SHRP-P-387

SHRP-LTPP General Pavement Studies: Five-Year Report

William O. Hadley

Texas Research and Development Foundation
Austin, Texas

Strategic Highway Research Program
National Research Council
Washington, DC 1994

SHRP-P-387
ISBN 0-309-05766-3
Product no. 5001

Program Manager: *Neil F. Hawks*
Project Manager: *Neil F. Hawks*
Five-Year Report Production Manager: *A. Robert Raab*
Program Area Secretary: *Cynthia Baker*
Production Editor: *Katharyn L. Bine*

key words:
asphalt concrete pavement
data collection
general pavement studies (GPS)
pavement data collection
pavement design
portland cement concrete pavement

March 1994

Strategic Highway Research Program
National Research Council
2101 Constitution Avenue N.W.
Washington, DC 20418

(202) 334-3774

1.5M/NAP/394

ACKNOWLEDGMENTS

The research described herein was supported by the Strategic Highway Research Program (SHRP). SHRP is a unit of the National Research Council that was authorized by section 128 of the Surface Transportation and Uniform Relocation Assistance Act of 1987.

Appreciation is extended for the cooperative efforts of the SHRP personnel. The author of this report is Dr. William O. Hadley. The work by Karen Benson, Robin High, and Ed Pensock in the General Pavement Studies is gratefully acknowledged. The manuscript was prepared by Jan Zeybel.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

SHRP-LTPP GENERAL PAVEMENT STUDIES (GPS) FIVE-YEAR REPORT

INTRODUCTION

The General Pavement Studies (GPS) are a series of studies selected in-service pavements structured to develop a comprehensive national pavement performance database that meets the objectives of the SHRP Long-Term Pavement Performance Program (SHRP-LTPP). These studies were restricted to pavements that incorporated materials and designs that represent good engineering practice and that have strategic future importance. The studies involved principally interstate and primary state highway pavements. Because of the program's nationwide thrust, the studies were limited to pavements in common use across the United States and did not include some pavement types with excellent performance characteristics but limited applicability (Ref 1).

The purpose of this report is to document the development, evolution, and current status of GPS. During the early stages of GPS, the original experimental designs were reviewed by an Expert Task Group, and modifications were made. Subsequently proposed candidate sites were submitted by participating highway agencies, highway sections were selected, and verification and approval were initiated (Ref 2). When it became clear that additional candidate projects were needed to fill the study cells, revised recruitment guidelines were published and distributed (Ref 3). Considerable effort was expended in these activities, and approximately 800 GPS test sections were verified. The terms "test section" and "section" are used interchangeably in this document to refer to the physical 500 feet of pavement that was actually studied in the GPS program, while the term "project" refers to a particular length of pavement having the same general characteristics, from which the actual test section was selected.

Data collection criteria were developed for each of the various data elements in GPS, including traffic, skid resistance, deflection, profile, distress, environment, material properties, and climate. Some data were collected by states, others by the SHRP regional offices. (The term "state" is used in this document to refer to any of the 50 states, the District of Columbia, Puerto Rico, or any of the 10 Canadian provinces.) All data were entered initially in the Regional Information Management System (RIMS) maintained within the regions. After the completion of regional quality assurance and quality control (QA/QC) checks, the data were transferred to the National Pavement Performance Database for further QA/QC checks in the NIMS (National Information Management System) before public release. The first data release was completed in January 1991; the fourth was completed in July 1992. A data release included all data entered in NIMS that had passed the comprehensive QA/QC checks. This data may be accessed through the Transportation Research Board.

DESCRIPTION OF SHRP REGIONS

The four SHRP regions were selected primarily on the basis of climatic and jurisdictional considerations (Ref 4). The North Atlantic region encompasses the wet-freeze classification, while the Southern region includes both wet-nonfreeze and dry nonfreeze zones. The North Central region is predominately wet-freeze, while the Western region contains both dry-freeze and dry-nonfreeze. The region boundaries were adjusted to correspond to state boundaries as illustrated in Figure 2.1 (Ref 5).

Four regional coordination offices (RCOs) were established to coordinate and communicate SHRP-LTPP-related activities across the United States and Canada. Each region includes a group of states in its jurisdiction, with test sections located throughout the defined area. The RCOs then operated as central data collection and validation centers for pavement section data. Inventory, maintenance, rehabilitation, and traffic data were collected at the state level and then submitted to the appropriate RCO center. The RCOs received these data from the states and collected specific test and monitoring data on the pavement sections.

GPS SAMPLING TEMPLATES

Evolution of GPS

The goal of GPS was to develop a database on materials, traffic, environment, and performance for many different types of pavements. The nine pavement types or studies originally planned for GPS were as follows (Ref 2):

GPS-1: Asphalt concrete (AC) on granular base
GPS-2: AC on stabilized base
GPS-3: Jointed plain concrete pavement (JPCP)
GPS-4: Jointed reinforced concrete pavement (JRCP)
GPS-5: Continuously reinforced concrete pavement (CRCP)
GPS-6: AC overlay of AC pavements
GPS-7: AC overlay of jointed concrete pavement (JCP)
GPS-8: Bonded JCP overlay of concrete pavement
GPS-9: Unbonded JCP overlay of concrete pavement

The preliminary work in the development of GPS was reviewed by the LTPP Advisory Subcommittee on Experimental Design in the fall of 1987. At that time, many of the candidate projects nominated by the states were entered in a database. Those nominated projects that clearly did not meet the requirements of the LTPP program were eliminated from further consideration and were not included in the nomination database. An initial project selection process was undertaken to identify and examine areas of possible statistical

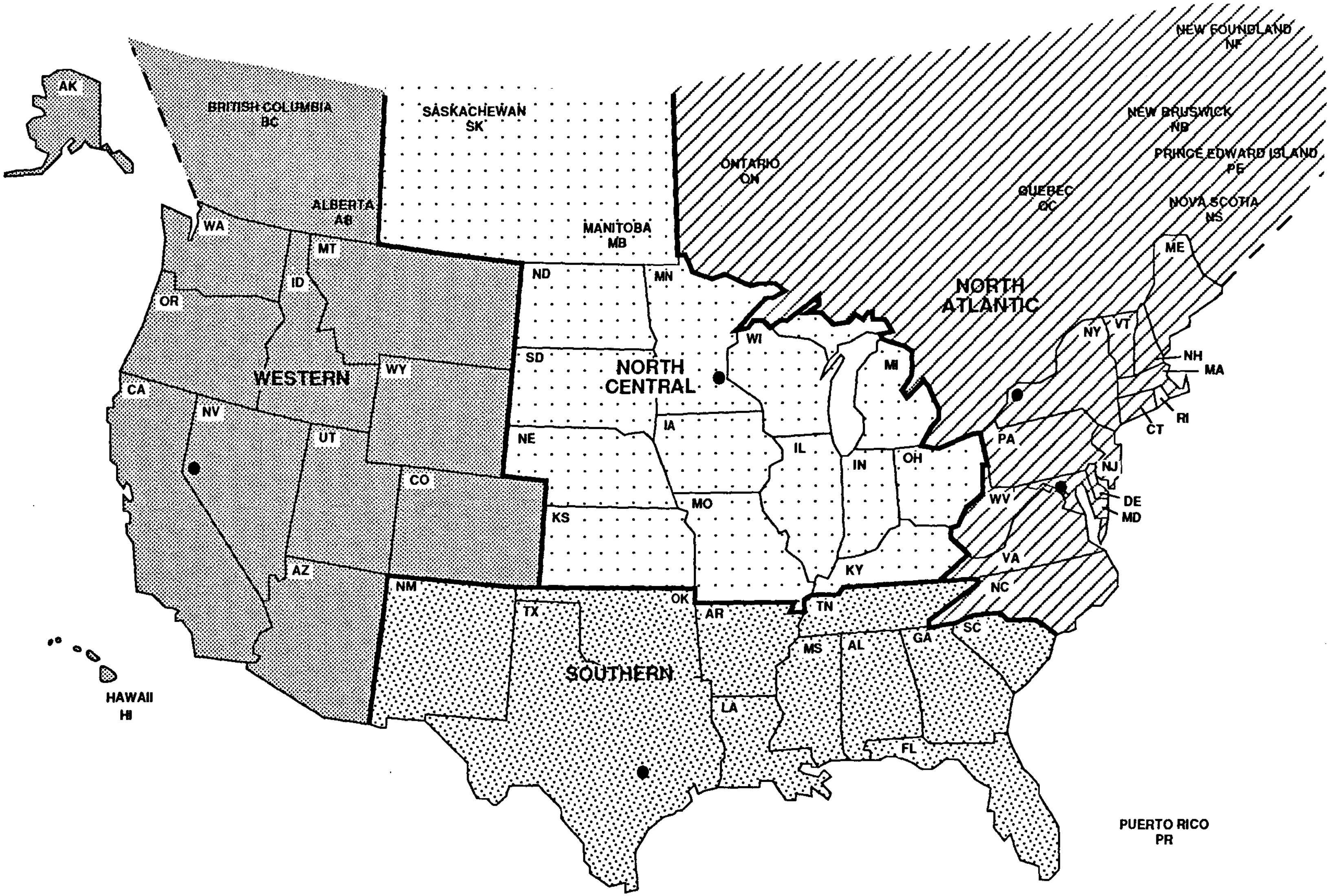


FIGURE 2.1. SHRP-LTPP Regional Boundaries

weakness in GPS. Several revisions to the GPS program were recommended by the Advisory Subcommittee, and further input and proposed revisions were offered by the Expert Task Group on Experimental Design and Analysis (May 1988).

Revisions to the GPS

The principal revisions implemented as a result of these meetings are presented below.

GPS-1 experiment

No significant changes were made to the study of AC on granular base.

GPS-2 experiment

Significant revisions were made to the study of AC on stabilized base. The original study included restrictions on allowable stabilized materials and severely limited the number of candidate projects suitable for the study.

After these restrictions on base types were relaxed to include other types of stabilized base materials, the principal stabilization practices for this study involved those in which the structural characteristics of the material were improved by the cementing action of the binding agent. The term "bound base" was then substituted for the term "stabilized base."

Two classifications of binder types, bituminous and nonbituminous, were defined as factor levels to properly account for a variety of bound base types in the sampling design while maintaining a reasonable number of test sites. Bituminous binders included asphalt cements, cutbacks, emulsions, and road tars; nonbituminous binders included all hydraulic cements, lime, fly ash, natural pozzolans, and combinations thereof. Broadening the list of acceptable binder types allowed the study to include more projects from different states and provinces.

In the original design, subgrade type was restricted to fine-grained soils, and there was no defined factor for traffic rate. Subgrade and traffic rates were then added to the design to make these factors consistent with the factors in other GPS layouts. Since a considerable number of potential projects were located on coarse subgrades, a coarse subgrade type was also included in the design. The same structural factors and levels designated in the original design were maintained, except that asphalt concrete stiffness was treated as a well-distributed covariate rather than a factor.

GPS-3 and 4 experiments

No significant changes were made to the studies of JPCP or JRCP.

GPS-5 experiment

In the study of CRCP, the base type structural factor was deleted, and the percentage of reinforcement was added as a structural factor.

GPS-6 and 7 experiments

The AC overlay studies underwent major revisions. Since the condition of the original pavement before overlay could significantly influence the overlay performance, this condition was added as a factor in the planned overlay experiments (i.e., GPS 6B and 7B). To ensure early overlay performance results, the original AC overlay studies were retained, but a new template for planned overlays was created. The original studies were renamed "existing AC overlay of AC pavement" (GPS-6A) and "existing AC overlay of portland cement concrete (PCC) pavement" (GPS-7A). The other change in the overlay studies involved the addition of CRCP as an original pavement type in GPS-7A.

Separate studies were developed to include original pavement condition as a factor. These studies were named "planned AC overlay of AC pavement" (GPS-6B) and "planned AC overlay of PCC pavement" (GPS-7B). Because the original pavement condition factor was added, AC stiffness was deleted as a design factor in the template to avoid increasing the number of factors and the size of the experiment.

GPS-8 experiment

The study of bonded JCP overlay of concrete pavement was deleted from the GPS program because of a lack of potential projects.

GPS-9 experiment

The original design for the study of unbonded JCP overlay of concrete pavement included two structural factors: overlay thickness and original pavement type. In addition, the experiment included only JPCP and JRCP overlays and was restricted to fine subgrades and high traffic conditions.

Revisions to GPS-9 included the addition of overlay type as a structural factor and the addition of a CRCP as an allowable overlay type. Both coarse and fine subgrade soils and both low and high traffic rates were accepted in the project, although these were not considered design factors. Both existing and planned overlay projects were included in the new sampling template. In addition, the original pavement condition was not included as a design factor. In general, the factors in GPS-9 were minimized to allow for the greatest number of potential projects, since relatively few of these types of projects were available.

With these developments in the GPS program, the following 10 studies evolved (Ref 3):

GPS-1: AC on granular base
GPS-2: AC on bound base
GPS-3: JPCP
GPS-4: JRCP
GPS-5: CRCP
GPS-6A: Existing AC overlay of AC pavement
GPS-6B: Planned AC overlay of AC pavement
GPS-7A: Existing AC overlay of PCC pavement
GPS-7B: Planned AC overlay of PCC pavement
GPS-9: Unbonded PCC overlay of PCC pavement

Design of GPS Program

The various GPS experiments were structured to fulfill the principal goal by developing a comprehensive database containing data on materials, traffic, environmental, and performance for the various types of in-service highway pavements defined for the GPS experiments. The factors deemed to affect performance of each pavement type were selected as a basis for the sampling factorials. The factors were defined as either qualitative (distinct, discrete levels) or quantitative (continuous, numerical levels).

The qualitative factors used in most of the GPS sampling factorials included

- Moisture conditions: wet or dry
- Temperature conditions: freeze or nonfreeze
- Subgrade type: fine or coarse

The lone exception in the general use of subgrade type as a factor was the GPS-9 sampling factorial design, in which the qualitative subgrade type factor was not used. The GPS subgrade classifications and computer database entry codes are listed in Table 2.1.

The moisture and temperature zones defined in LTPP are shown in Figure 2.2. Note that the figure is a general illustration of the environmental zones for the LTPP studies. There can be, and are, inclusions of one zone into another. The environmental zone for each pavement test section is included with the inventory data in NPPDB.

Since the quantitative factors represented continuous functions, midpoints were established from expected numerical ranges so that all values below the midpoint were generally considered low and all values above it high. The quantitative factors varied with each GPS experiment and, in general, included characteristics such as traffic rate in KESALs (i.e., thousands of Equivalent Single Axle Loads) and layer thicknesses. Two distinct levels were defined for all quantitative factors, except that three levels were defined for AC thickness in GPS-1.

TABLE 2.1. Subgrade Soil Description Codes

Soil Description	Code
Fine-grained subgrade soils:	
Clay (liquid limit > 50)	51
Sandy clay	52
Silty clay	53
Silt	54
Sandy silt	55
Clayey silt	56
Coarse-grained subgrade soils:	
Sand	57
Poorly graded sand	58
Silty sand	59
Clayey sand	60
Gravel	61
Poorly graded gravel	62
Clayey gravel	63
Shale	64
Rock	65

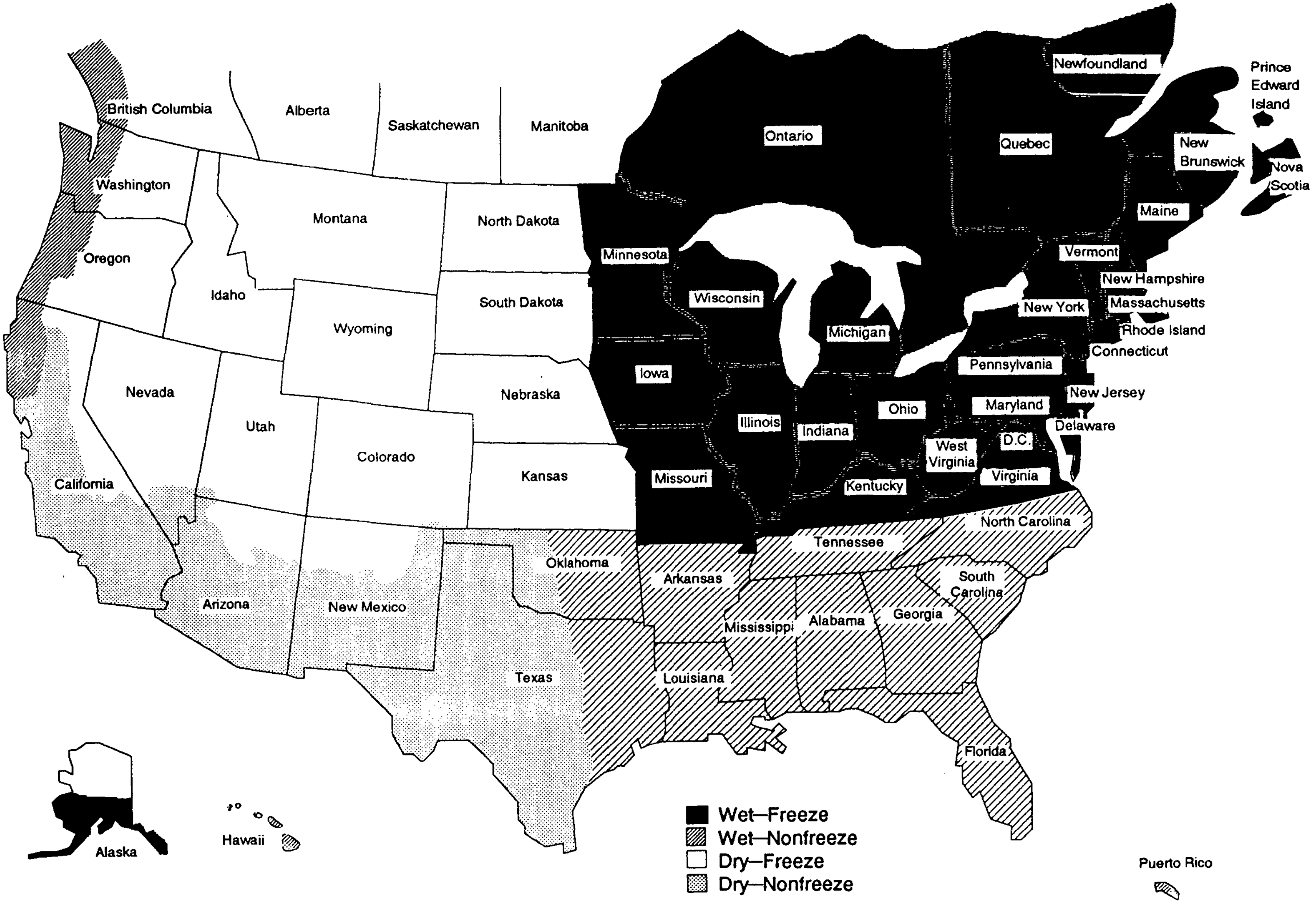


FIGURE 2.2. SHRP-LTPP Environmental Zones

It should be noted that the GPS studies did not conform to requirements for complete orthogonal factorials (factorials with all the cells filled), since some factor combinations represented pavement types that could not be located or simply had not been built by any highway agency. In reality, the GPS studies were not experiments in the classical sense, since the levels of the factors could not be strictly controlled but were defined by actual site conditions (traffic rate, layer thicknesses, etc.). The studies are, therefore, more properly classified as sampling studies. For this reason, the terminology "sampling design templates" was used in place of "experimental design" when referring to the GPS studies.

In addition to the many factors defined and controlled within the sampling designs, there were many other concomitant variables that were essentially uncontrolled but were considered important to pavement performance studies (e.g., prior maintenance, shoulder design). These uncontrolled variables were measured to the greatest extent possible and included in the database for use in data analysis.

Sampling Design Templates

The sampling design templates were developed to illustrate how the individual test sections fit within the overall layout with reference to the levels of qualitative and quantitative factors. The layouts were devised so that all combinations of levels of the design factors would appear in the template. The boxes in the template that represent specific combinations of factor levels are called sampling cells. The factor names are listed in the upper left-hand corner of each template, and the levels of the factors are shown by appended rows and columns.

The sampling template for GPS-1 (AC on granular base) is presented in Figure 2.3. The midpoints of the ranges of the quantitative factors are listed at the bottom of the sampling design. For quantitative factors, the letters "L" and "H" indicate values that are lower and higher than the midpoint (for AC thickness in GPS-1, medium values are indicated by "M"). Qualitative factor levels are defined with the words "wet" and "dry" for moisture conditions, "freeze" and "nonfreeze" for temperature conditions, and the letters "F" and "C" for fine and coarse subgrade types.

A system of design cell codes was established to easily identify where specific test sections fit in each sampling template. A code consists of a one-digit number defining the GPS study number (1 through 9), a dash, and a one- to three-digit number referring to a specific cell in the sampling design template. The codes provided a quick reference to the location of any project in the design layout. For example, a project from GPS-1 with wet moisture conditions, nonfreeze temperature conditions, fine subgrade, low traffic rate, medium AC thickness, high base thickness, and high AC stiffness would be assigned a design cell code of 1-56 (see Figure 2.3), since these factor levels match the characteristics of Cell 56.

Initial cell assignments were based on availability of as-built/design information provided by the responsible highway agency. After the design/construction characteristics of a project were defined in the drilling and sampling program, the cell assignment was subject to change

		MOISTURE	WET								DRY							
		TEMPERATURE	FREEZE				NO FREEZE				FREEZE				NO FREEZE			
		SUBGRADE TYPE	F		C		F		C		F		C		F		C	
AC STIFFNESS	BASE THICKNESS	AC THICKNESS TRAFFIC RATE	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H
L	L	L	1	13	25	37	49	61	73	85	97	109	121	133	145	157	169	181
		H	2	14	26	38	50	62	74	86	98	110	122	134	146	158	170	182
	H	L	3	15	27	39	51	63	75	87	99	111	123	135	147	159	171	183
		H	4	16	28	40	52	64	76	88	100	112	124	136	148	160	172	184
M	L	L	5	17	29	41	53	65	77	89	101	113	125	137	149	161	173	185
		H	6	18	30	42	54	66	78	90	102	114	126	138	150	162	174	186
	H	L	7	19	31	43	55	67	79	91	103	115	127	139	151	163	175	187
		H	8	20	32	44	56	68	80	92	104	116	128	140	152	164	176	188
H	L	L	9	21	33	45	57	69	81	93	105	117	129	141	153	165	177	189
		H	10	22	34	46	58	70	82	94	106	118	130	142	154	166	178	190
	H	L	11	23	35	47	59	71	83	95	107	119	131	143	155	167	179	191
		H	12	24	36	48	60	72	84	96	108	120	132	144	156	168	180	192

Quantitative Factor Midpoints

Traffic rate:	85 KESALs/year
AC stiffness:	650 ksi
Base thickness:	10 inches
AC thickness:	3 and 8 inches

FIGURE 2.3. **Sampling Template and Cell Identification Numbers for GPS-1 (Asphalt Concrete on Granular Base)**

depending on the actual factor values. For example, if the project with an initial assignment of 1-56 was found to have an AC thickness that was low (less than 3 inches) rather than medium (3 to 8 inches), the project would be reassigned to Cell 1-52.

The combination of the sampling design template and a detailed description defined the limits of pavement types, materials, and factor combinations studied in GPS.

The range limits (low/high or low/medium/high) for the quantitative factor midpoints of each sampling template were determined by two methods. The first method, used for many of the variables, was the midpoint method. The nomination database was checked and the median of all values chosen. For example, the AC stiffness factor midpoints were chosen in this manner. By this method, all projects could be divided equally between the two levels (low/high).

Engineering judgment was the second method, used in the definition of the trilevel factors (low/medium/high). This method may not have produced a boundary defined by engineering practice. These judgments were made to provide greater efficiency to the sampling template or to reduce the number of required observations while having a negligible effect on the sampling design.

Detailed descriptions were developed for each of the GPS experiments that defined the required pavement layers and allowable material types for each of the sampling templates. The pavement layers and material types were listed in the descriptions and identified by two-digit code which are presented in Tables 2.2 through 2.4. The subgrade codes are presented in Table 2.1. Detailed descriptions and sampling templates for each of the studies in GPS are presented in the following sections.

GPS-1: Asphalt Concrete on Granular Base

Pavements acceptable for GPS-1 included a dense-graded hot-mix asphalt concrete (HMAC) surface layer (Code 01 of Table 2.2), with or without other HMAC layers (Code 28 of Table 2.3), placed over an untreated granular base layer (Codes 22 and 23 of Table 2.3) or no base layer (Code 21 of Table 2.3). One or more subbase layers (Codes 22–26, 42, and 43 of Table 2.3) could be present but were not required. Two or more consecutive lifts of the same mixture design were treated as one layer. If a treated subgrade (Codes 42 and 43 of Table 2.3) was present, it was designated as a subbase.

"Full-depth" AC pavements were also allowed in this study. This designation was defined as a surface HMAC layer (Code 01 of Table 2.2) combined with one or more subsurface HMAC layers (Code 28 of Table 2.3) to make a minimum total HMAC thickness of 6 inches placed directly on a treated or untreated subgrade. For full-depth AC pavements, a base layer of zero thickness and material classification code for "no base" (Code 21 of Table 2.3) were necessary.

TABLE 2.2. Material Type Codes for Pavement Surface

Material Type	Code
Hot-mix, hot-laid AC dense-graded	01
Hot-mix, hot-laid AC, open-graded (porous friction course)	02
Sand asphalt*	03
PCC (JPCP)	04
PCC (JRCP)	05
PCC (CRCP)	06
PCC (prestressed)*	07
PCC (fiber reinforced)*	08
Plant mix (emulsified asphalt) material, cold-laid*	09
Plant mix (cutback asphalt) material, cold-laid*	10
Single surface treatment*	11
Double surface treatment*	12
Recycled AC*	
Hot-laid central plant mix	13
Cold-laid central plant mix	14
Cold-laid mixed in place	15
Heater scarification/recompaction	16
Recycled PCC*	
JPCP	17
JRCP	18
CRCP	19
Other	20

*Pavements with these surfaces were not allowed as GPS candidates.

TABLE 2.3. Material Type Classification Codes for Base and Subbase

	Code
No base (pavement placed directly on subgrade)	21
Gravel (uncrushed)	22
Crushed stone, gravel,or slag	23
Sand	24
Soil-aggregate mixture (predominantly fine-grained soil)	25
Soil-aggregate mixture (predominantly coarse-grained soil)	26
Soil cement	27
Bituminous bound base or subbase materials	
Dense-graded, hot-laid, central plant mix	28
Dense-graded, cold-laid, central plant mix	29
Dense-graded, cold-laid, mixed in place	30
Open-graded, hot-laid, central plant mix	31
Open-graded, cold-laid, central plant mix	32
Open-graded, cold-laid, mixed in place	33
Recycled AC, plant mix, hot-laid	34
Recycled AC, plant mix, cold-laid	35
Recycled AC, mixed in place	36
Sand asphalt	46
Cement-aggregate mixture	37
Lean concrete (less than 3 sacks cement per cubic yars)	38
Recycled PCC	39
Sand-shell mixture	40
Lime rock, caliche (soft carbonate rock)	41
Lime-treated subgrade soil	42
Cement-treated subgrade soil	43
Pozzolan-aggregate mixture	44
Cracked and seated PCC layer	45
Other	49

TABLE 2.4. Material Type Codes for Thin Seals and Interlayers

	Code
Chip seal coat	71
Slurry seal coat	72
Fog seal coat	73
Woven geotextile	74
Nonwoven geotextile	75
Stress-absorbing membrane interlayer	77
Dense-graded AC interlayer	78
Aggregate interlayer	79
Open-graded AC interlayer	80
Chip seal with modified binder (does not include crumb rubber)	81
Sand seal	82
Asphalt-rubber seal coat (stress absorbing membrane)	83
Sand asphalt	84
Other	85

Seal coats or porous friction courses were permitted on the surface layer, but not in combination with each other (e.g., a porous friction course placed over a seal coat was not acceptable). Seal coats were also permissible on top of granular base layers. At least one layer of dense-graded HMAC was required, regardless of the existence of seal coats or porous friction courses.

Sampling template factors and levels for GPS-1 are summarized below (see Figure 2.2 and Table 2.1):

Moisture:	Wet Dry
Temperature:	Freeze Nonfreeze
Subgrade type:	F = fine C = coarse
Traffic rate:	L = less than or equal to 85 KESALs/year H = greater than 85 KESALs/year
AC stiffness:	L = less than or equal to 650 ksi H = greater than 650 ksi
Base thickness:	L = less than 10.0 inches H = greater than or equal to 10.0 inches
AC thickness:	L = less than 3.0 inches M = 3.0 to 8.0 inches H = greater than 8.0 inches

The sampling template for GPS-1 is shown in Figure 2.3.

GPS-2: Asphalt Concrete on Bound Base

Pavements acceptable for GPS-2 included a dense-graded HMAC surface layer (Code 01 of Table 2.2), with or without other HMAC layers (Code 28 of Table 2.3), placed over a bound base layer (Codes 27—39, 42—44, and 46 of Table 2.3). One or more subbase layers (Codes 22—26, 42, and 43 of Table 2.3) could be present but were not required. Seal coats or porous friction courses were permitted on the surface layer, but not in combination (e.g., a porous friction course placed over a seal coat was not acceptable).

Sampling template factors and levels for GPS-2 are summarized below (see Figure 2.2 and Table 2.1):

Moisture: Wet
Dry

Temperature: Freeze
Nonfreeze

Subgrade type: F = fine
C = coarse

Traffic rate: L = less than or equal to 85 KESALs/year
H = greater than 85 KESALs/year

AC thickness L = less than or equal to 4.5 inches
H = greater than 4.5 inches

Base thickness: L = less than 8.0 inches
H = greater than or equal to 8.0 inches

Binder type: Bituminous treated
Nonbituminous treated

The sampling template for GPS-2 is shown in Figure 2.4.

GPS-3: Jointed Plain Concrete Pavement

Pavements acceptable for GPS-3 included jointed plain (i.e., unreinforced) PCC slabs (Code 04 of Table 2.2) placed over a base layer of any material listed in Table 2.3 except Codes 25 and 45. One or more subbase layers could be present but were not required. Subbase layers could consist of any material listed in Table 2.3. A seal coat was also permissible just above a granular base layer. The joints could include either no load-transfer devices or smooth dowel bars, but jointed slabs with load-transfer devices other than dowel bars were not acceptable. Transverse joint spacing was not a factor in determining candidate sections for this experiment.

Sampling template factors and levels for GPS-3 are summarized below (see Figure 2.2 and Table 2.1):

Moisture: Wet
Dry

Temperature: Freeze
Nonfreeze

Subgrade type: F = fine
C = coarse

			MOISTURE	WET								DRY							
			TEMPERATURE	FREEZE				NO FREEZE				FREEZE				NO FREEZE			
			SUBGRADE TYPE	F		C		F		C		F		C		F		C	
BINDER TYPE	BASE THICKNESS	SURFACE THICKNESS	TRAFFIC RATE	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H
BITUMINOUS	L	L		1	9	17	25	33	41	49	57	65	73	81	89	97	105	113	121
		H		2	10	18	26	34	42	50	58	66	74	82	90	98	106	114	122
	H	L		3	11	19	27	35	43	51	59	67	75	83	91	99	107	115	123
		H		4	12	20	28	36	44	52	60	68	76	84	92	100	108	116	124
NON-BITUMINOUS	L	L		5	13	21	29	37	45	53	61	69	77	85	93	101	109	117	125
		H		6	14	22	30	38	46	54	62	70	78	86	94	102	110	118	126
	H	L		7	15	23	31	39	47	55	63	71	79	87	95	103	111	119	127
		H		8	16	24	32	40	48	56	64	72	80	88	96	104	112	120	128

Quantitative Factor Midpoints

Traffic rate: 85 KESALs/year
AC thickness: 4.5 inches
Base thickness: 8.0 inches

FIGURE 2.4. **Sampling Template and Cell Identification Numbers for GPS-2 (Asphalt Concrete on Bound Base)**

Traffic rate: L = less than 200 KESALs/year
H = greater than or equal to 200 KESALs/year

Dowels: N = no
Y = yes

PCC thickness: L = less than 9.5 inches
H = greater than or equal to 9.5 inches

Base type: Granular
Stabilized

The sampling template for GPS-3 is shown in Figure 2.5.

GPS-4: Jointed Reinforced Concrete Pavement

Pavements acceptable for GPS-4 included jointed reinforced PCC slabs (Code 05 of Table 2.2) with doweled joints spaced less than 20 feet apart. Slabs could rest directly on a layer of any material listed in Table 2.3 except Codes 25 and 45 or on an unstabilized coarse-grained subgrade (Codes 57–65 of Table 2.1). A base layer and one or more subbase layers could be present but were not required. The base and subbase layers could consist of any material listed in Table 2.3.

A seal coat was also permissible just above a granular base layer. JRCP placed directly on a layer of fine-grained soil and aggregate (Code 25 of Table 2.3) or a fine-grained subgrade (Codes 51–56 of Table 2.1) were not considered for this study. JRCPs without load-transfer devices or with devices other than smooth dowel bars at the joints were not acceptable.

Sampling template factors and levels for GPS-4 are summarized below (see Figure 2.2 and Table 2.1):

Moisture: Wet
Dry

Temperature: Freeze
Nonfreeze

Subgrade type: F = fine
C = coarse

Traffic rate: L = less than 200 KESALs/year
H = greater than or equal to 200 KESALs/year

Joint spacing: L = less than or equal to 40 feet
G = greater than 40 feet

MOISTURE			WET								DRY							
TEMPERATURE			FREEZE				NO FREEZE				FREEZE				NO FREEZE			
SUBGRADE TYPE			F		C		F		C		F		C		F		C	
TRAFFIC RATE			L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H
BASE TYPE	PCC THICKNESS	DOWELS																
GRANULAR	L	N	1	9	17	25	33	41	49	57	65	73	81	89	97	105	113	121
		Y	2	10	18	26	34	42	50	58	66	74	82	90	98	106	114	122
	H	N	3	11	19	27	35	43	51	59	67	75	83	91	99	107	115	123
		Y	4	12	20	28	36	44	52	60	68	76	84	92	100	108	116	124
STABILIZED	L	N	5	13	21	29	37	45	53	61	69	77	85	93	101	109	117	125
		Y	6	14	22	30	38	46	54	62	70	78	86	94	102	110	118	126
	H	N	7	15	23	31	39	47	55	63	71	79	87	95	103	111	119	127
		Y	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120	128

Quantitative Factor Midpoints

Traffic rate:	200 KESAL/year
PCC thickness:	9.5 inches

FIGURE 2.5. Sampling Template and Cell Identification Numbers for GPS-3 (Jointed Plain Concrete Pavement)

PCC thickness:	L = less than 9.5 inches H = greater than or equal to 9.5 inches

The sampling template for GPS-4 is shown in Figure 2.6.

GPS-5: Continuously Reinforced Concrete Pavement

Pavements acceptable for GPS-5 included continuously reinforced PCC pavements (Code 06 of Table 2.2) placed directly on a layer of any material listed in Table 2.3 except Codes 25 and 45 or on an unstabilized coarse-grained subgrade (Codes 57—65 of Table 2.1). One or more subbase layers could be present but were not required. Subbase layers could consist of any material listed in Table 2.3. A seal coat was also permissible just above a granular base layer.

Sampling template factors and levels for GPS-5 are summarized below (see Figure 2.2 and Table 2.1).

Moisture:	Wet Dry
Temperature:	Freeze Nonfreeze
Subgrade type:	F = fine C = coarse
Traffic rate:	L = less than 300 KESALs/year H = greater than or equal to 300 KESALs/year
Percentage reinforcement:	L = less than or equal 0.61% G = greater than 0.61%
PCC thickness:	L = less than 8.5 inches H = greater than or equal to 8.5 inches

The sampling template for GPS-5 is shown in Figure 2.7.

GPS-6: Asphalt Concrete Overlay of Asphalt Concrete Pavement

Pavements acceptable for GPS-6A and 6B included a dense-graded HMAC surface layer (Code 01 of Table 2.2), with or without other HMAC layers (Code 28 of Table 2.3), placed over an existing HMAC pavement meeting the requirements of GPS-1 or 2.

MOISTURE		WET								DRY							
TEMPERATURE		FREEZE				NO FREEZE				FREEZE				NO FREEZE			
SUBGRADE TYPE		F		C		F		C		F		C		F		C	
TRAFFIC RATE		L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H
PCC THICKNESS	JOINT SPACING																
L	L	1	5	9	13	17	21	25	29	33	37	41	45	49	53	57	61
	H	2	6	10	14	18	22	26	30	34	38	42	46	50	54	58	62
H	L	3	7	11	15	19	23	27	31	35	39	43	47	51	55	59	63
	H	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64

Quantitative Factor Midpoints

Traffic rate:	200 KESALs/year
Joint spacing:	40 feet
PCC thickness:	9.5 inches

FIGURE 2.6. Sampling Template and Cell Identification Numbers for GPS-4 (Jointed Reinforced Concrete Pavement)

	MOISTURE	WET								DRY							
	TEMPERATURE	FREEZE				NO FREEZE				FREEZE				NO FREEZE			
	SUBGRADE TYPE	F		C		F		C		F		C		F		C	
	TRAFFIC RATE	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H
PCC THICKNESS	% REINFORCEMENT																
L	L	1	5	9	13	17	21	25	29	33	37	41	45	49	53	57	61
	H	2	6	10	14	18	22	26	30	34	38	42	46	50	54	58	62
H	L	3	7	11	15	19	23	27	31	35	39	43	47	51	55	59	63
	H	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64

Quantitative Factor Midpoints

Traffic rate:	300 KESALs/year
Percentage reinforcement:	0.61
PCC thickness:	8.5 inches

FIGURE 2.7. **Sampling Template and Cell Identification Numbers for GPS-5 (Continuously Reinforced Concrete Pavement)**

The designation "6A" refers to sections that were existing overlaid pavements when accepted into the GPS program. The designation "6B" refers to sections for which a planned overlay of existing pavement was undertaken after the section had been either accepted into GPS-1 or 2 or specifically selected for direct inclusion in GPS-6B.

Seal coats or porous friction courses were permitted on the surface layer, but not in combination. Fabric interlayers (Codes 74 and 75 of Table 2.4) and stress-absorbing membrane interlayers (SAMIs) (Code 77 of Table 2.4) were permitted between the original surface and the overlay. The total thickness of HMAC used in the overlay was to be at least 1.0 inch. Pavements overlaid more than once since originally constructed were not acceptable.

Sampling template factors and levels for GPS-6A are summarized below (see Figure 2.2 and Table 2.1):

Moisture:	Wet Dry
Temperature:	Freeze Nonfreeze
Subgrade type:	F = fine C = coarse
Traffic rate:	L = less than 130 KESALs/year H = greater than or equal to 130 KESALs/year
Original pavement structural number:	L = less than 3.6 H = greater than or equal to 3.6
Overlay stiffness:	L = less than or equal to 650 ksi H = greater than 650 ksi
Overlay thickness:	L = less than or equal to 2.5 inches H = greater than 2.5 inches

Sampling template factors and levels for GPS-6B are summarized below (see Figure 2.2 and Table 2.1):

Moisture:	Wet Dry
Temperature:	Freeze Nonfreeze
Subgrade type:	F = fine C = coarse

Traffic rate:	L = less than 130 KESALs/year H = greater than or equal to 130 KESALs/year
Original pavement condition:	B = bad G = good
Original pavement structural number:	L = less than 3.6 H = greater than or equal to 3.6
Overlay thickness:	L = less than or equal to 2.5 inches H = greater than 2.5 inches

The sampling templates for GPS-6A and 6B are shown in Figures 2.8 and 2.9.

GPS-7: Asphalt Concrete Overlay of Portland Cement Concrete Pavement

Pavements acceptable for GPS-7A and 7B included a dense-graded HMAC surface layer (Code 01 of Table 2.2), with or without other HMAC layers (Code 28 of Table 2.3), placed over an existing pavement meeting the requirements of GPS-3, 4, or 5.

The designation "7A" refers to sections that were existing overlaid pavements when accepted into the GPS program. The designation "7B" refers to sections for which a planned overlay of existing pavement was undertaken after the section had been either accepted in the GPS-3, 4, or 5 experiments or specifically selected for direct inclusion in GPS-7B.

The slab could be supported on any combination of the base and subbase layers indicated in Table 2.3 except Codes 25 and 45. The existing concrete slab could also have been placed directly on lime- or cement-treated fine- or coarse-grained subbase (Codes 27, 42, and 43 of Table 2.3) or on untreated coarse-grained subgrade (Codes 57–65 of Table 2.1). Slabs placed directly on untreated fine-grained subgrade (Codes 51–56 of Table 2.1) were not acceptable.

Seal coats or porous friction courses were permitted on the surface layer, but not in combination. Fabric interlayers (Codes 74 and 75 of Table 2.4) and SAMIs (Code 77 of Table 2.4) were permitted between the original surface (concrete) and the overlay. Overlaid pavements involving aggregate interlayers (Code 79 of Table 2.4) or open-graded AC interlayers (Code 80 of Table 2.4) were not considered for this study. The total thickness of HMAC used in the overlay was to be at least 1.5 inches. Pavements overlaid more than once since originally constructed were not acceptable.

Sampling template factors and levels for GPS-7A are summarized below (see Figure 2.2 and Table 2.1):

Moisture:	Wet Dry

		MOISTURE	WET								DRY							
		TEMPERATURE	FREEZE				NO FREEZE				FREEZE				NO FREEZE			
		SUBGRADE TYPE	F		C		F		C		F		C		F		C	
		TRAFFIC RATE	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H
ORIGINAL PVT. STRUCTURAL NO.	OL STIFFNESS	OL THICKNESS																
L	L	L	1	9	17	25	33	41	49	57	65	73	81	89	97	105	113	121
		H	2	10	18	26	34	42	50	58	66	74	82	90	98	106	114	122
	H	L	3	11	19	27	35	43	51	59	67	75	83	91	99	107	115	123
		H	4	12	20	28	36	44	52	60	68	76	84	92	100	108	116	124
H	L	L	5	13	21	29	37	45	53	61	69	77	85	93	101	109	117	125
		H	6	14	22	30	38	46	54	62	70	78	86	94	102	110	118	126
	H	L	7	15	23	31	39	47	55	63	71	79	87	95	103	111	119	127
		H	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120	128

Quantitative Factor Midpoints

Traffic rate:	130 KESALs/year
Original pavement structural number:	3.6
Overlay stiffness:	650 ksi
Overlay thickness:	2.5 inches

FIGURE 2.8. Sampling Template and Cell Identification Numbers for GPS-6A (Existing Asphalt Concrete Overlay of Asphalt Concrete Pavement)

		MOISTURE	WET								DRY							
		TEMPERATURE	FREEZE				NO FREEZE				FREEZE				NO FREEZE			
		SUBGRADE TYPE	F		C		F		C		F		C		F		C	
ORIGINAL PVT. CONDITION LEVEL	ORIGINAL PVT. STRUCTURAL NO.	OL THICKNESS \ TRAFFIC RATE	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H
L	L	B	1	9	17	25	33	41	49	57	65	73	81	89	97	105	113	121
		G	2	10	18	26	34	42	50	58	66	74	82	90	98	106	114	122
	H	B	3	11	19	27	35	43	51	59	67	75	83	91	99	107	115	123
		G	4	12	20	28	36	44	52	60	68	76	84	92	100	108	116	124
H	L	B	5	13	21	29	37	45	53	61	69	77	85	93	101	109	117	125
		G	6	14	22	30	38	46	54	62	70	78	86	94	102	110	118	126
	H	B	7	15	23	31	39	47	55	63	71	79	87	95	103	111	119	127
		G	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120	128

Quantitative Factor Midpoints

Traffic rate:	130 KESALs/year
Original pavement structural number:	3.6
Overlay thickness:	2.5 inches

FIGURE 2.9. Sampling Template and Cell Identification Numbers for GPS-6B (Planned Asphalt Concrete Overlay of Asphalt Concrete Pavement)

Temperature:	Freeze Nonfreeze
Subgrade type:	Fine Coarse
Traffic rate:	L = less than 300 KESALs/year H = greater than or equal to 300 KESALs/year
Original pavement type:	JPCP JRCP CRCP
Overlay stiffness:	L = less than or equal to 650 ksi H = greater than 650 ksi
Overlay thickness:	L = less than 3.5 inches H = greater than or equal to 3.5 inches

Sampling template factors and levels for GPS-7B are summarized below (see Figure 2.2):

Moisture:	Wet Dry
Temperature:	Freeze Nonfreeze
Subgrade type:	F = fine C = coarse
Traffic rate:	L = less than 300 KESALs/year H = greater than or equal to 300 KESALs/year
Original pavement condition"	B = bad G = good
Overlay thickness:	L = less than 3.5 inches H = greater than or equal to 3.5 inches
Original pavement type:	JPCP JRCP CRCP

The sampling templates for GPS-7A and 7B are shown in Figures 2.10 and 2.11.

		MOISTURE	WET								DRY							
		TEMPERATURE	FREEZE				NO FREEZE				FREEZE				NO FREEZE			
		SUBGRADE TYPE	F		C		F		C		F		C		F		C	
		TRAFFIC RATE	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H
OL THICKNESS	OL STIFFNESS	EXISTING PVT. TYPE																
L	L	JPCP	1	13	25	37	49	61	73	85	97	109	121	133	145	157	169	181
		JRCP	2	14	26	38	50	62	74	86	98	110	122	134	146	158	170	182
		CRCP	3	15	27	39	51	63	75	87	99	111	123	135	147	159	171	183
	H	JPCP	4	16	28	40	52	64	76	88	100	112	124	136	148	160	172	184
		JRCP	5	17	29	41	53	65	77	89	101	113	125	137	149	161	173	185
		CRCP	6	18	30	42	54	66	78	90	102	114	126	138	150	162	174	186
H	L	JPCP	7	19	31	43	55	67	79	91	103	115	127	139	151	163	175	187
		JRCP	8	20	32	44	56	68	80	92	104	116	128	140	152	164	176	188
		CRCP	9	21	33	45	57	69	81	93	105	117	129	141	153	165	177	189
	H	JPCP	10	22	34	46	58	70	82	94	106	118	130	142	154	166	178	190
		JRCP	11	23	35	47	59	71	83	95	107	119	131	143	155	167	179	191
		CRCP	12	24	36	48	60	72	84	96	108	120	132	144	156	168	180	192

Quantitative Factor Midpoints

Traffic rate:	300 KESALs/year
Overlay stiffness:	650 ksi
Overlay thickness:	3.5 inches

FIGURE 2.10. Sampling Template and Cell Identification Numbers for GPS-7A (Existing Asphalt Concrete Overlay of Portland Cement Concrete Pavements)

		MOISTURE	WET								DRY							
		TEMPERATURE	FREEZE				NO FREEZE				FREEZE				NO FREEZE			
		SUBGRADE TYPE	F		C		F		C		F		C		F		C	
		TRAFFIC RATE	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H
ORIG. PVT. TYPE	OL THICKNESS	ORIG. PVT. COND. LEVEL																
JPCP	L	B	1	13	25	37	49	61	73	85	97	109	121	133	145	157	169	181
		G	2	14	26	38	50	62	74	86	98	110	122	134	146	158	170	182
	H	B	3	15	27	39	51	63	75	87	99	111	123	135	147	159	171	183
		G	4	16	28	40	52	64	76	88	100	112	124	136	148	160	172	184
JRCP	L	B	5	17	29	41	53	65	77	89	101	113	125	137	149	161	173	185
		G	6	18	30	42	54	66	78	90	102	114	126	138	150	162	174	186
	H	B	7	19	31	43	55	67	79	91	103	115	127	139	151	163	175	187
		G	8	20	32	44	56	68	80	92	104	116	128	140	152	164	176	188
CRCP	L	B	9	21	33	45	57	69	81	93	105	117	129	141	153	165	177	189
		G	10	22	34	46	58	70	82	94	106	118	130	142	154	166	178	190
	H	B	11	23	35	47	59	71	83	95	107	119	131	143	155	167	179	191
		G	12	24	36	48	60	72	84	96	108	120	132	144	156	168	180	192

Quantitative Factor Midpoints

Traffic rate:	300 KESALs/year
Overlay thickness:	3.5 inches

FIGURE 2.11. Sampling Template and Cell Identification Numbers for GPS-7B (Planned Asphalt Concrete Overlay of Portland Cement Concrete Pavement)

GPS-9: Unbonded Portland Cement Concrete Overlay of Portland Cement Concrete Pavement

Pavements acceptable for GPS-9 included unbonded JPCP, JRCP, or CRCP overlays (Codes 04, 05, and 06 in Table 2.2) with a thickness of 5 inches or more placed over an existing JPCP, JRCP, or CRCP pavement. An interlayer (Codes 71, 77—80, and 85 of Table 2.4) used to prevent bonding of the two slabs was required. The overlaid concrete pavement could rest on any of the base and subbase types listed in Table 2.3 or directly on the subgrade.

Sampling template factors and levels for GPS-9 are summarized below (see Figure 2.2 and Table 2.1):

Moisture:	Wet Dry
Temperature:	Freeze Nonfreeze
Overlay thickness:	L = less than 7.5 inches H = greater than or equal to 7.5 inches
Original pavement type:	JPCP JRCP CRCP
Overlay type:	JPCP JRCP CRCP

The sampling template for GPS-9 is shown in Figure 2.12.

PROJECT RECRUITMENT

In the early stages of the SHRP-LTPP program, GPS consisted of nine separate studies: five for original pavements and four for first-time rehabilitated pavements. The designs for each study were called factorial sampling templates, and the cells represented all possible combinations of the design factor levels. The sampling units identified by each cell were the test sections that satisfied the GPS design specifications.

Preliminary analytical studies indicated that two sections should be selected to fit the characteristics of each design cell. It was recognized that a very large number of sections would be required to completely fill the sampling designs, which could include six or seven factors for each pavement type and two sections for each combination of factors. Fractional designs were considered but not recommended, for reasons related to the difficulty of locating specific types of projects at the expense of omitting others readily available.

		MOISTURE	WET		DRY	
		TEMPERATURE	F	NF	F	NF
OL TYPE	ORIG. PVT. TYPE	OL THICKNESS				
JPCP	JPCP	L	1	19	37	55
		H	2	20	38	56
	JRCP	L	3	21	39	57
		H	4	22	40	58
	CRCP	L	5	23	41	59
		H	6	24	42	60
JRCP	JPCP	L	7	25	43	61
		H	8	26	44	62
	JRCP	L	9	27	45	63
		H	10	28	46	64
	CRCP	L	11	29	47	65
		H	12	30	48	66
CRCP	JPCP	L	13	31	49	67
		H	14	32	50	68
	JRCP	L	15	33	51	69
		H	16	34	52	70
	CRCP	L	17	35	53	71
		H	18	36	54	72

Quantitative Factor Midpoints

Overlay thickness: 3.5 inches

FIGURE 2.12. Sampling Template and Cell Identification Numbers for GPS-9 (Unbonded Portland Cement Concrete Overlay of Portland Cement Concrete Pavement)

Initial Recruitment

In the initial recruitment process for the LTPP program, approximately 2200 candidate projects were submitted by all 50 states, the District of Columbia, Puerto Rico, and all 10 provinces of Canada. This set of projects conforming to the GPS sampling templates essentially defined the population of pavement sections from which an appropriate sample could be selected. The projects submitted by each highway agency were assumed to be representative of the highways that exist throughout each state or province. In addition, the entire range of condition levels was to be represented in the set. It was emphasized that pavements that exhibited the best performance were not to be submitted to the exclusion of pavements with poor or average performance.

To complete the sampling templates, 500-foot test sections were located and identified within the existing pavement projects. When a suitable section was found, it was then classified as "approved" and assigned to the proper cell of the design factorials. After approval, the various data collection activities were scheduled. On the other hand, a section that did not satisfy the GPS requirements was excluded from further consideration, and the highway agencies were notified of this determination.

Selection of test sections involved assimilating from available historical records the best estimate for each design factor and then assigning sections to each cell of each sampling design template. The rationale for selecting two or more sections per cell was related to the inference space of a particular GPS experiment. This approach extended the inference space beyond that defined by the basic design factors by increasing the ability to analyze other types of information (factors not included in the sampling designs). For example, as part of the initial recruitment process, the original candidate projects were screened so that whenever possible, different states or provinces were represented in each cell. The selection criteria also included age of the pavement so that two sections in a cell that had the same traffic factor level could represent different distributions of cumulative traffic loads.

Additional Recruitment

After the initial effort was complete, several design cells still had no identified candidate projects. Because of this situation, a major evaluation of the sampling designs was initiated. Templates were modified, design parameters were revised, allowable materials were added, and selection criteria were amended. All participating highway agencies were strongly encouraged to recruit additional projects.

The additional project recruitment emphasized two main areas. The first involved efforts to fill the incomplete high-priority missing cells in the basic unmodified experiments (GPS-1, 3, 4, and 5). Unfilled cells in the factorials were assigned priorities based on their potential contribution to the results of each study. Although emphasis was placed on locating projects for these high-priority cells, project nominations were accepted for any cell with fewer than two selected projects.

The second area of emphasis involved filling the cells in the modified GPS studies (GPS-2, 6B, 7B, and 9) with new projects. For the study of AC on bound base (GPS-2), nominations were requested for bound-base pavements conforming to the modified criteria. For the overlay studies (GPS-6B, 7B, and 9), nominations were requested for projects scheduled to be overlaid in 1989 or 1990. The objective was to inspect the pavement before overlay to determine the pavement condition for use in the performance analysis of the overlay. Projects including existing overlays were no longer sought unless an agency had enough pavement information to allow the quantification of condition before overlay.

Summaries describing the results of initial recruitment and identifying important types of test sections missing from the sampling templates were provided to the states and provinces and to the regional coordination contractors for use in further recruitment. These documents were provided to prevent the submission of additional projects with characteristics already contained in the factorials. An intensive search was then undertaken to locate test sections with characteristics corresponding to the unfilled portions of the sampling design templates. Nevertheless, it was understood that not all deficiencies in the designs could be eliminated, since some combinations of factor levels represented rarely constructed highway structures under extreme environmental and load conditions (e.g., thin flexible surface layers in high traffic areas or JRCP in the western United States).

The following figures show the results of all recruitment activity at the time of the fourth NIMS data release (July 1992). Figures 2.13 through 2.22 present approved and selected GPS sections by sampling template and design cell. Standard two-letter state and province abbreviations are used to indicate the section locations.

PROJECT APPROVAL

Before a pavement test section was approved for assignment to GPS, a recruited project was first selected as a potential project and then verified in an inspection. The term "test section" or "section" was used to refer to the actual 500 feet of pavement length included in a particular GPS experiment, while "project" referred to a length of pavement having the same general characteristics, from which the test section was selected. The processes of selection, verification, and approval are discussed in this section.

Project Selection

The first step in project selection was for the participating highway agencies to submit candidate projects for inclusion in the SHRP-LTPP program. The highway agencies submitted data forms that included information on critical site characteristics, pavement configuration, and traffic composition for each candidate project. These forms, called "candidate project recruitment data forms" (Figures 2.23 through 2.26), were submitted to an RCO for review. If the information provided on the data forms matched one of the GPS sampling design templates, the forms were submitted to the technical assistance contractor for further review and possible selection. The data from these forms were entered in a

		MOIST	Wet								Dry							
		TEMP	Freeze				NonFreeze				Freeze				Nonfreeze			
		SUBGRADE	F		C		F		C		F		C		F		C	
		TRAFFIC	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H
AC THK	BASE THK	AC STIFF																
L	L	L			MN*			TX*	FL*				WA* WY*	SA*	TX*		TX*	TX*
		H					SC* TN*		FL* SC*	FL* AL* FL* FL*					TX*		TX* AZ*	
	H	L	MI*		MI* AK*		TX*	TX*	TX* TX*		MT* WA*		AK*		TX* TX*	TX* TX*	TX*	TX* TX*
		H			NF* NF*	NF*		TX* NC*	FL* FL*	FL* FL*	CO* MT*		WA*		TX*			
M	L	L	ME* MI*		MN* MN* MN*		NC* NC*	NC* TX*	TN*	FL* TX*	NE*	AB*	UT* ID*	ID*	TX*	TX*	NM* TX*	TX* AZ*
		H	VA* MO*	NJ* ON*	MI* KY*	MI* ON*	AL* SC*	GA* SC*	GA*	FL* AL* GA*	WA* NV*		WY* NV* UT*		TX* CA*		NM*	AZ* TX*
	H	L	ID* VT* ME*	QB* QB*	PE* AK* ME*	NB QB*	TX* NC* HI*	NC* NC*	FL*	TX FL*	CO* MB* CO*	CO* AB*	ID* BC* ID*	AB* NM* ID* AK*		TX* TX*	TX* CA*	TX*
		H	NJ* PA*	ON*	MA* CT*	NJ*	NC* HI*	NC*	AL* HI*	NC FL*	SD*			WA*	AZ* CA*		AZ* CA*	AZ*
H	L	L	KY* MO*	MO* IA*	MN* MN* MN*	MN* MN*	TX* OK*	OK* TN*	WA*	AL*	KS* KS*	SA*		ID*	OK*		TX* AZ*	AZ* AZ* AZ*
		H	IN* IL*	IN* IL*		KY* VA*	MS* GA*	AL* MS*	NC* MS*	NC*		NM* UT*	KS* ID*			AZ*	AZ*	AZ* AZ* AZ*
	H	L		ME* PA*	PE*	ID* NH*		TX* TX*								TX*		TX*
		H	NB* VT* NY* PA*	MA* ME*		NJ* MA*		NC* TX*								TX*	AZ*	

Quantitative Factor Midpoints

Traffic rate:	85 KESAL/year
AC stiffness:	650 ksi
Base thickness:	10 inches
AC thickness:	3 and 8 inches

FIGURE 2.13. Approved (*) and Selected Sections for GPS-1 (Asphalt Concrete on Granular Base)

		MOIST	Wet								Dry							
		TEMP	Freeze				Nonfreeze				Freeze				Nonfreeze			
		SUBGRADE	F		C		F		C		F		C		F		C	
BINDER	BASE THK	AC THICK / TRAFFIC	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H
BITUMINOUS	L	L	NY* QB* IA*		NY* PE* MD*	NJ*	TX* AL* TN*	OK* AL*	TN* FL* GA*	PR* AL*	NM*			BC* NV*	TX* OK*	OK* OK*	OK*	
		H		IN* ON*	WV*			TN*	TN*		NM*	NM*		NV*				NV*
	H	L				NJ*	TN*	FL*	FL* FL*	PR* GA* GA*	CO*	MT* MB*				OK*		
		H		IN*				AR*		AR*						TX*		AZ* AZ*
NON BITUMINOUS	L	L					MS* AR* CA*	NC* CA*	GA* MS*		ND*		WY*	WY*				CA* CA*
		H	VA* VA*	MD* MD*	MD*	DE*	AR* MS*	CA* TN*	GA* MS*	MS* MS*	AB*				CA*		CA*	
	H	L	ON*	ON*			NC* NC* TX*	OR*	TX* GA*	TX*	WY*	WY*	WY* WY*	WY*		CA* CA* CA*	TX*	CA*
		H				NJ*	GA*	LA* CA* NC*	TX*	TX*		CA* WY*				OK* CA*		CA*

Quantititve Factor Midpoints:

Traffic rate:	85 KESAL/year
Surface thickness:	4.5 inches
Base thickness:	8.0 inches

FIGURE 2.14. Approved (*) and Selected Sections for GPS-2 (Asphalt Concrete on Stabilized Base)

		MOIST	Wet								Dry							
		TEMP	Freeze				Nonfreeze				Freeze				Nonfreeze			
		SUBGRADE	F		C		F		C		F		C		F		C	
BASE TYP	PCC THK	DOWELS / TRAFFIC	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H
GRANULAR	L	N	IA WI*	WI* WI* QB*	WI* NB*	WI* WI*		WA*	WA* PR*	WA*	NE* ND*		SD* ND*	WA* WA* ID*				
		Y	IN* MN*	QB* QB* WI*	MI* MN*		GA* GA*	NC*	FL*		SD*						NM*	
	H	N	IA*	WI* WI*	WI*			PR*			SD* SD* MB* WA*	SD* NE*	SD* WA*	WY* NE*				AZ*
		Y	IA ME*	KY* PA*	ME*			GA* AL*		FL*		CO*				TX*		
STABILIZED	L	N	IA	WI* WI*	MI* QB*		OK* OK*	OK* NC*	FL* FL*	FL* CA*	KS*		NE* CO*	NV* CA*	CA* OK*	CA*	CA* CA*	CA* NV*
		Y	IN* OH*	PA* WI* IA*			NC* TX*	MS* NC*	FL*	MS*		UT*						
	H	N						GA* GA*		GA* SC*	KS*	KS* SD* UT*		UT* NV* UT* NE*		CA* CA*	CA*	CA*
		Y	IA* IN*	IA* IN*		IA*	AR*	TX* NC*	GA*	FL* GA*				ID*			AZ*	

Quantitative Factor Midpoints

Traffic rate: 200 KESAL/year

PCC thickness: 9.5 inches

FIGURE 2.15. Approved (*) and Selected Sections for GPS-3 (Jointed Plain Concrete Pavement)

MOIST		Wet								Dry							
TEMP		Freeze				Nonfreeze				Freeze				Nonfreeze			
SUBGRADE		F		C		F		C		F		C		F		C	
TRAFFIC		L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H
PCC THK	JOINT SPC																
L	L	IL* MN*	IN* MN*	CT* MN* MN*	MN* MN*						KS*	KS*					
	H	MI* NY*	OH* MO* MO*	NY* DE*	NJ*	MS* AR*	AR*	AR*	AR*	KS*	KS* NE*						
H	L		IN* IL*	MN* WV* OH*	MN* CT*	TX* TX*	AL*				KS* KS*						
	H	MO* PA*	KY* PA* WV*	DE*	MO*	LA* TX*	AR* AL* TX*		TX*								

Quantitative Factor Midpoints:

Traffic rate: 200 KESAL/year

Joint spacing: 40 feet

PCC thickness: 9.5 inches

FIGURE 2.16. Approved (*) and Selected Sections for GPS-4 (Jointed Reinforced Concrete Pavement)

	MOIST	Wet								Dry							
	TEMP	Freeze				Nonfreeze				Freeze				Nonfreeze			
	SUBGRADE	F		C		F		C		F		C		F		C	
	TRAFFIC	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H
PCC THK	PCT REINF																
L	L	IL* IN*	MO* IA*	DE* WI*	VA* IL* IA*	AR* MS*	AL* TX* TX*	MS* MS*	AR* TX* MS*	SD* ND*	SD*	ID*		TX* TX*	TX* TX* CA*	TX* TX*	TX*
	H	WV* IL*	IL* WI*	VA* VA*		NC* NC*	NC*	SC* SC*		NE* SD*	OR*		OR*				
H	L	PA* IL*	PA* IN*	MD*	DE* CT*	TX* OK*	SC* TX*		GA*					TX* TX*	TX* TX* TX*	TX* TX*	AZ*
	H	OH* IL*	IL* VA*	MI*	MN*		AL* OK*	OK* OR*	OR* OR*				OR*				

Quantitative Factor Midpoints:

Traffic rate:	300 KESAL/year
Percentage reinforcement:	0.61
PCC thickness:	8.5 inches

FIGURE 2.17. Approved (*) and Selected Sections for GPS-5 (Continuously Reinforced Concrete Pavement)

		MOIST	Wet								Dry							
		TEMP	Freeze				Nonfreeze				Freeze				Nonfreeze			
		SUBGRADE	F		C		F		C		F		C		F		C	
STRCT NO	OVL STIFF	OVL THK TRAFFIC	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H
L	L	L	MO*										WY*	AK*	CA*			TX*
		H	NS*	KY*			TN*		WA*		KS* ND*	ID*		WA*		TX*		
	H	L									WY* WA*	SA* SA*		CO*	NM*			AZ*
		H	OH*	KY*	MI*		OK* OK*	AL*			WA*		UT* WY* UT* UT*	UT*			AZ*	
H	L	L		MN*					BC*			CO*		OR*		TX*	TX*	
		H		IA*	NB*			TN*		WA*	MT*		KS*	MT*				TX*
	H	L	IL*					OR*	BC*	AL*				NM*			AZ* NM*	AZ*
		H	IN*			NJ*						NM*						

Quantitative Factor Midpoints:

Traffic rate:	130 KESAL/year
Original pavement structural number:	3.6
Overlay stiffness:	650 ksi
Overlay thickness:	2.5 inches

FIGURE 2.18. Approved (*) and Selected Sections for GPS-6A (Existing Asphalt Concrete Overlay of Asphalt Concrete Pavement)

		MOIST	Wet								Dry							
		TEMP	Freeze				Nonfreeze				Freeze				Nonfreeze			
		SUBGRADE	F		C		F		C		F		C		F		C	
OVL THK	STRCT NO	PRIOR COND \ TRAFFIC	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H
L	L	Bad	MO*				TN* AL* TX*				SD*	SA*	MB*					
		Good	PA* MO*				MS* AL*			FL*	SD*		AK* CO*	AB*			HI*	
	H	Bad	VA* VA*				TN*				CO*			WA*				
		Good	VA* VT*	VA*	VT* NY*		MS*	MS*	MS*	MS*								TX*
H	L	Bad								FL* FL*		SA*	MB*					
		Good	PA*					TX*		FL*	NE*							
	H	Bad				DC*	TN*					MT*				CA*		
		Good						TN* GA*			CO*	MT*				CA*		

Quantitative Factor Midpoints:

Traffic rate:	130 KESAL/year
Original pavement structural number:	3.6
Overlay thickness:	2.5 inches

FIGURE 2.19. Approved (*) and Selected Sections for GPS-6B (Planned Asphalt Concrete Overlay of Asphalt Concrete Pavement)

		MOIST	Wet								Dry							
		TEMP	Freeze				Nonfreeze				Freeze				Nonfreeze			
		SUBGRADE	F		C		F		C		F		C		F		C	
		TRAFFIC	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H
OVL THK	OVL STIFF	PVMT TYPE																
L	L	JPCP			WI*			OK*			NE*	CO*						
		JRCP		OH*					OR*		NE*							
		CRCP																
	H	JPCP	MO*			RI*			SC*									
		JRCP	IL*	WV*			MS*											
		CRCP		IL*				TX* MS*										
H	L	JPCP	MN*	MO*							SD*	CO*						
		JRCP						TX*			KS*	NE*	KS*					
		CRCP																
	L	JPCP						GA*						NE*				
		JRCP	PA*	PA*	ME*	MI*		OR*		OR*								
		CRCP		IL*														

Quantitative Factor Midpoints:

Traffic rate:	300 KESAL/year
Overlay stiffness:	650 ksi
Overlay thickness:	3.5 inches

FIGURE 2.20. Approved (*) and Selected Sections for GPS-7A (Existing Asphalt Concrete Overlay of Portland Cement Concrete Pavement)

		MOIST	Wet								Dry							
		TEMP	Freeze				Nonfreeze				Freeze				Nonfreeze			
		SUBGRADE	F		C		F		C		F		C		F		C	
PVMT TYP	OVL THICK	PRIOR COND / TRAFFIC	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H
JPCP	L	Bad	OH*															
		Good	MO*		VT*													
	H	Bad																
		Good																
JRCP	L	Bad	IN*	IL*														
		Good	PA* IN* MO*	MO* IL*														
	H	Bad		PA* IA*				AR*			MB*			NE*				
		Good	PA*	PA*				AR*										
CRCP	L	Bad	OH*			IL*												
		Good																
	H	Bad		IN*				MS*										
		Good		PA*		IA*												

Quantitative Factor Midpoints:

Traffic rate:	300 KESAL/year
Overlay thickness:	3.5 inches

FIGURE 2.21. Approved (*) and Selected Sections for GPS-7B (Planned Asphalt Concrete Overlay of Portland Concrete Cement)

MOIST			Wet		Dry	
TEMP			Freeze	Nonfreeze	Freeze	Nonfreeze
OVL TYPE	PVMT TYPE	OVL THICK				
JPCP	JPCP	L	MN* QB*			CA*
		H		TX*	CO* CO* CA*	CA*
	JRCP	L			KS* NE*	
		H	PA* IN* MN*			
	CRCP	L				
		H	OH* OH*	TX*		
JRCP	JPCP	L				
		H				
	JRCP	L	MI*			
		H	OH* PA*			
	CRCP	L	MI*			
		H	MN*	MS*		
CRCP	JPCP	L				
		H		GA* TX* OK*		
	JRCP	L				
		H		TX*		
	CRCP	L				
		H				

Quantitative Factor Midpoint:
Overlay thickness: 7.5 inches

FIGURE 2.22. Approved (*) and Selected Sections for GPS-9 (Unbonded Portland Cement Concrete Overlay of Portland Cement Concrete Pavement)

GPS CANDIDATE PROJECT
RECRUITMENT DATA FORMS

SHEET A

STATE CODE __ __
STATE ASSIGNED ID __ __ __ __

DATE ________________

PROJECT AND SECTION IDENTIFICATION*

EXPERIMENT NUMBER ____

CELL ID NO. __ __ __
(IF KNOWN)

ENVIRONMENTAL ZONE __-__ __

STATE HIGHWAY AGENCY (SHA) DISTRICT NUMBER __ __

ROUTE SIGNING (NUMERIC CODE) __

Interstate.........1	State..............3
U.S. 2	Other..............4

ROUTE NUMBER __ __ __ __ __

PROJECT LENGTH (miles) __ __

NUMBER OF THROUGH LANES (ONE DIRECTION) __

OUTSIDE SHOULDER SURFACE TYPE __

Turf...............1	Concrete............4	Other (Specify)
Granular...........2	Surface Treatment...5	______________...6
Asphalt Concrete...3		Curb and Gutter...7

AGE AND MAJOR PAVEMENT IMPROVEMENTS

YEAR OPENED TO TRAFFIC __ __

EXPECTED YEAR OF OVERLAY (IF NONE, LEAVE BLANK) __ __

SUBJECTIVE ASSESSMENT OF PAVEMENT CONDITION ("GOOD" OR "BAD") PRIOR TO OVERLAY (PLEASE COMMENT):______________________________

____

____

TRAFFIC DATA

YEAR OF COUNT	ANNUAL AVERAGE DAILY TRAFFIC (AADT)	% HEAVY TRUCKS AND COMBINATIONS	ESAL/LANE-YR** (THOUSANDS)
__ __	__ __ __ __ __ __	__ __.__	__ __ __ __

* Please include a map indicating locations of GPS candidate projects.

** Leave blank if estimate is not available.

FIGURE 2.23. GPS Candidate Project Recruitment Data Forms—Sheet A

GPS CANDIDATE PROJECT
RECRUITMENT DATA FORMS

SHEET B

STATE CODE __ __
STATE ASSIGNED ID __ __ __ __

LAYER DESCRIPTIONS

LAYER[1] NUMBER	LAYER[2] DESCRIPTION	MATERIAL TYPE[3] CLASSIFICATION	THICKNESS (inches)
1	SUBGRADE (07)	____	__ __.__
2	__	__ __	__ __.__
3	__	__ __	__ __.__
4	__	__ __	__ __.__
5	__	__ __	__ __.__
6	__	__ __	__ __.__
7	__	__ __	__ __.__

NOTES:

1. Layer 1 is subgrade soil, last layer is existing surface.
2. Layer description codes:
   Overlay............01
   Seal Coat..........02
   Original Surface...03
   HMAC Layer (Below Surface Layer)...04
   Base Layer.........05
   Subbase Layer......06
   Subgrade...........07
   Interlayer.........08
   Porous Friction Course.............09
   Surface Treatment....10
   Embankment (Fill)....11
3. See Tables C.1 through C.4 for material type classification codes*.
   (* Presented in Tables 2.1 through 2.4 in this report)

INDIVIDUAL LAYER DATA

STABILIZED OR BOUND BASE LAYERS (FILL IN FOR GPS-2 ONLY)

TYPE AND PERCENT STABILIZING AGENT
STABILIZING AGENT 1 TYPE CODE* ___ PERCENT __ __.__
STABILIZING AGENT 2 TYPE CODE* ___ PERCENT __ __.__

*Stabilizing Agent Type Codes:
Asphalt Cement.......1
Emulsified Asphalt...2
Cutback Asphalt......3
Portland Cement....4
Lime...............5
Fly Ash, Class C....6
Fly Ash, Class N...7
Other (Specify)
______________....8

ADDITIONAL STABILIZED OR BOUND BASE LAYER DATA (FILL IN IF AVAILABLE)

ESTIMATED AASHTO STRUCTURAL LAYER COEFFICIENT .__ __

UNCONFINED COMPRESSIVE STRENGTH AT 7 DAYS (psi)
(FOR NON-BITUMINOUS LAYERS ONLY) __ __ __ __

MARSHALL STABILITY, POUNDS (FOR BITUMINOUS LAYERS ONLY) __ __ __ __

FIGURE 2.24. GPS Candidate Project Recruitment Data Forms—Sheet B

GPS CANDIDATE PROJECT
RECRUITMENT DATA FORMS

SHEET C

STATE CODE __ __
STATE ASSIGNED ID __ __ __ __

INDIVIDUAL LAYER DATA

RIGID PAVEMENT LAYERS

LAYER NUMBER (FROM SHEET B) __

AVERAGE TRANSVERSE CONTRACTION JOINT SPACING (feet) __ __
RANDOM JOINT SPACING, IF ANY ______________________________

TRANSVERSE CONTRACTION JOINT LOAD TRANSFER SYSTEM
ROUND DOWELS YES __ NO __

REINFORCING (BARS OR MESH) YES __ NO __

PERCENTAGE OF LONGITUDINAL STEEL (CRCP ONLY) __.__ __

HOT MIX ASPHALT CONCRETE (HMAC) LAYERS
(MATERIAL CODES 01, 28, OR 31, ONLY)

LAYER NUMBER (FROM SHEET B) __

TYPE OF ASPHALT CEMENT
VISCOSITY GRADE OF ORIGINAL AC AC - __ __
VISCOSITY GRADE OF RESIDUE FROM RTFOT AR - __ __ __ __
PENETRATION GRADE __ __ __-__ __ __

ASPHALT CONTENT (% by weight of total mixture) __ __.__

IN PLACE DENSITY (PCF) __ __ __
METHOD OF DENSITY DETERMINATION
MEASURED . . . . . 1 ESTIMATED . . . . . 2 __

ADDITIONAL HMAC LAYER DATA (FILL IN IF AVAILABLE)

KINEMATIC VISCOSITY OF ORIGINAL AC AT 140°F, poise __ __ __ __

ABSOLUTE VISCOSITY OF ORIGINAL AC AT 275°F, centistokes __ __ __

PENETRATION OF ORIGINAL AC AT 77°F, 0.1 mm __ __ __

BULK SPECIFIC GRAVITY OF AGGREGATES __ __ __

IN-PLACE AIR VOIDS (%) __ __.__

FIGURE 2.25. GPS Candidate Project Recruitment Data Forms—Sheet C

GPS CANDIDATE PROJECT
RECRUITMENT DATA FORMS

SHEET D

STATE CODE ___ ___
STATE ASSIGNED ID ___ ___ ___ ___

INDIVIDUAL LAYER DATA CONTINUATION SHEET
(FOR ADDITIONAL LAYERS)

RIGID PAVEMENT LAYERS

LAYER NUMBER (FROM SHEET B) ___

AVERAGE TRANSVERSE CONTRACTION JOINT SPACING (feet) ___ ___
RANDOM JOINT SPACING, IF ANY ______________________________

TRANSVERSE CONTRACTION JOINT LOAD TRANSFER SYSTEM
ROUND DOWELS YES ___ NO ___

REINFORCING (BARS OR MESH) YES ___ NO ___

PERCENTAGE OF LONGITUDINAL STEEL (CRCP ONLY) ___.___ ___

HOT MIX ASPHALT CONCRETE (HMAC) LAYERS
(MATERIAL CODES 01, 28, OR 31, ONLY)

LAYER NUMBER (FROM SHEET B) ___

TYPE OF ASPHALT CEMENT
VISCOSITY GRADE OF ORIGINAL AC AC - ___ ___
VISCOSITY GRADE OF RESIDUE FROM RTFOT AR - ___ ___ ___ ___
PENETRATION GRADE ___ ___ ___-___ ___ ___

ASPHALT CONTENT (% by weight of total mixture) ___ ___.___

IN PLACE DENSITY (PCF) ___ ___ ___
METHOD OF DENSITY DETERMINATION
MEASURED . . . . . 1 ESTIMATED . . . . . 2 ___

ADDITIONAL HMAC LAYER DATA (FILL IN IF AVAILABLE)

KINEMATIC VISCOSITY OF ORIGINAL AC AT 140°F, poise ___ ___ ___ ___

ABSOLUTE VISCOSITY OF ORIGINAL AC AT 275°F, centistokes ___ ___ ___

PENETRATION OF ORIGINAL AC AT 77°F, 0.1 mm ___ ___ ___

BULK SPECIFIC GRAVITY OF AGGREGATES ___ ___ ___

IN-PLACE AIR VOIDS (%) ___ ___.___

FIGURE 2.26. GPS Candidate Project Recruitment Data Forms—Sheet D

computerized database, and a decision process was undertaken to determine (1) whether the project matched the detailed description and (2) whether the project fit into a defined sampling template and specific design cell. Once the candidate project was identified with aparticular design cell, the following criteria were used to determine whether the project would be selected:

- Generally, at most two projects per cell were selected.
- When possible, a cell was filled with projects from different states but the same climatic zone.
- Projects were included from every state to ensure good national representation and to avoid loading any one state with too many projects.
- When several projects were available for a particular cell, pavement age was considered in the final choice of two projects per cell. This approach yielded an additional associated age factor (i.e., a covariate). Since traffic rate was included as a design factor, selecting the sections on the basis of age provided a distribution of accumulated traffic loads.
- When possible, requests to investigate certain types of projects important to individual states were accommodated.

Project Verification

The selected GPS projects were investigated in the field to verify that they possessed the characteristics needed to fill the design cells. Verification was performed as the first on-site activity for the following reasons:

- After the specific monitoring location or section was selected during verification, additional monitoring activities could be scheduled from within the submitted project.
- An extensive material sampling and laboratory testing process, independent of monitoring activities, was undertaken with greater confidence in the continued use of the test section. The verification of projects before material sampling resulted in lower costs, particularly if the impact of verifying (or possibly rejecting) the section during material sampling was considered.
- Project characteristics necessary to fill vacant template cells could be determined earlier.

Project verification was performed by the RCO engineers and involved a visit to the participating highway agency office as well as an on-site inspection. The office visit allowed the engineers to become familiar with the project before the site visit, resulting in an earlier and more complete data verification in the field.

Office visit

During the visit to the highway agency office, the following activities were performed:

- Project records, including as-built plans and pertinent specifications, were reviewed.
- Candidate project data were confirmed in comparing the as-built plans with the data previously submitted.
- Traffic data were reviewed, safety in the material sampling program was investigated, and future monitoring requirements were considered.
- Photo logs or other available site-specific data were reviewed to allow the engineer to become more familiar with the project.
- Recent or planned maintenance or rehabilitation activities were identified that could have affected the project.
- For the overlay studies, available information was collected on pavement condition before overlay.
- Potential test sections in the project were identified.

Potential test sections boundaries were identified using construction plan cross-section information and known limits of the appropriate typical section. Within these station boundaries, the as-built profile was compared with the natural ground profile to eliminate areas with highly variable subgrade conditions. Test sections in deep cuts or fills were rejected whenever possible, to avoid inconsistent subgrade support and to minimize drainage conditions related to highway geometry rather than soil characteristics. The typical section was located within consistent cut, fill, or at-grade conditions. The depth of cut or fill was to be essentially constant throughout the section. Transitional areas (cut to fill, shallow fill to deep fill, etc.) were avoided.

Within the uniform cut, fill, or at-grade areas, potential monitoring sections were identified as those roadway sections that excluded major structures, sharp horizontal or vertical curvature, or steep grades. Specifically, the following guidelines were used:

- Bridges, railroad crossings, culverts, and other major structures were avoided.
- For horizontal alignment, a tangent section was preferred, but curves with a maximum curvature of 3 degrees were allowed.
- For vertical alignment, a constant grade that did not exceed 4 percent was preferred. If vertical curves were unavoidable, a maximum change in grade of 5 percent was allowed.

- A constant cross-slope or super-elevation rate less than 6 percent was preferred. Cross-slope reversals were not allowed.

- Candidate projects generally included at least 1/4 mile of continuous pavement between bridge abutments, large culverts, at-grade railroad crossings, or other discontinuities.

- Candidate projects for pavements overlaid with AC (GPS-6 and 7) or with unbonded PCC (GPS-9) were not selected if lanes had been widened or if new lanes or shoulders had been added.

- Candidate projects were required to have uniform traffic movements over a minimum distance of 1/2 mile.

- Candidate projects with curb and gutter less than 6 feet from the edge of the outside lane were not acceptable.

- Projects with HMAC surface courses or overlays containing recycled or reclaimed asphalt pavement as a component were not considered for inclusion in GPS.

- CRCP projects (GPS-5) on which grinding had been performed were acceptable if the grinding was performed soon after the project was completed.

- Projects with edge drain rehabilitation were not acceptable unless they were relatively new and in good condition before installation of the edge drains.

- PCC projects scheduled for crack and seat operations before overlay were not acceptable for GPS.

- Stage construction was not allowed in GPS except for those projects constructed in stages with a long period between overlays.

These guidelines were necessary, even though they could create bias in the experimental designs. Any potential bias was offset by the collection of usable data on a set of features more consistent with standard design practice. The primary reason for the decision to avoid steep grades, sharp corners, roadway structures, unusually deep cuts or high embankments, or other unusual geometry was to avoid effects of unusual roadway features on performance. While these effects were of interest and could have been studied separately through other funding, such features represented only a small percentage of the total existing length of roadway. If included in GPS, they could well bias the resulting predictive equations when the equations are applied in the future to the usual case of roadways that exclude these unusual features. On balance, it was considered more desirable to maintain representation for the general case (Ref 6).

The length of candidate projects was required to be at least 1/4 mile of continuous pavement between bridge abutments, large culverts, and other major structures to allow flexibility in selection of a test section within the project that would be representative for the experiment.

The exclusion of projects in which the outside lanes had been added or widened was also adopted to maintain representation for the majority of pavements. Eliminating those portions with nonuniform traffic movement over the length of the project was a practical criterion to avoid serious bias in the database (Ref 6).

These guidelines were considered necessary to obtain significant and meaningful results from the experiments. Controlling some variables while measuring others is a standard method of experimentation. However, it is vitally important that this restriction of the inference space be clearly delineated by analysts and recognized by those who use the results. It must be clearly understood that the results of this experiment are not applicable to steep grades, sharp corners, structure approaches, deep cuts, high embankments, or other unusual geometry. Other limitations of the inference space are also important.

On the whole, these guidelines were selected to identify pavement sections that represent the current design standards on the interstate and primary road networks in the United States. Although these restrictions may bias the population somewhat, their use represented a deliberate effort to select a sample of pavement sections that were representative of the population of pavement sections and current construction practices in North America.

During the on-site visit, certain activities were accomplished in the field:

- The monitoring test section was located.
- The bore hole locations were sampled.
- The test section was identified.
- The test section was videotaped.
- The field verification form was completed.
- A distress survey was conducted.

Location of monitoring test section

During the field visit, the actual monitoring (500-foot) test section was located on the basis of an inspection of all potential test sections identified in an office-based plan evaluation. In general, the longest available section that was considered representative of the general roadway condition and was deemed safe for traffic control and monitoring personnel during lane closure was chosen.

For JCP, the beginning of the 500-foot monitoring section was established 5 feet upstream of a joint (i.e., opposite the direction of traffic). This convention allowed joint-related distresses for the joint at the beginning of a test section to be included in the monitoring program. For CRCP, the beginning of the test section was located at the approximate midpoint of the distance between two existing transverse cracks, so that distresses associated with the initial crack were included in the monitoring program.

All test sections were selected to ensure sufficient buffer distance both before and after the designated 500-foot section to allow space for verification boring and subsequent material sampling and testing outside the test section. Ideally, 250 feet was provided before and after the section. These buffer zones were of the same cross section as the monitoring test section.

The beginning of the section was located with reference to some physical feature (bridge, overpass, intersection, etc.) by designating the distance from the beginning station to the selected physical feature. This method provided a technique for locating the beginning of a test section for future LTPP activities.

Bore holes

All projects included sampling bore holes carried to a depth of 4 to 6 feet below the pavement surface. The borings were extended at least to the subgrade to verify layer thickness and material types. Two borings were completed for AC pavements; for PCC pavements with flexible shoulders, a bore hole was completed at the pavement-shoulder joint. These borings were not necessary if a highway agency gave the assurance that its records were accurate and that there was no need for the bore hole measurements.

The two borings for flexible (AC) pavements were completed in the outer wheel path: one at least 50 feet before the beginning and the second 50 feet after the end of the 500-foot test section. The boring for PCC pavements was completed in the shoulder at least 50 feet after the end of the monitoring section (i.e., downstream of traffic), at the shoulder-pavement joint. If 50 feet was not available outside the test section, the point farthest from the end of the monitoring section but still considered part of the typical section was selected for the bore hole location.

Test section identification

The test site sign was to be located 500 feet before the beginning of the monitoring section, and delineators were to be installed at the beginning and end of the section. The sign, paint striping, and site identification requirements used for the GPS test sections are illustrated in Figures 2.27 and 2.28.

Videotaping of test section

A videotape of the test section provided a record of the overall features of the site, pavement condition, and characteristics of the surrounding area at the time of verification.

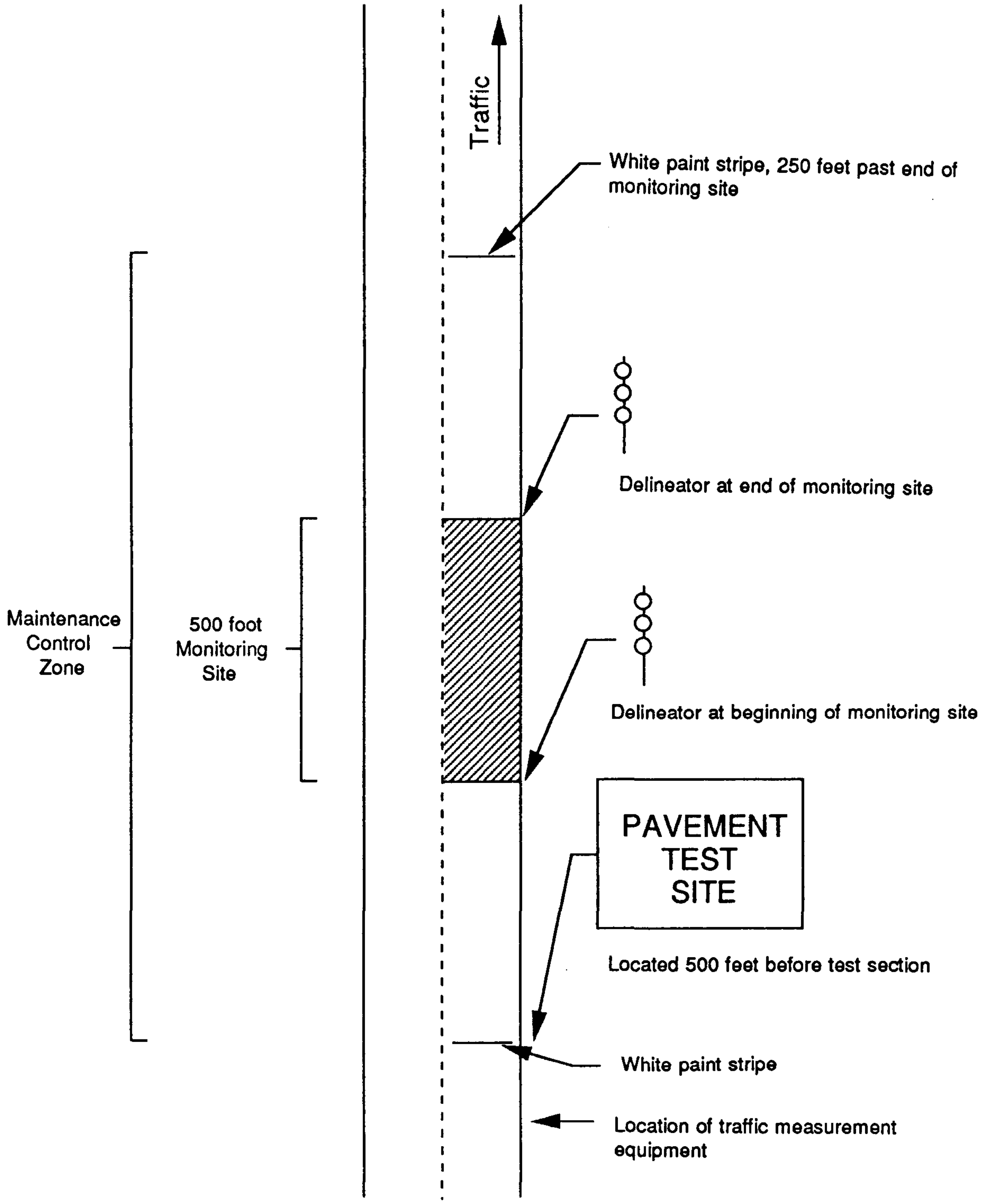


FIGURE 2.27. Sign and Paint Configuration for GPS Test Site

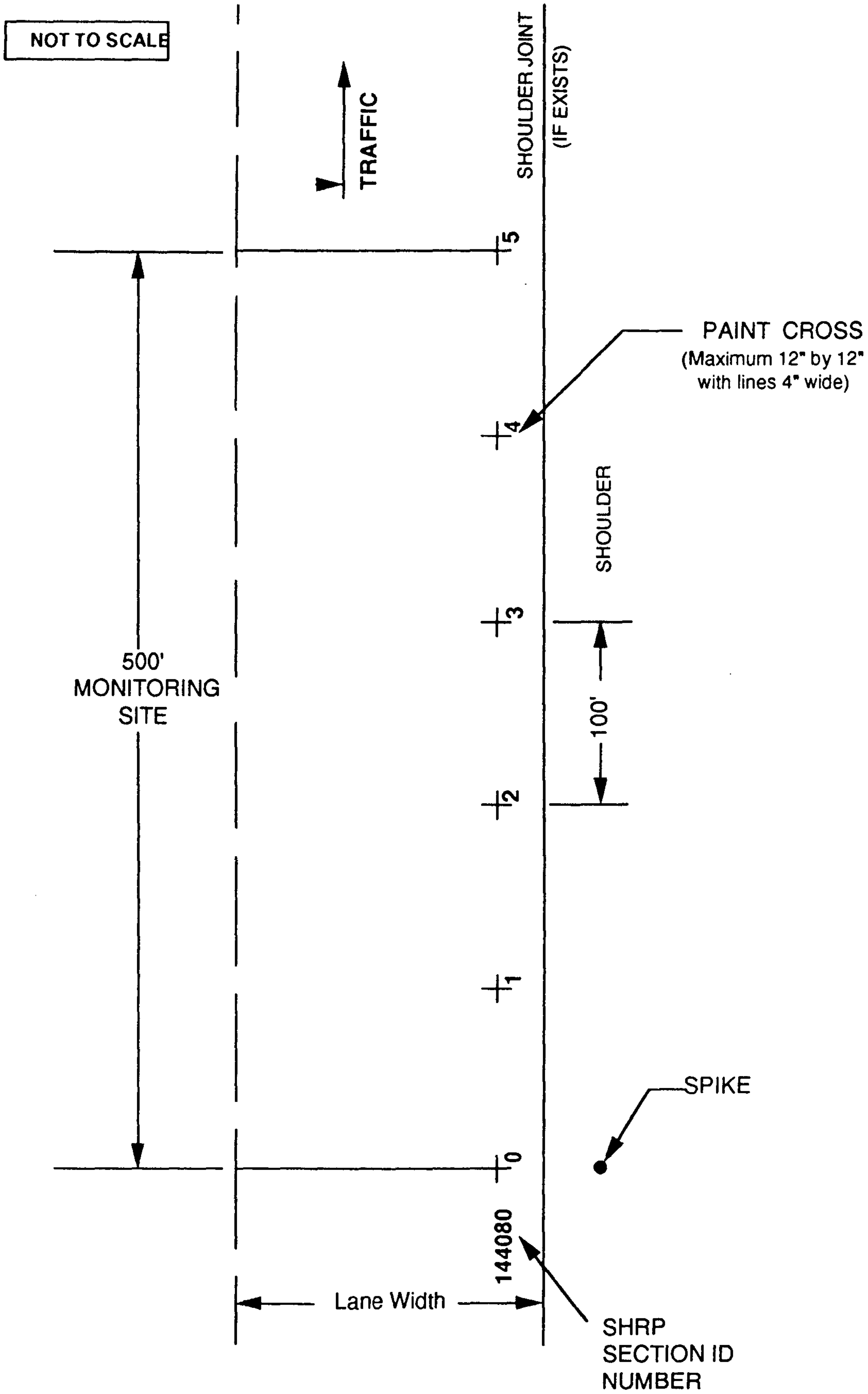


FIGURE 2.28. Details of GPS Monitoring Site Paint Configuration

Field verification form

The "section field verification form" (Figure 2.29) was completed in the field. The form included project and section identification information, geometric details, and measurements from the boring operations.

Distress survey

A manual (i.e., visual) condition survey was completed for each 500-foot monitoring test section, and type, amount, and severity level were recorded for each distress. The distresses for pavements with AC surface layers were alligator cracking, block cracking, patch deterioration, pumping, raveling or weathering, transverse cracking, bleeding, and rutting (Figure 2.30). The distresses for pavements with PCC surface layers were "D" cracking, joint seal damage, longitudinal cracking, patch or slab replacement deterioration, pumping, transverse cracking, corner breaks, and faulting (Figure 2.31). This information provided a record of the initial condition of the pavement surface.

Final Approval

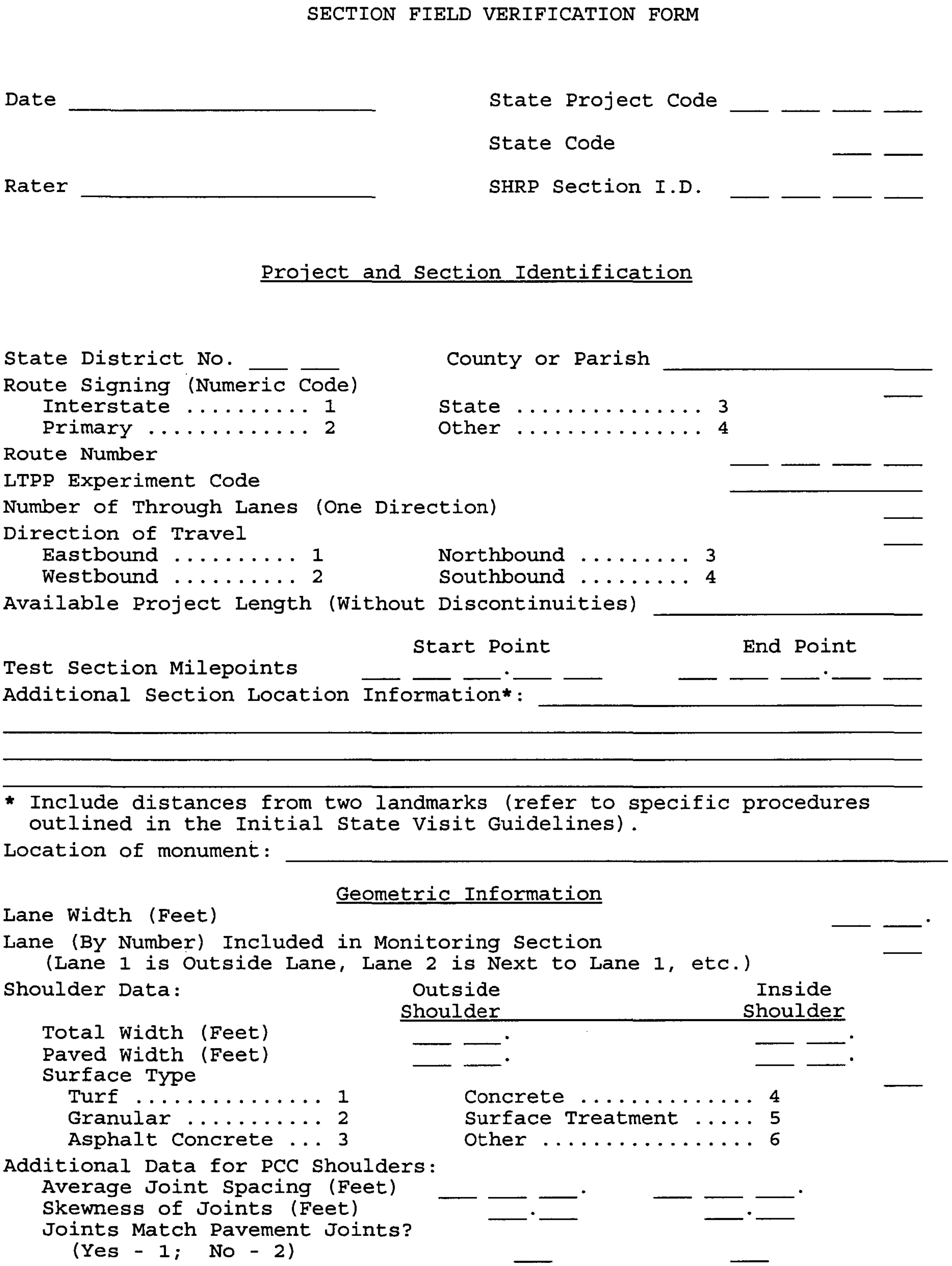
Since the candidate projects were tentatively assigned to specific cells in the various GPS sampling templates, final approval of projects as monitoring test sections depended on the results of the verification process.

The information provided on the section field verification form was compared with the previously submitted nomination data to verify the specific design cell. After field verification, the sections that met all other general GPS criteria and retained their original design cell assignments were then approved for GPS monitoring. On the other hand, when the field verification data required a change in cell assignment, an extended approval process was initiated to confirm a new cell assignment for the section. A flow diagram of the project approval process is shown in Figure 2.32.

If the information collected for a section required a cell assignment change from the previously assigned cell to a new design cell with fewer than two selected or approved sections, the section was moved into that cell on a first-in, first-approved basis.

If the information collected on a section required reassignment from the original cell to a cell already filled by two selected projects, the decision on classification of the project depended on the status of the other projects in that cell.

If the two projects identified with this new cell assignment had already been verified and designated as approved sections, any section reassigned to that same cell would not be approved and would no longer be considered for that GPS experiment.



SECTION FIELD VERIFICATION FORM

Date ______________________ State Project Code ___ ___ ___ ___

State Code ___ ___

Rater ______________________ SHRP Section I.D. ___ ___ ___ ___

Project and Section Identification

State District No. ___ ___ County or Parish ______________
Route Signing (Numeric Code) ___
Interstate .... 1 State 3
Primary .... 2 Other 4
Route Number ___ ___ ___ ___
LTPP Experiment Code ___________
Number of Through Lanes (One Direction) ___
Direction of Travel ___
Eastbound .... 1 Northbound 3
Westbound .... 2 Southbound 4
Available Project Length (Without Discontinuities) ___________

Start Point End Point
Test Section Milepoints ___ ___ ___.___ ___ ___ ___ ___.___ ___
Additional Section Location Information*: ________________
____
____
____

* Include distances from two landmarks (refer to specific procedures outlined in the Initial State Visit Guidelines).
Location of monument: ______________________________

Geometric Information

Lane Width (Feet) ___ ___.
Lane (By Number) Included in Monitoring Section ___
(Lane 1 is Outside Lane, Lane 2 is Next to Lane 1, etc.)

Shoulder Data:	Outside Shoulder	Inside Shoulder
Total Width (Feet)	___ ___.	___ ___.
Paved Width (Feet)	___ ___.	___ ___.

Surface Type ___
Turf .... 1 Concrete 4
Granular .... 2 Surface Treatment 5
Asphalt Concrete ... 3 Other 6

Additional Data for PCC Shoulders:		
Average Joint Spacing (Feet)	___ ___ ___.	___ ___ ___.
Skewness of Joints (Feet)	___.___	___.___
Joints Match Pavement Joints? (Yes - 1; No - 2)	___	___

FIGURE 2.29. Section Field Verification Form

SECTION FIELD VERIFICATION FORM (CONTINUED)

State Code ___ ___
SHRP Section I.D. ___ ___ ___ ___

Vertical Alignment (from plans)

Cut, Fill, or At Grade: ______________________________
Depth of Cut/Fill at Start of Section: ______________________________
Depth of Cut/Fill at End of Section: ______________________________

Joint Information for JCP

Average Contraction Joint Spacing (Feet) ___ ___ ___.___
Average Intermediate Sawed Joint Spacing (Feet) (JRCP Only) ___ ___.___
Skewness of Joints (Feet/Lane) ___.___

CORE 1 (Beginning of Project)

Layer No.	Layer Types*	Thickness	Brief Material Description
1	Subgrade (G)		
2			
3			
4			
5			
6			
7			

Notes: ______________________________

CORE 2 (End of Project)

Layer No.	Layer Types*	Thickness	Brief Material Description
1	Subgrade (G)		
2			
3			
4			
5			
6			
7			

Notes: ______________________________

*Layer Types: A = HMAC/Surface Treatment, P = PCC Layer, B = Base/Subbase, G = Subgrade

Figure 2.29 (continued)

DISTRESS SURVEY FORM
AC-Surfaced Pavements
(GPS Experiments 1, 2, 6, 7)

Date________________

Rater________________

State Code ___ ___

SHRP Section ID ___ ___ ___ ___

	Severity Level		
	Low	Medium	High
1. Alligator Cracking (Sq. Ft.)	______	______	______
2. Block Cracking (Sq. Ft.)	______	______	______
3. Patch Deterioration (Number and Sq. Ft.)	______	______	______
4. Pumping (Check highest severity found)	______	______	______
5. Raveling/Weathering (Sq. Ft.)	______	______	______
6. Transverse Cracking (Number of Cracks)	______	______	______

7. Bleeding (Measure only when extensive enough to cause a reduction in skid resistance, Sq. Ft.) ____________

8. Average Rut Depth
< 0.5" ______
0.5-1" ______
> 1" ______

Comments____

____

____

FIGURE 2.30. Distress Survey Form for AC-Surfaced Pavements

DISTRESS SURVEY FORM
PCC-Surfaced Pavements
(GPS Experiments 3, 4, 5, 9)

Date_______________ State Code ___ ___
Rater______________ SHRP Section ID ___ ___ ___ ___

	Severity Level		
	Low	Medium	High
1. "D" Cracking (Linear Feet of joints, cracks, and free edges affected)*	_______	_______	_______
2. Joint Seal Damage** (Number of joints)	_______	_______	_______
3. Longitudinal Cracking (Linear Feet)	_______	_______	_______
4. Patch or Slab Replacement Deterioration (Number and Sq. Ft.)	_______	_______	_______
5. Pumping (Check highest severity found)	_______	_______	_______
6. Transverse Cracking (Number of Cracks)	_______	_______	_______

7. Corner Break** (Number) ___________

8. Average Faulting**
< 0.4" _______
0.4-0.8" _______
> 0.8" _______

* Measured as percent surface area for CRCP.
** Not applicable to CRCP.

Comments____
____
____

FIGURE 2.31. Distress Survey Form for PCC-Surfaced Pavements.

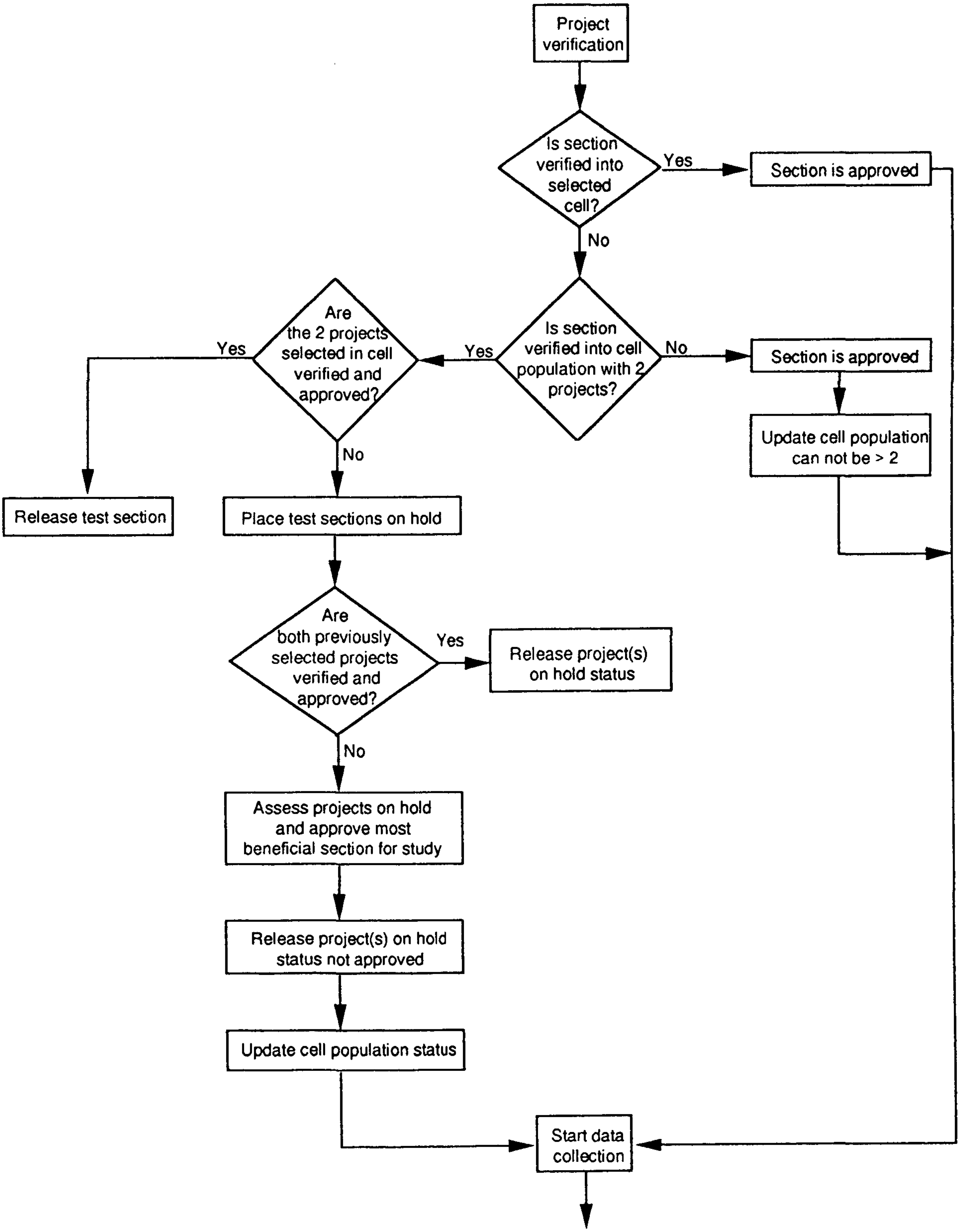


FIGURE 2.32. Flow Diagram of the Project Approval Process

If one or both of the selected projects originally assigned to a particular cell had not yet been verified, reassignment of any recently verified sections to the same cell would be placed on hold until the status of the two previously selected projects was known. If the two projects originally selected for the cell remained in the cell after verification, then the projects reassigned to the cell were released. If one or both of the originally selected projects for a particular cell changed cells after verification, the projects reassigned to that cell and any remaining original section assignment to the same cell were assessed, and the two most appropriate sections were approved for the study. Projects not approved for inclusion in GPS were released.

PROJECT STATUS CLASSIFICATIONS

GPS section status reports, prepared and printed each quarter, summarized the results of the verification visits and presented information on the status of each section. The reports were forwarded to SHRP and the four RCO contractors so that the current status of all sections could be verified and to ensure that the central database records agreed with records kept by the four RCOs. Factorial designs were also printed each quarter showing the layout of the sampling plans and the state abbreviations indicating the locations and types of the sections.

Information on the history of each section classification was stored in a database. The recorded information included the section identification number, the experimental design and cell number, the date of classification assignment, the date of deassignment, the classification code, and (when informative) a short reason for this assignment. This information aided in tracking the history of each section and ensuring a proper cell assignment.

The selection process involved several steps. The original candidate sections identified during initial recruitment for each sampling design template were classified as "primary, not selected." These were sorted by design factor levels and placed into appropriate template cells. For most pavement types, these were more than two projects with similar characteristics in many cells. Whenever possible, two projects were first selected for each design cell according to their ages: one relatively new and one relatively old. If only one or two projects existed in a cell, they were automatically selected, regardless of age. These projects were classified as "selected, not verified."

In the early phases of GPS project selection, the number of projects originally submitted by the states was more than could ever be selected or approved. These surplus projects were returned to the states with appropriate explanations and were not used in GPS.

Backup projects were generally designated for cells that included more than two projects. These were designated as alternates, since they exhibited characteristics similar to those of the group originally selected. These alternates were maintained in an available pool in case one or both of the originally selected projects were unusable or had to be reassigned. Once the two selected projects were approved, however, it was unnecessary to maintain the alternate sections as potential candidates. After this initial selection process was completed, more than 430 projects were thus dismissed from further consideration.

Fieldwork to verify and locate test sections on the selected projects began in April 1988. The four RCO contractors made visits to the highway agencies in their regions to compare project characteristics against design factor levels to verify the cell assignment and to locate a 500-foot test section in each project. If no suitable test section could be found in a project, a test section would be selected from one of the backup projects or another project with the same characteristics in the same state. Two classifications were reserved for the approved sections: if cores were drilled to verify layer thicknesses, a section was labeled "approved"; if no cores were drilled, it was labeled "approved, not verified."

The final development affecting GPS recruitment was the internal relocation of approved sections from one cell to another in the same design or from one GPS design to another. Occasionally, circumstances developed that required the removal of a test section from its original cell. If the section could be reassigned, it was placed in the new cell unless that cell was already occupied by two sections. If significant monitoring or material data had already been collected, the section was kept in the GPS experiment even if two other sections had been approved for the same cell.

Whenever the decision was made to remove a GPS-1, 2, 3, 4, or 5 section from the LTPP program, the first consideration was to move it into one of the rehabilitation studies (GPS-6B, 7B, or 9). Depending on its acquired status, the section either continued to be approved for a rehabilitation study or was completely removed from GPS.

With the passage of time and the accumulation of traffic loads, all test sections will eventually reach some terminal condition level or in some rare circumstances may no longer satisfy the criteria for the assigned GPS design. Because of these possibilities, two classifications---"released" and "out-of-study"---were defined in the national pavement performance database (NPPDB) to identify the status of these sections. In some cases, a section could no longer be used, and data collection activities were terminated. In other situations, sections were reassigned to one of the studies for rehabilitated pavements.

The category of "released" was reserved for sections previously approved but no longer considered suitable for inclusion in GPS. The following situations represent a few examples of the basis for releasing a section: The GPS section selection criteria were not met, highway construction activities disrupted normal traffic flow on the section, or dangerous traffic conditions existed. The principal basis for the release of a section was some uncontrollable factor, other than pavement condition, that disrupted the continuity of data collection.

Before a section was classified as released, analytical information, test results and performance data were investigated. If enough data were available, the section was reclassified as out-of-study. Efforts were made to ensure that all approved GPS sections satisfied the selection criteria before any data were collected and that no expected construction activities would disrupt the normal use of the section.

When a section was classified as released, a search was undertaken for a replacement GPS section with the same design factors and in the same state. This policy was especially important if the released section contained a unique combination of design factors that was considered important to the efficiency of the GPS design.

The "out-of-study" classification implied that pavement deterioration had reached the point where travel on the highway was no longer safe or that the section was no longer suitable for the assigned GPS experiment. This terminal level was a functional definition of pavement condition that depended on the type of pavement and other factors. The criterion for removing a section from GPS was related to pavement condition and was defined by a terminal serviceability rating of 1.5. When this rating was reached, it was assumed that the maximum amount of information possible had been obtained for that test section, and the section was considered out-of-study.

The status classification for GPS sections are summarized below:

1. Selected, not verified: Two projects for each cell in the sampling design (when available) were selected from the "primary, not selected" classification. These GPS projects were then forwarded to the regions for verification.

2. Approved: These projects were visited, locations for the sections were identified, design factor levels were verified (including verification of pavement layer materials and thicknesses by boring), and the projects were officially approved for GPS.

3. Approved, not verified: These sections met the same conditions as approved sections except that the pavement layer thicknesses were not verified by boring. Once the pavement layer thicknesses were verified (usually during material sampling) the status of a section was changed to approved.

4. Verified, on hold, same cell: This category indicates that a section was verified and fit into a proper design cell, but because of certain features of the section another project with the same design factor levels, if available, was to be considered for study.

5. Verified, on hold, new cell: This category was similar to the previous one except that one or more of the design factor levels changed for the section and it was assigned to a new cell. If the new cell was empty or had only one section selected or approved, the section that had just moved into the new cell was approved. However, if two sections were already selected for that cell, the section that moved into the cell remained on hold until the status of the other two sections was determined.

6. Primary, not selected: When a project was first submitted, it was usually classified in this category. These sections served as the primary source to fill gaps in the sampling designs or to replace approved sections that were released.

7. Returned: In the early phases of GPS project selection, many more projects were originally submitted by the states than could ever be selected or approved. These surplus project nominations were returned to the states and were not considered for use in GPS.

8. Released: This category was reserved for previously selected or approved sections that were no longer considered suitable for inclusion in GPS for reasons not related to pavement condition.

9. Out-of-study: This category was used to identify projects that had come to the end of their performance periods and had data collection activities discontinued. If a state planned to overlay a project that had already been overlaid once (and was assigned to GPS-6A, 6B, 7A, 7B, or 9) or if the project could not be moved into one of the overlay sampling templates, it was classified out-of-study. Data collected from these sections over time were considered the primary source to achieve overall LTPP objectives.

SHRP-LTPP STATUS (July 1992)

The approved GPS sections identified by U.S. state or Canadian province are presented on the map in Figure 2.33 and listed by GPS experiment type in Table 2.5. As of July 1992, a total of 777 sections have been approved for all GPS experiments. During verification, 13 sections have been released from GPS, while 3 have been declared out-of-study.

The GPS program includes 437 flexible pavement sections and 340 rigid pavement sections (see Figure 2.34). The distribution of flexible and rigid pavements within the various GPS experiments is illustrated in Figures 2.35 and 2.36.

DATA COLLECTION

This section summarizes the data collection activities planned and currently under way in GPS. Development of final collection specifications for most data elements is complete, while criteria for some remaining elements and programming of the LTPP database are approaching completion. Actual acquisition of data elements is progressing at different rates.

Data employed in the LTPP effort are being collected from a diverse group of sources. This information is being provided by more than 60 participating agencies. Different data elements will be supplied from multiple departments in each agency. Data collection, processing, and storage were preformed under 15 different SHRP-LTPP contracts. Data was also extracted from other sources, such as the National Oceanic and Atmospheric Administration. The database for storage of this information, referred to as the National Pavement Performance Database (NPPDB) in this document and the data management system for data retrieval (NIMS) were developed under a separate SHRP contract.

Final details of the data collection, processing, and storage have not been completed yet. For example, interpreting the distress photographs has been difficult. The equipment being used is new, and operational problems have occurred. As this equipment is used and refined, the methods for interpreting distress data will no doubt improve.

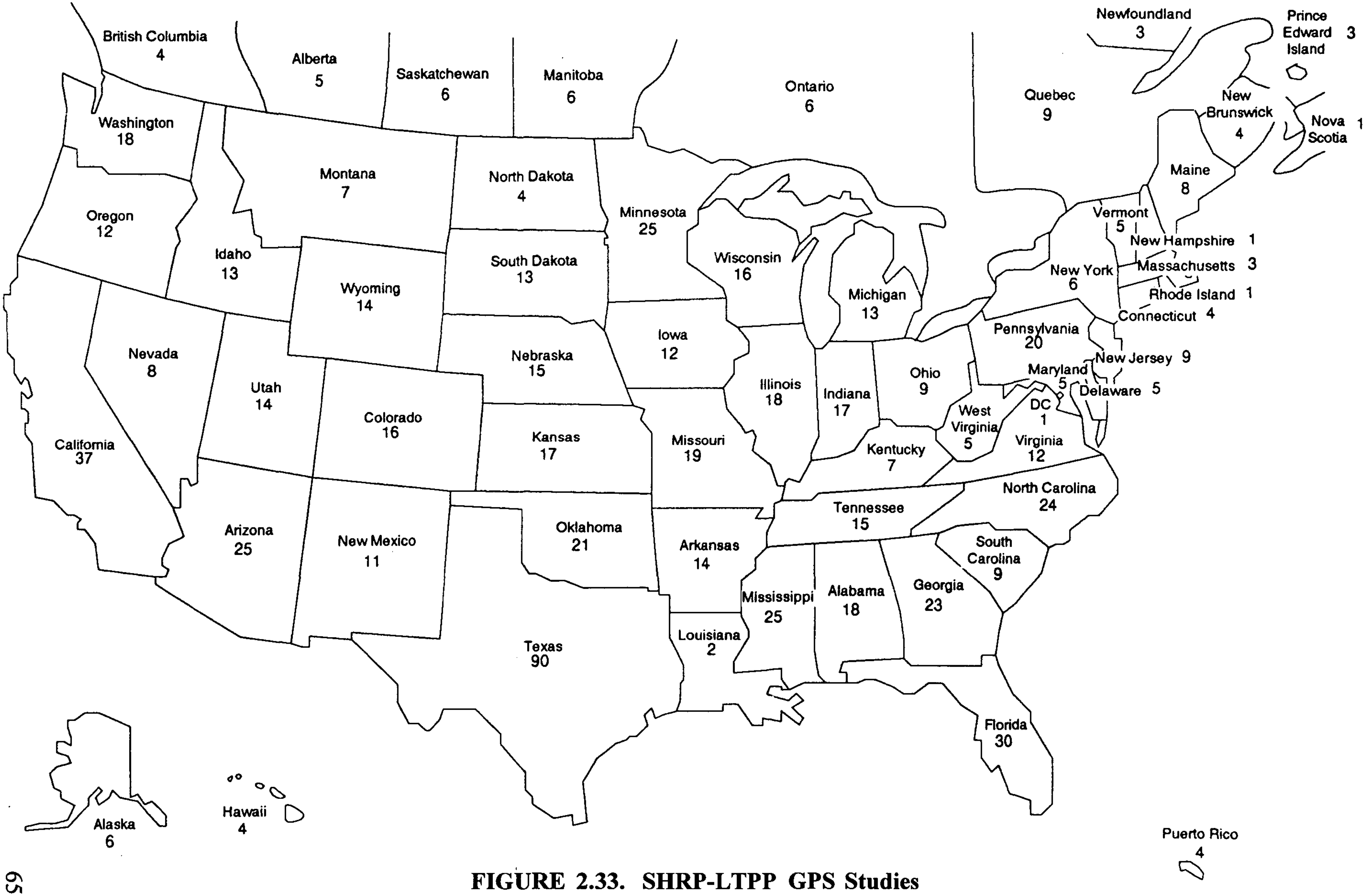


FIGURE 2.33. SHRP-LTPP GPS Studies

TABLE 2.5. GPS Section Totals by State/Province

State/Province	1	2	3	4	5	6A	6B	7A	7B	9	TOTALS
Alabama	6	3	1	2	2	2	2				18
Alaska	4					1	1				6
Arizona	16	2	2		1	4					25
Arkansas		4	1	5	2				2		14
California	4	15	11		1	1	2			3	37
Colorado	4	1	2			2	3	2		2	16
Connecticut	1			2	1						4
Delaware		1		2	2						5
District of Columbia							1				1
Florida	15	4	7				4				30
Georgia	4	7	8		1		1	1		1	23
Hawaii	3						1				4
Idaho	9		2		1	1					13
Illinois	2			3	7	1		3	2		18
Indiana	2	2	4	2	2	1			3	1	17
Iowa	1	1	5		2	1			2		12
Kansas	3		3	6		2		2		1	17
Kentucky	3		1	1		2					7
Louisiana		1		1							2
Maine	5		2					1			8
Maryland		4			1						5
Massachusetts	3										3
Michigan	5		2	1	1	1		1		2	13
Minnesota	9		2	8	1	1		1		3	25
Mississippi	3	6	2	1	4		5	2	1	1	25
Missouri	3			7	1	1	2	2	3		19
Montana	2	1				2	2				7
Nebraska	1		5	1	1		1	4	1	1	15
Nevada	2	3	3								8
New Hampshire	1										1
New Jersey	3	4		1		1					9
New Mexico	4	2	1			4					11
New York	1	2		2			1				6
North Carolina	12	4	5		3						24
North Dakota		1	2		1						4
Ohio			1	2	1			1	2	2	9
Oklahoma	3	7	4		3	2		1		1	21
Oregon		1			6	2		3			12
Pennsylvania	3		2	2	2		2	2	5	2	20
Rhode Island								1			1
South Carolina	4		1		3			1			9
South Dakota	1		6		3		2	1			13
Tennessee	3	6				2	4				15

TABLE 2.5. (Continued)

State/Province	1	2	3	4	5	6A	6B	7A	7B	9	TOTALS
Texas	39	10	3	5	19	5	3	2		4	90
Utah	3		7			4					14
Vermont	2						2		1		5
Virginia	2	2			4		4				12
Washington	5		7			5	1				18
West Virginia		1		2	1			1			5
Wisconsin			13		2			1			16
Wyoming	2	8	1			3					14
Puerto Rico		2	2								4
Alberta	3	1					1				5
British Columbia	1	1				2					4
Manitoba	1	1	1				2		1		6
New Brunswick	2		1			1					4
Newfoundland	3										3
Nova Scotia						1					1
Ontario	3	3									6
Prince Edward Island	2	1									3
Quebec	3	1	4							1	9
Saskatchewan	2					2	2				6
	---	---	---	---	---	---	---	---	---	---	------
TOTALS	218	113	124	56	79	57	49	33	23	25	777

Pavement Type Codes	
1	AC on granular base
2	AC over bound base
3	JPCP
4	JRCP
5	CRCP
6A	Existing AC overlay of AC pavement
6B	Planned AC overlay of AC pavement
7A	Existing AC overlay of PCC pavement
7B	Planned AC overlay of PCC pavement
9	Unbonded PCC overlay of PCC pavement

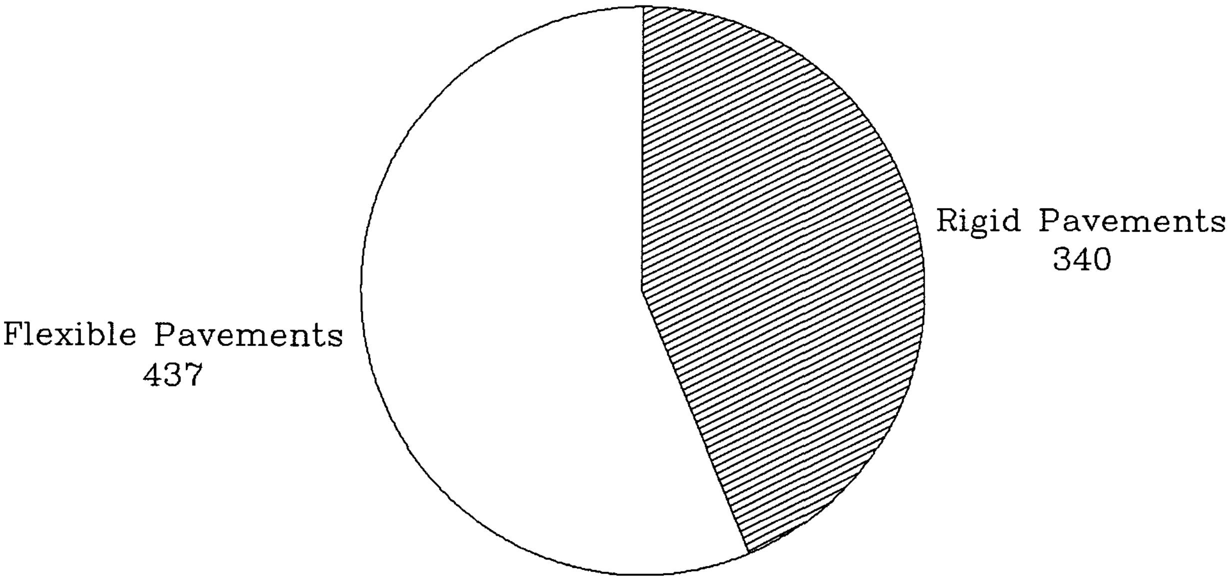


FIGURE 2.34. Distribution of Approved GPS Sections

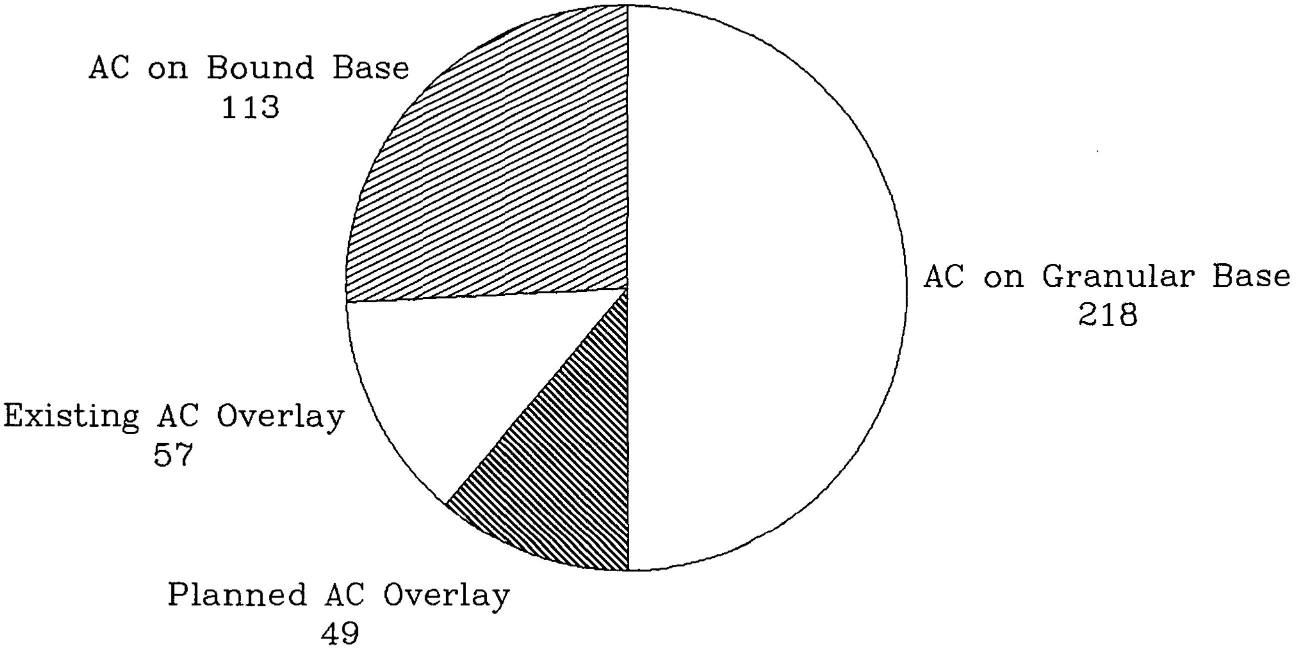


FIGURE 2.35. Distribution of GPS Flexible Sections

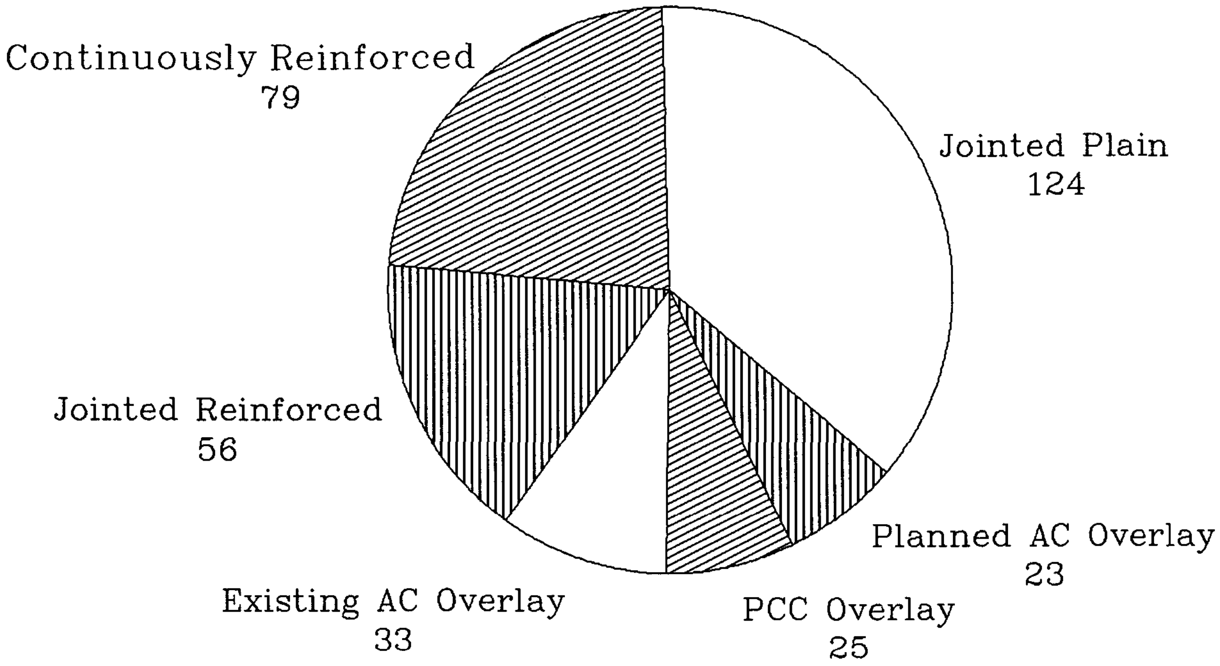


FIGURE 2.36. Distribution of SHRP GPS Rigid Sections

EARLY AVAILABLE DATA SOURCES

GPS Nomination Database

The technical assistance contractor maintained a database to administer the status of the test sections in the GPS experiments. This database contained information used to classify test sections in the sampling experiment factorials for each GPS experiment. It also contained the information from the GPS test section candidate data forms (Ref 3).

Field Verification Data Forms

During verification and layout of nominated test sections in the field, a set of field verification data forms was completed by the RCO contractor. In addition to verifying project compliance with site selection criteria and measurement of layer thicknesses and preliminary material type identification, a summary distress survey was performed. A videotape of the test section was also made. The field data verification data forms have now been submitted to SHRP. This information was used to update the project nomination database. The distress information and other data sheets are stored in SHRP files. The videotapes are stored in the RCOs (Ref 7).

DATA MODULES ACTIVITIES

The information to be collected in LTPP-GPS has been grouped into the data modules. These activities are documented in various chapters of the LTPP Data Collection Guide (Ref 8). This document is updated periodically as development of the details of the data elements within the chapter is completed and as needed on the basis of experience with the current data sheets. The data modules are as follows:

- Inventory
- Materials and laboratory testing data
- Traffic
- Distress
- Profile
- Deflection
- Skid resistance (friction)
- Environment
- Maintenance
- Rehabilitation

Details of the information contained in these modules and the anticipated schedule of availability are discussed by data type in the following sections.

Inventory

Inventory data refer to the data elements contained in Chapter 2 of the LTPP Data Collection Guide (Ref 8). This data includes the following categories of information:

- Project location and route description
- Geometry, shoulders, and drainage
- Layer structure and material types
- Pavement construction information
- Construction materials test data
- Material mix design data

Most of this information was obtained from agency construction records. Although this information is project specific, in most cases it will not be specific to the location of the test section, since agency records are rarely so detailed.

The number of inventory data elements varied for each test section. Participating agencies provided these data elements from available construction and testing records. In some cases records were lost or destroyed. Data elements that were considered a high priority were marked with an asterisk on the data sheets. Agencies were asked to provide as many of these data elements as possible and appropriate.

Materials and Laboratory Testing Data

Although much of the information contained in the inventory data module is related to materials, it is unlikely to be specific to the test section location. However, this module is the only source of information on the likely properties of the materials at the time of construction. The most accurate information on layering and the present characteristics of the materials will be available in the materials and laboratory testing data module of NPPDB (Ref 8). As described in Chapter 8 of the LTPP Data Collection Guide (Ref 8). An explanation of the entire materials characterization program is contained in the SHRP-LTPP Materials Characterization 5-year report (Ref 9).

The most current source for details of the material tests performed on samples from the GPS sections is contained in the SHRP-LTPP Interim Guide for Laboratory Materials Handling and Testing (PCC, Bituminous Materials, Aggregates and Soils) (Ref 10). Information on insitu measurements and field sampling procedures is contained in the SHRP-LTPP Guide for Field Materials Sampling, Testing and Handling (Ref 11).

Tests are being performed in accordance with the test protocols in the Interim Lab Guide (Ref 10). These procedures are sometimes changed as experience is gained with their use. An analyst may have to consider similar material test results derived from slightly different procedures. This situation is expected to occur for a relative small subset of test values. Results from different test procedures will be flagged in the database.

Traffic

The quality and amount of traffic data will vary greatly between sections. For the purpose of this discussion, traffic data can be classified into current estimates, historical data, and monitoring data.

Current estimates

The nomination database contains an estimate of the level of traffic loading in the test section lane at the time the test section was nominated. The nomination data forms contained little information on the source of this data. Most of this information is thought to be based on systemwide traffic statistics, not specific measurements at the test section site. In some cases, agencies used the SHRP-provided traffic nomographs to estimate equivalent single-axle loadings from annual average daily traffic and percentage trucks. This information was used to classify projects into sampling cells within each GPS experiment and is currently available for all approved GPS test sections in the GPS nomination database.

Historical data

Participating agencies were asked to provide available traffic data considered applicable to the test section, an estimate of the annual traffic loadings on the test section from construction to the start of monitoring for SHRP, and the basis of these estimated traffic statistics. This information will be provided on the data sheets contained in Chapter 4 of the LTPP Data Collection Guide (Ref 8). It is expected that the bulk of these data will be based on non-site-specific measurements and will be highly extrapolated. Although these data may be considered less precise than desired because of the absence of site-specific measurements, they form the best initial estimate of the historical loadings on a test section. When enough site monitoring traffic measurements are obtained, these estimates will be evaluated with respect to the measured loadings and may be adjusted as appropriate. Historical data will be stored in the traffic database, which will be used to develop annual loading estimates for transfer to NPPDB.

Monitoring data

The nature and extent of traffic monitoring measurements will vary greatly from site to site. Although SHRP has established minimum traffic data collection guidelines, it is expected that traffic data collection efforts that are considered substandard will have to be used for some test sections. SHRP has devised a data availability code that will be attached to the summary traffic statistics derived from all traffic data provided to SHRP. The ultimate goal will be to establish confidence ranges for the traffic statistics provided in NPPDB. Until there is enough information in the traffic database on which to base these estimates, this availability code will serve as a guide to the general source of the traffic data.

Distress

Distress information was collected primarily through strip photography of the test sections. These photographs were interpreted and input into NPPDB. Distress data from the strip photographs and hand-drawn distress maps are specified in NPPDB on a 1 foot by 1 foot grid. Cross-profile measurements were developed by a photographic technique for measuring the relative transverse profile. Methods employing hand-drawn distress maps and manual measurements were also used by RCO staff when it was not possible to obtain measurements by the automated techniques.

Although this data module is called distress data, information on the general condition of the test sections is included. For example, measurements of transverse crack spacings on CRCP are included even though such cracking is not necessarily a distress condition.

Profile

Automated profile measurements were performed by the RCO contractors using profiling equipment with noncontact sensors. Profiling equipment was delivered to the Western, North Central, and North Atlantic regions in 1989. In addition to such measurements, profile was also measured with a manual profile device in situations in which automated measurements could not be performed.

The profiles along the left and right wheel paths were included in the database. Summary statistics based on these profiles including the international roughness index, the Mays ride meter, and the root mean square of vertical acceleration at various base lengths up to 256 feet have been stored in NPPDB (or NIMS). A profile-based estimate of the serviceability index has not been included in the database. Other profile-based ride-quality statistics may be developed for implementation in the database.

Deflection

Deflection measurements were obtained with a falling-weight deflectometer (FWD) operated by RCO staff concurrent with the material drilling and sampling. This was done to provide deflection measurements at the same time the material samples were taken. The peak values of load and deflection for each measurement have been stored in NPPDB. Time histories of the load and deflection pulses at each sensor will also be available in an off-line mode. Details of the test procedures and data being collected can be found in the SHRP-LTPP Manual for FWD Testing (Ref 12).

Skid Resistance (Friction)

Skid resistance measurements were provided by participating agencies using the procedures and equipment they normally use. Measurements with locked-wheeled skid trailers were recommended. It was requested that these measurements be provided using two-year intervals as a minimum.

Environment

Environmental data for the GPS test sections consists of climatological data drawn from the weather database maintained by the National Oceanic and Atmospheric Administration. These data will be grouped in blocks of monthly statistics. The data in this module for GPS test sections do not include detailed information on temperatures in the pavement structure, frost depths, etc., because of the prohibitive cost of placing temperature-measuring devices in each section. It should be noted that pavement temperatures were measured during deflection measurements and were included in the deflection data module. Details of the proposed statistics can be found in the Guide for SHRP LTPP P-001 Environmental Data Collection (Ref 13).

All the details concerning GPS environmental data have not yet been finalized. At present an extrapolated virtual weather station is created for each test section on the basis of measurements from nearby weather stations. This data module contains a set of monthly records from a variety of weather stations (ranging from one to five) closest to each test section. These records are associated with test sections through a reference table. Locations of the weather stations are included in the data record.

Maintenance

The operation of maintenance units within most highway agencies was not suited to the detailed reporting of site-specific information of the detail requested on the LTPP data forms. At best, this information was expected to be specific to the project and not to the test section. In addition, it was anticipated that historical maintenance information might not be available in all instances. Because of the reporting emphasized in LTPP, maintenance information on treatments applied since the start of monitoring for SHRP is likely to be more reliable than information on earlier treatments.

Allowable maintenance treatments on the GPS test sections are presented in Guidelines for Maintenance of General Pavement Studies Test Sections (Ref 14). The maintenance data sheets are contained in Chapter 6 of the LTPP Data Collection Guide (Ref 8).

Rehabilitation

Rehabilitation data were provided by participating agencies. Although rehabilitation data were similar to maintenance data, they are expected to be of better quality, since rehabilitation projects are funded and managed differently from maintenance operations and require more detailed record keeping. Information on rehabilitation treatments applied before to SHRP was project-specific and in many cases incomplete with respect SHRP needs. Rehabilitation data from treatments applied during the SHRP period were no doubt more accurate and complete.

PRODUCTS

The principal product of SHRP-LTPP was the comprehensive, detailed, and complete long-term NPPDB. The database contains information on approximately 800 GPS test sections in the United States, Canada, and Puerto Rico. The information in the database extends the benefit of LTPP for decades and will allow future researchers to pursue and answer important questions about pavement maintenance, management, rehabilitation, and design. A more detailed review of NPPDB is offered in the SHRP-LTPP Information Management System 5-Year Report (Ref 15).

Second only to NPPDB in importance was the development of a National Information Management System (NIMS) to allow access to the data in the database. A detailed and extensive QA/QC program was implemented with NIMS to ensure quality of the data elements in the database through appropriate validation and verification. This NIMS is also discussed in the SHRP-LTPP Information Management System 5-Year Report (Ref 15).

The collection of SHRP-LTPP techniques developed in materials characterization, visual distress, profile, deflection, and instrumentation will certainly affect the adoption of more standard and fundamental pavement evaluation diagnostic techniques. The SHRP-LTPP standards, specifications, and protocols, when considered as companion documents to the data in NPPDB, offer a great opportunity for national and international standardization.

The traffic issues considered and traffic-monitoring activities pursued during the SHRP-LTPP program could certainly, by themselves, be considered products of the GPS program. The dialogue and cooperation developed among the traffic and highway organizations of the states participating in the SHRP-LTPP program has led to the development of standard specifications, methods, and protocols for all phases of traffic monitoring, including weigh-in-motion devices, automatic traffic classification, and data interpretation techniques. More definitive traffic-related products are anticipated in future LTPP activities as more states become more involved in traffic-monitoring activities and as comprehensive traffic volumes and vehicular loading data are obtained.

Products that will evolve from data analysis include improved pavement design equations, improved design and analysis techniques, distress-specific performance models, construction variability, factors important in rutting initiation, and a technique for reevaluating load-equivalency factors. These initial efforts offer a baseline for launching future research efforts.

Finally, a product of the SHRP-LTPP program is the national and international focus generated by the interest in long-term pavement performance. This focus was an overture to widespread cooperative studies and research efforts among not only states, but also countries. The information in the SHRP-LTPP database, and similar information gathered by the

Canadian SHRP and other international efforts, will certainly foster the development of a variety of standardized specifications, techniques, and protocols.

RECOMMENDED ACTIVITIES IN GPS

The activities in the GPS experiment design and data sampling template should be oriented toward the combination of GPS and Specific Pavement Studies (SPS) into a composite set of experiments that could provide the best intermediate data available to fill the gap between GPS (i.e., near-term results) and SPS (i.e., long-term [20-years] results). The early returns from SPS could be combined with the initial and continuing results obtained from GPS to form a data source that would include comprehensive, up-to-date information on pavement performance, traffic, materials characterization, pavement behavior, and pavement deterioration with time and with environmental and climatic conditions. The design matrices could be defined as Combined Pavement Studies (CPS).

All GPS data collection requirements should be evaluated and new or revised requirements should be developed. The necessity for multiple nondestructive testing (NDT) measurements (i.e., FWD, profiling, and distress and cross profile) on the GPS sites, as well as the frequency of NDT (i.e., both locations and number of repeated measurements) necessary to adequately characterize the pavement conditions should be established through a statistical evaluation of existing data. A reduction in test requirements---or increase, if warranted---would allow for better use and easier scheduling of the various monitoring devices.

Forensic studies should be undertaken to identify the conditions, construction techniques, materials, and pavement structures that resulted in pavement performance both much poorer and much better than that of most sections included in the GPS. The key to the forensic studies is the definition of the combination of structural elements, environmental factors, and load conditions that resulted in the poorest- and best-performing sections. It should be noted that "poorest" is a relative term, since poorly performing sections were essentially eliminated in the initial selection process.

Finally, consideration should be given to a redefinition of GPS-1 and 2. Even though there is an implied separation between flexible pavements with granular bases (GPS-1) and flexible pavements with bound bases (GPS-2), the distinction is not really relevant to the general status of the pavement sections in GPS-1. In the selection process, AC binder layers or those AC layers underneath the surface layer were considered subsurface layers (i.e., assigned a material classification code of 28) and essentially excluded in the process of assigning a section to GPS-1. Some of these sections are apparently full-depth asphalt sections supported on the subgrade. Since a material classification code of 21 (i.e., no base) allows assignment to GPS-1, full-depth sections were assigned to that experiment.

Since some of these subsurface layers reached thicknesses exceeding 10 inches, it is unlikely that this pavement structure (AC surface layer over a thick subsurface AC layer over a granular layer) behaves or performs as a GPS-1 (AC over granular base) test section.

The basic flexible pavement experiments (GPS-1 and 2) should be evaluated, and appropriate experiment and cell assignments should be redefined. In the process, any full-depth, deep-strength asphalt sections should be appropriately identified.

REFERENCES

1. Report on the Evolution and Development of GPS. Prepared for SHRP-LTPP by the Texas Research and Development Foundation. Austin, Texas. December 1990.

2. Final Development of General Pavement Studies Sampling Plan. Prepared for SHRP-LTPP by the Texas Research and Development Foundation. Austin, Texas. June 1988.

3. Recruitment Guidelines for Additional GPS Candidate Projects. Prepared for the SHRP-LTPP by the Texas Research and Development Foundation. Austin, Texas. October 1988.

4. *Operations and Quality Assurance Manual.* Long-Term Pavement Performance Informational Management System. SAIC. April 1990.

5 Long-Term Pavement Performance Information Management Researchers. SHRP. July 1991.

6. Gardner, M.P., and J.B. Rauhut. Development of the Detailed Experiment Plan for SHRP Long-Term Pavement Performance Studies. Brent Rauhut Engineering. Austin, Texas. March 1988.

7. Guidelines for Initial State Visits, Section Selection, and Section Verification. Prepared for SHRP-LTPP by the Texas Research and Development Foundation. Austin, Texas. July 6, 1988.

8. SHRP Draft Data Collection Guide for LTPP Studies. SHRP Report SHRP-LTPP-OM-001. revised January 17, 1990.

9. SHRP-LTPP Materials Characterization 5-Year Report. Prepared for SHRP-LTPP by the Texas Research and Development Foundation. Austin, Texas. 1992

10. SHRP-LTPP Interim Guide for Laboratory Materials Handling and Testing (PCC, Bituminous Materials, Aggregates and Soils). SHRP. November 1989.

11. SHRP-LTPP Guide for Field Materials Sampling, Testing and Handling. Version 1.0. SHRP. January 20, 1989.

12. SHRP-LTPP Manual for FWD Testing. SHRP Report SHRP-LTPP-OG-003. January 1989.

13. Guide for SHRP LTPP P-001 Environmental Data Collection. PCS-Law Memorandum. September 1989.

14. Guidelines for Maintenance of General Pavement Studies Test Sections. SHRP Report SHRP-LTPP-OM-001. July 1988.

15. SHRP-LTPP Information Management System 5-Year Report. Prepared for SHRP-LTPP by the Texas Research and Development Foundation. Austin, Texas. 1992