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RESEARCH RESULTS DIGEST

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Conversion of AASHTO Documents to Metric Units

This is an NCHRP digest of the findings from the final report on NCHRP Project 20-40, "Conversion of AASHTO Publications to Metric Units," conducted by Texas Transportation Institute, Texas A & M University. Mr. Byron C. Blaschke was the project's Principal Investigator.

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SUMMARY

This digest summarizes the work carried out in NCHRP Project 20-40 to hard convert 16 major AASHTO publications to the SI system of measurement units and provide them to AASHTO in reproducible format suitable for publication (hard conversion is a process in which an inch-pound standard size is replaced with an accepted metric standard size for a particular purpose). This digest discusses the research agency's experience with the conversion of each specific AASHTO Document and estimates the time and funds expended for each conversion. Finally, it presents guidelines for the efficient conversion of complex technical documents to assist public agencies tackling this difficult issue.

The need for converting the documents and software developed, administered, published and marketed by the American Association of State Highway and Transportation Officials (AASHTO) and the establishment of a metric clearinghouse is the result of a FHWA rule. This rule required that the "System International d'Unites" (generally referred to as "SI") be used for federal aid highway projects beginning October 1, 1996. (Note: In this document, any reference to the metric system or conversion to metric is intended to mean SI.)

AASHTO adopted a Master Plan for Metric Conversion to guide the conversion effort. This plan included the following tasks: (1) Assess

metric conversion needs, (2) Develop a plan of action, (3) Design a clearinghouse, (4) Convert AASHTO publications and software to metric units, (5) Convert member department publications and software to metric units, and (6) Operate the clearinghouse.

NCHRP Project 20-7, Task 61, "Assessment of AASHTO Needs for Metric Conversions and Design of Metrication Clearinghouse," provided a list of AASHTO publications recommended for conversion to metric units. In addition, the design of a clearinghouse to support the metrication activities in the highway community was developed. The project also provided for a pilot clearinghouse operation.

NCHRP Project 20-40 included the metric conversion of 20 AASHTO publications. Ultimately, AASHTO directed that metrication of four documents not be initiated or be terminated prior to completion of the conversion. The following documents have been metricized as part of this project:

<u>CODE</u>	<u>TITLE</u>
GDPS-4	<i>AASHTO Guide for the Design of Pavement Structures</i>
HDG-2	<i>Highway Drainage Guidelines, Vol. 1-11 & Glossary</i>
MDM-1	<i>Model Drainage Manual</i>
QA	<i>Quality Assurance Guide Specification</i>
IMQA	<i>AASHTO Implementation Manual for Quality Assurance</i>
US-5	<i>U.S. Numbered Highways</i>
GSFEB	<i>Guide Specs. for Fatigue Evaluation of Existing Steel Bridges</i>
HB-16	<i>Appendix E of Standard Specifications for Highway Bridges (16th Edition)</i>
ALFD-2	<i>Guide Specs. for Alternate Load Factor Design Procedures for Steel Beam Bridges</i>
GPEB	<i>Guide Specifications for Fatigue Design of Steel Bridges</i>
GSCBS	<i>Guide Specifications for Thermal Effects in Concrete Bridge Superstructures</i>
-	<i>A Guide to Standard Highway Drainage Products</i>
GSSB	<i>Guide Specifications for Structural Design of Sound Barriers</i>
HDG-2	<i>Highway Drainage Guidelines, Vol. 12 & 13</i>
MCEB	<i>Manual for Condition Evaluation of Bridges</i>
TG-1	<i>Transportation Glossary</i>

The metrication standards specified in AASHTO Designation: R1-91, *Standard Metric Practice Guide*, (ASTM Designation: E 380-89a) were used for the conversion. The AASHTO *Guide to Metric Conversion* also was used for guidance in the metrication effort.

The operation of the AASHTO Metrication Clearinghouse was added to this project together with enhancements involving Internet access and expanding the customer focus to include local governments.

A spring 1997 survey of metric coordinators was conducted to identify needed metric standards. Although the responses did not indicate any significant areas of consensus, it was apparent that there was a need to inform the AASHTO community of the many standards that have been adopted. A clearinghouse newsletter has been published to accomplish this. Several other needs or issues were also identified, including the following:

1. Guidelines for assisting local governments and other agencies involved in the highway program to implement the metric system,
2. Working with railroads and utility companies in the metric system,
3. Inconsistency in ANSI and AASHTO symbols,
4. Construction equipment limitations and characteristics,
5. Metric bolts, and
6. Numerous inconsistencies among state DOT metric standards.

The survey responses and the inquiries and issues tracked by the clearinghouse indicate that several major metric issues remain unresolved. These include metric signing, kilometer versus milepost reference markers, vehicle size and weight matters, and public acceptance of the metric system.

The report concludes with the following recommended future AASHTO actions regarding metrication:

1. Revisit the metric standards adopted by AASHTO;
2. Consider the adoption of IEEE/ASTM SI 10-97, *Standard for Use of the International System of Units*, which is the current U.S. national standard for SI; and
3. Continue to promote national metric standards for the highway industry and to minimize the differences of the metric practices of the state DOTs.

The enactment of the Transportation Efficiency Act for the Twenty-First Century (TEA-21) eliminated the deadline for metric conversion. Nevertheless, about half the state DOTs have indicated plans to continue the metrication efforts.

CHAPTER 1

BACKGROUND AND INTRODUCTION

PROJECT BACKGROUND

A series of events, beginning with the Metric Conversion Act of 1975, and continuing with the Omnibus Trade and Competitiveness Act of 1988 and subsequently Executive Order 12770, issued by President Bush on July 25, 1991, required that federal agencies develop conversion policies, plans, and timetables that would result in their use of the SI (metric) system in their procurement, grants, and other business-related activities. The U.S. DOT issued its metric conversion planning guidelines on May 8, 1990 (with amendments on March 23, 1992). The FHWA Metric Conversion Plan was approved by the Secretary of Transportation on October 31, 1991.⁽¹⁾ It required that for federal aid projects for which project agreements were executed after October 1, 1996, all plans, specifications and estimates (PS&E) must be in metric units. This regulation required AASHTO and its member departments to initiate extensive efforts to modify standards, guidelines, specifications, pay units, and numerous other items to convert their highway development programs for compliance with the targeted 1996 date.

The AASHTO Standing Committee on Highways appointed a Task Force on Metrication in 1992 to aid the conversion effort. Under its leadership and guidance, the various AASHTO committees reviewed the design policies, standards, guidelines, and other publications to identify the metrication requirements. The apparent extensiveness of the conversion efforts generated requirements to assess these conversion needs and to develop an action plan to guide the conversion effort. AASHTO also established a Master Plan for Metric Conversion (see Figure 1).

During summer 1993, the AASHTO Administrative Subcommittee on Information Systems developed a listing of metrication issues and conducted a survey of the states to determine conversion decisions and the status of metrication in the states. At subsequent meetings where this information was presented, it became apparent that a clearinghouse to reduce redundancy in the conversion activities, to serve as a repository of metric conversion documents for reference purposes, and to aid in coordination of the metrication activities was warranted.

NCHRP PROJECT 20-7, TASK 61

These AASHTO activities led to NCHRP Project 20-7, Task 61, "Assessment of AASHTO Needs for Metric Conversions and Design of Metrication Clearinghouse."⁽²⁾ This project resulted in the following conclusions and recommendations:

The metrication of the federal aid highway program as required by rules promulgated by the FHWA has and will continue to have a significant impact on AASHTO and its member departments. Since the federal aid highway program constitutes a significant part of the nation's total highway program and since it would be impractical to metricate [metricize] only a part of the highway development program, it is anticipated that the total program, regardless of funding, will be metricated [metricized]. Many local governments employ the standards and specifications adopted by the state transportation departments. It therefore is most probable that all highway, road, street and bridge construction will be metricized during the next several years.

The numerous documents that AASHTO develops and maintains establish the state of the art and list standard and acceptable practices for the highway program. It is important that they be updated and converted to metric units at an early date.

The very nature of the warrants for the creation of a metric clearinghouse, i.e., the numerous independent and uncoordinated activities and the duplicative efforts marking the metrication process to date, clearly indicates that an early establishment of the clearinghouse is desirable. A more coordinated metrication process, timely access to metrication information and a forum for the resolution of metric issues are expected to provide significant benefits to the highway programs in the United States. It is recommended that AASHTO proceed with the establishment of a metric clearinghouse as soon as possible.

Task 1. Assess Metric Conversion Needs

- Analyze each of AASHTO's publications (more than 90) and software products (more than 12) to determine the need for metric conversion of each.
- On the basis of contact with the AASHTO committee or other group responsible for each item, determine the status of any current or planned conversion efforts.
- Estimate the cost and duration of required conversion efforts.
- Gather such information as may be available on conversion needs for software and publications that are the responsibility of individual AASHTO member departments and summarize this information by type.

Task 2. Develop a Plan of Action

- Specify the steps needed to execute the necessary conversions within the required time frame.
- Recommend funding and institutional options for carrying out the steps needed to convert each AASHTO item.

Task 3. Design a Clearinghouse

- Identify the specific needs for coordination and communication during metric conversion of software and publications by AASHTO and by its member departments.
- Recommend a plan for organizing and operating the clearinghouse.

Task 4. Convert AASHTO Publications and Software to Metric Units

Task 5. Convert Member Department Publications and Software to Metric Units

Task 6. Operate the Clearinghouse

- Collect relevant information on the progress of metric conversion by AASHTO committees and member departments. Periodically distribute the information to those in need of it.

Figure 1. Master Plan for Metric Conversion.

In NCHRP Project 20-7, Task 61, the 132 documents then published by AASHTO were reviewed to determine the documents that required conversion to metric units. This assessment identified 44 documents that required metric conversion. Twenty-four of these documents were classified as "high" priority, and the remaining 20 documents were classified as "low" priority.

Subsequently, NCHRP Project 20-40, "Conversion of AASHTO Publications to Metric Units," was authorized with a goal of converting selected AASHTO publications to metric units. Phase I of this project listed six documents for conversion, and an additional 23 documents were selected for Phase II.

Criteria and Prioritization

The criteria used in NCHRP Project 20-7, Task 61, for establishing the need for metric conversion was as follows: *Criteria for determining the need to convert were related to the use of non-metric units of weight or measure in the documents. If any totally non-metric units were included in an active document not already scheduled for replacement, it was classified as conversion "required." Those documents which include dual units of weight and measure (both metric and English) and those which have only been soft converted to metric were classified as conversion "not required." Where documents are currently being revised, including metrication, but have not to date been adopted by AASHTO, the classification of "in progress" was assigned.*

The basis employed in NCHRP Project 20-7, Task 61, for prioritizing the documents to be converted was as follows: *Those documents which are associated with the development of plans, specifications and estimates (PS&E) were classified as "high" priority. Those documents not associated with PS&E development, such as maintenance, were classified as "low" priority.*

AASHTO's subsequent strategy to convert all of the documents to metric units by October 1, 1996, significantly reduced the importance of the prioritization scheme employed in NCHRP Project 20-7, Task 61. Hence, the prioritization designation was not continued into NCHRP Project 20-40.

AASHTO Documents Requiring Metrication

The documents that were identified in NCHRP Project 20-7, Task 61, as requiring conversion are listed in Tables 1 and 2. The documents that were originally selected to be metricized in NCHRP Project 20-40 are shown in *italics*.

AASHTO Metrication Clearinghouse

The AASHTO Metrication Clearinghouse was established and began operation as a pilot project as part of NCHRP Project 20-7, Task 61. In June 1995, the clearinghouse operation was incorporated into NCHRP Project 20-40. The continued operation of the Metrication Clearinghouse with several enhancements was included as part of Phase II.

NCHRP Project 20-40

NCHRP Project 20-40, "Conversion of AASHTO Documents to Metric Units," continued the fulfillment of the AASHTO Master Plan for Metric Conversion by providing for the metrication of selected AASHTO documents to SI units of measurement. The project was divided into two phases.

TABLE 1 AASHTO documents requiring conversion (high priority)

Code	Title
MSI	Manual on Subsurface Investigations
ALFD-2	<i>Guide Specs. for Alternate Load Factor Design Procedures for Steel Beam Bridges</i>
BWC	ANSI/AASHTO/AWS Bridge Welding Code D1.5-88
CMB-2	Construction Manual for Highway Bridges and Incidental Structures
GFC-2	<i>Guide Specs. for Fracture Critical Non-Redundant Steel Bridge Members</i>
GPEB	<i>Guide Specs. for Fatigue Design of Steel Bridges</i>
GSAHB	Guide Specs. for Aluminum Highway Bridges
GSBR	<i>Guide Specs. for Bridge Railing</i>
GSCB	<i>Guide Specs. for Design and Construction of Segmental Concrete Bridges</i>
GSCBS	<i>Guide Specs. for Thermal Effects in Concrete Bridge Superstructures</i>
GSID	<i>Guide Specs. for Seismic Isolation Design</i>
GVCB-1	Guide Specs. and Commentary for Vessel Collision Design of Highway Bridges, Vol. I
HB-15	Standard Specs. for Highway Bridges
SLWD	Guide Specs. for the Design of Stress-Laminated Wood Decks
DS-4	Design Standards -Interstate System
FCAH-3	Informational Guide on Fencing Controlled Access Highways
GDPS-4	<i>AASHTO Guide for Design of Pavement Structures</i>
HDG-2	<i>Highway Drainage Guidelines, Vol. 1-10</i>
MDM-1	<i>Model Drainage Manual</i>
SDMS	AASHTO SDMS™ Data Structure Technical Guide
MAPH	Hot-Mix Asphalt Paving Handbook
LPH	<i>Guide to Standardized Highway Lighting Pole Hardware</i>
Not Assigned	<i>A Guide to Standard Highway Drainage Products</i>
Not Assigned	A Guide to Small Sign Support Hardware

TABLE 2 AASHTO documents requiring conversion (low priority)

Code	Title
<i>TG-1</i>	<i>Transportation Glossary</i>
<i>US-5</i>	<i>U.S. Numbered Highways</i>
<i>GSEC</i>	<i>Guide Specs. for Strength Evaluation of Existing Steel and Concrete Bridges</i>
<i>GSFEB</i>	<i>Guide Specs. for Fatigue Evaluation of Existing Steel Bridges</i>
<i>GSSB</i>	<i>Guide Specs. for Structural Design of Sound Barriers</i>
SDTB-1	Guide Specs. for Strength Design of Truss Bridges (Load Factor Design)
TRW-2	Informational Guide for Training Right of Way
GHOV-2	Guide for the Design of High Occupancy Vehicle Facilities
GPRF-1	Guide for the Design of Park-and-Ride Facilities
GSGLC-3	Guide for Selecting Supplemental Guide Signs and List of Control Cities
PSOS-2	Guide for Protective Screening of Overpass Structures
BM-2	AASHTO Manual for Bridge Maintenance
GBM-1	Guide for Bridge Maintenance Management
MM-2	AASHTO Maintenance Manual
GSW-3	Guide for Maximum Dimensions and Weights of Motor Vehicles
UBA	A Manual on User Benefit Analysis of Highway and Bus Transit Improvements
<i>QCQA</i>	<i>Quality Control/Quality Assurance</i>
<i>HDG-2 (Vol. 12)</i>	<i>Vol. 12, Highway Drainage Guidelines</i>
<i>MCEB</i>	<i>Manual for Condition Evaluation of Bridges</i>
Not Assigned	Guide Specs. for Distribution of Loads for Highway Bridges

At the initiation of NCHRP Project 20-40, the member departments of AASHTO were preparing to do business using the International System of Units (SI) by October 1, 1996, to comply with FHWA mandates and a movement in the transportation industry to the metric system. With the enactment of the National Highway System legislation, the Secretary of Transportation now cannot withhold federal funds if metrication is not implemented prior to October 1, 2000. Nevertheless, the member departments' commitments to metric conversion and their progress toward total metrication were sufficient to warrant the continuation of this project.

TEA-21—AN UPDATE

In 1998, Congress enacted the Transportation Efficiency Act for the Twenty-First Century (TEA-21). This law eliminated the deadline for metric conversion, thereby making state DOT metrication optional. About half of the state DOTs have subsequently elected to continue to use the metric system.

FHWA Administrator Kenneth Wykle stated in an October 22, 1998, letter to the state DOTs, "Full conversion by all the state DOTs remains an FHWA goal since it will improve efficiency within the highway construction industry by reducing translation errors and enabling the contractors, consultants, fabricators, and material suppliers to return to a single system of units." He further stated that FHWA will continue to use metric in its daily business, including data collection.

In November 1998, the AASHTO Board of Directors directed that AASHTO publications be published in dual units, metric first, followed in parentheses or italics by soft conversions to customary U.S. units. They further directed that the Standing Committee on Highways will have the flexibility to determine the appropriate use of dual units.

CHAPTER 2

SCOPE OF WORK

RESEARCH PROBLEM STATEMENT

Project 20-40 corresponded to Task 4 of the Master Plan for Metric Conversion and included the metrication of selected (approximately 35) AASHTO documents to SI units of measurement. The AASHTO documents originally selected for conversion are listed in Table 3 and are divided into the two project phases.

PROJECT OBJECTIVE

The original objective of NCHRP Project 20-40 was to convert selected AASHTO documents to SI units of measurement, concurrently providing limited technical updating of some documents on the basis of state-of-the-art information that was to be provided by AASHTO subcommittees and task forces. The operation of the Metrication Clearinghouse was subsequently added to the objectives of the project.

STEPS FOR METRICATION OF DOCUMENTS

The metrication of the specified documents required several steps and a significant degree of coordination. The steps and the coordination are listed in Table 4.

An AASHTO representative from the AASHTO committee, task force, or other group responsible for the document to be metricized was appointed for each document to be metricized. A document manager for the researcher was also appointed for each of the documents.

METRIC STANDARDS

The metric conversion complied with the Standard Metric Practice Guide as adopted by AASHTO (AASHTO Designation: R1-91) (3) and with the AASHTO document, *The AASHTO Guide to Metric Conversion* (1). AASHTO R1-91 is identical to ASTM E 380-89a, except for the foreword. *The AASHTO Guide to Metric Conversion* is a somewhat simpler and more direct description of the guidelines.

The only exception to the AASHTO R1-91 guide used in the conversion was the spelling of meter and liter. AASHTO authorized the use of "meter" and "liter" in lieu of the "metre" and "litre" spelling included in AASHTO R1-91.

Early in the metrication of the *Highway Drainage Guidelines* (HDG-2), AASHTO granted an exception permitting the use of centimeters for the unit hydrograph. Subsequently, AASHTO decided to use millimeters for the hydrograph. AASHTO R1-91 does not support the use of centimeters.

Appendix A, *Guidelines for Metrication*, includes the instructions issued to the document managers regarding the usage and style for the metric system.

TABLE 3 AASHTO documents originally selected to be metricized

Phase	Code	Title
I	GDPS-4	<i>AASHTO Guide for the Design of Pavement Structures</i>
I	HDG-2	<i>Highway Drainage Guidelines, Vol. 1-11 & Glossary</i>
I	MDM-1	<i>Model Drainage Manual</i>
I	QCQA	<i>Quality Control/Quality Assurance</i>
I	US-5	<i>U.S. Numbered Highways</i>
I	GSFEB	<i>Guide Specs. for Fatigue Evaluation of Existing Steel Bridges</i>
II	ALFD-2	<i>Guide Specs. for Alternate Load Factor Design Procedures for Steel Beam Bridges</i>
II	GFC-2	<i>Guide Specs. for Fracture Critical Non-Redundant Steel Bridge Members</i>
II	GPEB	<i>Guide Specs. for Fatigue Design of Steel Bridges</i>
II	GSBR	<i>Guide Specs. for Bridge Railing</i>
II	GSCB	<i>Guide Specs. for Design and Construction of Segmental Concrete Bridges</i>
II	GSCBS	<i>Guide Specs. for Thermal Effects in Concrete Bridge Superstructures</i>
II	GSEC	<i>Guide Specs. for Strength Evaluation of Existing Steel and Concrete Bridges</i>
II	Not Assigned	<i>A Guide to Standard Highway Drainage Products</i>
II	GSID	<i>Guide Specs. for Seismic Isolation Design</i>
II	GSSB	<i>Guide Specs. for Structural Design of Sound Barriers</i>
II	HDG-2 (Vol. 12 & 13)	<i>Highway Drainage Guidelines, Vol. 12 & 13</i>
II	LPH	<i>Guide to Standardized Highway Lighting Pole Hardware</i>
II	MCEB	<i>Manual for Condition Evaluation of Bridges</i>
II	TG-1	<i>Transportation Glossary</i>
--	BM-2	<i>AASHTO Manual for Bridge Maintenance</i>
--	GBM-1	<i>Guide for Bridge Maintenance Management</i>
--	GSDL	<i>Guide Specs. for Distribution of Loads for Highway Bridges</i>
--	Not Assigned	<i>A Guide to Small Sign Support</i>
--	GVCB-1	<i>Guide Specs. and Commentary for Vessel Collision Design of Highway Bridges, Vol. 1</i>
--	HB-15 *	<i>Standard Specifications for Highway Bridges</i>
--	MM-2	<i>AASHTO Maintenance Manual</i>
--	SDTB-1	<i>Guide Specs. for Strength Design of Truss Bridges (Load Factor Design)</i>
--	SLWD	<i>Guide Specs. for the Design of Stress-Laminated Wood Decks</i>
--	UBA **	<i>A Manual on User Benefit Analysis of Highway and Bus Transit Improvements</i>

* Updating of Appendix E was subsequently requested as part of Phase I.

** Substitute computer software is being metricized under a separate NCHRP project

TABLE 4 Suggested steps for the metric conversion of AASHTO documents

Task	Step	Description	Resp.	Contract Period											
1-4	1	Contact AASHTO representative for coordination and communication	Doc. Mgr.*												
1	2	Identify technical updates required, date to be provided and any specific, associated issues	Doc. Mgr.												
2	3	Identify the required metric conversions	Doc. Mgr.												
2&4	4	Identify stakeholders (AASHTO units, standard setting organizations, FHWA, industry, etc.) and coordinate appropriate issues during the metrication effort	Doc. Mgr.												
2	5	Develop recommendations for hard conversions and obtain approval of AASHTO representative	Doc. Mgr.												
2&4	6	Develop a spreadsheet to list metric conversions, recommended actions and final disposition	Doc. Mgr.												
1-4	7	Structural related documents: Coordinate entire effort with structures document coordinator	Doc. Mgr.												
2	8	Develop electronic files - File 1 (original)	Doc. Mgr.												
2	9	Develop electronic files - File 2 (draft metricized document w/o technical updates)	Doc. Mgr.												
2&4	10	Develop electronic files - File 3 (draft metricized document w/ technical updates)	Doc. Mgr.												
2&4	11	Develop electronic files - File 4 (comparison document File 1 vs. File 3)	Doc. Mgr.												
2&4	12	Develop hard copy from File 4 (deliverable for Task 2 and possibly Task 4)	Doc. Mgr.												
2-4	13	Editing of hard copies and electronic files by ITEC (after steps 8, 9, 10, 11, and 12 as considered necessary)	TTI ITEC												
2	14	Submit draft metricized document (comparison) to NCHRP	TTI ITEC												
3	15	NCHRP and AASHTO review	-												
4	16	Respond to comments and make appropriate modifications (File 3 and File 4)	Doc. Mgr.												
4	17	Prepare metricized document (hard copies) for NCHRP and AASHTO review and balloting (up to 65 copies from either File 3 or File 4 - option of AASHTO)	TTI ITEC												
4	18	NCHRP and AASHTO review	-												
6	19	Respond to any comments and make appropriate changes to File 3	Doc. Mgr.												
4	20	Submit camera-ready hard copy and electronic files to NCHRP (final deliverables)	TTI ITEC												

* Doc. Mgr.- document manager

** TTI ITEC - Texas Transportation Institute Information & Technology Exchange Center

CHAPTER 3

DISCUSSION OF DOCUMENTS METRICIZED

OVERVIEW

The number of documents to be converted as part of the project was reduced from the originally selected 35 to the 21 ultimately included in Phases I and II of the project. Table 3 lists these documents. Each of the documents included in Phases I and II is discussed in further detail in this chapter. Note that the descriptions for each document are taken from the AASHTO *Catalogue of Publications* (4) unless otherwise noted.

PHASE I DOCUMENTS

Code:	GDPS-4
Title:	<i>AASHTO Guide for Design of Pavement Structures</i>
Description:	This guide provides state-of-the-art approaches to pavement design including design and management principles, procedures for new construction or reconstruction, procedures for rehabilitation of existing pavements, and mechanistic-empirical design procedures. This guide also provides new material on overlay design methodology and rehabilitation, including seven different overlay procedures and associated options. This guide supersedes Volume 1 of the same title published in 1986.
AASHTO Committee:	Highway Subcommittee on Design (Joint Task Force on Pavements)
Technical Updates:	None
Major Issues:	<ul style="list-style-type: none"> • Hard conversions included the following: 18 kip ESAL was converted to 80 kN; conversion factor for 1 inch was 25 mm. • The hard conversion of several graphs posed problems where equations documenting the development of the graphs were not found. In these cases, equations were developed to support the graphics, or the existing graphs were interpolated/extrapolated to produce the hard-converted figures. • The reinforcing steel sizes were changed to be consistent with the soft conversion sizes adopted by AASHTO.

Code:	GSFEB
Title:	<i>Guide Specifications for Fatigue Evaluation of Existing Steel Bridges</i>
Description:	These guide specifications establish a methodology for rating existing steel bridges. 1990.
AASHTO Committee:	Highway Subcommittee on Bridges and Structures (Technical Committee for Structural Steel Design, T-14)
Notes:	Interim specifications adopted subsequent to 1990 have been incorporated into the metricized document.
Technical Updates:	None
Major Issues:	None

Code:	HDG-2
Title:	<i>Highway Drainage Guidelines, Vol. 1-11 and Glossary</i>

Description:	These guidelines present an acceptable approach to hydrology and hydraulic problems. Subjects addressed include highway planning and location and facilities.
AASHTO Committee:	Highway Subcommittee on Design (Task Force on Hydrology and Hydraulics)
Technical Updates:	None
Major Issues:	<ul style="list-style-type: none"> • AASHTO granted an exemption for using centimeters for the unit hydrograph in lieu of millimeters. The Task Force subsequently elected to use millimeters. • The <i>AASHTO Guide to Metric Conversion (4)</i> specifies that decimals be used in lieu of fractions. It is not clear, however, whether the prohibition on fractions applies to exponents. The Task Force directed that fractional exponents continue to be used in frequently used equations (e.g., $s^{1/2}$, $r^{2/3}$).

Code:	MDM-1
Title:	<i>Model Drainage Manual</i>
Description:	The model drainage manual has been developed for use by any federal, state or local agency that intends to publish their own drainage policy and procedures manual. This manual is written in generic terms such that the user agency will only have to add their specific design policies and procedures to the pre-prepared text by changing the design criteria reflecting their own policies, saving the time and research on the design procedures. 1991.
AASHTO Committee:	Highway Subcommittee on Design (Task Force on Hydrology and Hydraulics)
Technical Updates:	None
Major Issues:	None

Code:	QC/QA (Original) Changed to QA and IMQA (2 documents)
Title:	Original - <i>Quality Control/Quality Assurance Specifications and Implementation Guide</i> New - <i>AASHTO Quality Assurance Guide Specification and AASHTO Implementation Manual for Quality Assurance</i>
Description:	<p>Original - This manual outlines how a department can implement a QC/QA program and explains what barriers may exist in attempting to create such an approach. The manual examines the general specifications principles of the QC/QA program, and it assists the user in creating a timetable for the plan and in determining how to present the program to agency personnel, contractors and suppliers. 1993.</p> <p>New - These quality assurance documents supersede the 1993 document entitled <i>Quality Control/Quality Assurance Specifications and Implementation Guide</i>. These companion documents outline how a department can implement a QA program, explain what barriers may exist in attempting to create such an approach, examine the general specification principles of a QA program and assist the user in determining how to present the program to agency personnel, contractors and suppliers.</p>
AASHTO Committee:	Highway Subcommittees on Construction
Technical Updates:	The 1993 document was totally replaced by two new documents.
Major Issues:	<ul style="list-style-type: none"> • Testing frequency and sub-lot sizes were hard converted.

Code:	US-5
Title:	<i>U.S. Numbered Highways</i>
Description:	Update of the 1979 edition. Listing of U.S. numbered routes, showing mileage (<i>converted to kilometers</i>) between towns and important junctions. The Official Log of the U.S. Numbered System. 1989.
AASHTO Committee:	Special Committee on U.S. Route Numbering
Technical Updates:	Current route information was provided.
Major Issues:	<ul style="list-style-type: none"> The soft conversion of miles to kilometers and rounding to the nearest kilometer has possibly introduced some error into the distances indicated.

Code:	Appendix E - HB-16
Title:	<i>Appendix E of Standard Specifications for Highway Bridges (16th Edition)</i>
Description:	The <i>Standard Specifications for Highway Bridges (16th Edition)</i> is in conventional English units. Appendix E lists the metric versions of all of the equations, thereby supporting metric design using the document.
AASHTO Committee:	AASHTO Subcommittee on Bridges and Structures
Notes:	The AASHTO Subcommittee on Bridges and Structures has adopted the <i>AASHTO LRFD Bridge Design Specifications</i> as an alternate design procedure and has been considering adopting the LRFD procedure as the AASHTO design procedure. Due to this pending decision, the <i>Standard Specifications for Highway Bridges (15th Edition)</i> was not directed to be metricized. However, since numerous states and many other entities continue to use this document, Appendix E, which had originally been developed in the 1970s, was directed to be updated to current metric standards.
Technical Updates:	Upon publication of the 16th Edition, the appendix was further modified to be consistent with this most current version of these bridge design specifications.
Major Issues:	<ul style="list-style-type: none"> The document was metricized to be consistent with the metric usage in the <i>AASHTO LRFD Bridge Design Specifications</i>.

PHASE II DOCUMENTS

Code:	ALFD-2
Title:	<i>Guide Specifications for Alternate Load Factor Design Procedures for Steel Beam Bridges</i>
Description:	Provides new compact section requirements and gives procedures for calculating the resistance of continuous beams by the mechanism method. 1991.
AASHTO Committee:	Highway Subcommittee on Bridges and Structures
Notes:	Interim specifications adopted subsequent to 1991 are incorporated into the metricized document.
Technical Updates:	None
Major Issues:	None

Code: GFC-2

Title: *Guide Specifications for Fracture Critical Non-Redundant Steel Bridge Members*

Description: Suggested requirements relating to identifying, fabricating, welding and testing of those members whose failure would be expected to result in bridge collapse. 1978, updated to 1986.

AASHTO Committee: Highway Subcommittee on Bridges and Structures

Notes: Work was discontinued due to inclusion of the document's Fracture Control Plan provisions into the *ANSI/AASHTO/AWS 1995 Bridge Welding Code*.

Technical Updates: None

Major Issues: None

Code: GPEB

Title: *Guide Specifications for Fatigue Design of Steel Bridges*

Description: These guide specifications have been developed as an alternative to the fatigue provisions in the AASHTO Standard Specifications for Highway Bridges, Articles 10.3.1 and 10.3.2. They are intended to more accurately reflect the actual fatigue conditions in bridges subjected to traffic loadings. 1989.

AASHTO Committee: Highway Subcommittee on Bridges and Structures

Technical Updates: None

Major Issues: None

Code: GGBR

Title: *Guide Specifications for Bridge Railing*

Description: These guide specifications have been developed to provide an alternative to the bridge railing design procedures contained in the AASHTO Standard Specifications for Highway Bridges. Contains three bridge railing performance levels and associated crash tests and performance requirements along with guidance for determining the appropriate railing performance level for a given bridge site. 1989.

AASHTO Committee: Highway Subcommittee on Bridges and Structures

Notes: Work was discontinued when the subcommittee decided to incorporate the document into the LRFD.

Technical Updates: None

Major Issues: None

Code: GSCB

Title: *Guide Specifications for Design & Construction of Segmental Concrete Bridges*

Description: Comprehensive guidelines embody several new concepts that are significant departures from previous design and construction provisions. Based on recent research conducted in the United States and abroad. 1989.

AASHTO Committee: Highway Subcommittee on Bridges and Structures

Notes: Work was discontinued when the subcommittee decided to rewrite the document.

Technical Updates: None

Major Issues: None

Code: GSCBS

Title: *Guide Specifications for Thermal Effects in Concrete Bridge Superstructures*

Description: These guide specifications contain design guidelines for thermal effects in highway concrete bridge superstructures. 1989.

AASHTO Committee: Highway Subcommittee on Bridges and Structures

Technical Updates: None

Major Issues: Several maps with temperature information were not converted. In lieu of conversion, a graphical conversion scale was added to the maps. This permits a convenient and fast means of converting temperatures from °C to °F.

Code: GSEC

Title: *Guide Specifications for Strength Evaluation of Existing Steel and Concrete Bridges*

Description: These guidelines establish a methodology for rating existing steel and concrete bridges. Utilizing load and resistance factors, the procedures allow for combining probability theory, statistical data and engineering judgment into a decision-making tool. 1989.

AASHTO Committee: Highway Subcommittee on Bridges and Structures

Notes: The document was initially selected for metrication as part of Phase II. The Subcommittee on Bridges and Structures subsequently elected not to initiate metrication.

Technical Updates: None

Major Issues: None

Code: Not Assigned

Title: *A Guide to Standard Highway Drainage Products*

Description: This guide is one of a series of guides prepared by Task Force 13 in an effort to promote beneficial standardization of details for bridge and road hardware. It is provided as a supplement to existing specifications. It provides guidance for users and specifiers of highway drainage products who may not have ready access to such information or who may be looking for potentially more economical specifications or details that are in use for these products. (Taken from the introduction for the guide)

AASHTO Committee: Joint AASHTO-AGC-ARTBA Cooperative Committee Task Force 13

Notes: The current guide was developed by Task Force 13 in December 1986. It is not included in the AASHTO Catalogue of Publications.

Technical Updates: Extensive technical updates to the 1986 document were provided by members of Task Force 13.

Major Issues:	None
Code:	GSID
Title:	<i>Guide Specifications for Seismic Isolation Design</i>
Description:	This document covers specifications for the seismic isolation design of highway bridges and is supplemental to the AASHTO Standard Specifications for Highway Bridges. The fundamental requirements for seismic design are presented. 1991.
AASHTO Committee:	Highway Subcommittee on Bridges and Structures
Notes:	The document was initially selected for metrication as part of Phase II. The Subcommittee on Bridges and Structures subsequently elected not to initiate metrication.
Technical Updates:	None
Major Issues:	None
Code:	GSSB
Title:	<i>Guide Specifications for Structural Design of Sound Barriers</i>
Description:	This publication provides for the first time consistent design criteria for the preparation of plans and specifications for sound barriers, a relatively new area of design intended to alleviate the impact of highway noise upon surrounding communities. 1989.
AASHTO Committee:	Highway Subcommittee on Bridges and Structures
Notes:	Interim specifications adopted subsequent to 1989 are incorporated into the metricized document.
Technical Updates:	None
Major Issues:	None
Code:	HDG-2 (Volumes 12 & 13)
Title:	<i>Highway Drainage Guidelines (Volumes 12 and 13)</i>
Description:	(Please refer to HDG-2 in Phase I.) These guidelines present an acceptable approach to hydrology and hydraulic problems. Subjects addressed include storm water management and training and career development of hydraulic engineers.
AASHTO Committee:	Highway Subcommittee on Design (Task Force on Hydrology and Hydraulics)
Notes:	These are two new volumes for the <i>Highway Drainage Guidelines</i> that have been recently approved by AASHTO.
Technical Updates:	None
Major Issues:	None
Code:	LPH
Title:	<i>Guide to Standardized Highway Lighting Pole Hardware</i>

Description: This guide contains suggested standard details and specifications for those lighting pole items that are widely used and that have well-defined service requirements.

AASHTO Committee: Joint AASHTO-AGC-ARTBA Cooperative Committee-Task Force 13

Notes: Document required extensive technical updating that could not be accomplished within the time restraints of the project. Accordingly, no metrication activity was initiated.

Technical Updates: None

Major Issues: None

Code: MCEB

Title: *Manual for Condition Evaluation of Bridges*

Description: This document supersedes the 1983 document *Manual for Maintenance Inspection of Bridges*. This manual provides uniformity in the procedures and policies for determining the physical condition, maintenance needs and load capacity of highway bridges. 1994.

AASHTO Committee: Highway Subcommittee on Bridges and Structures

Technical Updates: Numerous changes to the prestressed concrete sections and to the steel stringer rating example, together with editorial modifications, were submitted by the subcommittee.

Major Issues: None

Code: TG-1

Title: *Transportation Glossary*

Description: A glossary of over 1,500 terms used in the aviation, highway, public transportation, railway and water transportation modes.

AASHTO Committee: Standing Committee on Administration

Technical Updates: None

Major Issues: None

HISTORY OF DOCUMENT SUBMISSIONS AND FINANCIAL STATUS

Tables 5 and 6 reflect the history of submissions of the draft and final metricized documents and the expenditures by document (estimated through January 1999).

TABLE 5 History of submission and financial status of Phase I documents

Code	Title	Expenditures (Estimated)	Submission Dates			
			Draft Document	Comments Rec'd	Final Document	Final Deliverables
HDG-2	Highway Drainage Guidelines (Volumes 1-11 & Glossary)	93,981	6/95	7/95 7/96 8/97 4/98	6/97 2/98*	1/99
			5/96 (w/mod)	*Second edition of final metricized document		
US-5	U.S. Numbered Highways	16,416	4/95	9/95	1/96	7/96
GSFEB	Guide Specs. for Fatigue Evaluation of Existing Bridges	35,481	6/95	9/95	1/96	7/96
GDPS-4	AASHTO Guide for the Design of Pavement Structures	234,832	6/96 ¹ 4/97 ² 6/9 ³ 7/97 ⁴	8/96 ¹ 6/97 ² 7/97 ³ 5/98	3/98	1/99
			Note 1: Original draft document Note 2: Submission of Appendix D Note 3: Text of modified portion of document including reinforcing steel modification, although completed, will be submitted when associated graphics are complete. Note 4: Remaining graphics			
MDM-1	Model Drainage Manual	167,696	6/97	6/97 4/98	11/97	6/98
QA and IMQA	Quality Assurance Guide Specification and Implementation Manual for Quality Assurance (formerly Quality Control/Quality Assurance)	6,004	6/96	2/97	5/97 & 6/97*	12/97
			*Original submission was destroyed in U.S. Mail. Resubmitted in 6/97			
HB-16, Appendix E	Appendix E of HB-16, Standard Specifications for Highway Bridges	23,733	10/96	1/97	5/97	8/97
Totals		578,143				

TABLE 6 History of submission and financial status of Phase II documents

Code	Title	Expenditures (Estimated)	Submission Dates			
			Draft Document	Comments Rec'd	Final Document	Final Deliverables
ALFD-2	Guide Specs. for Alternate Load Factor Design Procedures for Steel Beam Bridges	28,153	11/96	1/97	2/98	10/98
GFC-2	Guide Specs. for Fracture Critical Non-Redundant Steel Bridge Members	5,708	-	-	-	3/97
			Work was discontinued due to the inclusion of the material in the ANSI/AASHTO/AWS 1995 Bridge Welding Code. The final deliverable was the electronic file of the original document.			
GPEB	Guide Specs. for Fatigue Design of Steel Bridges	14,043	1/97	-	-	7/97
			The subcommittee decided to archive the document. The final deliverable was the electronic files and hard copy of the draft metricized version.			
GSBR	Guide Specs. for Bridge Railing	19,490	-	-	-	8/96
			Work was terminated when the subcommittee decided to incorporate the document into the LRFD. The products completed prior to notification to terminate the metrication effort were assembled and submitted as the final deliverable.			
GSCB	Guide Specs. for Design and Construction of Segmental Concrete Bridges	14,021	-	-	-	3/97
			Work was terminated when the subcommittee decided to rewrite the document. The work accomplished was submitted as the final deliverable.			
GSCBS	Guide Specs. for Thermal Effects in Concrete Bridge Superstructures	9,903	11/96	1/97	3/97	5/97
GSID	Guide Specs. for Seismic Isolation Design	0	Work was not initiated at the request of AASHTO.			
LPH	Guide to Standardized Highway Lighting Pole Hardware	0	Work was not initiated at the request of AASHTO.			
Not Assigned	A Guide to Standard Highway Drainage Products	62,491	3/97	5/97	6/97 (Rev) 12/97	7/98
TG-1	Transportation Glossary	8,413	8/96	-	10/97	8/98
GSEC	Guide Specs. for Strength Evaluation of Existing Steel and Concrete Bridges	0	Work was not initiated at the request of AASHTO.			
GSSB	Guide Specs. for Structural Design of Sound Barriers	43,981	8/96	7/97	11/97	3/98
MCEB	Manual for Condition Evaluation of Bridges	28,973	4/97	6/97	12/97	10/98
HDG-2 (Vol. 12 & 13)	Highway Drainage Guidelines, Vol. 12 & 13	18,837	2/96	12/96	3/97	1/99*
			*Task Force requested that Volumes 12 & 13 be submitted with Volumes 1-11.			
Total		254,012				

ACKNOWLEDGMENTS

The authors wish to acknowledge the contributions made by the many parties who provided guidance, information, and assistance in the metric conversion activities and the operation of the AASHTO Metrication Clearinghouse. Special thanks are due to the many individuals appointed as AASHTO contacts for the converted documents and to the members of the AASHTO committees who have reviewed the metricized documents.

The extensive work and assistance of the staff of the Texas Transportation Institute's Information & Technology Exchange Center (ITEC), especially Michelle Walker, Kelly West, and Chris Pourteau, in editing the documents and preparing the electronic files are most appreciated and acknowledged.

Our appreciation and thanks are also extended to the many state DOTs and the FHWA metric coordinators who have been active participants in the unofficial network associated with the clearinghouse operations. Their suggestions and contributions have significantly contributed to the success of the clearinghouse.

REFERENCES

1. *Guide to Metric Conversion*, American Association of State Highway and Transportation Officials, Washington, D.C. (1993).
2. Blaschke, Byron C., Draft Final Report, NCHRP Project 20-7, Task 61, "Assessment of AASHTO Needs for Metric Conversions and Design of Metrication Clearinghouse" (April 1994).
3. *AASHTO Specifications for Materials*, AASHTO Designation: R1-91, Standard Metric Practice Guide, American Association of State Highway and Transportation Officials, Washington, D.C. (1993).
4. *AASHTO Publications, The Forefront of Transportation Knowledge, Fall 1993*, American Association of State Highway and Transportation Officials, Washington, D.C. (1993).

APPENDIX A

GUIDELINES FOR METRICATION

The following style book was developed as a guide for the document conversion. These guidelines were prepared for Phase II and incorporated the lessons learned in Phase I.

STYLE BOOK
NCHRP Project 20-40
Phase II
Conversion of AASHTO Publications to Metric Units

INTRODUCTION

The conversion of the AASHTO publications to metric units will involve several document managers and several organizations. It is critical that the conversion effort and the resultant converted documents be consistent. This style book has been developed to serve as a guideline to aid in achieving this consistency.

STANDARDS FOR THE METRICATION OF DOCUMENTS

Compliance with the Standard Metric Practice Guide as adopted by AASHTO (AASHTO Designation: R1-91) is an essential requirement of this project. This document is identical to ASTM E 380-89a, except for the foreword to each practice guide. The

AASHTO Standing Committee on Highways, at their most recent meeting in November 1994, reaffirmed their adoption of R1-91 as the AASHTO standard. A somewhat simpler and more direct description of the guidelines is included in the AASHTO document, *The AASHTO Guide to Metric Conversion*.

The *AASHTO Guide to Metric Conversion* and AASHTO R1-91 will be the basis of metrication. For any conflicts between the two documents, AASHTO R1-91 will prevail. The only changes in AASHTO R1 that have been approved for this project are the following:

- AASHTO has determined that *meter* and *liter* are the preferred spelling rather than *metre* and *litre* as indicated in the last sentence of the Foreword of the document.
- The use of the unit centimeter has been approved for the unit hydrograph. (*Note: Subsequent to the AASHTO approval, the AASHTO Task Force on Hydraulics and Hydrology decided to use the millimeter for the unit hydrograph.*)

The proper use of AASHTO R1-91—specified conversion factors, the appropriate conversions with respect to significant figures, and the accuracy and precision of the converted unit values must be especially emphasized and closely monitored.

- The metric system does not permit the flexibility of usage, which is common in the English system. Examples are as follows:
 - In technical documents, the metric symbol should always be used with the quantity (e.g., 24 kg, not 24 kilograms).
 - A space should be provided between the quantity and the symbol (24 kg, not 24kg), except for °C (e.g., 33°C, not 33 °C).
 - For numbers where the number of digits either right or left of the decimal point is more than four, groups of three digits should be separated by a space, not by commas (e.g., 123 456.789 012). An exception is when a number of four digits is included in a table of numbers with more digits, in which spaces may appropriately be used to permit proper alignment of digits.
 - For charts and graphs, use symbols since these are closely associated with the numbers reflected in the graph.
 - AASHTO R1-91, Section 4, Rules for Conversion and Rounding should be used in determining converted values.

FORMAT OF DOCUMENTS

The AASHTO committees, subcommittees, and task forces have been afforded considerable latitude in the format employed for their publications. Accordingly, there are many differing formats and sizes represented among the numerous publications. The sheet size and format of the current documents should be replicated in the metricized document unless otherwise directed by the NCHRP project panel.

HARD VERSUS SOFT CONVERSIONS

Decisions on hard versus soft conversions will be made on a "use hard conversions where practical" basis and will be subject to the decision of the AASHTO subcommittee or task force responsible for the document. The converted documents will be in SI units only unless otherwise directed by the NCHRP project panel. If an AASHTO subcommittee or task force recommends dual units, this must be brought to the attention of the NCHRP project panel. Where dual units may be authorized, the SI unit should be indicated first, with the English unit following and enclosed in parentheses.

Decisions regarding hard conversions may be dictated by prior or pending decisions of AASHTO, industry, standard-setting organizations, and trade associations. It will be critical to identify these prior and pending decisions. Therefore, the early and comprehensive identification of these stakeholders and the early coordination of hard conversions must be a special emphasis area. The hard conversions incorporated in the metric version of the new LRFD design specifications is an example of the prior decisions, which must be carefully reviewed and incorporated on a consistent basis in the documents to be metricized in this project.

The decisions regarding hard conversions are the responsibility of the AASHTO representative. As contractors, our responsibility is to recommend the appropriate hard conversions.

APPENDIX B

A DISCUSSION REGARDING THE METRICATION OF GDPS-4, *AASHTO GUIDE FOR THE DESIGN OF PAVEMENT STRUCTURES*, AND HDG-2, *HIGHWAY DRAINAGE GUIDELINES*

The experiences in converting GDPS-4, *AASHTO Guide for the Design of Pavement Structures* and HDG-2, *Highway Drainage Guidelines*, incorporated many, and, in fact, most of the numerous issues that were encountered in the metrication of the AASHTO documents included in this project. These experiences are related in this appendix to provide some insight and recommendations for those who may be undertaking similar conversion efforts.

THE OBJECTIVE

The objectives of the project included the following:

- Produce a camera-ready hard copy of the metricized document.
- Produce electronic files of the text, tables, and graphics included in the final document.
- Where electronic files of the graphics were not practical, provide a camera-ready copy to cut and paste into the complete camera-ready hard copy of the document.
- Produce a comparison document that indicates the changes from the original to the final metricized document.
- Employ hard conversions to the maximum extent.

BEGINNING RESOURCES

In addition to the printed version of the document, AASHTO provided the following:

- **GDPS-4, *AASHTO Guide for the Design of Pavement Structures***

AASHTO provided ASCII files of the text and tables. The electronic files were developed by the publisher of the document and included numerous embedded printer's codes. Electronic files of the graphics were nonexistent.

- **HDG-2, *Highway Drainage Guidelines***

AASHTO provided electronic files of the text and tables. Volumes 1 through 10 were in ASCII format, while Volume 11 was in Ventura/WordPerfect 5.0. Original photographs were provided for some of the pictures included in the document, while halftones were provided for others. For several of the pictures, the picture included in the published document was the only version available. Electronic files of the graphics were nonexistent.

THE CONVERSION EFFORTS

- **GDPS-4, *AASHTO Guide for the Design of Pavement Structures***

The initial steps in the development of the document involved preparation of a complete, formatted WordPerfect document. The ASCII files provided were apparently developed by a printer using Afga Miles software. The Afga Miles software was not available; therefore, the typesetter codes had to be manually removed. Furthermore, the ASCII files required reformatting. In retrospect, the effort required to produce an electronic file of the published document employing this strategy exceeded the estimated effort to keypunch the material into a new word-processing file.

The graphics were plotted and developed using Freehand for the Macintosh. The graphics were easy to edit; however, this format could not be easily placed into the WordPerfect document. Conversion or scanning of the figures was necessary to import the figure into WordPerfect. Afterwards, we found that CorelDraw on the PC was very effective, and figures converted easily to wpg format (WordPerfect graphic).

After attempting a computerized alteration of the scales on the figures and nomographs, it was decided to convert them manually, redraw the figures, and then scan them to convert to electronic format. It was found that this process of redrawing and scanning the figures produced a desirable quality of graphic; hence, it was decided to redraw all of the figures and nomographs.

Some of the comments received from the AASHTO Joint Task Force on Pavements (JTFFP) raised questions regarding the expression of the structural number (SN) in millimeters, the AREA equation, and the conversion of graphs

and tables to "reasonable" SI units (i.e., hard conversion).

The initial version of the draft metricized document was based on the hard conversion of reinforcing steel sizes originally adopted by the industry. The industry's subsequent decision to soft convert the reinforcing steel sizes was incorporated into new ASTM specifications and adopted by AASHTO during the term of the project.

Following extensive communications with the JTFF, the following directions were established:

- The structural number (SN) was to be expressed in millimeters.
- The reinforcing steel sizes and ASTM grades were to be consistent with the newly adopted ASTM specifications (i.e., soft conversions of current sizes).
- Approximately 15 graphs were to be modified to indicate families of curves in rounded, hard-converted units.
- The tables in Appendix D, "Conversion of Mixed Traffic to Equivalent Single Axle Loads for Pavement Design," were to be hard converted.

Many, but not all, of the graphics were supported by documentation included in the text of the document and/or in Volume II of the *AASHTO Guide for the Design of Pavement Structures*, which included documentation for the 1986 version of the document. In these cases, it was possible to re-create the graphics based on the appropriate equations.

Documentation for several of the graphics was not found. Attempts to re-create some of the graphs proved unsuccessful. Research, including discussions with the authors of the 1986 document, could not produce the necessary documentation. In each of these cases, equations were developed to support the procedure. In a few instances, the resultant equation yielded a graphic which differed from the published version. Except for those cases where it was clearly evident that the original graphic was nonsupportable, the existing graphic was hard converted to metric units using a graphical interpolation and/or extrapolation.

During the development of the metricized document, it was necessary to employ several different entities for the development of the graphic files. This has provided extra challenges in monitoring the versions of the graphics and ensuring the inclusion of the most current version.

Several other factors resulted in extensive extra resource requirements. It was determined that an experienced editor was needed to review and revise the document. The formatting of the document was very time consuming. Additionally, the development of the comparison document was difficult to generate. The automatic feature in WordPerfect yielded comparison documents that were almost impossible to read. Hence, the comparison document was developed manually.

Despite the extensive review by an experienced in-house pavement engineer, the initial version of the final metricized document submitted to the Joint Task Force on Pavements (JTFF) was found to include numerous inconsistencies. The extensive time required for members of the JTFF to thoroughly review the document resulted in the employment of a pavement engineering consultant to independently review this initial version and the subsequently submitted final metricized document.

• **HDG-2, *Highway Drainage Guidelines***

One of the initial efforts of the conversion process was the development of a spreadsheet that documented an inventory of the needed conversions, together with recommended conversions, commentary and AASHTO Task Force decisions (refer to Figure E-1). The initial metric version of the document was produced in WordPerfect 6.0, and the graphics were produced in MicroStation. Problems in maintaining the stability of the files led to employing Quark, a publishing software, to develop the final version of the document.

Original photographs were not available for several of the pictures in the document. Despite extensive efforts to produce a high-quality reproduction, scanning of the halftones and the printed versions of the photographs often yielded poor quality reproductions, including moire patterns.

The AASHTO Task Force on Hydrology and Hydraulics received an exemption from the AASHTO Board of Directors to use centimeters for the unit hydrograph. (The metric standard adopted by AASHTO does not allow the use of centimeters.) Subsequently, the Task Force decided to use millimeters for the unit hydrograph, and the document was correspondingly revised.

Thorough reviews of the draft and final versions of the metricized document were conducted by members of the AASHTO Task Force on Hydrology and Hydraulics. As appropriate, their recommendations were incorporated into the final metricized document.

GENERAL

The challenges of developing the electronic files, preparing the graphics, editing, and proofreading proved to be much more demanding than the technical conversions. The proofreading activity was made even more difficult with the instability

of the initial versions of the electronic files. Much of this resulted from sharing electronic files among multiple computers, some of which were set up with different printer drivers.

Wordprocessing software, in lieu of publishing software, was found to be challenging for laying out these voluminous, complicated documents. Problems were experienced in handling graphics, the two-column format and equations.

RECOMMENDATIONS

The following recommendations are based on the strategies that have been beneficial in this project and the lessons learned from experience:

- Develop a spreadsheet that lists an inventory of items requiring conversion, documents recommended changes, lists review comments and indicates final decisions. Figure B-1 includes an example spreadsheet.
- Identify linkage between equations, graphs, nomographs, text, tables, and example problems prior to beginning conversion to metric units. For soft conversions, this is not critical. However, for hard conversions, succeeding elements must use the same hard-converted factors to ensure consistency.
- Integrate any document updates early in the conversion process, where possible.
- Identify and resolve technical issues as early in the conversion process as possible (e.g., the SN issue, documentation for nomographs, and changes in national standards).
- If existing electronic files contain embedded printer's code or are formatted in a software other than that to be used, developing a new version of electronic files for the document should be given serious consideration.
- Obtain original photographs if photos are to be incorporated into the document. Scanning of printed pictures or halftones can produce poor quality figures which often include moire patterns.
- Maintain a master copy of the electronic files. This is critical when multiple individuals using different computers, different versions of software packages, and different printer drivers work on the same document. One person only should maintain the electronic files, using a consistent version of the authoring software and a consistent printer driver. Modifications to the document can be indicated on hard copy by technical contacts and reviewers.
- Establish a file-naming system which clearly identifies the versions of files developed, including the date of development.
- Maintain a log of all work accomplished, who performed the work, and when it was completed.
- Select a publishing software that is compatible with the wordprocessing software and the graphics software employed.
- In selecting the graphics software, insure that it is compatible with the wordprocessing software to be used and with the publishing software, if used.
- The conversion of graphics is problematic when it involves the hard conversion of families of curves. This requires redrafting, which can best be accomplished with original equations. However, when original documentation cannot be found to support the graphs, new equations must be derived. If this derivation yields relationships differing from the published version, the choice is to:
 - Develop a new graphic based on the derived equation or
 - Graphically interpolate and extrapolate the published version.
 If the former option is selected, related changes must be made in equations, text, example problems, and so on to ensure consistency.
- The review of the document can be a very time-consuming endeavor for AASHTO committee members. Retaining an independent consultant to review, or assist with the review of, the document can be a viable alternative.
- Employ experienced editors to ensure consistent formats and styles in the documents.
- Employ experienced graphic operators to obtain high-quality reproductions of photos and other graphics.
- All corrections of graphics should be made by modifying the graphics file itself, not by patching the authoring program.
- Budget for extensive editing, proofreading, and checking of documents, especially those involving extensive technical detail (i.e., equations, nomographs, example problems, etc.).
- A standard format and style established by AASHTO would aid in the development of documents. Current practice allows each AASHTO committee to select the size, style and format of their documents.
- Development of comparison documents (i.e., a document which clearly shows items added, deleted or modified in developing the modified document) is problematic. Although this function is included in most wordprocessing software (e.g., using the "Add Compare Markings..." in WordPerfect), it is not always easily accomplished without extensive manual intervention. If comparison documents are to be developed, plan to develop them manually.

NCHRP Project 20 -40 COMMENT- RESOLUTIONS - METRICATION of AASHTO Manuals									
Highway Drainage Guidelines									
Metrication of text, equations, numbers, nomographs, figures and Maps									
25-Oct-95									
DMJM WGB									
Job No. 6502.01									
Volume I Guidelines for Hydraulic considerations in Highway Planning and Locations									
Page No.	Section	Description of item to be changed	Conversion Work Sheet		Consultant Suggestions		AASHTO REMARKS		
			Conversions	Remarks			and or changes		
5	2.3.4 2.	greater than 1 foot...	greater than 0.30 meters...	2	greater than 0.3 meters...		Ok		
5	2.3.4 4.	greater than 1 foot...	greater than 0.30 meters...	2	greater than 0.3 meters...		OK		
14	3.4.1	Figure 2. General Types of Longitudinal Encroachments	delete bold title over figure	Errata	delete bold title		Ok		
15	3.4.2	several miles	several kilometers	1	several kilometers		Ok		
Volume II Guidelines for Hydrology									
Page No.	Section	Description of item to be changed	Conversion Work Sheet		Consultant Suggestions		AASHTO REMARKS		
			Conversions	Remarks			and or changes		
2	2.1.1	in acres or square miles, is determined	in hectares, or square kilometers	1	hectares, or square km		hectares or km ²		
7,8	2.3.2	inches of rainfall...inches of snow and "l-hr snowmelt rate of T years	millimeters or rain...millimeters of	1	millimeters...millimeters		Ok		
10	3.2.2	8 inches diameter	203 millimeter diameter	2	200 millimeter diameter		Delete		
12	3.2.2	inches of rainfall...	millimeters of rainfall...	1	millimeters of rainfall...		Delete measurement		
14	4.1.	Infiltration Capacity (In/Hr)	Infiltration Capacity (mm/Hr)	1	Infiltration Capacity (mm/h)		Ok		
*		0.50-1.00	12.7-25.4	2	13 - 25		Ok		
*		0.10-0.50	2.54-12.7	2	2.5 - 13		Ok		
*		0.01-0.10	0.25-2.54	2	0.25 - 2.5		Ok		
15	4.2.	Table 2. (all values in inches)	change inches to millimeters						
*		0.05-0.15	1.27-3.81	2.54	Table 1.3-3.8	2.5	Ok		
*		0.10-0.30	2.54-7.62	2.54	Table 2.5-7.6	2.5	Ok		
*		0.05-0.10	1.27-2.54	1.27	Table 1.3-2.5	1.3	Ok		
*		0.20-0.50	5.08-12.7	7.62	Table 5-13	7.6	Ok		
*		0.20-0.60	5.08-15.2	10.16	Table 5-15	10	Ok		
16	4.4.1.1	S C S Equation	$t_b = 0.42(nL)^{0.6}/(P_2)^{0.5}S^{0.4}$	$t_b = 1.732(nL)^{0.6}/(P_2)^{0.5}S^{0.4}$	7	$t_b = 1.73(nL)^{0.6}/(P_2)^{0.5}S^{0.4}$	Ok		
		Federal Aviation Equation	$t_b = (1.1-C)L^{0.5}/2.6S^{0.33}$	$t_b = (1.1-C)L^{0.5}/2.6S^{0.33}$ backup	7	$t_b = (1.1-C)L^{0.5}/2.6S^{0.33}$	Constant = 1.435		
		Kinematic Wave Equation	$t_b = 0.93(nL)^{0.6}/i^{0.4}S^{0.3}$	$t_b = 2.782(nL)^{0.6}/i^{0.4}S^{0.3}$	7	$t_b = 2.78(nL)^{0.6}/i^{0.4}S^{0.3}$	Ok		
		L = feet	L = meters	7	Length = meters		Ok		
		S = ft/ft.	S = m/m.	7	Slope = m/m.		meters per meter		
		i = in/hr.	i = cm/hr.	7	i = centimeters/h		centimeters per hour		
		P = inches	P = centimeters	7	P ₂ = centimeters		Ok		
17	4.4.1.2	Mannings Equation $V=1.49/nxR^{2/3}xS^{1/2}$	$V = (1.00/n)R^{2/3}S^{1/2}$	7	$V = (1.00/n)R^{2/3}S^{1/2}$		$V = R^{2/3}S^{1/2} /n$		
		R = feet	R = meters	7	R = meters		Ok		
		S = ft/ft.	S = m/m	7	S = m/m		meters per meter		
		L = feet	L = meters	7	Length = meters		Ok		
		V = ft/sec	V = m/sec	7	V = m/s		meters per second		
		1.49	1.00	7	1.00		place over "n"		
17	4.5.	volume of one inch of excess	one centimeter	2	one centimeter		Ok		
*		having one inch of excess	one centimeter	2	one centimeter		Ok		
*		not be grater than 2,000 square miles	than 5,180 square kilometers	2	5,000 square kilometers		5000 km ²		
18	*	200 square miles	518 square kilometers	2	500 square kilometers		500 km ²		
	*	12 to 15 square miles	31.08 to 38.85 square kilometers	2	30 to 40 square kilometers		30 to 40 km ²		
18	5.3.	in square miles...	change to in square kilometers	2	in square kilometers		km ²		
20	6.2.3	a 4" to 6" water depth	a 102mm to 152mm water depth	2	100 mm to 150 mm water		Ok		
26	7.2.2.1	FHWA-Harley Method...25 square miles	64.749 square kilometers	2	65 square kilometers		65 km ²		
27	7.2.3	Rational Method $Q = C I A$	$Q = 2.78 C I A \times 10^{-3}$	7	$Q = 2.78 C I A \times 10^{-2}$		Challenge Constant		
27	7.3.1	Q = cfs	Q = m ³ /s	7	Q = m ³ /s		cubic meters per second		
*		I = in/hr	I = centimeters/hour	7	I = centimeters/hour		centimeters per hour		
		A = acres	A = hectares, or square meters	7	A = hectares		Ok		

Figure B-1. Example of spreadsheet used to document metrication of HDG-2 "Highway Drainage Guidelines."

These **Digests** are issued in order to increase awareness of research results emanating from projects in the CRP. Persons wanting to pursue the project subject matter in greater depth should contact the Cooperative Research Programs Staff, Transportation Research Board, 2101 Constitution Ave., NW, Washington, DC 20418.

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