	22951	19337	41417	9981	9350	4960	24724	22515	28773	24882	27020	17625	28094	28740	23430	10486	16330	365961
Earth	2049	974	680	720	1103	1249	3010	3054	1085	1135	400	100	500	1216	1997	3001	2785	1695	26753
Riprap	984	0	400	0	0	0	0	0	0	0	0	0	0	0	550	170	1318	0	3422
Concrete	200	0	596	0	0	0	0	0	500	443	70	0	0	0	0	130	0	0	1939
No Ditch	600	0	700	816	0	0	50	7319	2488	5133	800	3294	1695	9845	11528	0	967	4674	49909
North Bound																			
Shoulder																			
Earth	7173	14903	10823	24523	0	0	1579	12926	20458	27314	22216	19162	3188	4095	2367	56	0	2989	173772
Gravel	1406	5683	2151	17614	9506	10572	6291	14852	3416	2937	3136	7958	14237	24611	27510	23244	13897	15036	204057
Concrete	0	3339	8039	0	1578	27	100	0	226	100	0	0	700	604	1410	3431	692	0	20246
Dropoff	1335	3375	1230	3106	3010	640	5933	19888	10151	16606	10933	12170	7574	11915	16480	18952	9526	9997	162821
Heave	360	1121	800	1717	140	120	40	315	556	333	360	220	100	70	80	10	0	10	6352
Scoured	20	260	40	463	0	0	0	376	735	350	150	60	50	20	70	130	30	0	2754
Side Ditch																			
None	8095	17701	17981	33819	6375	6553	6492	25594	22090	29551	25082	26609	15951	29122	29986	26013	14589	17317	358920
Earth	484	4681	2249	8168	4709	4046	590	2150	1550	800	150	202	1024	188	610	418	0	708	32727
Riprap	0	1543	783	100	0	0	0	30	0	0	0	0	496	0	400	0	0	0	3352
Concrete	0	0	0	50	0	0	888	4	460	0	120	309	654	0	291	300	0	0	3076
No Ditch	0	3322	400	7448	0	0	930	2526	4249	4090	6297	3400	6228	100	2401	0	0	2996	44387
Total																			
Shoulder																			
Earth	15552	24972	22604	48280	100	800	2475	28445	38016	54744	44511	36202	7696	12962	5030	1057	0	5090	348536
Gravel	1606	16200	3595	35784	18798	20371	13065	27111	9958	5514	6193	17777	27154	44450	54724	45543	28004	30960	406807
Concrete	0	6678	15827	210	3270	27	400	0	226	444	0	261	1400	1208	2820	6862	1174	0	40807
Dropoff	1715	5200	2035	5296	5102	2577	9684	31999	22518	31156	20669	20044	14024	19298	30154	27207	16585	16519	281782
Heave	510	1165	820	3277	355	170	250	805	696	413	600	310	210	90	90	10	0	10	9781
Scoured	330	360	40	658	120	120	80	2182	955	600	220	160	130	80	150	130	60	0	6375
Side Ditch																			
None	13441	40652	37318	75236	16356	15903	11452	50318	44605	58324	49964	53629	33576	57216	58726	49443	25075	33647	724881
Earth	2533	5655	2929	8888	5812	5295	3600	5204	2635	1935	550	302	1524	1404	2607	3419	2785	2403	59480
Riprap	984	1543	1183	100	0	0	0	30	0	0	0	0	496	0	950	170	1318	0	6774
Concrete	200	0	596	50	0	0	888	4	960	443	190	309	654	0	291	430	0	0	5015
No Ditch	600	3322	1100	8264	0	0	980	9845	6737	9223	7097	6694	7923	9945	13929	0	967	7670	94296

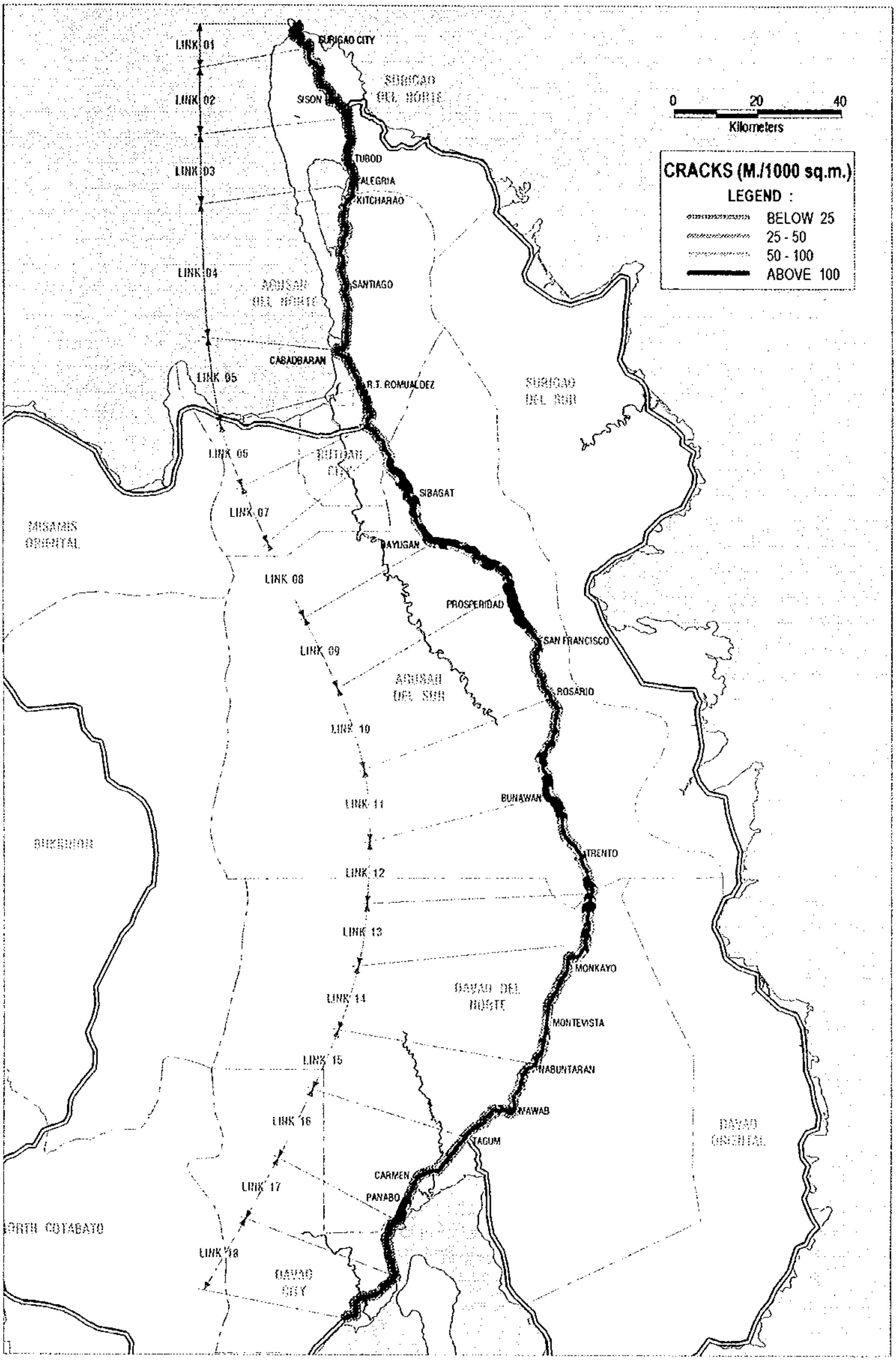


FIGURE 9.1 - 1 CRACKS (IN METER / 1000 SQ. METER) ALONG THE STUDY ROAD

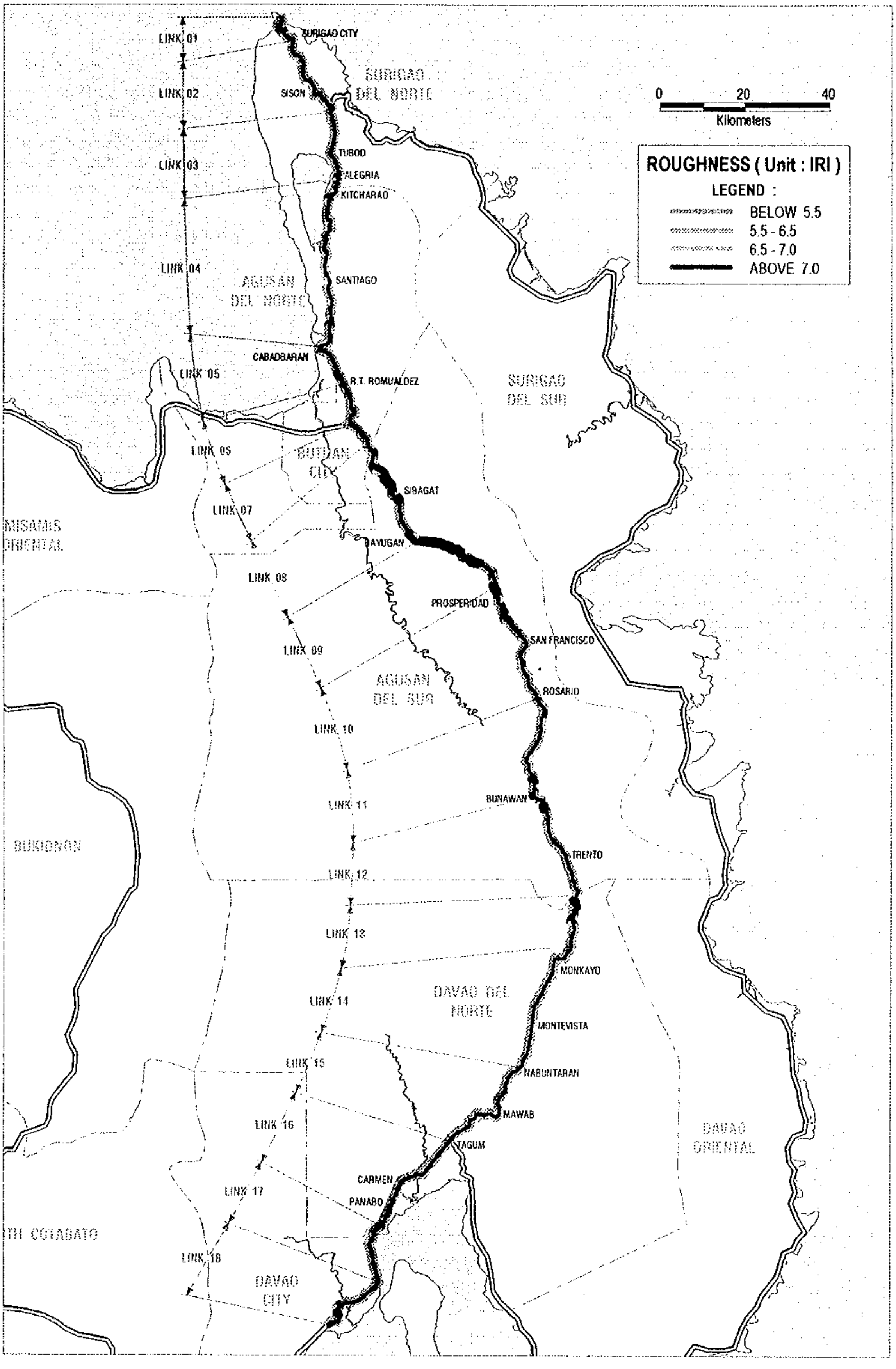


FIGURE 9.1 - 2 ROUGHNESS (IN IRI) ALONG THE STUDY ROAD

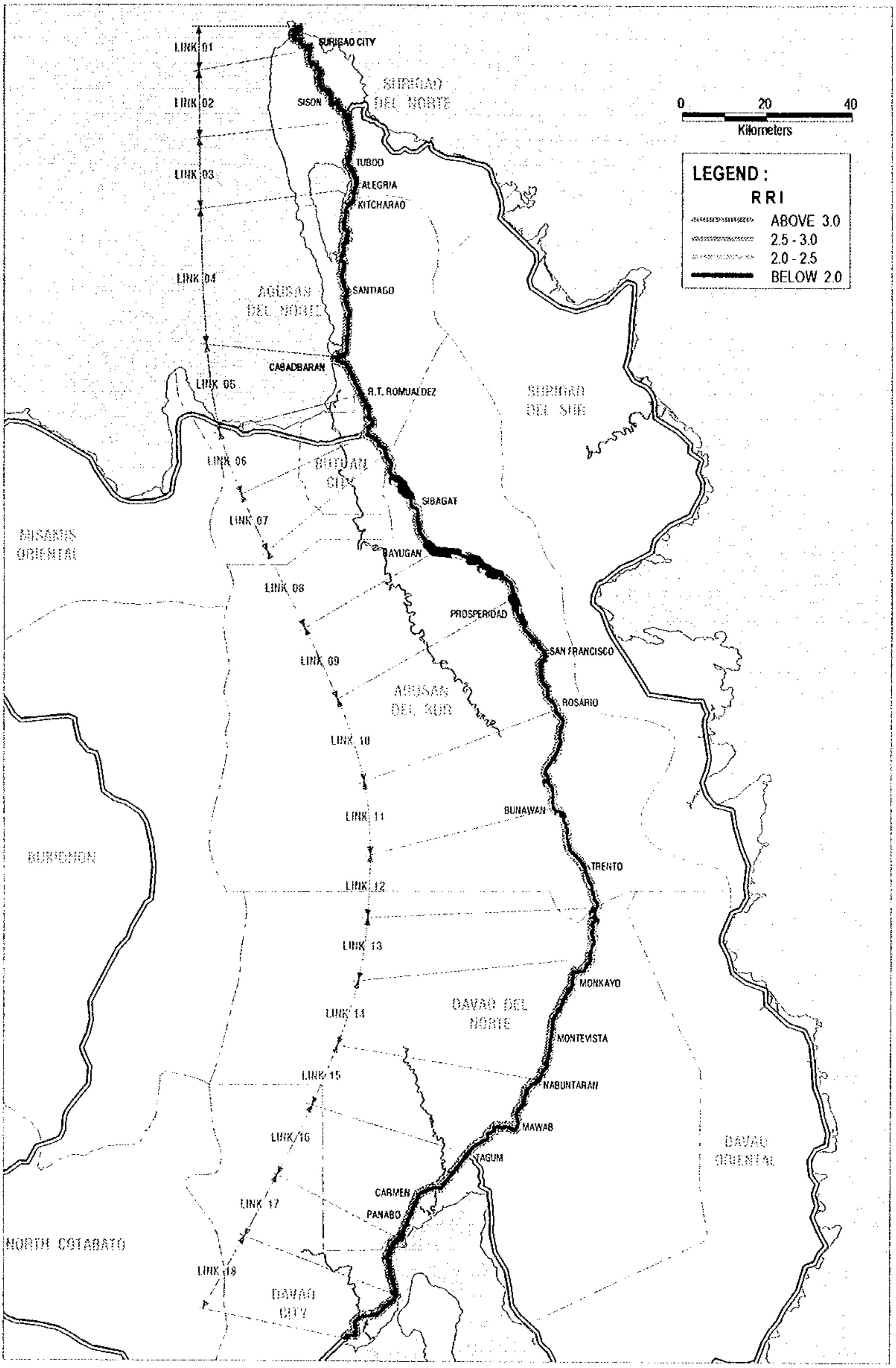


FIGURE 9.1 - 3 RRI ALONG THE STUDY ROAD

Pavements in Agusan del Sur and the northern section of Davao del Norte are generally in very bad conditions. The worst condition sections are summarized as follows:

The Worst Condition Section (Total = 86.2 km)

- Section from the Butuan City/Agusan del Sur Boundary to Bayugan in Agusan del Sur (km 1240 + 700 - km 1268 + 900, L-28.2 km)
- Section from Bayugan to Prosperidad in Agusan del Sur (km 1268 + 900 - 1293 + 300, L=24.4 km)
- Section from Prosperidad to San Francisco in Agusan del Sur (km 1293 + 300 - km 1308 + 400, L=15.1 km)
- Section from the Agusan del Sur/Davao del Norte boundary to Monkayo in Davao del Norte (km 1376 + 800 - km 1395 + 300, L=18.5 km)

In the worst condition sections, pavement deterioration has progressed to a very serious level, therefore, rehabilitation is not applicable, but reconstruction is required, and most common pavement distresses are as follows:

- Extensive block/alligator cracks with depressions
- Potholes (small sized blocks made by block/alligator cracks were removed and turned into potholes)
- Severe scaling (concrete slab surfaces were removed to a depth of one to two centimeters)

9.1.3 Shoulder Condition

Shoulder condition of the Study Road is summarized in Table 9.1-4.

TABLE 9.1-4 SHOULDER CONDITION OF THE STUDY ROAD

	South Bound		North Bound		Total	
	km	(%)	km	(%)	km	(%)
Type of Shoulder						
Earth	174.77	(43.9)	173.77	(43.6)	348.54	(43.8)
Gravel	202.75	(50.9)	204.06	(51.3)	406.81	(51.1)
Concrete	20.56	(5.2)	20.25	(5.1)	40.81	(5.1)
Total	398.08	(100.0)	398.08	(100.0)	796.16	(100.0)
Shoulder Damage						
Drop-off	118.96	(29.9)	162.82	(40.9)	281.78	(35.4)
Heave	3.43	(0.9)	6.35	(1.6)	9.78	(1.2)
Scoured	3.62	(0.9)	2.75	(0.7)	6.37	(0.8)
Total	126.01	(31.6)	171.92	(43.2)	297.93	(37.4)

About 44% of shoulders are still earth material, and about 37% have shoulder damages.

Sections in Surigao del Norte, Agusan del Norte and Butuan City are generally in fair condition, although there are still earth shoulders in many sections. Sections within the municipal towns were mostly paved with concrete.

Shoulders of sections in Agusan del Sur are generally in bad condition. Shoulders are mostly earth and have defects such as drop-off or heave.

Sections in Davao del Norte and Davao City are generally in bad condition. About one half of the shoulders are defective. Sections within the municipal towns were mostly paved with concrete.

9.1.4 Roadway Drainage Condition

Roadway drainage facilities are generally in bad condition throughout the Study Road as shown in Table 9.1-5.

TABLE 9.1.-5 CONDITION OF ROADWAY DRAINAGE FACILITIES

Drainage Facility	South Bound	North Bound	Total	
Side Ditch(km)				
Earth	26.75	32.74	59.49	
Riprap	3.42	3.35	6.77	
Concrete	1.94	3.08	5.02	
No ditch though needed	49.91	44.39	94.30	
RCPC				
No. of RCPC in DPWH Inventory			1,260	
No. of RCPC not located or abandoned			269	
No. of RCPC surveyed			991	(100%)
No. of RCPC in good condition			179	(18%)
No. of RCPC with problems			812	(82%)
RCBC				
No. of RCBC in DPWH Inventory			193	
No. of RCBC not located or abandoned			6	
No. of RCBC surveyed			187	(100%)
No. of RCBC in good condition			101	(54%)
No. of RCBC with problems			86	(46%)

Most earth side ditches are silted and not functioning well. In several sections, riprap or concrete side ditches are provided, however, these have following problems:

- Riprap/concrete ditches were usually constructed for a long stretch (500 meters or more) without cross drainage facilities and without changing dimension of ditch, thus water overflows along the shoulder at high velocity, resulting in shoulder and slope damages.

- End of riprap/concrete ditches is not adequately connected with a cross-drainage facility or a river, which is causing scouring or failure of a slope.
- Inadequate maintenance is oftenly causing overflow of water, resulting in scouring of shoulders.

Problems of cross drainage facilities (RCPC and RCBC) are summarized as follows:

- DPWH Straight Road Diagram needs to be always updated.
- About 39% of pipe culverts and 25% of box culverts are said to be insufficient in capacity. These culverts should be re-examined their capacity in detail.
- Outlet facilities of most culverts are not provided or not properly constructed. As a result, about 12% of pipe culverts and 14% of box culverts are damaging nearby slope or roadbed. Outlet facilities must be properly designed and constructed.
- Maintenance of culverts needs to be strengthened.

9.1.5 Uneven Surface due to Weak Subgrade

Many uneven surface sections caused by consolidation of soft ground were observed. Aggregate length of such sections is aboaut 7.6 km and mostly concentrated in the section between Prosperidad and Trento in Agusan del Sur. Uneven surface sections exist in Surigao del Norte, Agusan del Norte, Butuan City and Davao del Norte, however, conditions of these sections are not so serious.

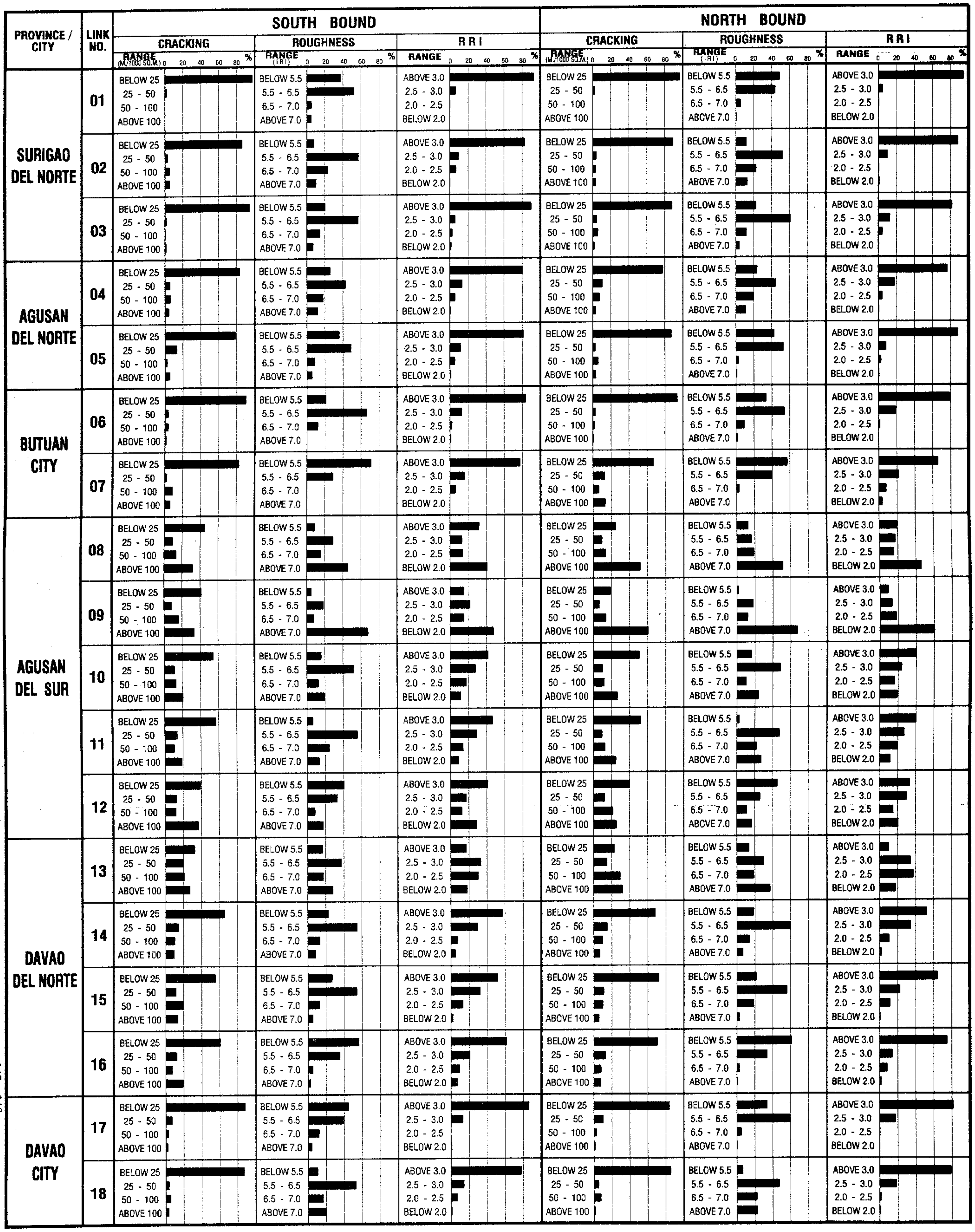
9.1.6 Roadway Condition by Road Link

Roadway conditions by a road link are summarized in Table 9.1-6 and pavement conditions in Table 9.1-7.

TABLE 9.1-6 ROADWAY CONDITION BY ROAD LINK

Province/ City	Road Link No.	From - To	Link Length (km)	Pavement Condition	Shoulder Condition	Surface Drainage Condition	Uneven Surface	Flood Section
Surigao del Norte	01	Lipata- Jct. Surigao Wharf Road	8.6	• Fair to bad condition	• Mostly earth shoulder. • Relatively in fair condition.	• Generally in bad condition • Lack side ditches for about 0.6 km.	• Negligible in length and condition	• Flood problems at scattered locations.
	02	Jct. Surigao Wharf Road - Jct. to Placer	23.9	• Fair to bad condition	• 14% are concrete. • 52% are earth • Relatively in fair condition.	• Generally in bad condition. • Lack side ditches for about 3.3 km.	• Negligible in length and condition	• Flood problems at scattered locations.
	03	Jct. to Placer - Provincial Boundary	21.0	• Fair to bad condition	• 38% are concrete. • 54% are earth • Relatively in fair condition.	• Generally in bad condition. • Lack side ditches for about 1.1 km.	• Negligible in length and condition	• Flood problems at scattered locations.
Agusan del Norte	04	Provincial Boundary - Cabadbaran Bridge	42.2	• Fair to bad condition	• 57% are earth • Relatively in fair condition.	• Generally in bad condition. • Lack side ditches for about 8.3 km.	• Uneven surface observed, but not so serious	• One of the worst sections • Serious flood problems at scattered locations
	05	Cabadbaran Bridge - Province/City Boundary	11.1	• Fair to bad condition	• 15% are concrete. The rest are gravel. • Relatively in fair condition.	• Generally in bad condition.	-	• Flood problems at scattered locations.
Butuan City	06	Province/City Boundary - Jct. to Butuan City Proper	10.6	• Fair to bad condition	• Mostly gravel • Relatively in fair condition.	• Generally in bad condition.	-	• Flood problems at scattered locations.
	07	Jct. to Butuan City Proper - Province/City Boundary	8.0	• Fair to bad condition	• Mostly gravel • 63% have deffects.	• Generally in bad condition. • Existing concrete side ditches have problems. • Lack side ditches for about 1.0 km.	• Negligible in length and condition	• Flood problems at scattered locations.
Agusan del Sur	08	Province/City Boundary - Jct. to Esperanza	27.8	• One of the worst sections. • A lot of block/alligator cracks and serious scaling	• 51% are earth The rest are gravel. • 63% have deffects.	• Generally in bad condition. • Lack side ditches for about 9.8 km.	• Uneven surface observed, but not so serious	-
	09	Jct. to Esperanza - Jct. to Talacogon	24.1	• One of the worst sections. • A lot of block/alligator cracks and serious scaling	• Mostly earth • 50% have deffects.	• Generally in bad condition. • Lack side ditches for about 6.7 km.	• In several places, un-even surface observed.	-
	10	Jct. to Talacogon - Jct. to Rosario	30.4	• About one half of the sections very serious with a lot of block/ alligator cracks and scaling	• Mostly earth • 53% have deffects.	• Generally in bad condition. • Lack side ditches for about 9.2 km.	• One of the worst sections • About 9% in length are un-even surface.	• Flood problems at scattered locations.
	11	Jct to Rosario - Jct. to Bunawan	25.4	• About one third of the section very serious	• Mostly earth • 42% have deffects.	• Generally in bad condition. • Lack side ditches for about 7.1 km.	• One of the worst sections • About 10% in length are un-even surface.	• Flood problems at scattered locations.
	12	Jct. to Bunawan - Provincial Boundary	27.1	• Sections near Bunawan and the provincial boundary very serious.	• Mostly earth • 38% have deffects.	• Generally in bad condition. • Lack side ditches for about 6.7 km.	• Serious un-even surface observed in several places	• One of the worst sections • Flood section concentrates near Simulao Bridge
Davao del Norte	13	Provincial Boundary - Kalaw Bridge	18.1	• One of the worst sections • A lot of block/alligator cracks along the road center line.	• Mostly gravel • 40% have deffects.	• Generally in bad condition. • Lack side ditches for about 7.9 km.	-	• One of the worst sections. • Serious flood problem at Kalaw Bridge & Monkayo.
	14	Kalaw Bridge - Nabunturan Bridge	29.3	• Fair to bad condition	• Mostly gravel. • 33% have deffects.	• Generally in bad condition. • Lack side ditches for about 9.9 km.	• Negligible in length and condition.	• Flood problems at scattered locations.
	15	Nabunturan Bridge - Jct. to Mati	31.3	• Fair to bad condition	• Mostly gravel • 49% have deffects.	• Generally in bad condition. • Lack side ditches for about 13.9 km.	• Uneven surface observed, but not so serious.	-
	16	Jct. to Mati - Province/City Boundary	26.7	• Fair to bad condition with short serious condition sections.	• 13% are concrete The rest are gravel. • 51% have deffects	• Generally in good condition.	• Uneven surface observed, but not so serious.	• One of the worst sections. • Flood section con-centrates near Liboganon Bridge.
Davao City	17	Province/City Boundary - Jct. to Davao City Diversion Road	14.6	• Fair to bad condition	• Mostly gravel. • 57% have deffects.	• Generally in bad condition. • Lack side ditches for about 1 km.	-	• Flood problems at scattered locations.
	18	Davao City Diversion Road	18.0	• Fair to bad condition.	• Mostly gravel. • 46% have deffects.	• Generally in bad condition. • Lack side ditches for about 7.7 km.	-	-

TABLE 9.1 - 7 PAVEMENT CONDITION BY ROAD LINK



9.2 REHABILITATION DESIGN CRITERIA

9.2.1 Pavement Rehabilitation Design Criteria

In this Section, the following will be discussed:

- Rehabilitation Criteria
- Design Method
- Minimum Initial Performance Period
- Alternative Rehabilitation Methods

1) Rehabilitation Criteria

The rehabilitation criteria in this Report is defined as:

" the lowest acceptable level of pavement deterioration before rehabilitation or reconstruction becomes necessary "

At present, there is no authorized or commonly applied rehabilitation criteria in DPWH. In some sections of the Pan-Philippine Highway, rehabilitation work is being implemented/proposed, even though pavement condition seems to be still tolerable. On the other hand, pavement condition in some sections become so deteriorated that rehabilitation work is no longer applicable, but total reconstruction is needed. It is quite important to establish a standard rehabilitation criteria, based on which a rehabilitation program should be formulated and implemented.

a) Unacceptable Level of Pavement Condition by Road Users and Experienced Road Engineers

In this Study, two surveys, i.e., the present serviceability rating (PSR) survey and the rehabilitation requirement rating (RRR) survey, were undertaken. The former is to obtain road users' acceptable level of pavement condition. The latter is to obtain the experienced road engineers' requirement with regards to road rehabilitation. The results of two surveys and AASHTO Road Test are presented in Table 9.2-1.

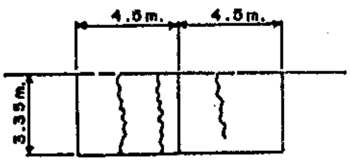
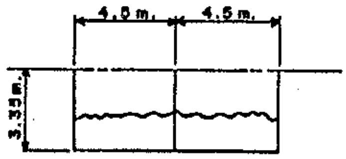
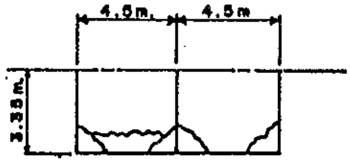
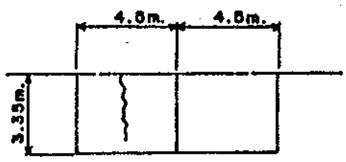
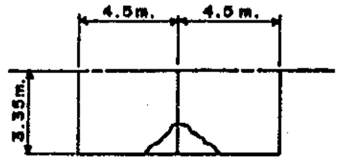
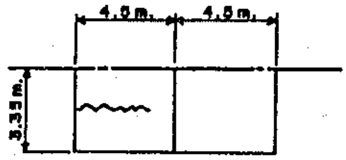
TABLE 9.2-1 PERCENTAGE OF PEOPLE STATING ACCEPTABLE/UNACCEPTABLE

	PSI/RRI			PSI or RRI for which 50% of people stated unacceptable
	3.0	2.5	2.0	
PSI (Road Users' Judgement)				
Acceptable	75%	40%	15%	PSI = 2.1
Unacceptable	10%	32%	60%	
Undecided	15%	28%	25%	
RRI (Experienced Road Engineers' Judgement)				
Acceptable	48%	25%	10%	RRI = 2.6
Unacceptable	30%	55%	78%	
Undecided	22%	20%	12%	
AASHTO Road Test PSI (Road Users' Judgement)				
Acceptable	88%	45%	15%	PSI = 2.6
Unacceptable	12%	55%	85%	

When a pavement condition deteriorates to a level of PSI = 2.1, 50% of road users stated that the pavement condition is unacceptable. Fifty percent of experienced road engineers stated that the pavement condition is unacceptable at RRI = 2.6.

Typical pavement condition for which 50% of people stated unacceptable is as shown in Table 9.2-2.

TABLE 9.2-2 TYPICAL PAVEMENT CONDITION FOR WHICH 50% OF PEOPLE STATED UNACCEPTABLE

	PSI	RRI
50% of people stated unacceptable	2.1	2.6
Pavement Condition	Roughness = 7.3 Cracks = 312 m/1000 sq.m. (or 4.70 m/slab)	Roughness = 6.4 Cracks = 90.4 m/1000 sq.m. (or 1.36 m/slab)
Typical Crack Condition	1) Transverse cracks  2) Longitudinal cracks  3) Corner cracks 	1) Transverse cracks  2) Longitudinal cracks  3) Corner cracks 

Judgement of road users in Mindanao are more generous to pavement condition than that of experienced road engineers. This is probably because road users in Mindanao are rather accustomed to pavements in bad conditions, whereas, experienced road engineers are more concerned about pavement maintenance for which they are responsible. Judgement of experienced road engineers seems to better indicate the timing of pavement rehabilitation.

Physical condition of pavement in terms of roughness and cracks for each level of PSI, RRI and AASHTO PSI is presented in Table 9.2-3. RRI corresponds more or less to AASHTO PSI.

b) Rehabilitation Criteria

AASHTO Guide for Design of Pavement Structures, 1993 recommends the following rehabilitation criteria:

Major Highways : PSI = 2.5 or 3.0
Highway with a lower classification : PSI = 2.0
Minor Highways : PSI = 1.5

As discussed a) above, RRI was developed based on the engineering judgement of experienced Filipino engineers and indicates more properly the timing of rehabilitation than PSI. RRI is recommended to be used as an index for rehabilitation criteria. At RRI of 2.5, more than 50% (or 55%) of experienced road engineers stated the pavement condition unacceptable, thus RRI of 2.5 is judged to be the lowest acceptable level of pavement condition before rehabilitation becomes necessary.

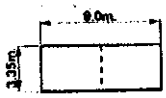
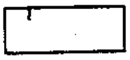
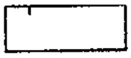
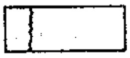
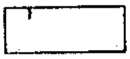
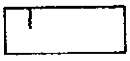
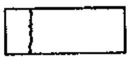
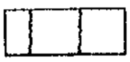
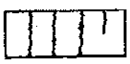
Pavement rehabilitation criteria are recommended as shown in Table 9.2-4.

TABLE 9.2-4 PAVEMENT REHABILITATION CRITERIA

Highway Class	Rehabilitation Required at RRI of:	Typical Pavement Condition	
		Roughness in IRI (m/km)	Cracks (m/1000 sq.m)
Major Highway	2.5	6.5	110.1
Highway with a low classification	2.0	7.2	230.1
Minor Highway	1.5	7.8	403.0

As the Pan-Philippine Highway is the most important arterial road in the Philippines, pavement rehabilitation is recommended to be implemented at RRI of 2.5.

TABLE 9.2-3 AVERAGE CRACK AND ROUGHNESS CONDITION

	ROUGHNESS (IRI)		CRACKS (m/1000 sq.m.)	CRACKS PER 2 SLABS (3.35 x 9.0m) (m)		
PSI						**PSI**
3.5	4.5		1.3	-		3.5
3.0	5.8		20.1	0.6		3.0
2.5	6.6		138.3	4.2		2.5
2.0	7.5		364.3	11.0		2.0
1.5	8.5		702.1	21.2		1.5
RRI						**RRI**
3.5	3.8		21.4	0.6		3.5
3.0	4.9		59.4	1.8		3.0
2.5	6.5		110.1	3.3		2.5
2.0	7.2		230.1	6.9		2.0
1.5	7.8		403.0	12.2		1.5
AASHTO PSI						**PSI**
3.5	190	1	28.0	0.8		3.5
3.0	220	1	50.0	1.5		3.0
2.5	260	1	110.0	3.3		2.5
2.0	300	1	220.0	6.6		2.0
1.5	360	1	390.0	11.8		1.5

Note: 1 Roughness measured by Bump Integrator (cm/km)

2) Design Method and Design Requirements

a) Design Method

DPWH's Design Guidelines, Criteria and Standards recommends two design methods, i.e. AASHTO method (AASHTO Interim Guide for Design of Pavement Structures, 1972) and TRRL method (Road Note 29, A Guide to the Structural Design Pavement for New Roads, 1970). TRRL method gives thinner concrete slab thickness than AASHTO method. Previous studies such as the JICA-assisted Feasibility Study of the Road Improvement Project on the Pan-Philippine Highway, suggested that a concrete slab thickness determined by TRRL method may result in under-design (or dangerous side design) in the Philippines. In this Study, AASHTO method for pavement design is recommended.

The latest AASHTO method is compiled in the AASHTO Guide For Design of Pavement Structures, 1993, (hereinafter referred to as "1993 AASHTO Guide") which covers design of new pavement as well as design of various rehabilitation methods.

b) Design Requirements

Design requirements for rigid (PCC) pavement and flexible (AC) pavement are summarized in Table 9.2.5.

a. DESIGN VARIABLE

a.1 Time Constraints (or Dimension of Time)

Initial Performance Period: This refers to the period of time that an initial pavement structure will last before it needs rehabilitation. This issue will be discussed in 3) of Section 9.2.1 of this report.

Analysis Period: this refers to the period of time for which the analysis is to be conducted. An analysis period of 25 years was adopted.

a.2 Traffic Loading: The analysis is based on cummulative 18-kip equivalent single axle loads (ESAL) during the analysis period.

Based on the results of the axle load survey undertaken by the Study Team at four stations along the Study Road, following two factors were developed:

Bus Factor : Number of ESAL per bus

Truck Factor: Number of ESAL per truck

TABLE 9.2-5 DESIGN REQUIREMENTS

Category	Description
a. Design Variable	
a.1 Time Constraints	
o Performance Period	Life of Initial Pavement Structure
o Analysis Period	Planned Stage Construction; 25 years
a.2 Traffic Loading	W_{18} = 18 kip Equivalent Single Axle Load (ESAL) Application Traffic Loading Classes; 6 classes (A to E)
a.3 Reliability	Z_R = 1.645 for 95% Reliability R, not considered S_o = 0.3~0.4 for Standard Error, not considered
a.4 Environmental Impact	
o Roadbed Swelling	PSI_{sw} = Loss of PSI; not considered
b. Performance Criteria	
b.1 Serviceability	$PSI = P_o - P_t = P_o - \Delta PSI_w - \Delta PSI_{sw}$ (ΔPSI_{sw} ; not considered)
c. Material Properties for Structural Design	
c.1 Effective Roadbed Soil Resilient Modulus (Flexible)	MR (pci); estimated based on CBR
c.2 Effective Modulus of Subgrade Reaction (Rigid)	K-Value (pci); estimated based on CBR and subbase thickness
c.3 Pavement Layer Materials Characterization	E_{SB} = Modulus of Subbase (13,0000 psi) E_{BS} = Modulus of Base (23,000 psi) E_{AC} = Modulus of Asphalt Concrete (350,000 psi) E_C = Modulus of Elasticity of PCC (3.28×10^6 psi)
c.4 PCC Modulus of Rupture (Rigid) (Flexural Strength)	S'_c = Estimated Mean Value for PCC Modulus of Rupture (psi); 580 psi
c.5 Structural Layer Coefficient (Flexible)	Asphalt Concrete Layer Coefficient ; 0.39 Bitumen Stabilized ; 0.2 Crushed Gravel Base ; 0.105 Subbase ; 0.095
d. Pavement Structural Characteristics	
d.1 Drainage	Flexible m = Layer Coefficient Modifying Factor; 0.9 Rigid CD = Drainage Coefficient; 1.0
d.2 Load Transfer (Rigid)	
o Jointed Pavement	
o Tied Shoulder or Widened Outside Lane	J = Load Transfer Coefficient; 4
d.3 Loss of Support (Rigid)	LS = Loss of Support 1.0~3.0 for unbounded granular materials 2.0~3.0 for fine granular or natural subgrade materials 0~1.0 for cement Treated Granular Base
e. Reinforcement Variables (Rigid)	
e.1 Slab Length	
e.2 Working Stress	Depending on local conditions, subbase type, course aggregate, etc.
e.3 Friction Factors	

Bus and truck factors recommended for the Study are shown in Table 9.2-6, whereas these factors derived from the survey for each survey station are presented in Table 9.2-7.

TABLE 9.2-6 RECOMMENDED BUS AND TRUCK FACTORS

	Survey Station	
	L-1, L-2, L-3 (Section from Lipata Ferry Terminal to Tagum)	L-4 (Section from Tagum to the end of Davao City)
Bus Factor	1.5	0.9
Truck Factor	1.8	2.5

Six traffic loading classes were established as shown in Table 9.2-8 and Figure 9.2-1. Traffic loading class of each section of the Study Road is shown in Figure 9.2-2.

a.3 Reliability: Reliability concept was introduced in 1993 AASHTO Guide to account for chance variation in both traffic prediction and performance prediction. In this Study, reliability was concluded not to be considered after discussion with representative of DPWH.

a.4 Environmental Impacts: Serviceability loss due to roadbed swelling was not considered, because the effects of seasonal temperature and moisture changes on material properties are not known yet.

b. PERFORMANCE CRITERIA

The primary measure of serviceability is the Present Serviceability Index (PSI) which ranges from 0 to 5. The initial serviceability (Po) observed at the AASHTO Road Test were:

Po = 4.5 for rigid pavement
Po = 4.2 for flexible pavement

1993 AASHTO Guide suggests the lowest allowable PSI or the terminal serviceability index (Pt) as follows:

Pt = 2.5 for design of major highway
Pt = 2.0 for design of highway

The terminal serviceability of 2.5 was adopted in this Study, which nearly correspond to RRI of 2.5.

TABLE 9.2-7 BUS AND TRUCK FACTORS BASED ON AXLE LOAD SURVEY

Survey Station	Direction	Bus Factor	Truck Factor											
			Empty Trucks				Loaded Trucks				(Empty + Loaded) Trucks			
			2-Axle Truck	3-Axle Truck	Trailer	All Trucks	2-Axle Truck	3-Axle Truck	Trailer	All Trucks	2-Axle Truck	3-Axle Truck	Trailer	All Trucks
L-1	South B.	1.46	0.05	0.20	0.28	0.09	0.48	5.88	18.22	3.75	0.22	3.22	13.09	1.76
	North B.	1.39	0.03	0.12	0.25	0.08	1.16	4.36	13.81	1.89	0.98	3.09	5.68	1.53
L-2	South B.	1.31	0.11	0.26	0.58	0.18	0.59	4.70	9.49	1.46	0.37	1.57	3.01	0.77
	North B.	1.43	0.05	0.47	0.17	0.13	1.48	7.01	5.83	2.89	0.87	4.34	4.89	1.77
L-3	South B.	1.45	0.08	0.39	0.45	0.18	1.37	4.84	12.05	3.10	0.80	2.79	6.83	1.79
	North B.	1.48	0.03	0.15	0.58	0.11	0.93	5.86	10.76	2.71	0.53	4.20	3.48	1.60
L-4	South B.	0.85	0.10	0.32	0.48	0.23	1.57	4.37	7.58	3.17	1.22	3.44	5.17	2.48
	North B.	0.88	0.12	0.21	0.56	0.19	1.39	3.75	7.70	2.70	1.07	1.89	6.24	1.82

Notes: Bus Factor = Number of 18-kip Equivalent Single Axle Load (ESAL)/Number of Buses
Truck Factor = Number of 18-kip Equivalent Single Axle Load (ESAL)/Number of Trucks
L - 1 : Boundary Between Surigao del Norte and Agusan del Norte
L - 2 : Boundary Between Butuan City and Agusan del Sur
L - 3 : Boundary Between Agusan del Sur and Davao del Norte
L - 4 : Boundary Between Davao del Norte and Davao City

TABLE 9.2-8 TRAFFIC LOADING CLASS

Traffic Loading Class	Truck and Bus Traffic Per day (Both directions)		AADT (Veh/day)	Initial Year 18-kip ESAL (x10^6)
	Truck	Bus		
A	2,810 - 2,840	1,420 - 400	9,400 - 6,700	1.52 - 1.36
B	2,020 - 2,080	1,240 - 610	7,200 - 9,500	1.13 - 1.05
C	1,560	670	4,100	0.69
D	920 - 690	430 - 420	2,700 - 2,200	0.42 - 0.34
E	670 - 490	270 - 210	2,400 - 1,400	0.29 - 0.22
F	400 - 220	160 - 95	1,500 - 960	0.18 - 0.10

Note: Initial year was assumed to be 1998.
Truck and bus traffic and AADT are for 1998.

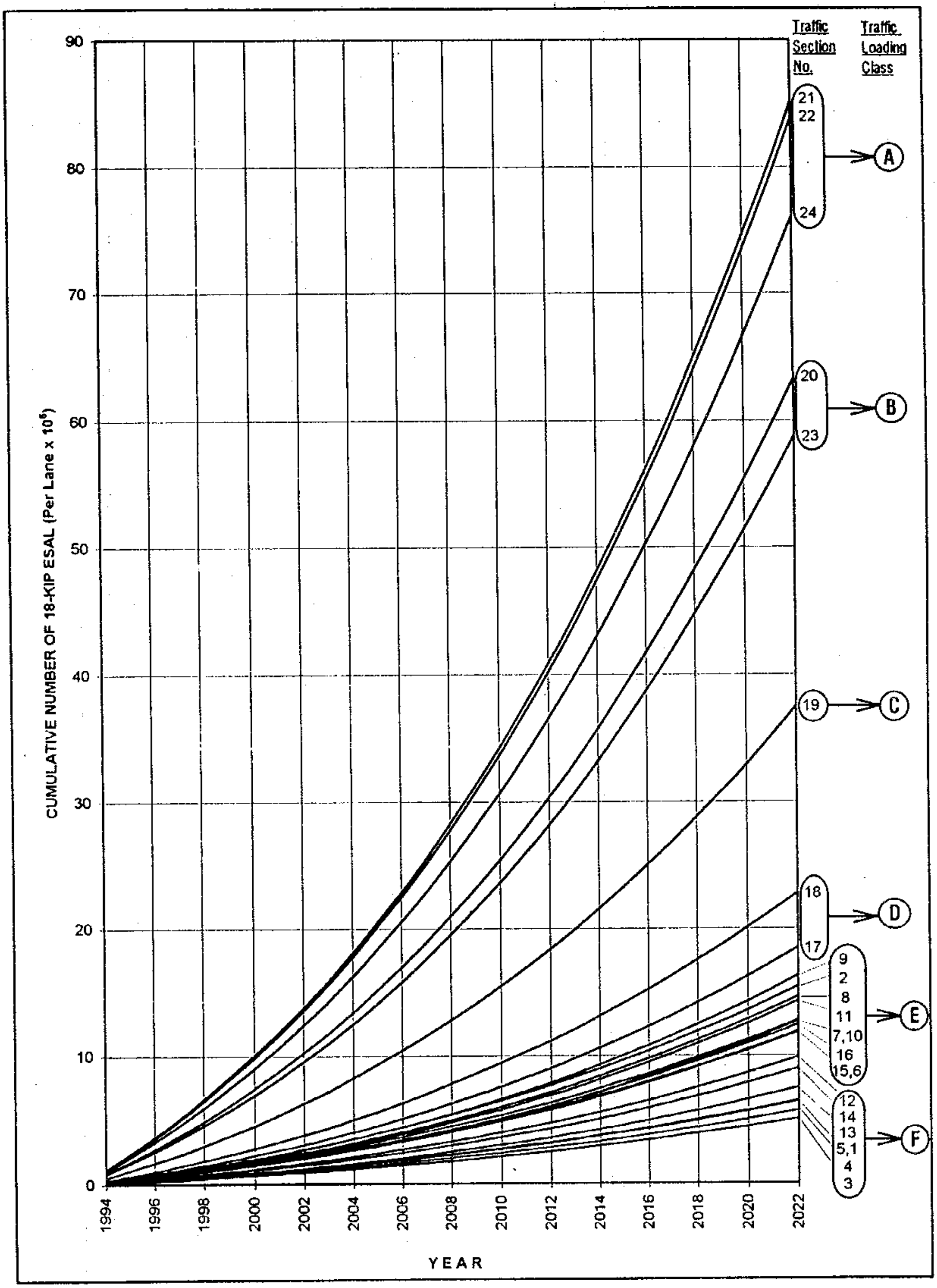


FIGURE 9.2-1 TRAFFIC LOADING CLASS

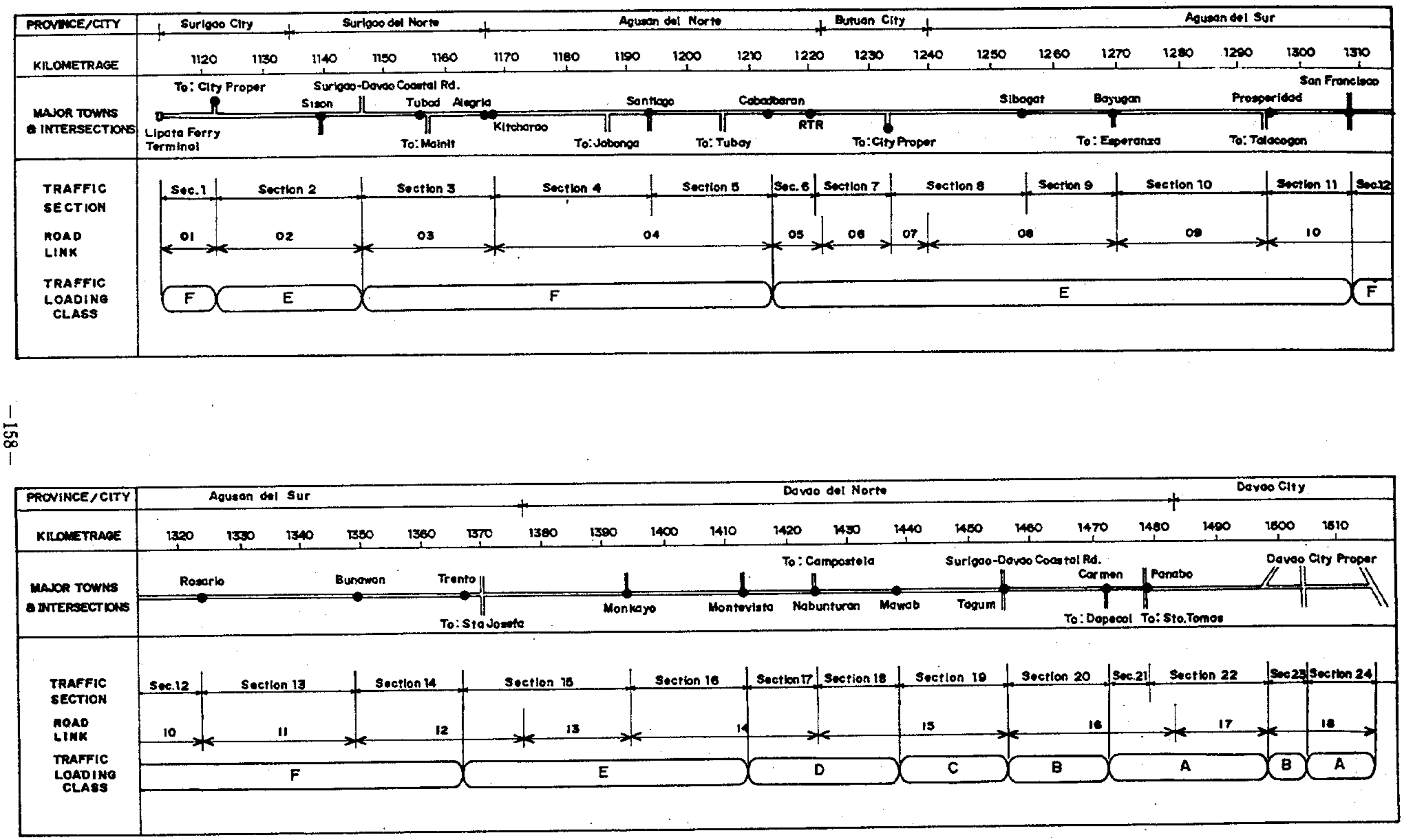


FIGURE 9.2-2 TRAFFIC LOADING CLASS BY SECTION

c. MATERIAL PROPERTIES FOR STRUCTURAL DESIGN

c.1 Effective Roadbed Soil Resilient Modulus (MR) for Flexible Pavement: This value was estimated based on CBR as shown in Table 9.2-9.

c.2 Effective Modulus of Subgrade Reaction (k-value) for Rigid Pavement: This value was estimated based on subgrade CBR and subbase thickness as shown in Table 9.2-9:

TABLE 9.2-9 MR AND K-VALUE

Subgrade CBR (%)	MR (psi)	K-Value (pci) Subbase Thickness 20cm	Subbase Thickness 15cm
2	2,500	180	160
3	4,000	250	220
4	5,000	300	280
6	6,000	350	330
8	7,000	390	370
10	8,000	420	400
15	12,000	580	550
20	15,000	700	680

c.3 Pavement Layer Materials Characteristics: modulus of pavement layer materials were estimated following the suggestion by 1993 AASHTO Guide.

- Modulus of Subbase (CBR = 20) E_{SB} = 13,000 psi
- Modulus of Base (CBR = 45) E_{BS} = 23,000 psi
- Modulus of Asphalt Concrete E_{AC} = 350,000 psi
- Modulus of Portland Cement Concrete E_C = 3.28×10^6 psi

c.4 PCC Modulus of Rupture: in accordance with the DPWH specifications, the modulus of rupture of 580 psi was used in this Study.

c.5 Layer Coefficients for Flexible Pavement: layer coefficient for the following materials was estimated based on 1993 AASHTO Guide suggestion.

Layer Material	Layer Coefficient
Asphalt Concrete Surface Course	0.39
Bitumen Stabilized Base	0.20
Crushed Gravel Base (CBR=45)	0.105
Subbase (CBR=20)	0.095

d. PAVEMENT STRUCTURAL CHARACTERISTICS

d.1 Drainage: drainage level defined by 1993 AASHTO Guide is as follows:

Drainage Level

Quality of Drainage	Water Removed Within
Excellent	2 hours
Good	1 day
Fair	1 week
Poor	1 month
Very poor	(water will not drain)

Drainage level is planned to be improved to a level of fair condition, and following values were used:

- Value for modifying structural coefficient of base and subbase materials for flexible pavement; m = 0.9

- Value of drainage coefficient for rigid pavement; Cd = 1.0

d.2 Load Transfer (Rigid Pavement): the load transfer coefficient, J, is a factor used in rigid pavement design to account for the ability of a concrete pavement structure to transfer (distribute) load across discontinuities such as joints. Load transfer coefficient of 4 was used in consideration of effect of plain joint.

d.3 Loss of Support (Rigid Pavement): this is to account for the potential loss of support arising from subbase erosion and/or differential vertical soil movement. In this Study, loss of support of 1 was used.

e. REINFORCEMENT VARIABLES (RIGID PAVEMENT)

As the plain jointed concrete pavement is adopted, reinforcement variables are not required for the design.

3) Initial Performance Period

a) Factors to be considered for establishment of most appropriate initial performance period

An initial performance period is defined as the performance period of the initially rehabilitated or reconstructed pavement before next rehabilitation is required. Selection of an appropriate initial performance period is quite important. When a longer initial performance period is selected, thicker pavement structure is required resulting in higher initial investment. A shorter initial performance period results in thinner pavement structure and lower initial investment, however, next rehabilitation is required in a shorter period of time. Initial performance period should be determined in due consideration of the following:

- Most economic initial performance period (or rehabilitation strategy) within a life cycle period.
- The minimum initial performance period before next rehabilitation is required.

First subject is achieved by a life cycle cost analysis. Three examples of a life cycle cost analysis are presented in Figure 9.2-3, which indicates the following:

- Pavement structure of the lowest initial cost which has the shortest initial performance period is not always economical in a 25-year period, due to required recurrent rehabilitations.

- In case of an example of AC overlay of PCC pavement in Figure 9.2-3, the most economical initial performance period is 7.1 years, however, a life cycle cost analysis oftenly gives an answer of rather short initial performance period (4 to 6 years). It would not be practical to implement rehabilitation work every 4 to 6 years, therefore, the practical minimum initial performance period should be established.

Second subject is a matter of DPWH's policy, therefore, it should be decided in due consultation with DPWH officials.

b) Most Economical Initial Performance Period

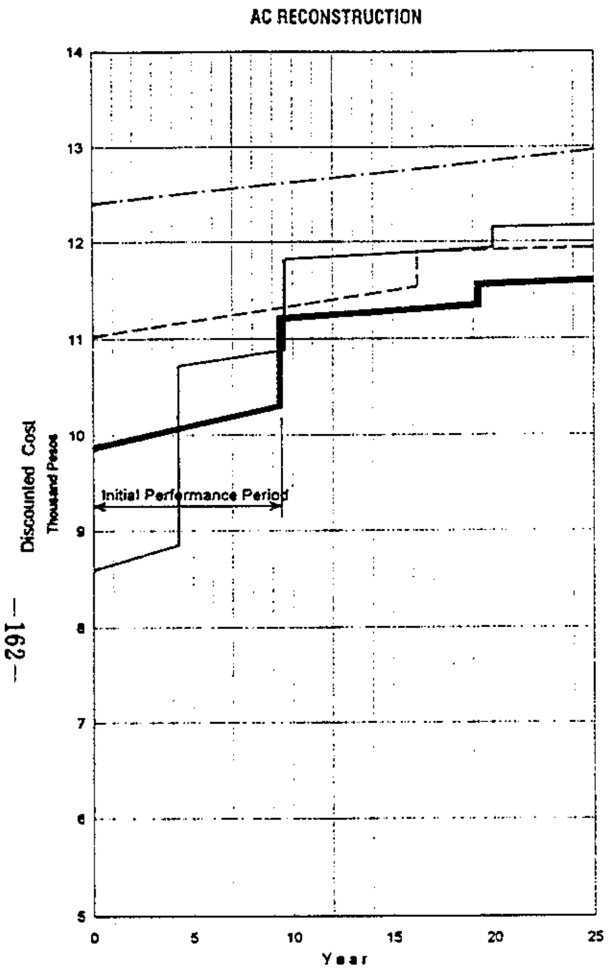
A life cycle cost analysis was undertaken for the following cases:

Rehabilitation Methods (3 cases)	:	AC reconstruction PCC reconstruction AC overlay of PCC pavement
Traffic Loading Class (6 cases)	:	A to F
Subgrade Strength (4 cases)	:	CBR 3, 6, 10 and 15
Assumed Range of Structural Capacity	:	

Traffic Class	AC Reconstruction (SN)	PCC Reconstruction (Slab thickness)	AC overlay of PCC (Overlay thickness)
A,B,C	3.2 - 5.3	23 - 28cm	10 - 15cm
D,E,F	2.7 - 4.8	23 - 28cm	8 - 15cm

Analysis Period : 25 years

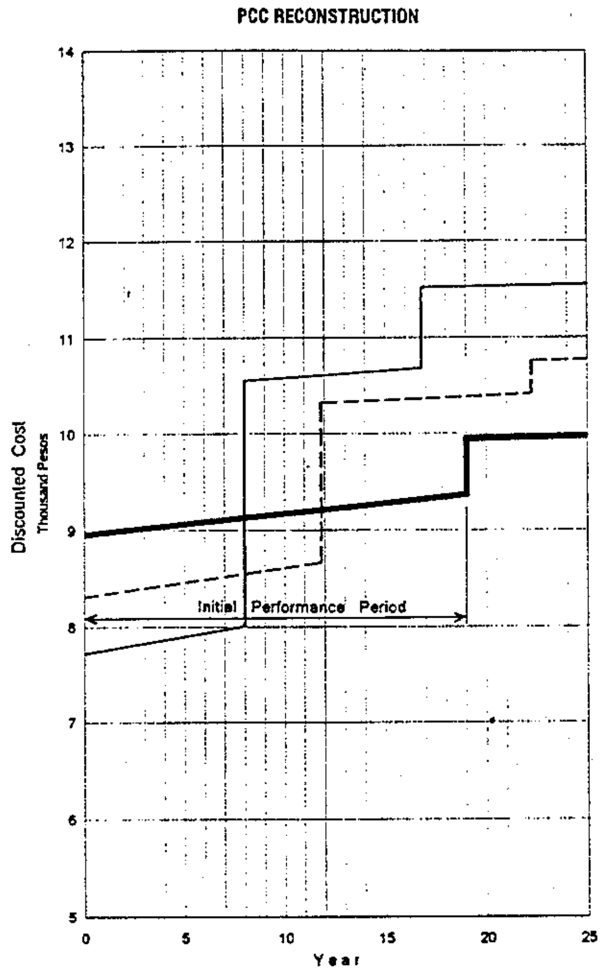
AC RECONSTRUCTION



Legend:	SN	Initial Performance Period (Years)	Initial Cost (P/m)	Total Discounted Cost (P/m)
———	3.7	4.2	8,599	12,106
━━━	4.3	9.4	9,884	(11,535)
— — —	4.8	16.2	11,036	11,909
—·—·—	5.3	25.0	12,405	12,964

Conditions:
Traffic Loading Class : C
CBR = 6.0 (M_R = 6,000)

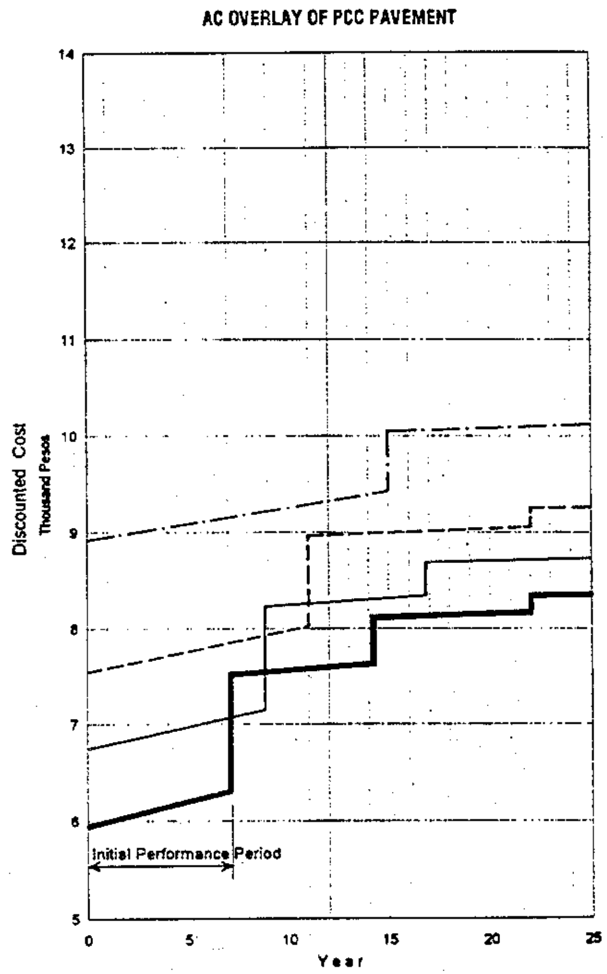
PCC RECONSTRUCTION



Legend:	D (cm)	Initial Performance Period (Years)	Initial Cost (P/m)	Total Discounted Cost (P/m)
———	23	8.0	7,725	11,426
— — —	25	11.7	8,309	10,553
━━━	28	19.0	8,952	(9,807)

Conditions:
Traffic Loading Class : C
CBR = 6.0 (k = 350 pci)

AC OVERLAY OF PCC PAVEMENT



Legend:	Initial Overlay Thickness (cm)	Initial Performance Period (Years)	Initial Cost (P/m)	Total Discounted Cost (P/m)
━━━	8	7.1	5,941	(8,269)
———	10	8.9	6,761	8,737
— — —	12	11.0	7,587	9,163
—·—·—	15	15.0	8,923	10,075

Conditions:
Traffic Loading Class : C
CBR = 6.0 (k = 330 pci)

Note : Total discounted cost includes residual value of pavement at the end of 25th year

FIGURE 9.2-3 EXAMPLE OF LIFE CYCLE COST ANALYSIS

A computer program which searches the most economical performance period and its corresponding structural capacity, initial cost and total discounted cost, was developed. Results of analysis are summarized in Table 9.2-10, and interpreted as follows:

AC Reconstruction

- Shorter initial performance period is economically advantageous for heavier traffic loading and weaker subgrade.

- Longer initial performance period is economically advantageous for lighter traffic loading and stronger subgrade.

- Most economical initial performance period ranges from 6.3 years to 14.8 years.

PCC Reconstruction

- Longer initial performance period which means thicker slab thickness is always advantageous within the assumed range of structural capacity for traffic loading classes A, B and C. Maximum slab thickness assumed (28 cm) was selected for all cases.

- For traffic loading classes D, E and F, initial performance period of 20 to 23 years is advantageous.

AC Overlay of PCC Pavement

- For traffic loading class A and B (heaviest and second heaviest loading along the Study Road), initial performance period of about 5 years is the most advantageous, although it is not practical to rehabilitate again after 5 years of the initial rehabilitation. Most of the cases, thinner overlay is economically advantageous.

- For traffic loading classes C to F, the minimum overlay thickness (8cm) is found to be most economical and initial performance period ranges from 6.2 years to 21.2 years.

TABLE 9.2-10 MOST ECONOMICAL INITIAL PERFORMANCE PERIOD

Traffic Loading Class		AC Reconstruction					PCC Reconstruction					AC Overlay of PCC				
		CBR=3	6	10	15	Ave.	3	6	10	15	Ave.	3	6	10	15	Ave.
A	IPP	6.3	9.1	9.1	9.2	8.4	9.9 *	10.3	11.5 *	12.1	11.0	5.1	4.2	5.0	5.1 **	4.9
	ST	(SN=5.2)	(4.8)	(4.4)	(3.8)		(D=28.0)	(27.7)	(28.0)	(27.7)		(t=11.0)	(8.2)	(9.2)	(8.0)	
B	IPP	5.0	9.1	10.1	10.0	8.6	12.4 *	13.5 *	14.2 *	15.6 *	13.9	5.0	5.4	6.1	6.6	5.8
	ST	(SN=4.8)	(4.6)	(4.2)	(3.7)		(D=28.0)	(28.0)	(28.0)	(28.0)		(t=8.8)	(8.2)	(8.6)	(8.2)	
C	IPP	7.1	9.4	11.0	11.2	9.7	17.5 *	19.0 *	19.1	20.1	18.9	6.2 **	7.1 **	8.0	9.1	7.6
	ST	(SN=4.7)	(4.3)	(4.0)	(3.5)		(D=28.0)	(28.0)	(27.7)	(27.4)		(t=8.0)	(8.0)	(8.4)	(8.4)	
D	IPP	8.4	11.2	11.1	14.1	11.2	24.1 *	22.0	23.1	23.3	23.1	7.6 **	8.7 **	9.4 **	10.7 **	9.1
	ST	(SN=4.5)	(4.1)	(3.7)	(3.4)		(D=28.0)	(26.8)	(26.8)	(26.2)		(t=8.0)	(8.0)	(8.0)	(8.0)	
E	IPP	8.1	10.1	14.3	12.1	11.2	23.0	19.1	20.2	21.1	20.9	10.0 **	11.4 **	12.3 **	14.2	12.0
	ST	(SN=4.2)	(3.8)	(3.7)	(3.1)		(D=26.2)	(24.4)	(24.4)	(24.0)		(t=8.0)	(8.0)	(8.0)	(8.2)	
F	IPP	9.0	12.7	14.1	11.0	11.7	21.2	21.2 **	23.1	24.9 **	22.6	14.5 **	16.4 **	17.4 **	19.5 **	17.0
	ST	(SN=4.0)	(3.7)	(3.4)	(2.8)		(D=23.6)	(23.0)	(23.2)	(23.0)		(t=8.0)	(8.0)	(8.0)	(8.0)	

Note: IPP : Initial Performance Period
ST : Structural Thickness
* : Performance period of maximum pavement structure
** : Performance period of minimum pavement structure

Assumed Range of Structural Capacity

Traffic Class	AC Reconstruction (SN)	PCC Reconstruction (Slab Thickness)	AC Overlay of PCC (Overlay Thickness)
A, B, C	3.2 - 5.3	23cm - 28cm	10cm - 15cm
D, E, F	2.7 - 4.8	23cm - 28cm	8cm - 15cm

c) Minimum Initial Performance Period

There is no firm policy on the minimum initial performance period in DPWH. Pavement type and thickness has been governed by the economic viability. DPWH officials expressed that the minimum performance period of the initial rehabilitation should preferably be 10 years, because the Pan-Philippine Highway is the country's most important arterial road and the project involves major rehabilitation and reconstruction.

As shown in Table 9.2-10, pavement rehabilitation methods of which the most economical initial performance period is less than 10 years are as follows:

- AC reconstruction for traffic loading class A and B
- AC overlay of PCC pavement for traffic loading classes A,B,C, and D

Increase of an initial cost and a total discounted cost was examined when above cases are designed for the 10-year initial performance period and results are summarized in Table 9.2-11.

In case of AC reconstruction for traffic loading classes A and B, increase of an initial cost ranges 1 to 16% and increase of a total discounted cost is minimal at about 1 to 2%, even though an initial performance period of 10 years is adopted.

In case of AC overlay of PCC pavement for traffic loading classes A and B, increase of an initial cost ranges from 54 to 27%, however, an initial performance period is almost doubled resulting in small (or about 10%) increase in a total discounted cost. For traffic loading classes C and D, increase of both an initial cost and a total discounted cost is not significant.

It is recommended that the minimum initial performance period should be 10 years.

d) Recommended Initial Performance Period

Table 9.2-12 summarizes the recommended initial performance period for this Project.

TABLE 9.2-11 COST COMPARISON BETWEEN MOST ECONOMICAL AND RECOMMENDED INITIAL PERFORMANCE PERIOD (1/2)

AC RECONSTRUCTION

Traffic Loading Class	CBR	Item	Most Economical Initial Performance Period (A)	Recommended Initial Performance Period (B)	B/A
A	3	Structural Number (SN)	5.2	5.6	
		IPP (Year)	6.3	10.0	
		Initial Cost (P/m)	11,994	13,226	1.10
		Total Discounted Cost (P/m)	14,503	14,756	1.02
	6	Structural Number (SN)	4.8	4.9	
		IPP (Year)	9.1	10.0	
		Initial Cost (P/m)	11,036	11,310	1.02
		Total Discounted Cost (P/m)	12,733	12,836	1.01
	10	Structural Number (SN)	4.4	4.4	
		IPP (Year)	9.1	10.0	
		Initial Cost (P/m)	9,999	10,114	1.01
		Total Discounted Cost (P/m)	11,693	11,765	1.01
	15	Structural Number (SN)	3.8	3.8	
		IPP (Year)	9.2	10.0	
		Initial Cost (P/m)	8,728	8,813	1.01
		Total Discounted Cost (P/m)	10,418	10,462	1.01
B	3	Structural Number (SN)	4.8	5.4	
		IPP (Year)	5.0	10.0	
		Initial Cost (P/m)	10,921	12,679	1.16
		Total Discounted Cost (P/m)	13,896	14,174	1.02
	6	Structural Number (SN)	4.6	4.7	
		IPP (Year)	9.1	10.0	
		Initial Cost (P/m)	10,575	10,806	1.02
		Total Discounted Cost (P/m)	12,270	12,300	1.00

TABLE 9.2-11 COST COMPARISON BETWEEN MOST ECONOMICAL AND RECOMMENDED INITIAL PERFORMANCE PERIOD (2/2)

AC OVERLAY OF PCC PAVEMENT

Traffic Loading Class	CBR	Item	Most Economical Initial Performance Period (A)	Recommended Initial Performance Period (B)	B/A
A	3	Overlay Thickness (cm)	11.0	16.8	
		IPP (year)	5.1	10.0	
		Initial Cost (P/m)	7,174	9,678	1.35
		Total Discounted Cost (P/m)	10,652	11,948	1.12
	6	Overlay Thickness (cm)	8.2	15.9	
		IPP (year)	4.2	10.0	
		Initial Cost (P/m)	6,023	9,300	1.54
		Total Discounted Cost (P/m)	10,145	11,219	1.11
	10	Overlay Thickness (cm)	9.2	15.4	
		IPP (year)	5.0	10.0	
		Initial Cost (P/m)	6,433	9,091	1.41
		Total Discounted Cost (P/m)	9,849	10,961	1.11
	15	Overlay Thickness (cm)	8.0	14.4	
		IPP (year)	5.1	10.0	
		Initial Cost (P/m)	5,941	8,656	1.46
		Total Discounted Cost (P/m)	9,351	10,522	1.13
B	3	Overlay Thickness (cm)	8.8	14.8	
		IPP (year)	5.0	10.0	
		Initial Cost (P/m)	6,269	8,834	1.41
		Total Discounted Cost (P/m)	9,678	10,700	1.11
	6	Overlay Thickness (cm)	8.2	13.8	
		IPP (year)	5.4	10.0	
		Initial Cost (P/m)	6,023	8,389	1.39
		Total Discounted Cost (P/m)	9,225	10,249	1.11
	10	Overlay Thickness (cm)	8.6	13.2	
		IPP (year)	6.1	10.0	
		Initial Cost (P/m)	6,187	8,121	1.31
		Total Discounted Cost (P/m)	9,019	10,140	1.12
	15	Overlay Thickness (cm)	8.2	12.2	
		IPP (year)	6.6	10.0	
		Initial Cost (P/m)	6,023	7,676	1.27
		Total Discounted Cost (P/m)	8,688	9,530	1.10
C	3	Overlay Thickness (cm)	8.0	12.2	
		IPP (year)	6.2	10.0	
		Initial Cost (P/m)	5,941	7,676	1.29
		Total Discounted Cost (P/m)	8,713	9,478	1.09
	6	Overlay Thickness (cm)	8.0	11.1	
		IPP (year)	7.1	10.0	
		Initial Cost (P/m)	5,941	7,215	1.21
		Total Discounted Cost (P/m)	8,269	9,013	1.09
	10	Overlay Thickness (cm)	8.4	10.5	
		IPP (year)	8.0	10.0	
		Initial Cost (P/m)	6,105	6,968	1.14
		Total Discounted Cost (P/m)	8,168	8,763	1.07
	15	Overlay Thickness (cm)	8.4	9.3	
		IPP (year)	9.1	10.0	
		Initial Cost (P/m)	6,105	6,474	1.06
		Total Discounted Cost (P/m)	7,884	8,426	1.07
D	3	Overlay Thickness (cm)	8.0	10.4	
		IPP (year)	7.6	10.0	
		Initial Cost (P/m)	5,941	6,926	1.17
		Total Discounted Cost (P/m)	8,170	8,877	1.09
	6	Overlay Thickness (cm)	8.0	9.2	
		IPP (year)	8.7	10.0	
		Initial Cost (P/m)	5,941	6,433	1.08
		Total Discounted Cost (P/m)	7,864	8,152	1.04
	10	Overlay Thickness (cm)	8.0	8.6	
		IPP (year)	9.4	10.0	
		Initial Cost (P/m)	5,941	6,187	1.04
		Total Discounted Cost (P/m)	7,669	7,781	1.01

TABLE 9.2-12 RECOMMENDED INITIAL PERFORMANCE PERIOD FOR THE PROJECT

Rehabilitation Method	Traffic Loading Class	Most Economical Initial Performance Period (years)	Recommended Initial Performance Period (years)
AC Reconstruction	A	8.4	10
	B	8.6	
	C	9.7	
	D	11.2	
	E	11.2	
	F	11.7	
PCC Reconstruction	A	11	12
	B	13.9	
	C	18.9	15
	D	23.1	
	E	20.9	20
	F	22.6	
AC Overlay of PCC Pavement	A	4.9	10
	B	5.8	
	C	7.6	
	D	9.1	
	E	12.0	
	F	17.0	

e) Required Structural Capacity of Pavement

Required structural capacity for each type of rehabilitation method under traffic loading classes and subgrade capacities is summarized in Table 9.2-13. Maximum or minimum pavement structure adopted was as follows:

<u>PCC Reconstruction</u>

Maximum PCC Slab Thickness : 28cm
Minimum PCC Slab Thickness : 23cm

<u>AC Overlay of PCC Pavement</u>

Maximum AC Overlay Thickness : 16cm
Minimum AC Overlay Thickness : 8cm

TABLE 9.2-13 REQUIRED STRUCTURAL CAPACITY OF PAVEMENT

1) AC RECONSTRUCTION

Required Structural Number (SN)

Traffic Loading Class	Initial Year ESAL (x10^6)	Subgrade CBR								Initial Performance Period
		2	3	4	6	8	10	15	20	
A	1.52 ~ 1.36	5.5	5.5	5.0	5.0	4.5	4.5	4.0	3.5	10 years
B	1.13 ~ 1.05	5.5	5.5	5.0	5.0	4.5	4.0	3.5	3.5	
C	0.69	5.5	5.0	4.5	4.5	4.0	4.0	3.5	3.0	
D	0.42 ~ 0.34	5.5	5.0	4.5	4.0	4.0	3.5	3.0	3.0	
E	0.29 ~ 0.22	5.0	4.5	4.0	4.0	3.5	3.5	3.0	3.0	
F	0.18 ~ 0.10	5.0	4.0	4.0	3.5	3.5	3.0	3.0	2.5	

Note: 1) Provision of filter layer is required for CBR less than 3.
2) Improvement method for weak subgrade should be applied for CBR 2 or less.

2) PC RECONSTRUCTION

Slab Thickness (cm)

Traffic Loading Class	Initial Year ESAL (x10^6)	Subgrade CBR								Initial Performance Period
		2	3	4	6	8	10	15	20	
A	1.52 ~ 1.36	28.0 (10)	28.0 (10)	28.0 (11)	28.0 (11)	28.0	28.0	28.0	28.0	12 years
B	1.13 ~ 1.05	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	
C	0.69	28.0	28.0	28.0	28.0	28.0	28.0	25.0	25.0	15 years
D	0.42 ~ 0.34	28.0	25.0	25.0	25.0	25.0	25.0	25.0	23.0	
E	0.29 ~ 0.22	28.0	25.0	25.0	25.0	25.0	25.0	25.0	23.0	20 years
F	0.18 ~ 0.10	25.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	

Note: 1) Provision of filter layer is required for CBR less than 3.
2) Improvement method for weak subgrade should be applied for CBR 2 or less.
3) ( ) shows initial performance period which is less than recommended initial performance period.

3) AC OVERLAY

AC Overlay Thickness (cm)

Traffic Loading Class	Initial Year ESAL (x10^6)	Subgrade CBR								Initial Performance Period
		2	3	4	6	8	10	15	20	
A	1.52 ~ 1.36	16.0 (9)	16.0 (9)	16.0	16.0	16.0	16.0	14.0	14.0	10 years
B	1.13 ~ 1.05	16.0	16.0	14.0	14.0	14.0	14.0	12.0	12.0	
C	0.69	14.0	12.0	12.0	12.0	12.0	10.0	10.0	8.0	
D	0.42 ~ 0.34	12.0	10.0	10.0	10.0	10.0	10.0	8.0	8.0	
E	0.29 ~ 0.22	10.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	
F	0.18 ~ 0.10	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	

Note: 1) ( ) shows initial performance period which is less than recommended initial performance period.

4) Comparative Study of Rehabilitation Methods

a) Selection of Alternative Rehabilitation Methods

The type of existing pavement along the Study Road is PCC pavement. Rehabilitation methods of PCC pavement are as follows:

- Reconstruction
  - AC Reconstruction (Reconstruction with AC)
  - PCC Reconstruction (Reconstruction with PCC)

- Rehabilitation Methods With Overlay
  - AC overlay of PCC pavement
  - PCC overlay of PCC pavement

- Rehabilitation Methods Other Than Overlay
  - Full Depth Pavement Repair
  - Partial Depth Pavement Repair
  - Joint and Crack Sealing
  - Subsealing of Concrete Pavements
  - Grinding/Milling of Pavements
  - Subdrainage Improvements
  - Pressure Relief
  - Restoration of Joint Load Transfer
  - Surface Treatments

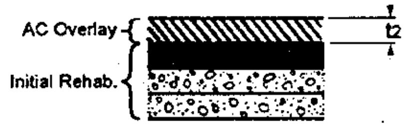
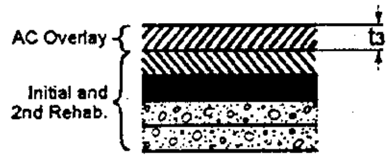
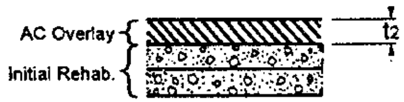
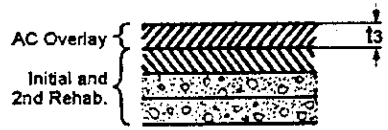
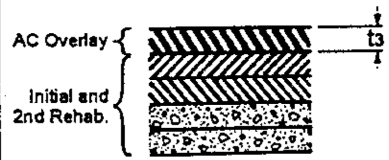
As the Study Road requires major rehabilitation, rehabilitation methods other than overlay were not discussed in this Study. PCC overlay of PCC pavement has not been experienced in this country, thus was not discussed in this Study.

The following three rehabilitation methods which are commonly adopted in this country were compared in this Study.

- AC Reconstruction
- PCC Reconstruction
- AC Overlay of PCC Pavement

Structural thickness of initial rehabilitation as well as succeeding rehabilitation of each rehabilitation method is presented in Table 9.2-14. For AC reconstruction, assumed thickness and corresponding structural number (SN) is illustrated in Figure 9.2-4.

TABLE 9.2-14 ASSUMED STRUCTURAL THICKNESS FOR INITIAL AND SUCCEEDING REHABILITATIONS

Rehabilitation Method	Initial Rehabilitation	2nd Rehabilitation	3rd / After 3rd Rehabilitation
AC RECONSTRUCTION	SN = 2.2, 2.7, 3.2, 3.7, 4.3, 4.8, and 5.3 	t_2 is so determined that performance life becomes the same as life of initial rehab. 	$t_3 = t_2$ 
PCC RECONSTRUCTION	Ð = 23 cm., 25 cm., and 28 cm. 	t_2 is so determined that performance life becomes the same as life of initial rehab. 	$t_3 = t_2$ 
AC OVERLAY OF PCC PAVEMENT	t_1 = 8 cm., 10 cm., 12 cm., 14 cm., and 16 cm. 	t_2 is so determined that performance life becomes the same as life of initial rehab. 	$t_3 = t_2$ 

SN = 2.2 (total thickness shown: none)

Layer	Thickness	T	BSC	DC	SN
SURFACE COURSE	5.0	2	0.39	—	0.780
BASE COURSE (CRUSHED GRAVEL)	20.0	8	0.105	0.9	0.756
SUBBASE COURSE	20.0	8	0.095	0.9	0.684
					TOTAL = 2.22

SN = 2.7 (total thickness 48.0)

Layer	Thickness	T	BSC	DC	SN
SURFACE COURSE	4.0	1.6	0.39	—	0.624
BINDER COURSE	4.0	1.6	0.39	—	0.624
BASE COURSE (CRUSHED GRAVEL)	20.0	8	0.105	0.9	0.756
SUBBASE COURSE	20.0	8	0.095	0.9	0.684
					TOTAL = 2,688

SN = 3.2 (total thickness 55.0)

Layer	Thickness	T	BSC	DC	SN
SURFACE COURSE	5.0	2	0.39	—	0.780
BINDER COURSE	5.0	2	0.39	—	0.780
BASE COURSE (CRUSHED GRAVEL)	20.0	8	0.105	0.9	0.756
SUBBASE COURSE	25.0	10	0.095	0.9	0.855
					TOTAL = 3,171

SN = 3.7 (total thickness 70.0)

Layer	Thickness	T	BSC	DC	SN
SURFACE COURSE	5.0	2	0.39	—	0.780
BINDER COURSE	5.0	2	0.39	—	0.780
BASE COURSE (CRUSHED GRAVEL)	30.0	12	0.105	0.9	1.134
SUBBASE COURSE	30.0	12	0.095	0.9	1.026
					TOTAL = 3,720

SN = 4.3 (total thickness 75.0)

Layer	Thickness	T	BSC	DC	SN
SURFACE COURSE	5.0	2	0.39	—	0.780
BINDER COURSE	5.0	2	0.39	—	0.780
BITUMINAS STABILIZED BASE	10.0	4	0.20	—	0.800
BASE COURSE (CRUSHED GRAVEL)	25.0	10	0.105	0.9	0.945
SUBBASE COURSE	30.0	12	0.095	0.9	1.026
					TOTAL = 4,331

SN = 4.8 (total thickness 82.0)

Layer	Thickness	T	BSC	DC	SN
SURFACE COURSE	6.0	2.4	0.39	—	0.936
BINDER COURSE	6.0	2.4	0.39	—	0.936
BITUMINAS STABILIZED BASE	10.0	4	0.20	—	0.800
BASE COURSE (CRUSHED GRAVEL)	30.0	12	0.105	0.9	1.134
SUBBASE COURSE	30.0	12	0.095	0.9	1.026

SN = 5.3 (total thickness 85.0)

Layer	Thickness	T	BSC	DC	SN
SURFACE COURSE	5.0	2	0.39	—	0.780
BINDER COURSE	5.0	2	0.39	—	0.780
BINDER COURSE	5.0	2	0.39	—	0.780
BITUMINAS STABILIZED BASE	10.0	4	0.20	—	0.800
BASE COURSE (CRUSHED GRAVEL)	30.0	12	0.105	0.9	1.134
SUBBASE COURSE	30.0	12	0.095	0.9	1.026
					TOTAL = 5,300

FIGURE 9.2-4 ASSUMED THICKNESS AND STRUCTURAL NUMBER FOR AC PAVEMENT

b) Cost Comparison of Rehabilitation Methods

Based on the recommended initial performance period, required structural capacity for each type of rehabilitation was selected from Table 9.2-13 for various traffic loading classes and subgrade capacities. Based on the required structural capacity, costs, i.e., initial cost and total discounted cost which includes initial/succeeding rehabilitation cost, maintenance cost and residual value of pavement at the end of 25th year, were compared among rehabilitation methods.

Initial cost, succeeding rehabilitation cost and maintenance cost are summarized in Table 9.2-15.

Cost comparison is presented in Figure 9.2-5. From Figure 9.2-5, it is concluded that:

- AC reconstruction is the most expensive in almost all cases.
- Except for loading class A, AC overlay is the most economical.
- For loading class A, there is little difference between PCC reconstruction and AC overlay. From the viewpoint of local availability of material, PCC reconstruction is more advantageous.

c) Recommended Rehabilitation Method

From the economic viewpoint, PCC reconstruction and AC overlay are recommended as the rehabilitation methods for traffic loading class A and classes B-F, respectively. It should, however, be noted that AC overlay should not be applied under the following conditions.

<u>Conditions and Distresses Under Which AC Overlay Should Not Be Applied</u>

- Heavy depression (localized settlement area) in one slab caused by settlement or consolidation of subgrade/subbase.
- Pumping and water bleeding (suspicious to void under PCC slab which causes loss of support).
- Block cracks with depressions.
- Slab rocking suspicious to uneven settlement.
- Remarkable differences in elevation between cracked fragments in one slab.
- Bad drainage condition.
- IRR less than 1.5

Where AC overlay should not be applied and loading class is A irrespective of the condition, PCC reconstruction is recommended for the rehabilitation method.

TABLE 9.2-15 INITIAL COST, SUCCEEDING REHABILITATION COST AND MAINTENANCE COST

Rehabilitation Method	Initial Cost	2nd and Succeeding Rehabilitation Cost	Maintenance Cost	Remarks
AC Reconstruction	P/m SN = 2.2 5,480 SN = 2.7 6,780 SN = 3.2 7,810 SN = 3.7 8,600 SN = 4.3 9,880 SN = 4.8 11,040 SN = 5.3 12,410	cm P/m t2 = 5.0 3,260 t2 = 7.5 4,310 t2 = 10.0 5,300 t2 = 12.5 6,290 t2 = 15.0 7,370	AC Surface 76 P/m/year	Initial cost includes - removal of existing PCC pavement. - shoulder improvement (shoulder width=2m)
PCC Reconstruction	P/m D =23cm 7,730 D =25cm 8,310 D =28cm 8,950	cm P/m t2 = 5.0 4,630 t2 = 7.5 5,750 t2 = 10.0 6,760 t2 = 12.5 7,770 t2 = 15.0 8,920	PCC Surface 56 P/m/year AC Surface 76 P/m/year	Initial cost includes - removal of existing PCC pavement. - shoulder improvement (shoulder width=2m)
AC Overlay	P/m t1 = 8cm 5,940 t1 =10cm 6,760 t1 =12cm 7,590 t1 =14cm 8,480 t1 =16cm 9,340	cm P/m t2 = 5.0 3,260 t2 = 7.5 4,310 t2 = 10.0 5,300 t2 = 12.5 6,290 t2 = 15.0 7,370	AC Surface 76 P/m/year	Initial cost includes - pre-overlay repair; i.e. repair of broken PCC (10% of surface area) and crack/joint sealing. - shoulder improvement (shoulder width=2m) - overlay support block.

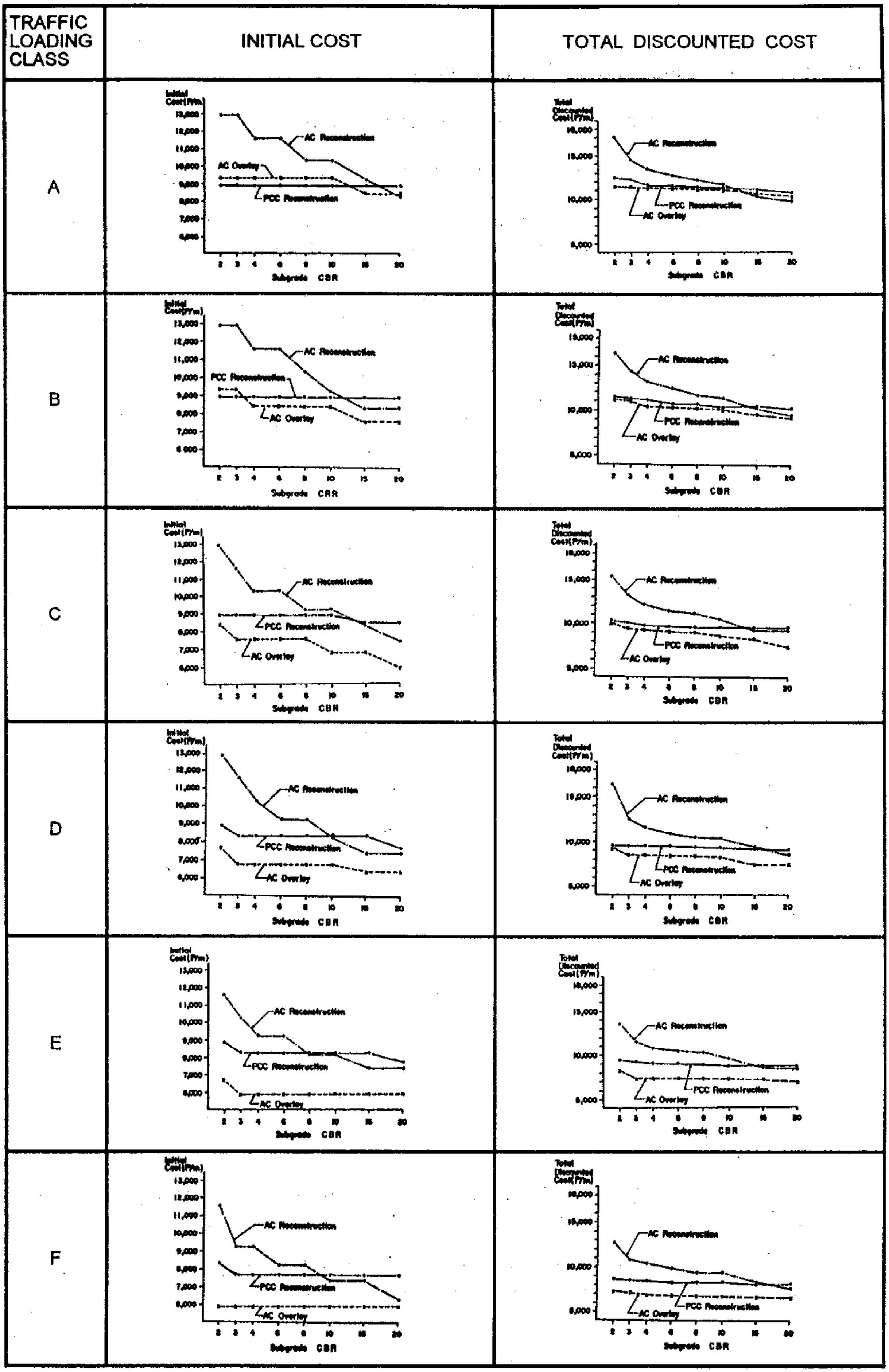


FIGURE 9.2-5 COST COMPARISON OF ALTERNATIVE REHABILITATION METHODS

9.2.2 Other Rehabilitation Design Criteria

1) Shoulder Rehabilitation/Improvement Design Criteria

A shoulder has various functions of which major ones are as follows:

- A space for accommodation of stopped vehicles and for emergency use.
- A space for lateral clearance for vehicles thereby increasing traffic capacity.
- Structural support to subbase, base and surface course.
- Storm water being discharged further from the pavement and seepage adjacent to the pavement being minimized.
- Space for pedestrians, pedicabs and tricycles.

In due consideration of above functions, shoulder rehabilitation/improvement criteria were established as follows:

i) Earth shoulders shall be improved with better quality of material.
ii) Shoulders with distress such as drop-off, heave or scour shall be rehabilitated.
iii) Shoulders along sections whose vertical gradient is 5% or more shall be paved in order to prevent scouring.
iv) Shoulders in a dense residential area shall be paved to provide spaces for pedestrians and/or pedicabs/tricycles.

In a section where only shoulder rehabilitation/improvement works under criteria i) and ii) are required, but other rehabilitation works such as pavement rehabilitation and/or drainage improvement are not needed, shoulder rehabilitation/improvement works are proposed to be undertaken by maintenance works and not to be included in this project.

2) Drainage Rehabilitation/Improvement Criteria

Surface and subsurface drainage is quite important to keep a road in good condition as well as to prolong the life of a road. Drainage rehabilitation/ improvement criteria were established as follows:

a) Side Ditches

i) Existing earth ditches shall be replaced with riprap/concrete ditches.

ii) Damaged or insufficient capacity riprap/concrete ditches shall be rehabilitated/improved.

iii) Riprap/concrete side ditches shall be provided for sections where no ditches exist, although those are needed.

iv) Side ditch rehabilitation/improvement shall be always incorporated with shoulder rehabilitation/improvement.

b) Cross Drainages (RCPC and RCBC)

i) Existing cross drainages with insufficient capacity shall be replaced with new ones or additional cross drainages shall be provided.

ii) Existing cross drainages which are damaging slopes (or causing slope failure) shall be improved by providing proper inlet/outlet facilities and/or vertical drains along slopes.

iii) Additional cross drainages shall be provided incorporating with side ditch drainage system.

iv) Additional cross drainages shall be provided in the flood prone areas.

Cross drainage works related to ii) shall be properly coordinated with slope protection works and iv) with countermeasures for sections subject to flooding.

c) Subsurface Drainage

Subsurface drainages shall be provided for sections where underground water level is high.

3) Treatment of Weak Subgrade

Sections of significant uneven surface due to consolidation of weak subgrade shall be properly treated. Method of treatment shall be selected in due consideration of probable settlement, embankment slope stability, cost effectiveness and traffic management during construction.

9.3 PRELIMINARY DESIGN

9.3.1 Preliminary Design of Pavement

1) Evaluation of Quality of Existing PCC Pavement Materials

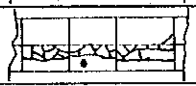
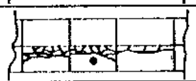
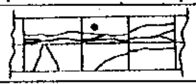
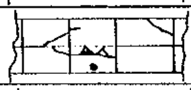
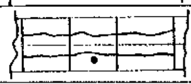
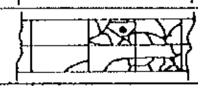
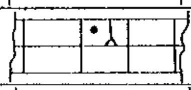
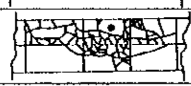
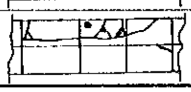
Pavement corings and soils tests were undertaken at selected 20 PCC slabs (see Appendix 9.1).

Test results of cored PCC slab concrete, subbase materials and subgrade bearing capacity are summarized in Table 9.3-1.

a) PCC Slab

The standard PCC slab thickness adopted for the Pan-Philippine Highway was 23cm. Thickness of existing PCC slab ranges from 18 to 26cm. Ten out of 20 cored slab specimens have thinner thickness than the standard thickness.

TABLE 9.3-1 PAVEMENT MATERIALS TEST RESULTS

NO.	SECTION	KM.	CRACK CONDITION	PCC SLAB THICKNESS (cm)	PCC SLAB COMP. STRENGTH (kg/cm²)	SUBBASE THICKNESS (cm)	SUBBASE CBR (%)	SUBBASE LL	SUBBASE PI	SUBBASE % PASSING SIEVE 1"	SUBBASE % PASSING SIEVE 3/8"	SUBBASE % PASSING SIEVE No. 200	SUBGRADE CBR (%)	MAJOR MATERIAL DEFECTS AND CAUSES OF DISTRESS
01	Kitcharao - Cabadbaran	1193 + 200		20.3	420	(No Subbase Borrow Material)	30.5	NP	NP	58	36	1	(30.5)	• Insufficient PCC Slab thickness
02	- do -	1196 + 060		20.3	327	(No Subbase Borrow Material)	29.1	NP	NP	100	69	4	(29.1)	• Insufficient PCC Slab thickness
03	Afga Bridge - Bayugan	1243 + 590		20.2	236	15	9.5	30	12	35	19	8	2.3	• Very poor quality of subbase material • Low strength and insufficient thickness of slab concrete
04	- do -	1248 + 750		22.4	219	38	24.2	NP	NP	86	46	6	6.7	• Low strength of slab concrete
05	- do -	1261 + 400		23.0	221	37	27.0	NP	NP	76	46	8	3.3	• Low strength of slab concrete
06	- do -	1268 + 190		21.0	242	39	25.0	NP	NP	100	80	23	4.2	• Insufficient PCC slab thickness • Improper subbase material
07	Bayugan - Prosperidad	1272 + 700		25.0	92	35	28.0	NP	NP	100	79	17	12.8	• Very low strength of slab concrete • Improper subbase material
08	- do -	1278 + 980		24.0	248	16	39.1	NP	NP	80	57	15	1.5	• Very weak subgrade. • Pavement thickness was not designed properly.
09	- do -	1288 + 850		21.0	104	29	39.0	NP	NP	93	63	18	3.8	• Very low strength of slab concrete • Improper subbase material
10	- do -	1297 + 950		18.0	244	42	10.8	NP	NP	100	64	52	1.9	• Insufficient PCC slab thickness • Improper subbase material • Very weak subgrade
11	Prosperidad - Rosario	1316 + 400		23.0	219	27	20.0	NP	NP	100	74	22	5.6	• Improper subbase material • Low strength of slab concrete
12	Rosario - Bunawan	1328 + 600		23.0	121	37	27.5	NP	NP	64	22	5	6.7	• Very low strength of slab concrete
13	- do -	1347 + 020		19.0	231	(No Subbase Borrow Material)	34.0	NP	NP	84	55	9	(34.0)	• Insufficient thickness of and low strength of PCC slab
14	Bunawan - Boundary	1352 + 950		22.0	264	28	50.0	NP	NP	69	54	10	3.7	• Insufficient PCC slab thickness
15	- do -	1362 + 700		23.0	254	27	60.0	NP	NP	72	56	13	6.7	
16	- do -	1375 + 600		23.0	179	67	39.0	NP	NP	91	66	10	5.8	• Very low strength of slab concrete
17	Boundary - Monkayo	1381 + 500		23.0	202	(No Subbase Borrow Material)	3.9	39	18	100	100	80	(3.9)	• Low strength of slab concrete • Very poor quality of material under PCC slab
18	- do -	1389 + 060		26.0	173	27	33.0	NP	NP	81	51	9	3.4	• Very low strength of slab concrete
19	- do -	1393 + 220		24.0	208	56	40.8	NP	NP	93	65	18	3.8	• Low strength of slab concrete • Improper subbase material
20	Monkayo - Nabuntaran	1413 + 300		22.0	323	38	39.0	NP	NP	94	77	19	3.3	• Insufficient PCC slab thickness • Improper subbase material
REQUIREMENT OF 1972 SPECIFICATIONS				(23.0)		(15-20)		Less than 25	Less than 6			0 - 20	–	
REQUIREMENT OF 1988 SPECIFICATIONS				(23.0)	245	(15-20)	25	Less than 35	Less than 12	55 - 85	40 - 75	0 - 12	–	

The compressive strength of PCC slab concrete ranges widely from 92 kgf/cm^2 to 420 kgf/cm^2. The 1988 DPWH Standard Specifications require the compressive strength of 245 kgf/cm^2. Thirteen out of 20 specimens do not meet the said requirement.

In general, low quality of concrete with insufficient slab thickness was used for the Study Road, which is one of major causes of prematured pavement deterioration.

b) Subbase

At 4 out of 20 locations, subbase course was not layed and concrete slab was constructed directly on the embankment material. Subbase course thickness at the rest of 16 locations is more or less satisfactory ranging from 15cm to 67cm.

CBR of existing subbase course ranges widely from 9.5 to 60.0. Required CBR for subbase course by the 1988 DPWH Standard Specification is 25. Existing subbase materials do not meet the said requirement at 4 out of 16 locations.

Subbase materials at 8 out of 16 locations were not appropriate with improper grading and with high contents of silty/clay fragments.

c) Subgrade

Very weak subgrade of which CBR is less than 3 exists at 3 out of 20 locations, where no proper provisions against weak subgrade were not introduced.

2) Preliminary Design of Pavement Rehabilitation Works

Preliminary design was undertaken based on the findings of the Study. Design precedents of previous/on-going rehabilitation projects are presented in Appendix 9.2.

a) Selection of Sections to be Rehabilitated

Criteria for selection of sections to be rehabilitated were established as follows:

- A section of which Rehabilitation Requirement Index (RRI) in 1994 is 3.0 or less shall be selected for rehabilitation.

Construction work is expected to start in 1997. In accordance with the Rehabilitation Criteria established in Section 9.2 of this report, sections of which RRI of 2.5 or less in 1997 should be rehabilitated. In consideration of decrease of RRI from 1994 to 1997, sections of which RRI is 3.0 or less in 1994 were selected for rehabilitation.

- When a non-rehabilitation section sandwiched with rehabilitation sections is 3.0km or less in length, the section shall be rehabilitated simultaneously with the adjacent sections.

b) Selection of Rehabilitation Method

Criteria for selection of rehabilitation method were established as follows:

PCC Reconstruction

- RRI in 1994 is 1.5 or less
- Requirement from pavement conditions as stated in 4) of Section 9.2-1 of this report
- Sections in Traffic Loading Class A (from the viewpoint of economy)
- A section to which AC overlay is applicable, however, its section length is less than 4 km and there is no AC overlay section nearby (from the viewpoint of economy)

AC Reconstruction

- weak subgrade section where existing pavement settled

AC Overlay

- All sections other than PCC reconstruction or AC reconstruction

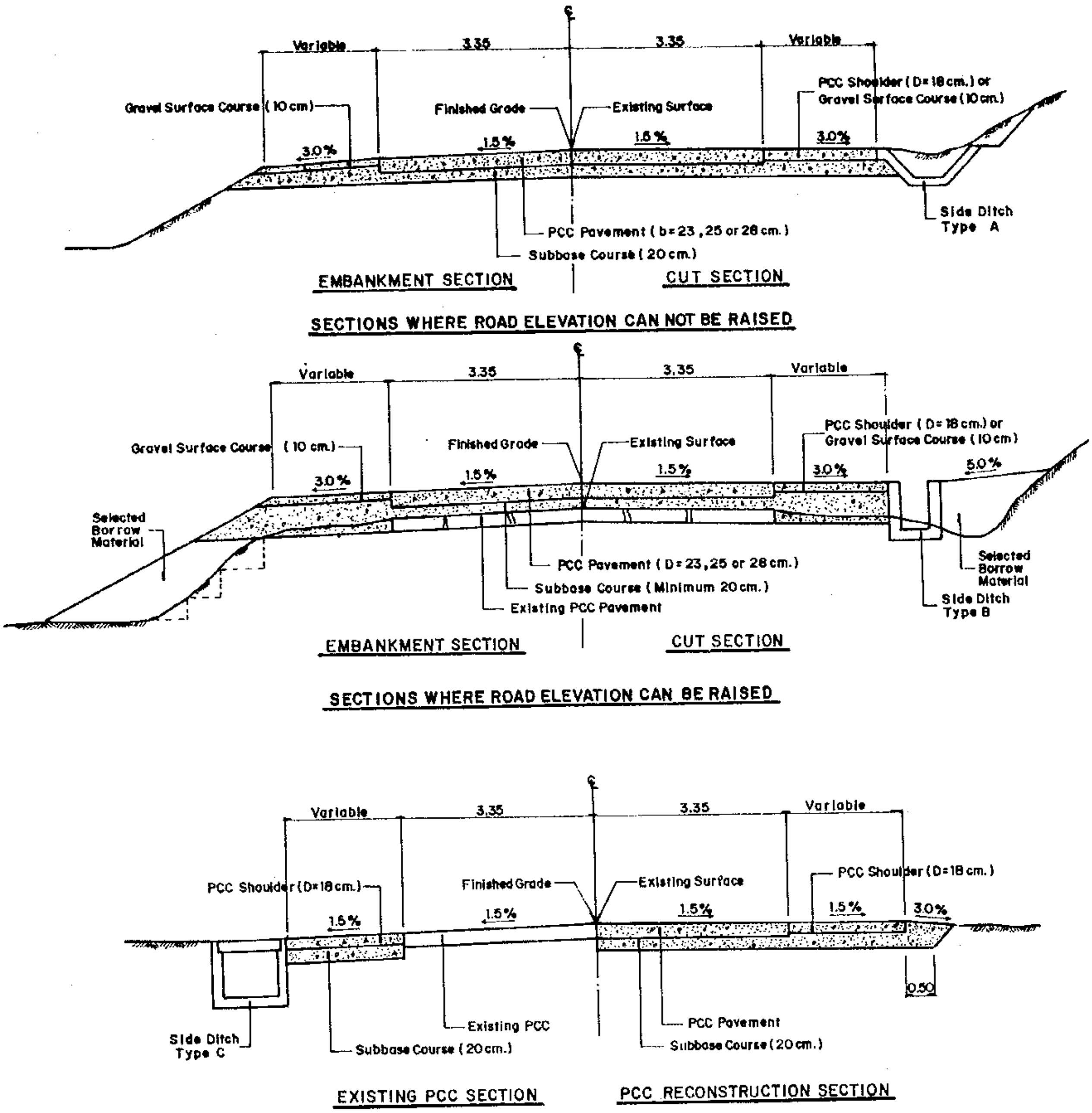
c) Required Pavement Thickness

Required pavement thickness for each traffic loading class and subgrade CBR is shown in Table 9.2-13, based on which following pavement thickness was assumed:

	Traffic Loading Class					
	A	B	C	D	E	F
PCC Reconstruction (slab thickness in cm)	28	28	28	25	25	23
AC Overlay (overlay thickness in cm)	16	14	12	10	8	8
AC Reconstruction (in Structural Number)	5.0	5.0	4.5	4.5	4.0	4.0

d) Typical Roadway Cross Section

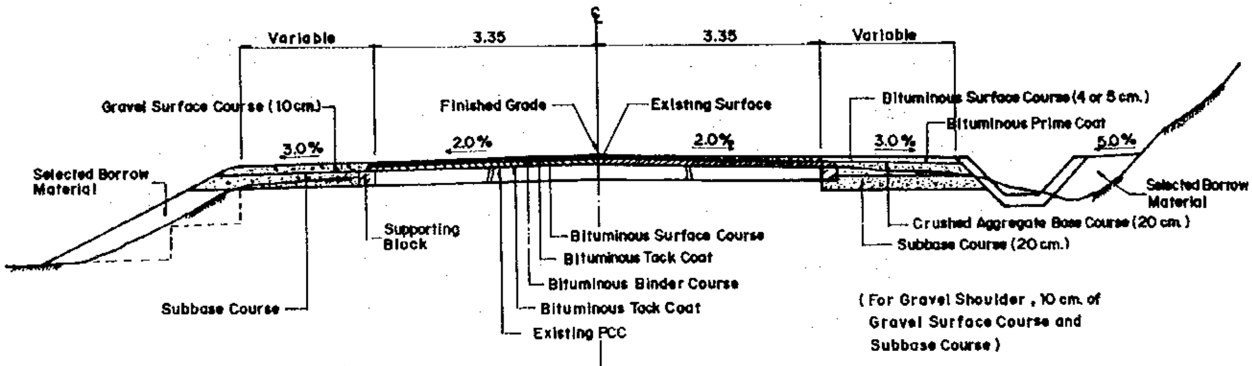
Typical roadway cross sections for PCC reconstruction and AC overlay are presented in Figure 9.3-1, and 9.3-2, respectively.



URBAN SECTION

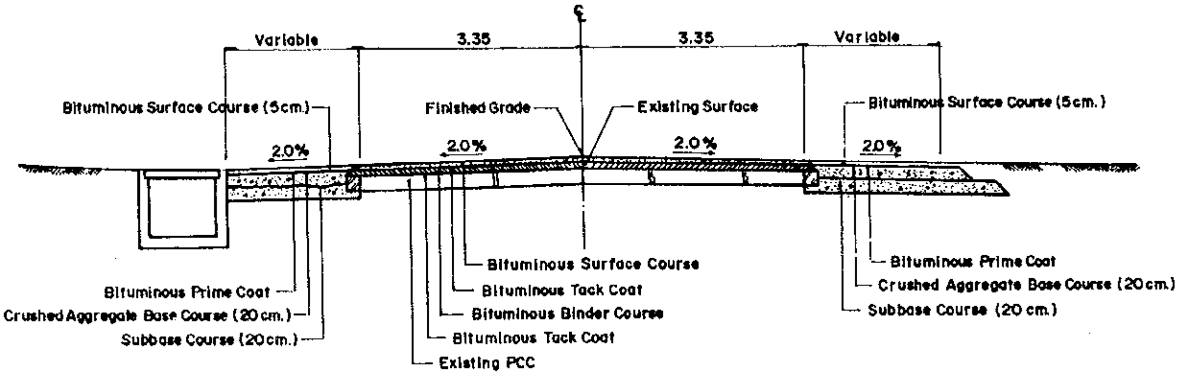
PCC RECONSTRUCTION

FIGURE 9.3-1 TYPICAL ROADWAY CROSS SECTION



· Surface Course	4	4	5	4	5
· Binder Course	–	–	–	5	5
· Binder Course (Minimum)	4	6	7	5	6
Total	8	10	12	14	16

EMBANKMENT SECTION CUT SECTION



URBAN SECTION

AC OVERLAY OF PCC PAVEMENT

FIGURE 9.3-2 TYPICAL ROADWAY CROSS SECTION

Typical roadway cross section for AC reconstruction to be applied to weak subgrade section is shown in Figure 9.3-3.

9.3.2 Preliminary Design of Shoulder

In accordance with the rehabilitation criteria established in Section 9.2.2 of this report, shoulder rehabilitation sections were selected.

PCC pavement shoulder was selected for sections of which roadway pavement rehabilitation is PCC reconstruction. Thickness of PCC pavement shoulder in the urban section from Tagum to the end of the Study Road in Davao City was selected to be 23cm in view of frequent utilization of heavy vehicles. For other sections, 18cm PCC pavement shoulder was selected.

AC pavement shoulder of 5cm was selected for sections of which roadway pavement rehabilitation is AC overlay or AC reconstruction.

Gravel shoulder was adopted for the sections where paving of shoulder is not required.

9.3.3 Preliminary Design of Drainage

Sections which require side ditches were selected in accordance with the rehabilitation criteria discussed in Section 9.2.2 of this report. Concrete side ditches as shown in the typical roadway cross sections were adopted in view of efficiency in discharge and maintainability.

Cross drainages to be replaced were identified during the field survey undertaken by the Study Team and all of them were proposed to be replaced. Additional cross drainages were considered for the section where side ditches were planned.

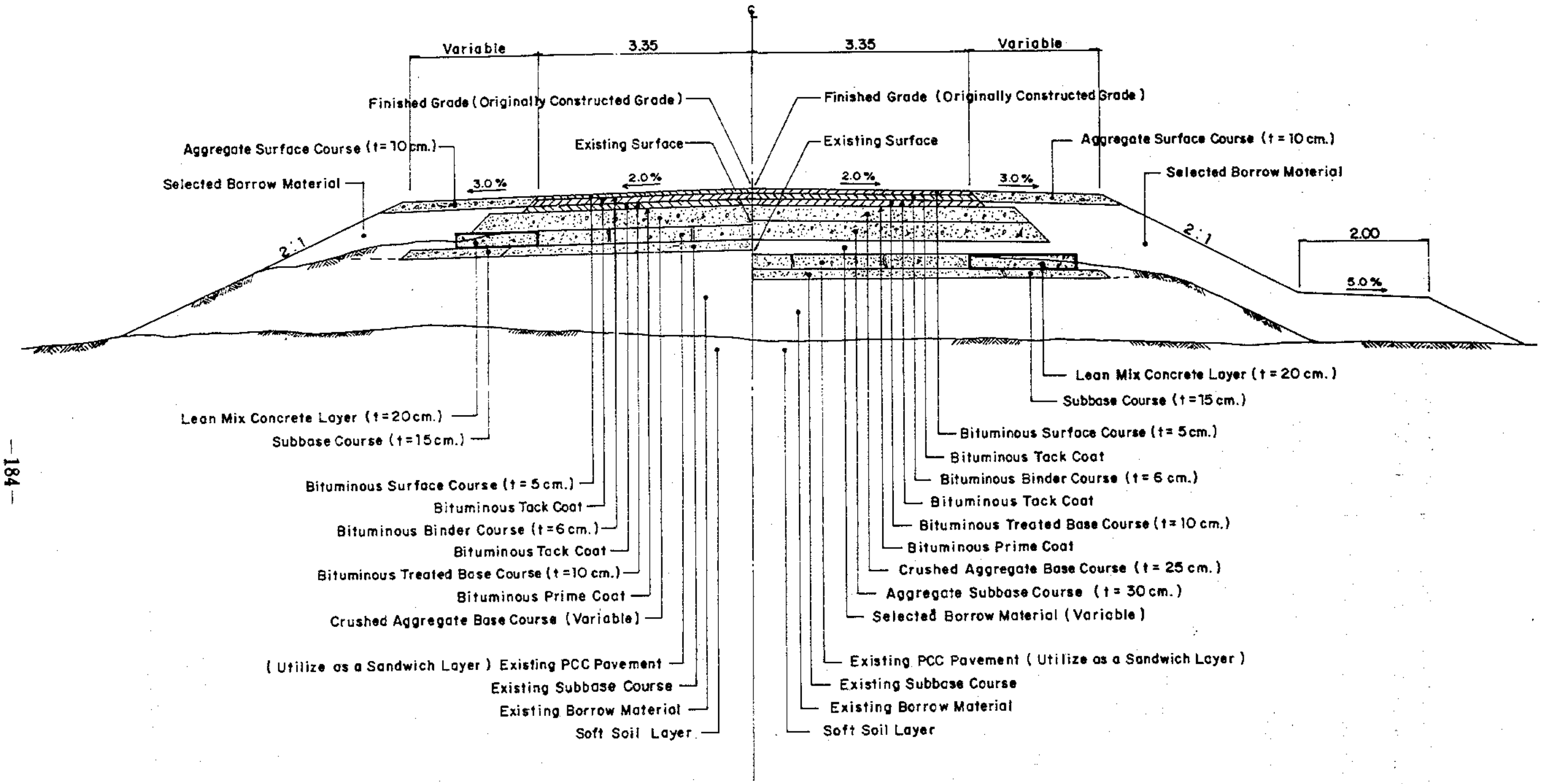
9.3.4 Preliminary Design for Treatment of Weak Subgrade Section

Subsurface investigation was undertaken at five locations (refer to Appendix 9.1) and results are shown in Figure 9.3-4. Thickness of soft layers (N-value is 2 or less) is approximately 6.5 meters for the most of locations. Maximum settlement of 1.2 meters was observed at Km. 1330+700. Although there are uneven settlements along the weak subgrade sections, cracks of PCC pavement slabs are not so extensive.

All weak subgrade sections were constructed with low embankment ranging from 1.5 to 2.0 meters.

In these sections, major causes of uneven settlement are considered to be as follows:

- Due to low embankment, traffic loads are not distributed to wide area within embankment, but reach to weak soil layers, which greatly attributed to an uneven settlement.



SHALLOW SETTLEMENT SECTION

DEEP SETTLEMENT SECTION

FIGURE 9.3-3 TYPICAL ROADWAY CROSS SECTION FOR SOFT SUBGRADE SECTION

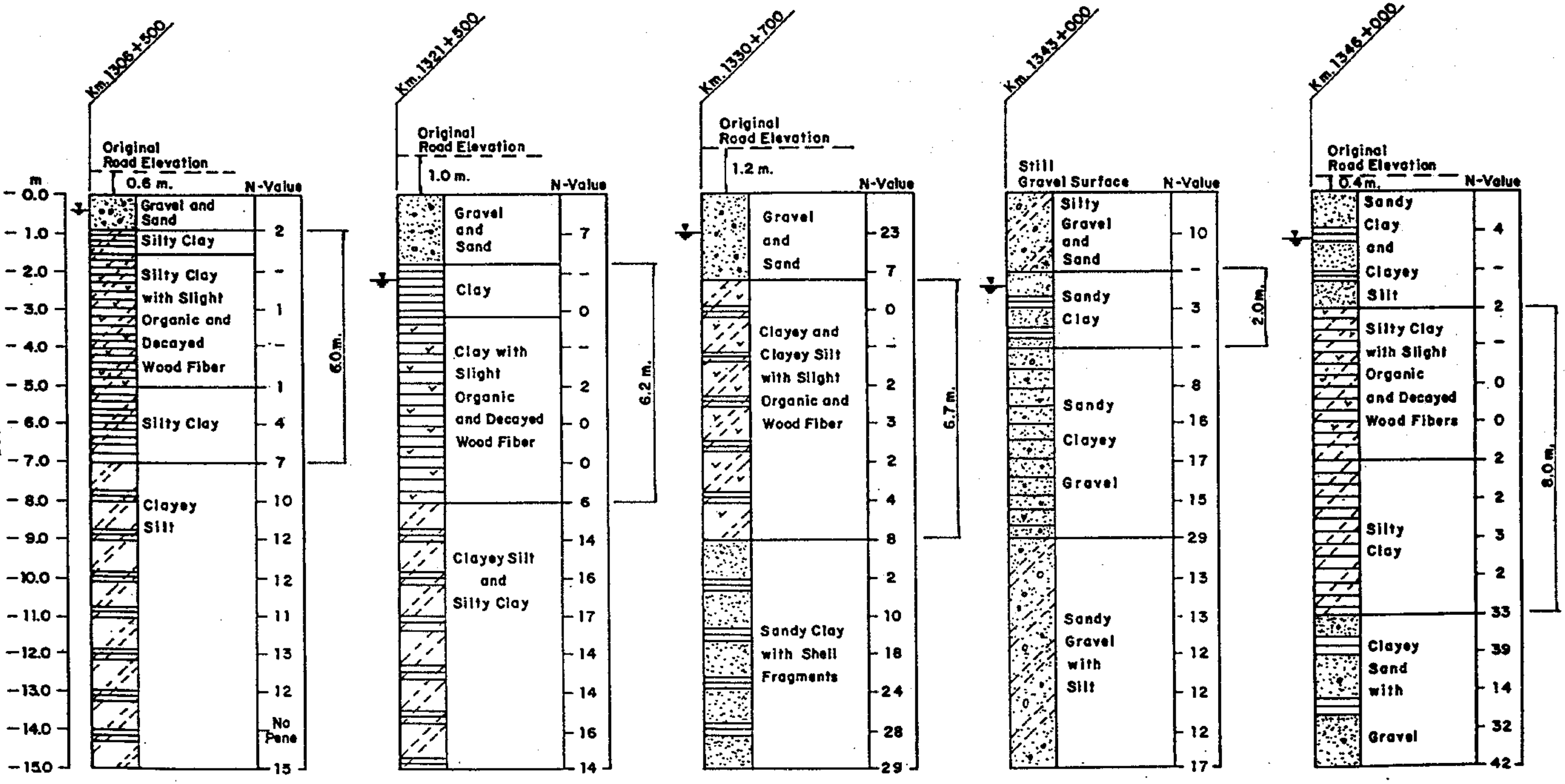


FIGURE 9.3-4 BORING RESULTS OF SOFT SUBGRADE SECTIONS

- During construction, upper portion of subgrade could not be compacted to a satisfactory level, resulted in low bearing capacity of subgrade.
- Underground water table is, in general, is high in these sections which affects bearing capacity of subgrade.
- Vibration of traffic loads reaches to soft soil layers which contributed greatly to an uneven settlement.

There are many kinds of methods for weak subgrade improvement as shown below:

- Soil replacement method
- Soil stabilization method
- Sandwich method
- Surcharge method
- Sand compaction pile method
- Others

As this project is a rehabilitation of existing road and traffic flow must be maintained even during construction, therefore, applicable method is limited. It is recommended that a sandwich method be adopted for this project. This method is suitable for a road section with heavy traffic where deep excavation is not feasible and heavy equipment can not be introduced. The method is illustrated in Figure 9.3-3. It should be noted that consolidation settlement is inevitable and about 30 to 40cm settlement is anticipated as presented in Appendix 9.3.

CHAPTER 10

BRIDGE REHABILITATION

10.1 PRESENT CONDITION OF BRIDGES

10.1.1 Summary of Bridges

There are 125 bridges along the Study Road. Bridge locations and type of bridges are presented in Figure 10.1-1. A summary of bridges is shown in Table 10.1-1. Table 10.1-2 shows number of bridges by type, year built and load capacity.

RC Deck Girder shares the highest (85 bridges of 68%), followed by Steel I-Beam (15 bridges or 12%) and Steel Plate Girder (6 bridges or 4.8%). Three Through Truss bridges and one Steel Langer bridge are built over wide rivers.

About one half (56%) of bridges were built in the period from 1955 to 1964, when the road was constructed as a gravel surfaced road. Under the PJHL Project (1970-1979), 22 bridges were constructed. Steel plate girder bridges (6 bridges) were built in the period from 1980 to 1994 under the Jumbo Project.

There are two bridges of which load capacity is 10 tons. Majority of bridges (or 82 bridges) have load capacity of 15 tons. Thirty nine (39) bridges have load capacity of 20 tons.

10.1.2 Problems of Bridges

Problems of the existing bridges are summarized as follows:

a) Problems of Standards

<u>Substandard Width</u>

According to the "Standard Drawings for Roads and Bridges, Bureau of Design, DPWH", the standard widths of carriageway and sidewalk are 7.32m and 0.76m, respectively.

Carriageway width of the existing bridges varies from 6.70m to 8.10m except for Paypay Bridge which is composed of two one-lane bridges with a carriageway width of 4.26m. In 86 bridges out of 125, carriageway width is narrower than the DPWH standard width.

Sidewalk width varies from 0 to 0.77m. Most bridges, amounting to 112 bridges out of 125, have narrower sidewalks than the DPWH standard width, including 4 bridges without sidewalk. 81 bridges accounting for 65% of total bridges have 0.40-0.49m sidewalks.

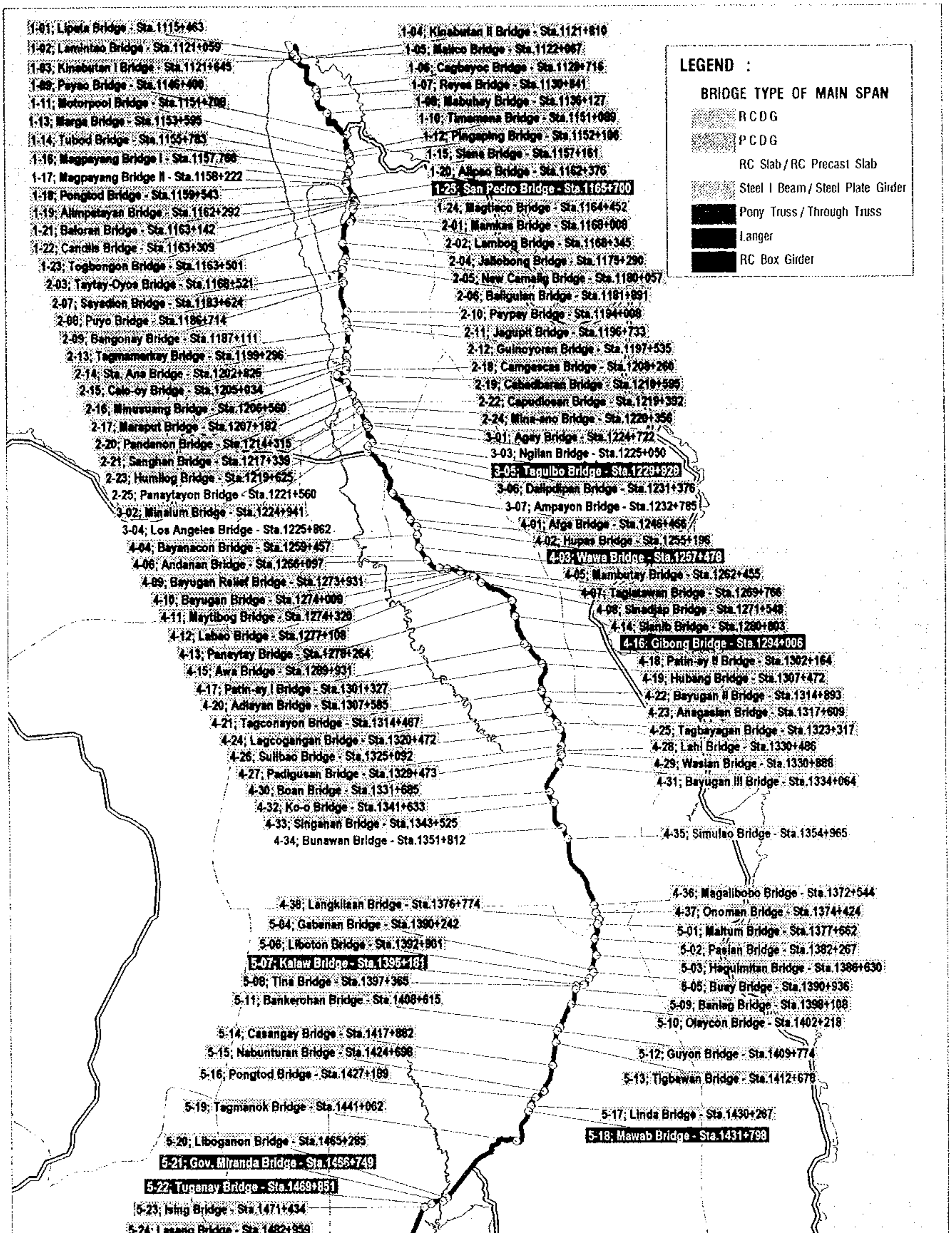


FIGURE 10.1 - 1 LOCATION OF BRIDGES

TABLE 10.1-1 SUMMARY OF BRIDGES (1/3)

Bridge Number	Bridge Name	Station	Bridge Type	Length (m)	Pavement Width (m)	Design Load (t)	Evaluation (see Footnote) (SGSFRBARF)
1-01	Lipata	1115.463	1-Span Steel I Beam	16	7.45	20	CBCCCCACC
1-02	Lamintao	1121.059	1-Span Steel I Beam	25	7.30	20	CBCBCCCCC
1-03	Kinabutan I	1121.645	1-Span Steel I Beam	16	7.30	20	BBCCCCCCC
1-04	Kinabutan II	1121.810	3-Span Steel I Beam	93	7.30	20	CBCCBCACC
1-05	Malico	1122.067	3-Span RC Deck Girder	32	7.50	20	BCCCCCACC
1-06	Cagbayoc	1128.716	1-Span RCDG (*)	21	6.86	20	BCCCCCCCC
1-07	Reyes	1130.841	3-Span RC Deck Girder	28	6.85	20	CCCCCCCCC
1-08	Mabuhay	1136.127	4-Span RC Deck Girder	48	6.80	20	CCCACCCAC
1-09	Payao	1146.400	3-Span RC Deck Girder	30	6.83	20	BCCBBCCCC
1-10	Timamana	1151.089	1-Span RC Deck Girder	15	6.80	20	CCCCBCCCC
1-11	Motorpool	1151.708	1-Span RC Deck Girder	8	7.40	20	CCCCCCCCC
1-12	Pingaping	1152.106	1-Span RC Deck Girder	14	6.80	20	BBCCCCCCC
1-13	Marga	1153.595	1-Span RC Deck Girder	14	6.70	20	BBCCCCCCC
1-14	Tubod	1155.783	1-Span Steel I Beam	25	7.30	20	BBCBBCCCC
1-15	Siana	1157.161	1-Span RC Deck Girder	15	7.36	20	BBCBCCCCC
1-16	Magpayang I	1157.766	3-Span RC Deck Girder	25	6.80	20	BBCCCCCCC
1-17	Magpayang II	1158.222	1-Span Precast Slab	6	6.80	20	ACCCBCCAC
1-18	Pongtod	1158.543	3-Span RC Deck Girder	36	6.80	20	CCCCCCCAC
1-19	Alimpatayan	1162.292	1-Span Steel I Beam	22	7.28	20	BBCACCCCA
1-20	Alipao	1162.376	1-Span RC Deck Girder	14	6.85	20	CBCBCCCCC
1-21	Baloran	1163.142	1-Span RCDG (*)	18	6.80	20	BBCABCCCC
1-22	Candiis	1163.309	1-Span Steel I Beam	15	7.09	20	CBCCBCCCC
1-23	Togbongon	1163.501	1-Span RC Deck Girder	10	6.90	20	AACCCCACC
1-24	Magtiaco	1164.452	6-Span Steel I Beam	186	7.38	20	BBCACCACC
1-25	San Pedro	1165.700	1-Span Pony Truss	45	7.32	20	ABCCCCAAA
2-01	Mamkas	1168.008	4-Span RC Deck Girder	51	6.70	15	BBBCCCAAC
2-02	Lambog	1168.345	1-Span RCDG (*)	24	6.75	15	ACCCCCACC
2-03	Taytay-Oyos	1168.521	1-Span RCDG (*)	21	6.75	15	ABCCCCCCC
2-04	Jaliobong	1175.290	3-Span RC Deck Girder	30	6.69	15	BBCCCACCC
2-05	New Camalig	1180.157	3-Span RC Deck Girder	42	7.36	15	CCCCCCCCC
2-06	Baliguian	1181.891	3-Span RC Deck Girder	28	6.85	15	CBCCCCCCC
2-07	Sayadion	1183.624	1-Span RCDG (*)	18	6.80	15	BCCBCCAAC
2-08	Puyo	1186.714	4-Span Steel I Beam	124	7.35	20	BBCABCAAC
2-09	Bangonay	1187.111	9-Span Steel I Beam	168	7.38	20	CBCABCAAC
2-10	Paypay	1194.008	1-Span RC Deck Girder 2-Span Pony Truss	84	8.52	20	ACCCBCACC
2-11	Jagupit	1196.733	1-Span RCDG (*)	17	6.70	15	BCCCCCCCA
2-12	Guinoyoran	1197.535	1-Span RCDG (*)	21	7.75	15	BBCCCCCCA
2-13	Tagmamarkay	1199.296	3-Span RC Deck Girder	26	7.35	15	CBCCCACCC
2-14	Sta. Ana	1202.825	4-Span Steel I Beam	99	7.35	20	BBCACCCCA
2-15	Calo-oy	1205.034	1-Span RCDG (*)	21	6.80	15	BCCCCCCCC
2-16	Minusuang	1206.560	3-Span RC Deck Girder	28	6.90	15	BBCBCCCCC
2-17	Maraput	1207.182	3-Span RC Deck Girder	28	6.70	15	BCCBCCCCC
2-18	Comagascas	1208.260	3-Span RC Deck Girder	29	6.80	15	ACCBCCCCC
2-19	Cabadbaran	1210.595	6-Span PC Deck Girder	222	7.40	20	BCCACCAAC
2-20	Pandanon	1214.315	3-Span RC Deck Girder	24	6.75	15	ACCCCCCCC
2-21	Sanghan	1217.339	2-Span RC Deck Girder	24	6.80	15	AAAACCAAC
2-22	Capudlosan	1219.392	1-Span RCDG (*)	18	6.80	15	BCCCCCACC
2-23	Humilog	1219.625	1-Span RCDG (*)	18	6.70	15	ABCCCCACC
2-24	Mina-ano	1220.356	2-Span RC Deck Girder	16	6.70	15	BCCCCCCCC
2-25	Panaytayon	1221.560	2-Span Precast Slab	12	6.85	15	BCCBCCCCC
3-01	Agay	1224.722	1-Span Steel I Beam	19	7.42	15	BBCCCCCAA
3-02	Minalum	1224.941	1-Span Steel I Beam	22	7.55	15	CBCCCCCCC
3-03	Ngilan	1225.050	3-Span Precast Slab	18	6.85	15	ACCCCCCCA
3-04	Los Angeles	1225.862	2-Span Precast Slab	12	6.90	15	ACCCCCCCA
3-05	Taguibo	1229.929	1-Span Steel I Beam 1-Span Steel Langer 2-Span Steel I Beam	222	7.45	15	BBCACCCAC

Evaluation :
Item : S = Slab, G = Girder, S = Substructure, F = Foundation, R = Railing,
B = Bearing/Bridge Seat, A = Approach Road, R = River Bank, F = Freeboard

Rating: A = Urgent replacement/repair needed B = Repair needed C = Repair not needed

Note : 1 Span RCDG (*) = 1 Span RC Deck Girder with Cantilevered Spans

TABLE 10.1-1 SUMMARY OF BRIDGES (2/3)

Bridge Number	Bridge Name	Station	Bridge Type	Length (m)	Pavement Width (m)	Design Load (t)	Evaluation (see Footnote) (SGSFRBARF)
3-06	Dalipdipan	1231.376	1-Span RCDG (*)	21	6.70	15	ABCACCCCC
3-07	Ampayon	1232.785	2-Span Precast Slab	12	6.85	15	ACCBBCACC
4-01	Afga	1246.466	1-Span RC Slab 1-Span RC Deck Girder	24	6.80	15	AACBCCCCC
4-02	Hupas	1255.196	1-Span Steel Plate Girder	36	7.25	15	ACCBCCCCA
4-03	Wawa	1257.478	2-Span Steel I Beam 2-Span Through Truss 1-Span Steel I Beam	228	7.45	20	AACABACCC
4-04	Bayanacon	1259.457	4-Span RC Deck Girder	56	6.75	15	ACCCCCCCC
4-05	Mambutay	1262.455	1-Span RCDG (*)	21	6.80	15	ACCBCCCAC
4-06	Andanan	1266.097	12-Span RC Deck Girder	180	6.86	15	ACCACCCCC
4-07	Taglatawan	1269.766	3-Span RC Deck Girder	26	6.76	15	AACBCCCCC
4-08	Sinadjap	1271.548	4-Span RC Deck Girder	50	6.74	15	ABCACCACC
4-09	Bayugan Relief	1273.931	1-Span RC Slab 1-Span RC Deck Girder 1-Span RC Slab	20	6.71	15	AACCCCCCC
4-10	Bayugan	1274.009	4-Span RC Deck Girder	60	6.70	15	AACACCCCC
4-11	Maytibog	1274.320	1-Span RC Slab 1-Span RC Deck Girder 1-Span RC Slab	27	6.70	15	AACACCCCC
4-12	Labao	1277.108	1-Span RCDG (*)	19	6.75	15	ABCCCCCCC
4-13	Panaytay	1278.264	3-Span RC Deck Girder	34	6.70	10	AACACCCCC
4-14	Sianib	1280.803	4-Span RC Deck Girder	53	6.78	15	AACBBCCAC
4-15	Awa	1289.931	1-Span Steel Plate Girder	41	7.40	15	CCCCCCCAC
4-16	Gibong	1294.006	2-Span RC Deck Girder 2-Span RC Box Girder 2-Span RC Deck Girder	121	6.75	15	BBACBCCCC
4-17	Patin-ay I	1301.327	1-Span RC Deck Girder	15	7.33	15	AACBCCACC
4-18	Patin-ay II	1302.164	3-Span RC Deck Girder	24	6.70	15	ABCACCCAC
4-19	Hubang	1307.472	1-Span RC Slab 1-Span RC Deck Girder 1-Span RC Slab	22	6.70	15	ACCBCCACC
4-20	Adlayan	1307.585	1-Span RC Slab 2-Span RC Deck Girder	30	6.75	15	ABCCCCCAC
4-21	Tagconayon	1314.467	1-Span RC Slab 1-Span RC Deck Girder 1-Span RC Slab	24	6.75	15	BBCCCCCCC
4-22	Bayugan II	1314.893	1-Span RC Slab 1-Span RC Deck Girder 1-Span RC Slab	22	6.75	15	BBCCCCCCC
4-23	Anagasian	1317.609	3-Span RC Deck Girder	32	6.70	15	BCCCCCACC
4-24	Lagcogangan	1320.472	1-Span RC Slab 1-Span RC Deck Girder 1-Span RC Slab	22	6.80	15	BAAACCACC
4-25	Tagbayagan	1323.317	3-Span RC Deck Girder	30	6.78	15	CACACCACC
4-26	Sulibao	1325.092	5-Span RC Deck Girder	75	6.78	15	CBCBCCCCC
4-27	Padigusan	1329.473	1-Span RC Slab 1-Span RC Deck Girder 1-Span RC Slab	22	6.80	15	BBCCCCCCC
4-28	Lahi	1330.486	3-Span RC Deck Girder	28	6.70	15	ABCCCCCCC
4-29	Wasian	1330.888	1-Span RC Slab 1-Span RC Deck Girder 1-Span RC Slab	22	6.70	15	AAAABCAAC
4-30	Boan	1331.685	1-Span RC Deck Girder	15	7.45	15	BCCACCCCC
4-31	Bayugan III	1334.064	1-Span RC Slab 1-Span RC Deck Girder 1-Span RC Slab	22	6.80	15	BBCBCCCCC

Evaluation :
Item : S = Slab, G = Girder, S = Substructure, F = Foundation, R = Railing,
B = Bearing/Bridge Seat, A = Approach Road, R = River Bank, F = Freeboard

Rating: A = Urgent replacement/repair needed B = Repair needed C = Repair not needed

Note : 1 Span RCDG (*) = 1 Span RC Deck Girder with Cantilevered Spans

TABLE 10.1-1 SUMMARY OF BRIDGES (3/3)

Bridge Number	Bridge Name	Station	Bridge Type	Length (m)	Pavement Width (m)	Design Load (t)	Evaluation (see Footnote) (SGSFRBARF)
4-32	Ko-o	1341.633	1-Span RC Slab 1-Span RC Deck Girder 1-Span RC Slab	27	6.70	15	BBCCCCCCC
4-33	Singanan	1343.525	1-Span RC Slab 1-Span RC Deck Girder 1-Span RC Slab	24	6.70	15	ABCCCCCCC
4-34	Bunawan	1351.812	1-Span RC Box Girder 1-Span RC Box Girder 1-Span RC Box Girder	73	6.70	15	ABCCACCCC
4-35	Simulao	1354.965	3-Span Steel Plate Girder	137	7.30	20	BCCACCCCC
4-36	Magalibobo	1372.544	1-Span Steel Plate Girder	25	7.25	20	CCCCCCCCC
4-37	Onoman	1374.424	3-Span RC Deck Girder	24	6.70	15	CCCCCCCCC
4-38	Langkilaan	1376.774	1-Span Steel Plate Girder	41	7.35	20	CCCACCCCC
5-01	Maitum	1377.662	1-Span RCDG (*)	19	6.80	15	CCCCCCCCC
5-02	Pasian	1382.267	1-Span Steel Plate Girder	36	7.40	15	CCCCCCCCC
5-03	Haguimitan	1386.630	1-Span RC Slab 1-Span RC Deck Girder 1-Span RC Slab	27	6.80	15	CBCBCCACC
5-04	Gabanan	1390.242	3-Span RC Deck Girder	45	6.80	15	BACACCACC
5-05	Buay	1390.936	5-Span RC Deck Girder	58	6.80	15	BACACCBBB
5-06	Liboton	1392.901	3-Span RC Deck Girder	28	6.80	15	BBCBCCCCC
5-07	Kalaw	1395.181	2-Span RC Deck Girder 3-Span Pony Truss 1-Span RC Deck Girder	111	6.80	15	ABBCCCCCC
5-08	Tina	1397.365	3-Span RC Deck Girder	31	6.85	15	CCCACCACA
5-09	Banlag	1398.108	3-Span RC Deck Girder	27	6.80	15	CCCACCACA
5-10	Olaycon	1402.218	2-Span RC Deck Girder	30	6.80	15	AACABCACC
5-11	Bankerohan	1408.615	1-Span RC Deck Girder	15	7.40	15	CCCACCCCC
5-12	Guyon	1409.774	2-Span RC Deck Girder	21	6.80	15	BCCCCCCCC
5-13	Tigbawan	1412.678	3-Span RC Deck Girder	21	6.80	15	CBCBCCCCC
5-14	Casangay	1417.882	1-Span RC Slab 1-Span RC Deck Girder 1-Span RC Slab	26	6.80	15	BCCCCCCCC
5-15	Nabunturan	1424.698	1-Span RC Deck Girder	15	6.80	15	CCCCCCCCC
5-16	Pongtod	1427.189	1-Span RC Deck Girder	15	6.80	15	CCCACCCCC
5-17	Linda	1430.358	3-Span RC Deck Girder	34	6.80	15	ACCCCCCCC
5-18	Mawab	1431.798	1-Span RC Slab 1-Span RC Box Girder 1-Span RC Slab	32	7.40	15	BCCCCCCCC
5-19	Tagmanok	1441.062	1-Span RC Slab 1-Span RC Deck Girder 1-Span RC Slab	26	6.80	15	BACCCCCCC
5-20	Liboganon	1465.285	3-Span RC Deck Girder	32	6.80	10	BAAACCACC
5-21	Gov. Miranda	1466.749	1-Span RC Box Girder 2-Span Through Truss 1-Span RC Box Girder	146	7.45	15	CCCACCACA
5-22	Tuganay	1469.851	1-Span Through Truss	50	7.40	15	ACCCCCCCC
5-23	Ising	1471.434	1-Span Steel I Beam 1-Span RC Deck Girder	25	7.40	18	AACABCCCC
5-24	Lasang	1482.959	3-Span RC Deck Girder	55	7.40	18	CCCCCCCCC
6-01	Bunawan	1487.404	1-Span RC Deck Girder 1-Span Steel I Beam 1-Span RC Deck Girder	42	7.40	15	ABCCCACCA
6-02	Ilang	1494.420	2-Span RC Deck Girder	18	7.40	20	BCCCCCCCC
6-03	Awad	1495.401	1-Span RC Slab	6	7.50	20	CCCCCCCCC
6-04	Panacan	1497.203	1-Span RCDG (*)	18	7.50	20	CCCCCCCCC
6-05	Davao River	1506.776	5-Span PC Deck Girder	124	8.10	20	CCCACCCCC
6-06	Pangi	1513.763	4-Span PC Deck Girder	99	8.10	20	CCCACCCCC

Evaluation :
Item : S = Slab, G = Girder, S = Substructure, F = Foundation, R = Railing,
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Rating: A = Urgent replacement/repair needed B = Repair needed C = Repair not needed

Note : 1 Span RCDG (*) = 1 Span RC Deck Girder with Cantilevered Spans

TABLE 10.1-2 NUMBER OF BRIDGES BY TYPE , YEAR BUILT AND LOAD CAPACITY

		BRIDGE TYPE OF MAIN SPAN										Remarks
		RC Deck Girder	RC SLAB	RC Pre Cast Slab	RC Box Girder	PC Deck Girder	Steel I-Beam	Steel Plate Girder	Pony Truss	Thru Truss	Steel Langer	Total	
1) Year Built	(Age)												
1950 - 1954	(41 - 45)	8	-	-	-	-	-	-	-	-	-	8 (6.4%)	
1955 - 1959	(36 - 40)	42	-	1	1	-	2	-	1	1	-	48 (38.4%)	Gravel Road Construction
1960 - 1964	(31 - 35)	14	-	2	2	1	2	-	1	-	-	22 (17.6%)	Gravel Road Construction
1965 - 1969	(26 - 30)	10	-	-	-	-	-	-	-	1	-	11 (8.8%)	
1970 - 1974	(21 - 25)	2	-	-	-	-	9	-	-	1	1	13 (10.4%)	PJHL Project
1975 - 1979	(16 - 20)	4	-	1	-	1	2	-	1	-	-	9 (7.2%)	PJHL Project
1980 - 1984	(11 - 15)	-	-	-	-	-	-	1	-	-	-	1 (0.8%)	Jumbo Project
1985 - 1989	(6 - 10)	-	-	-	-	-	-	1	-	-	-	1 (0.8%)	Jumbo Project
1990 - 1994	(0 - 5)	1	1	-	-	1	-	4	-	-	-	7 (5.6%)	Jumbo Project
Unknown		4	-	1	-	-	-	-	-	-	-	5 (4.0%)	
Total		85 (68.0%)	1 (0.8%)	5 (4.0%)	3 (2.4%)	3 (12.0%)	15 (4.8%)	6 (2.4%)	3 (2.4%)	3 (2.4%)	1 (0.8%)	125 (100%)	
2) Load Capacity													
10 Ton		2	-	-	-	-	-	-	-	-	-	2 (1.6%)	
15 Ton		65	-	4	3	-	3	3	1	2	1	82 (65.6%)	
18 Ton		1	-	-	-	-	1	-	-	-	-	2 (1.6%)	
20 Ton		17	1	1	-	3	11	3	2	1	-	39 (31.2%)	
Total		85	1	5	3	3	15	6	3	3	1	125 (100%)	

Load Limit

While DPWH stipulates the design load of 20 tons, the existing bridges are given the following load limits:

10 tons -	2 bridges
15 tons -	82 bridges
18 tons -	2 bridges
20 tons -	39 bridges
Total -	125 bridges

b) Problems of Hydraulic Regime

Insufficient Freeboard

There are 11 bridges in which freeboards are remarkably insufficient causing rivers to flood during high-water. There are two cases in this situation; the elevation of bridge was too low from the beginning in one case and the riverbed has been raised due to sedimentation in the other case. Sometimes, both cases are combined.

Insufficient Length of Bridge

Where approach road embankment encroaches on the stream, the river is flooded due to shortage of discharge capacity at the bridge and the approach road embankment slope is subjected to erosion. This situation is often seen in the Philippines especially on rural roads but there is no remarkable case on the Study Road.

Where span length is too short even if total bridge length is reasonable, piers located at short intervals cause the reduction of discharge capacity. Many bridges on the Study Road are in such situation.

Lateral Scour

Where the river is meandering at the upstream of bridge, the river bank is eroded and the approach road embankment is damaged. This situation is often found in the Study Road.

Local Scour

Abutment ends and pier foundations are subjected to local scour in many bridges on the Study Road.

c) Structural Deterioration

Structural deterioration is observed in many bridges due to various causes such as insufficient structural capacity, passage of overloaded vehicles, collision of vehicles, river stream action, lack of maintenance operation, etc. Structural conditions of the existing bridges are summarized in Table 10.1-3.

TABLE 10.1-3 STRUCTURAL CONDITION OF EXISTING BRIDGES

Component	Class A	Class B	Class C
Slab	42	47	36
Girder	20	49	56
Substructure	5	2	118
Foundation	36	23	66
Railing	1	17	107
Bearing/Bridge Seat	4	-	121
Approach Road	31	1	93
River Bank	18	1	106
Freeboard	13	1	111

Note: Class A : Seriously deteriorated needing urgent repair/replacement.
Class B : Deteriorated but still in operational condition, needing repair to extend usable life.
Class C : Not deteriorated.

d) Lack of Aseismicity

No special aseismatic consideration is given to the existing bridges. Especially, width of bridge seat is insufficient in most bridges. There is a danger of falling in the occurrence of big earthquake in the worst case.