Bridge Safety Inspection Quality Assurance: Pennsylvania Department of Transportation

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In December 1986, the Pennsylvania Department of Transportation inaugurated its enhanced Bridge Management System. This system is the resource for district and statewide management decisions involving bridges. Much of the data base for the Bridge Management System is provided by inspectors assigned to decentralized district bridge safety inspection units. It is vital that the system have accurate information with consistent interpretation statewide. Each district has the responsibility for quality control within its inspection units. The Bridge Management System Division's Bureau of Bridge and Roadway Technology, located in the Central Office, monitors the overall quality of bridge safety inspection quality assurance activities. In 1985, Wilbur Smith Associates' Byrd, Tallamy, MacDonald and Lewis Division was selected to develop a quality assurance manual and implement the procedure for a 3-yr period beginning in 1986. The manual defines the quality assurance procedure and details the steps necessary to make it operational. This entails a review of the inspection activities in each district and statistical analysis of the findings. Various aspects of the findings are compared statewide. An annual report is also provided each year as part of the quality assurance implementation. This document contains a summary of the district reports and a comparison of the findings statewide. Although bridge safety inspection quality control and quality assurance are important, few if any state or local transportation agencies have developed standard procedures. The activities are often performed on a hit-or-miss basis, and the results may be difficult to interpret. This paper, in which the bridge safety inspection quality assurance activities developed and implemented for PennDOT are described, should be of interest to other practitioners involved in bridge management and inspection.

The Commonwealth of Pennsylvania Department of Transportation (PennDOT) has a decentralized bridge safety inspection program managed by each of the 11 districts. The inspection activities comply with federal requirements as contained in the National Bridge Inspection Standards (NBIS). The bridge safety inspection provides PennDOT with information on each bridge that is used to complete and update the bridge-inspection-related data base for the Bridge Management System (BMS). This portion of the system accepts, stores, updates, and reports physical and operating characteristics for all public bridges in Pennsylvania. It includes the federal Structure Inventory and Appraisal (SI & A) information. In addition, BMS is the resource for district and statewide management decisions, such as prioritization, rehabilitation, replacement and maintenance needs, costs, future needs, and predictions, and thus becomes a tool for budgeting. It provides about 20 standardized monthly management reports based on data contained in the system.

Much of the BMS information related to bridge inventory structural condition and load capacity determinations of the bridges is provided by inspectors assigned to district bridge safety inspection units, or consultants. Damage or deterioration is reported. Timely remedial actions are programmed by the district and traffic is restricted until appropriate repair or replacement is effected.

Responsibility for Quality Inspections

The accuracy and consistency of the inspection and documentation is vital, not only because it affects programming and funding appropriations but also because it will initiate responsive corrective actions to ensure that bridges remain safe for public use. The department therefore addresses this need with quality control (QC) and quality assurance (QA) procedures. QC is the responsibility of each district. The district develops and enforces bridge inspection QC procedures, which are updated regularly. An outline of the procedures is submitted to the BMS Division, Bureau of Bridge and Roadway Technology (BART). The BMS Division functions as a technical resource to coordinate and standardize the bridge inspection program and disperse appropriate information. This division is also responsible for controlling the overall state compliance with the NBIS. Bridge inspection QA is an independent central office function performed by the BMS Division to ensure that the districts are operating in accordance with the approved QC plans and hence with the NBIS.

Definition of QC and QA

The distinction between QC and QA should first be clarified as the terms are applied to this project. QC is the

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enforcement, by supervisor, of procedures that are intended to maintain the quality of a product or service at or about a specified acceptable level. QC of the inspection of PennDOT's bridges is a daily operational function performed within each district for designated staff members under the supervision of the district engineer.

QA is the verification or measurement of the level of quality of a sample product or service generally by a third party organization. The sampling must be sufficiently representative to permit a statistical correlation with the whole group. The findings are compared against accepted standards to determine whether specified procedures are followed. QA must be performed by an organization external to the operational QC function in order to be objective and unbiased. Statewide bridge inspection QA activities are the responsibility of the BMS Division, Bureau of Bridge and Roadway Technology.

Formalization of QA Activities

Because of the ever-growing demand for quality BMS data, a need was identified by the BMS Division to develop and implement a formalized QA program. Early in 1985, it was decided to engage a consultant to supplement the Bridge Management System Division staff in the execution of the existing QA activities, formalize the procedures, and expand the program. Proposals were evaluated and the Byrd, Tallamy, MacDonald and Lewis (BTML) Division of Wilbur Smith Associates (WSA) Consulting Engineers was selected to perform these activities. The 3-yr contract was executed in January of 1986. The work was to be accomplished in three phases, with each phase completed in a 1-yr time frame.

The work plan for Phase I consisted of developing and analyzing the merits of various QA concepts. A concept was then recommended. After the department's concurrence, the next task was to develop a manual that translated the QA concept into clearly defined procedures and to implement the procedures in four districts on a total of 120 bridge inspections. QA procedures were implemented in the remaining 7 districts in Phase II on 210 representative bridge inspections. The QA procedures and manual were refined during Phase II. Phase III consisted of QA evaluations on representative inspections of state bridges in all 11 districts. Also included in Phase III were QA evaluations for local inspection programs and bridges less than 20 ft long. Approximately 1,000 QA evaluations were performed during the 3-yr program.

QA CONCEPT

Initial Study

Earlier studies by the Operations Review Group within the department indicated the need to improve the uniformity of the inspection procedures statewide. In response to these studies, the BMS Division had bridge safety inspection verification checks in place and operational before this project began. The procedures were, however, performed by individuals with a number of other responsibilities. It was necessary to schedule the quality assurance activities around their other duties. The QA activities were performed on an "as time available" basis while holding documentation to a minimum. The previous program was helpful in monitoring the quality of the statewide inspection program; however, because of overriding priorities, there was a problem staying on schedule. Also, because of those priorities, it became difficult to apply the findings statewide.

During QA development interviews, the department identified several priorities for evaluating the bridge safety inspection program. The first priority is quality. The inspection should be thorough and in accordance with PennDOT guidelines and NBIS. Secondly, there should be a uniform level of inspection and documentation between the districts.

The QA evaluation should not be subjective. The QA manual should provide procedures that permit an objective, quantitative measure of the quality and uniformity achieved by each district bridge inspection program, as well as providing an operational guideline that is to be followed by the department's QA staff that will also inform the districts how their performance is to be measured.

Selecting the Samples

Many possible approaches for selecting sample inspections for QA were identified during the initial studies. The study was reported in a "Letter Report" entitled "Various Concepts Suitable for Use in Implementing a Statewide High Quality Bridge Safety Inspection Quality Assurance Program," dated November 1986, revised December 1986. This study was authored by Ron L. Purvis, Heinz P. Koretzky, and Leonard E. Schwartz. Some of these concepts or approaches are:

Concentrate on worst sources: This approach involves identifying a mean quality level and classifying district bridge inspection programs as above or below that level. The evaluations would concentrate on the bottom x percent of districts.

Concentrate on selected critical bridge types: This approach would involve identifying and classifying critical bridge types, then concentrating on the worst of those types, with priorities based on the degree of redundancy. For example, top priority would be two girder types with pin and hanger details.

Concentrate on condition and deficiencies: This approach would identify bridges by condition, or other BMS deficiencies or FHWA sufficiency points, and apply QA to the worst x percent.

Concentrate on coding items: This approach would classify BMS coding items by order of importance and QA those in order, with priority given to the federal SI&A items.

Concentrate on sensitive items: This approach would

classify those items that are identified as critical through sensitive analysis and assign various ranges of acceptable deviation based on sensitivity.

Concentrate on bridge types: This approach would classify bridge types based on overall conditions and QA in order of urgency.

Concentrate on posted bridges and candidates for posting: This approach would require QA on all items of the previously mentioned bridges, but only carry out x percent of the items on any bridge on a rotating basis.

Concentrate on routes: This approach would QA bridges as they appear on a selected segment of certain highway routes.

Concentrate on statistical distribution: This approach would identify the bridge population as it exists in every district and inspection x percent sample that best represents the existing bridges.

The last method was chosen for selecting the bridges for QA inspections because it best suited the requirements of the initial program with limited funds. A relatively small sample size of 5 percent was considered adequate (2.5 percent/yr) because the objective of QA is not to supplement the existing inspections but to measure the quality of the overall program. Most of the other concepts already listed could have accomplished similar objectives but were found unsuitable at this time because the samples selected would not represent the overall bridge population on the PennDOT highway system. As QA data are collected and analyzed statewide for one or two years, the QA procedures can be logically refined by incorporating some of these other concepts.

Conceptual Procedure

After the method to be used in selecting the sample bridges was determined, the procedure for performing the QA on each bridge was studied. Potential procedures for conducting the evaluation are as follows:

A. Accompany the inspection team in the field (by PennDot);
B. Conduct independent inspection and complete documentation (by consultant);
C. Conduct independent inspection but document only deviations (by consultant);
D. Conduct partial inspection based on report review but document only deviations;
E. Spot-check certain documents based on sensitivity;
F. Spot-check certain items or districts based on past performance;
G. Review inspection file;
H. Question individuals involved in supervising district inspection programs; and
I. Accompany district personnel during district's quality control visits.

To properly evaluate the potential concepts, a detailed listing of objectives (work items) was necessary. The objectives identified were: evaluate thoroughness of inspection; evaluate judgment of inspector; evaluate adequacy of documentation; evaluate follow-up to the inspection; evaluate load rating; evaluate posting document; monitor compliance with district's quality control plan; identify differences in quality compared with a statewide norm; identify differences in quality between teams; identify need to improve existing guidelines; identify need to improve inspector certification training programs; identify need to alter resource commitment; obtain representative QA results; obtain accurate QA results; and make effective use of QA resources.

Because some of the work items and objectives were considered more important than others, a weighted number from 1 to 3 was given to each. Each potential item was then given a rating from 0 to 5 to reflect how it met each objective. A rated effectiveness is totaled for each item. The overall objectives recommended were a combination of several of the items evaluated in Figure 1. A discussion at the end of this paper lists the concepts (A to J) with the advantages and disadvantages of each.

QA Intensity Level

Most of the activities included in the initial QA concept were refined into four levels of intensity. The reason for the four levels was to permit adjustment of the procedures to match the anticipated current and future needs and available resources of the department's BMS Division. Each level was also costed in relative terms and the results presented to the department in the previously referenced letter report.

- Level 1 is the minimum acceptable approach. This provides a verification of limited field condition and appraisal ratings. There is no check of the inventory and inspection documentation other than the ratings. This is, of course, the least expensive level.
- Level 2 provides a quality verification of the sensitive inspection items and inspection file check for completion. A few more basic BMS inventory items are also verified. On Level 2 there is also no detail check of file data. The cost of Level 2 was estimated to be 1.6 times greater than that of Level 1.
- Level 3 provides an independent quality review of sensitive inspection and inventory items related to items considered most important, sufficiency, and a check of file documentation. As with Levels 1 and 2, the BMS data are available to the QA team and only out-of-tolerance deviations are documented. Level 3 is estimated to cost 2.6 times that of Level 1.
- Level 4 is the most thorough. An independent check is made of all meaningful inspection data. The inspection and inventory documentation is recreated by the QA team. This approach is estimated to cost 6.6 times that of Level 1.

OBJECTIVES	WEIGHT FACTOR	A	B4	B3	Q.A. CONCEPT RATING* C	D	E	F	G	H	I	J
Evaluate thoroughness of inspection	2.00	3	5	4	3	2	2	3	1	0	1	2
Evaluate judgement of inspector	2.00	5	5	4	2	3	3	3	2	1	3	2
Evaluate adequacy of documentation	2.00	4	5	3	3	3	2	3	3	1	2	2
Evaluate follow-up to inspection	2.00	1	0	0	3	2	3	3	5	4	4	1
Evaluate load rating/posting	2.00	2	2	2	2	3	3	3	5	3	3	1
Monitor compliance with quality control plan	2.00	4	4	4	1	3	2	2	2	4	4	5
Identify differences in quality between districts	1.50	4	4	4	2	3	3	0	4	3	3	2
Identify differences in quality between teams	1.50	4	5	4	2	3	3	0	4	2	3	3
Identify need to alter guidelines	1.00	4	4	4	3	3	4	4	4	3	4	2
Identify need to alter training	1.00	5	5	4	2	3	3	4	3	3	4	2
Identify need to alter resource commitment	1.00	5	5	5	1	4	3	3	2	2	3	1
Obtain representative QA results	3.00	1	5	4	3	3	3	0	4	2	2	1
Obtain accurate QA results	3.00	3	5	4	3	3	3	2	4	2	2	2
Conservative use of QA resources	2.50	5	1	3	5	4	5	4	3	3	3	2
TOTAL WEIGHTED EFFECTIVENESS		92	107	94	70	82	82	64	90	62	76	54

* Level of Intensity Rating Scale

5 = maximum 3 = fair 1 = minimal
4 = good 2 = marginal 0 = none

This table is of use in determining relative importance of various QA items. For example, "B4" with a total of 107 would be the most important item while "J" with a total weight effectiveness of 54 would be the least important item using the combination of weight and level of intensity rating scale. Those factors could be updated to reflect new QA program objectives.

FIGURE 1 QA concept evaluation chart.

Figure 2 contains the approved Phase I QA concept. Note that the levels are partially developed. Since this was developed, the Structure Inventory Record System (SIRS) has been merged into the BMS. The appropriate codings are described in detail in the Coding Manual, PennDOT Publication #100A, dated December 1986.

QA MANUAL

Outline

The QA concept developed and approved under Phase I was then expanded into detailed procedures, which are

LEVEL I	II	III	IV		APPROVED PHASE I QA CONCEPT - All approved activities marked with an "X" - Activities not desired are noted accordingly.
					FIELD EVALUATION
			X	A4	Accompany District Inspection Team in field, evaluate procedures, log, tools, crane and traffic continuity
		X		A3	Accompany District Inspection Team in field, evaluate procedures, log, tools
	X			A2	Review inspection log and tools. Some field visits one team a year.
X				A1	Review inspection tools only
			X	B4	Independent field inspection and complete documentation (previous ratings not available)
X	X	X		B3	Independent field inspection document only deviations (SIRS printout available)
X	X	X	X	C	Computer edit of District's BMS data.
Not		desired		D	Partial inspection based on Office Report Review Document only deviations (inspection file available). (No field work.)
					SIRS DATA EVALUATION MOSTLY FIELD
			X	E4	Verify all SIRS items that can be obtained in the field.
		X		E3	Verify only sensitive SIRS items that can be obtained in the field.
	X			E2	Verify only SIRS items affecting Sufficiency Rating.
X				E1	Verify only SIRS items identifying bridge.
Not		desired		F	Spot check certain Teams or Districts based upon performance history.
					OFFICE EVALUATION
			X	G4	District file evaluation including independent checking of rating analysis computations, and timely implementation of appropriate repair and posting procedures.
		X		G3	District file evaluation for essential documentation related to repairs, capacity analysis, and posting
	X			G2	Cursory evaluation of files
X				G1	Spot check file
			X	H4	Evaluation back-up procedures including Bridge Collapse Board of Inquiry, crane and underwater scheduling and QC plan activities
		X		H3	Evaluate back-up procedures including QA plan activities
		X	X	I	Verbally quiz individuals involved in District Inspection Program to verify appropriate knowledge. Evaluate staffing and valid certifications
Not		practical		J	Accompanying District during QA activities
					BRIDGE MAINTENANCE EVALUATION
			X	K4	Bridge Maintenance, review coding and paper trails and simple repairs
		X		K3	Bridge Maintenance, review coding and simple repairs
	X			K2	Bridge Maintenance, review simple repairs
	X	X	X	L	Close-out meetings.

FIGURE 2 Approved Phase I QA concept.

described in the QA Manual (1989 edition). The procedures are divided into the following sections:

1. Planning the evaluation,
2. QA at the bridge site,
3. QA at the district office,
4. Computer edit of BMS data,
5. Bridge maintenance evaluation,
6. District findings, and
7. Annual report.

Planning the Evaluation

Planning the QA evaluation involves (a) selecting and approving the level of QA to be performed at the beginning of the year, (b) visiting the districts each year in a different sequence that must be also determined, and (c) selecting sample bridges for each district consistent with the distribution of bridge types in the district.

The QA Manual contains detailed procedures for selecting the sample bridge inspections. The recommendation is for 5 percent of the bridges to be inspected by the district teams during that year. The selection process is designed to provide a sampling that is representative of all the bridges inspected that year. A profile of all the bridges in the district is first developed for use in selecting the samples. The features that are considered most important in the sample selection process are: type of superstructure, total length, sufficiency rating, and district team performing the inspection. Figure 3 is an example of a district structure profile.

Because the QA review includes a field evaluation to assess the quality of the district inspection, it is important that it be performed soon after the district inspection is completed. Therefore, the sample bridges must be selected from those inspected within the last few months. The objective is to match the district's bridge population profile as closely as possible, selecting only from the group that was recently inspected. Beyond that, the selection is made at random. Difficulty of access to the bridge because of size or location should not disqualify a bridge from inclusion in the sample group.

QA at the Bridge Site

The QA at the bridge consists of an independent verification of certain sensitive condition/appraisal items prescribed in the QA Manual based on the intensity level of QA review (see Table 1 for the activities included in the field review). The QA procedure for each activity described in the manual contains a range of requirements that increase with the QA intensity level.

Assessing the quality of the field inspection is an important function of QA because deficiencies in this part of the program could affect the safety of the state's bridge system. A hands-on, close-up inspection of the bridge is therefore included in all QA intensity levels. The levels differ, however, in the information available to the QA team when it performs the evaluation and documentation required to describe the condition finding. Level 4 is a totally independent inspection without benefit of any previous inspection reports. Complete independent inspection documentation is provided at this level. In Levels 1 to 3 the QA team has the previous data and verifies them at the site. If the condition rating given by the district is not more than one number different from that of the QA team's

Structure Type		Code	County A	B	C	D	E	F	Total	%	AVAILABLE Total	Samp	%
	Beams	A	78	74	34	119	59	33	397	19.7	11	6	1.5
	Box Beams	B	-	-	-	-	-	-	-	-	-	-	-
Steel	Girder, Flr Bm	C	14	9	1	5	15	7	51	2.5	1	-	-
	Truss	D	4	11	4	4	6	16	45	2.3	1	1	2.0
	Arch	E	-	-	-	-	1	-	1	n	-	-	-
	Slabs	F	44	70	15	76	43	36	284	14.1	12	5	2
Concrete	Tee Beams	G	25	49	11	37	48	24	194	9.6	8	3	1.5
	Arch	H	8	3	1	6	-	1	19	1.0	n	-	-
	Channel Beams	I	1	-	-	-	-	1	2	n	1	1	5.0
Prestressed	"T" & "I" Beams	J	18	28	3	1	3	-	53	2.6	6	2	4.0
Concrete	Box Beams	K	64	89	41	43	33	16	286	14.2	13	3	1.0
Timber		L	-	-	-	-	-	-	-	-	-	-	-
Masonry		M	2	61	3	6	14	7	93	4.6	1	-	-
Wrought Iron		N	-	-	-	-	-	-	-	-	-	-	-
Concrete Encased		O	10	8	1	6	-	2	27	1.4	2	-	-
Culverts		P	95	154	65	117	81	53	565	28.0	24	9	1.8
Other			1	1	-	-	-	-	2	n	-		-
Unknown			1	-	-	-	-	-	1	n	-		
TOTAL			365	557	179	420	303	196	2020	100	80*	30	1.5
Length													
20' - 70'			205	320	100	240	170	110	1145	57	47	17	57
70 ' - 150'			74	109	35	83	62	41	404	20	16	6	20
Over 150'			86	128	44	97	71	45	471	23	17	7	23
Sufficiency Rating													
Less than 50			30	58	15	45	32	21	201	10	7	3	10
50 - 80			89	188	60	140	109	69	658	33	26	10	33
Over 80			243	311	104	235	162	106	1161	57	47	17	57
Inspection Team													
A			365		179		303	196	1043	52	49	17	57
B				557		420			977	48	31	13	43

FIGURE 3 Example of district structure profile.

TABLE 1 ACTIVITIES INCLUDED IN FIELD REVIEW

Field Q.A. Review Activities	QA Intensity Level I	II	III	IV
Verify and identify the structure	X	X	X	X
Photograph the structure		X	X	X
Verify inventory data based on QA intensity level	X	X	X	X
Take measurements for load rating check			X	X
Verify "safety" features and load posting signs	X	X	X	X
Perform independent condition and appraisal	X	X	X	X
Compare with district ratings and reconcile, if possible	X	X	X	
Document findings based on QA level	X	X	X	X
List and prioritize maintenance and repair needs		X	X	X

rating, then it is within "tolerance" and no further documentation is required. The QA team also has to collect inventory data details required to perform load rating and posting information. QA for these activities varies with the level selected.

QA at the District Office

QA at the district office consists of verifying the availability and accuracy of the documentation on file (see Table 2). The evaluation of each varies from cursory (*C*), to standard (*S*), to in-depth (*I*), depending on the level. The QA Manual includes details describing each level. The levels of the office review are designed to coordinate with the level of the field review. The details obtained in the field are confirmed in the office. The file is also evaluated to determine how the inspection is used. For example, were recommendations implemented, or was a new load rating analysis necessary? The QA teams use the form shown in Figure 4 to rate each item and comment as necessary.

A questionnaire is also completed during the office visit to monitor the district procedures. Because the districts are decentralized, there are no standardized procedural requirements as long as overall standards are met. However, it is helpful in evaluating the results to relate level of conformance to the unique organizational structure of the district under review.

Computer Edit of BMS Data

The BMS system is programmed to flag certain data and items for consistency and conformance with guidelines. It identifies certain erroneous entries; for example, codes that do not apply. It identifies inspections that are overdue. If teams are omitted this is also flagged. Because the function is performed within the BMS Division, it was not highlighted during the initial development of the manual. It is a part of the total QA effort, and is therefore included in the manual.

It is anticipated that at some time in the future the BMS system could be enhanced with additional indicators to select on command the appropriate sample bridges to receive QA. These are currently being selected from a computer printout containing the recent inspections in the district.

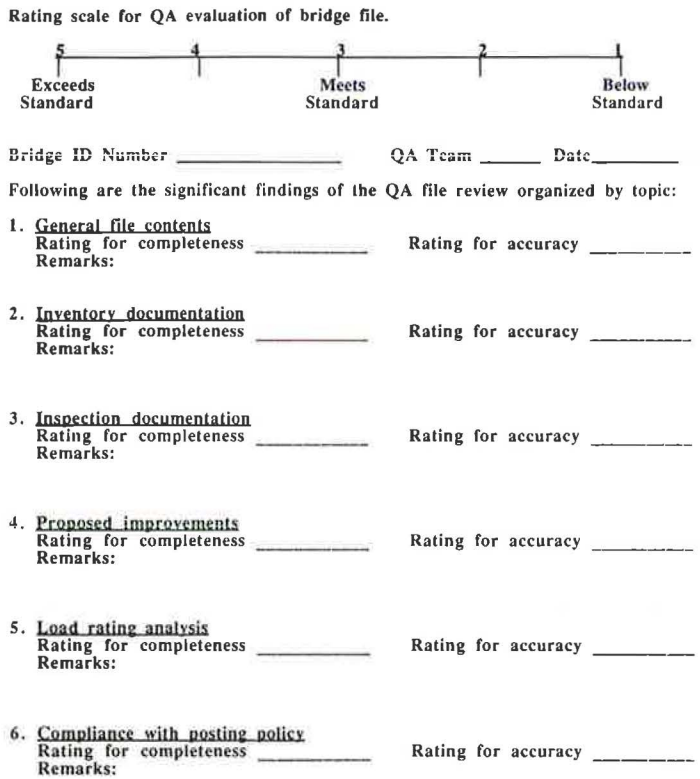
Bridge Maintenance Evaluation

An important purpose of the bridge safety inspection is to identify maintenance and repair needs and priorities. PennDOT has standardized this process in the December 1986 Coding Manual. This part of the QA evaluation focuses on the accuracy of the maintenance and repair needs identified by the districts and the procedures and paper trail for implementing the work. This portion of the QA effort was included in Phase III of the current QA program. An

TABLE 2 CHECKLIST FOR VERIFYING AVAILABILITY AND ACCURACY OF DOCUMENTATION ON FILE

Office QA Items	QA Level I	II	III	IV
General file contents	C	S	S	I
Inventory documentation	C	S	S	I
Inspection documentation	C	S	S	I
Proposed improvements		C	S	I
Load rating analysis		C	S	I
Compliance with posting policy		C	S	I

Note: C = cursory, S = standard, and I = in-depth.


Rating scale for QA evaluation of bridge file.

5 4 3 2 1

Exceeds Standard — Meets Standard — Below Standard

Bridge ID Number _____ QA Team _____ Date_____

Following are the significant findings of the QA file review organized by topic:

1. General file contents
   Rating for completeness _____ Rating for accuracy _____
   Remarks:

2. Inventory documentation
   Rating for completeness _____ Rating for accuracy _____
   Remarks:

3. Inspection documentation
   Rating for completeness _____ Rating for accuracy _____
   Remarks:

4. Proposed improvements
   Rating for completeness _____ Rating for accuracy _____
   Remarks:

5. Load rating analysis
   Rating for completeness _____ Rating for accuracy _____
   Remarks:

6. Compliance with posting policy
   Rating for completeness _____ Rating for accuracy _____
   Remarks:

FIGURE 4 PennDOT bridge safety inspection QA program bridge file evaluation form.

example of the QA levels developed for this activity is as follows:

- Level 1. Structural elements requiring repairs within 6 months are identified.
- Level 2. Same as Level 1 except that the recommended repair is included for the elements identified.
- Level 3. Same as Level 2 except that all maintenance and repair needs are listed. This list includes the repairs necessary to return or preserve structure at the original condition.
- Level 4. Same as Level 3 except that priorities are included for the maintenance and repair.

Ideally, the inspection documentation identifies immediate problems, potential problems, and necessary maintenance to avoid future problems. It is expected that the bridge safety inspection file will include a paper trail that, in combination with BMS data, indicates the recommended improvements, a priority for each, and the dates that the work is scheduled and completed. The QA evaluates this based on the required QA level.

District Findings

A report is submitted for each district QA evaluation that provides the details of the findings. After this report is reviewed, the findings are discussed with the district in a close-out meeting. The district report is designed to provide a quantitative measurement of the quality consistent with the original QA objectives. The same items are evaluated in the same order on each bridge review. The report provides a statistical correlation of the findings. The data are organized so that areas where the district consistently differs with the judgment of the QA team may be readily identified. See Figures 5 and 6 for examples of how this material is displayed in this report. Unique findings are also listed. The report contains a section for the summary and conclusion. After the report is submitted and reviewed, a close-out meeting is held with the district and BMS Division staff to discuss the findings and resolve any problems.

Annual Report

The annual report contains a summary of all QA activities performed for a given year and a comparison of these findings statewide. In this report, the bar charts for each inspection item are arranged so that all the district results are listed side by side. This format is helpful in identifying inspection items that have received a wide range of ratings for a given condition (see Figures 7 and 8). This information is helpful in identifying possible needed enhancements in the inspector's training information, or in the guidelines contained in the BMS coding. If deviations are experienced for a particular item in just one district, it is more likely an internal problem.

	STRUCTURE	CODE	TYPE	APPRDWY E15 QS	DECKWS E16 QS	DECK E17 QS	SUPSTR E18 QS	SUBSTR E20 QS	CHAN E21 QS	STRCOND E24 QS	DECKGEOM E25 QS	WATERWAY E27 QS	APPALIGN E28 QS	SAFEFEAT A24 Q S
1	4013	G	21103	77	77	64	56	54	56	55	54	56	66	4222 4222
2	4015	F	21101	77	77	77	67	67	66	76	56	76	88	4222 4222
3	5011	P	21931	NN	NN	NN	NN	NN	88	88	NN	76	NN	8888 8888
4	2044	J	42207	67	57	66	68	56	77	88	77	NN	77	6688 6688
5	2045	K	42204	57	76	76	77	77	67	67	66	76	56	6688 6688
6	6007	J	42206	66	77	56	56	66	76	75	77	76	75	6644 6668
7	5010	P	21931	68	77	N4	76	88	67	66	68	66	77	4222 4222
8	8001	D	19118	56	64	88	76	88	57	77	67	75	67	8688 8888
9	5018	A	16104	77	67	77	76	77	66	77	77	67	67	8884 8888
10	8001	P	21931	88	66	77	NN	56	78	68	77	56	75	4222 4222
11	5084	O	86104	77	76	77	67	67	66	76	56	75	88	6222 6222
12	9014	A	16104	75	56	N8	77	77	77	77	75	77	68	3388 4488
13	9011	D	16118	77	75	67	67	66	88	56	67	76	66	3222 3222
14	9027	A	16104	67	88	57	77	76	67	66	57	67	67	4222 4222
15	9021	A	16104	77	77	88	N8	88	78	57	66	75	75	4644 4888
16	2004	A	16104	67	88	56	66	88	77	67	76	67	57	4643 4884
17	7005	K	42204	77	77	88	77	88	77	N7	77	67	77	8884 8888
18	4001	A	16104	66	N7	77	77	56	76	57	67	66	46	4222 6222
19	2008	J	42206	47	77	67	56	75	NN	76	NN	75	7N	4333 4333
20	4001	C	18114	77	67	67	75	88	67	46	67	76	77	3222 3222
	OUT-OF-TOLERANCE +2			4	3	2	2	1	0	5	3	4	5	

The numbers across the top are BMS item numbers. There are two ratings below each item number for each bridge. The QA rating first then the district rating. The code letter is related to the STRUCTURE TYPE PROFILE.

FIGURE 5 Rating comparison of bridges selected for QA review.

There is also a section on recommendations for the next year. This section proposes modifications in the program based on the annual findings. A recommendation is made for the QA level for the next year. If there are improvements warranted in the QA procedures, these are also recommended. This section might also contain suggestions for improvements in the statewide BMS coding guidelines or inspector's training. When accepted by the department, the recommendations are implemented either by BTML, under Phase II and III of the existing contract, or by other agents of PennDOT.

IMPLEMENTING THE QA PROCEDURES

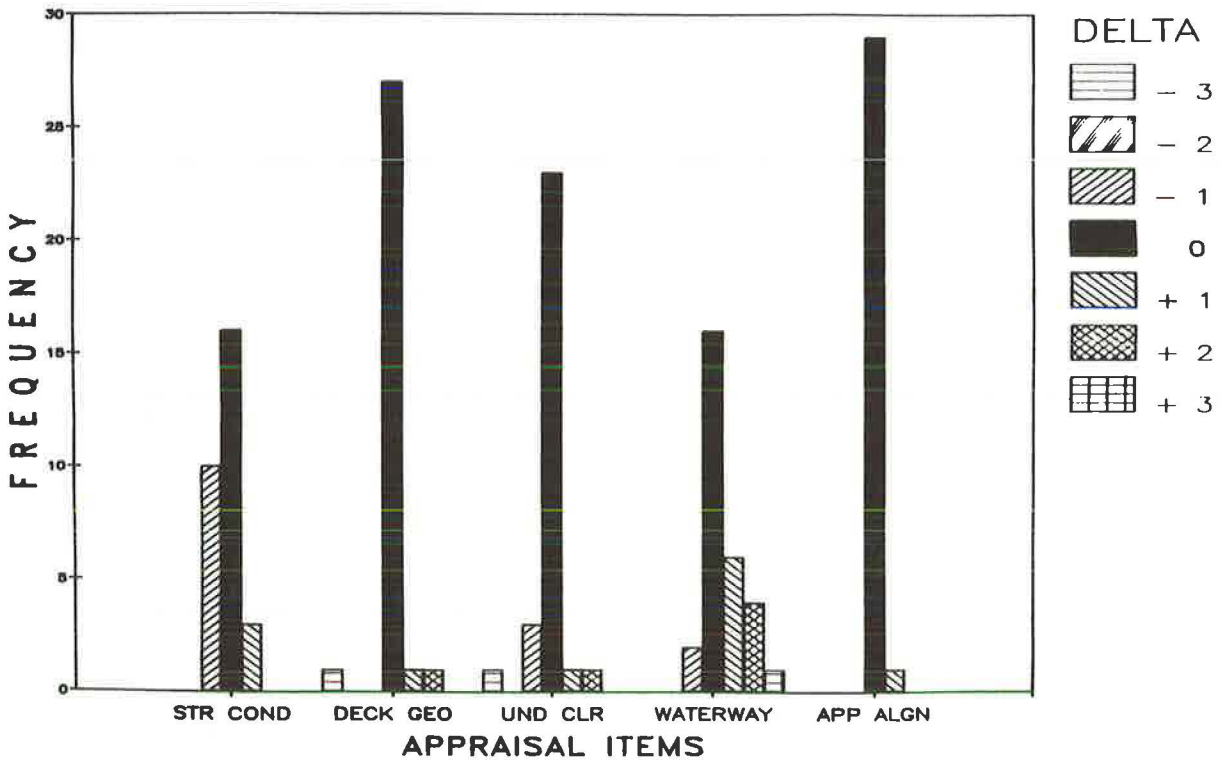
Start-up

Phase I QA evaluations were performed during the development of the manual using interim procedures. This meant that the districts did not receive specific QA procedural information before the review results that explained the focus of the Phase I evaluation. Some procedures were modified as the evaluation was in progress. In Phase II, the procedures were in accordance with the draft manual that was given to the districts for review and comments before the QA evaluations. The manual was refined again for Phase III.

The QA Team

The QA team leader must be approved by the chief of the BMS Division. The Phase I team leader is a registered professional engineer, and has attended the department's bridge safety inspection training course. The team is normally composed of two inspectors, the second member being a graduate engineer with 2 yr of bridge inspection experience. Occasionally the team was accompanied by the principal investigator, who was involved in defining the QA concept and developing the manual.

Because all the district's inspection ratings are compared with the QA ratings, the judgment should be the same on



NOTE: + INDICATES DISTRICT RATING GREATER THAN REVIEW

FIGURE 6 Difference between QA review and District *C* ratings.

each evaluation. Therefore, changes in QA team members were minimized while implementing the evaluations.

Time Requirements

The 3-yr QA implementation began in early June 1986 and was completed in December 1988. This does not represent a continuous effort because procedures were being developed, modified, and approved by the BMS Division. During the first 2 yr, 4 to 6 weeks were required for each district review to plan, evaluate, and report on 30 sample inspections and to complete the close-out requirements. Some overlapping of district reviews was possible during the report review and close-out scheduling. In Phase III (1988), QA evaluations were performed in all 11 districts. The number per district increased with the addition of local bridges, less than 20-ft long bridges, and special emphasis bridges. An additional QA team was added during Phase III to keep the evaluations on schedule.

	DISTRICTS					
CONDITION ITEMS	A	B	C	D	Sum	%
Approach Slab	30	30	30	29	119	99.2
Approach Roadway	23	26	29	26	104	86.7
Deck	30	28	29	27	114	95.0
Superstructure	29	30	30	30	119	99.2
Paint	30	30	30	30	120	100
Substructure	30	30	30	30	120	100
Channel	29	30	27	25	111	92.5
Culverts	30	30	30	30	120	100
Condition Sub Total	231	234	235	227	927	96.6
APPRAISAL ITEMS						
Structure Condition	30	30	30	30	120	100
Deck Geometry	29	27	27	25	108	90.0
Underclearance	30	30	27	30	117	97.5
Waterway	28	27	24	26	105	87.5
Approach Alignment	23	27	30	27	107	89.2
Appraisal Subtotal	140	141	138	138	557	92.8
TOTAL	371	375	373	365	1484	95.1

FIGURE 7 Summary ratings within tolerance.

Findings

The QA level performed for the 3-yr implementation was generally at or above Level II. The findings will be more meaningful as the program generates sufficient results to define reasonable expectations. The department was pleased with the correlation between the condition and appraisal ratings of the QA team and the district inspection teams. The overall correlation of the ratings within tolerance was 94.9 percent for 3 yr.

Most deviations seemed to be caused by the individual interpretation of the guidelines by the different district teams rather than a deficiency in the inspection procedures. The lowest correlation of the ratings within tolerance was for Approach Roadway at 92.0 percent, Deck

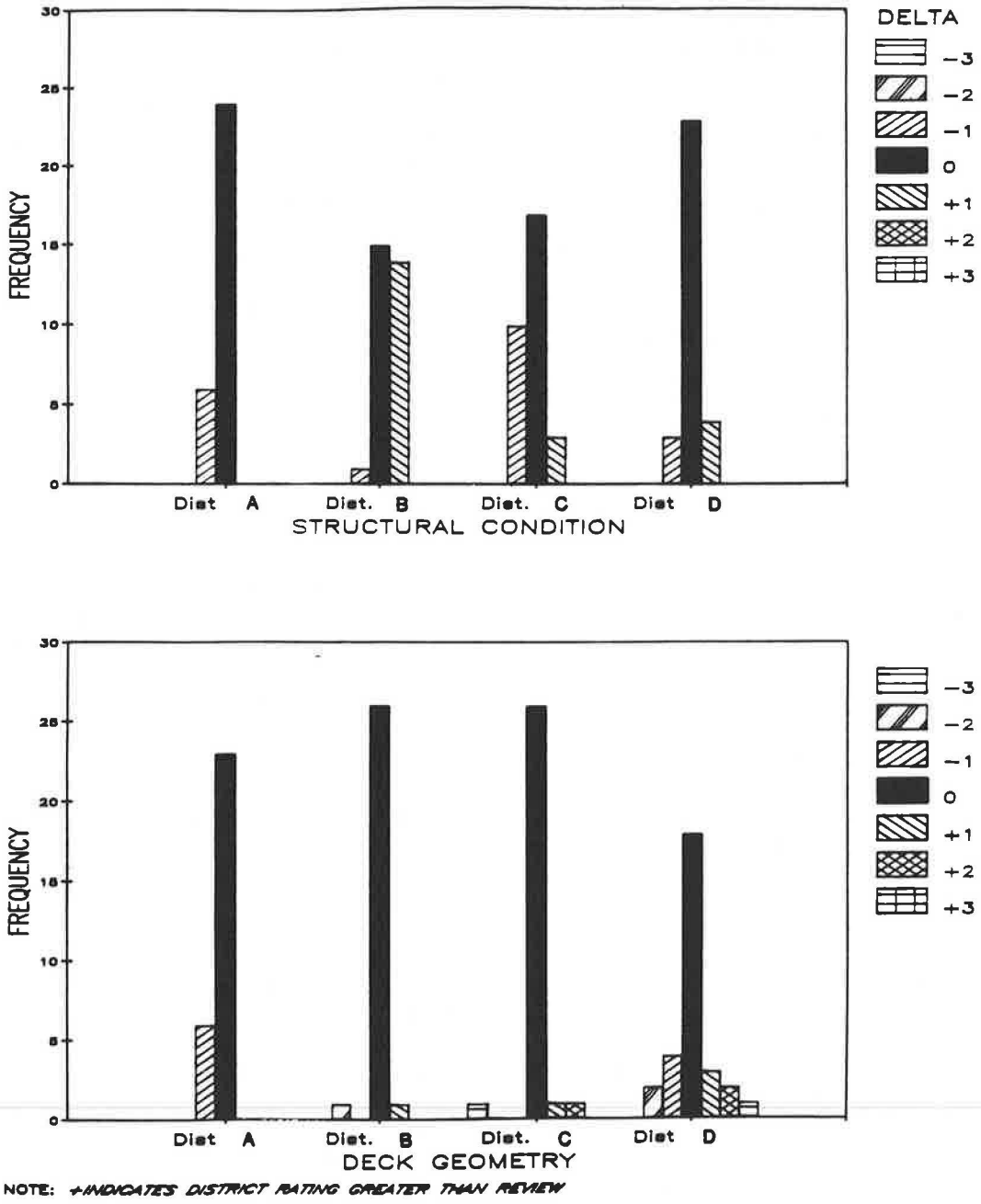


FIGURE 8 Difference between QA review and Districts *A*, *B*, *C*, and *D* ratings.

Wearing Surface at 91.5 percent, Approach Alignment at 92.7 percent, Deck Geometry at 91.4 percent, and Channel at 91.5 percent. Generally, the correlation was better on the condition rather than appraisal item. It was also better on the state rather than local inspections.

Details of the findings are contained in the district reports and summarized in the Phase I, II, and III annual reports. The annual report also contains the resolution of problems that were reported and discussed at the close-out meetings. Some common topics were load rating procedures, inspection documentation, and posting policy conformance.

Recommendations

The following recommendations were made for future QA implementation:

- Ensure implementation of Level IV QA procedures;
- Improve the instructional guidelines for Approach Roadway, Deck Wearing Surface, Structural Condition, Approach Alignment, Deck Geometry, and Channel;
- Develop a standard load rating and posting form to include in all bridge files;

- Improve guidelines for updating load ratings;
- Expand QA procedures involving bridge maintenance follow-up;
- Ensure that QA scope includes inspections of bridges owned by localities and railroads, bridges inspected by consultants and authorities, and bridges with 8- to 20-ft openings; and
- Put additional emphasis on proper inspection of scour, fracture critical details and underwater structure components during QA evaluations.

DISCUSSION OF QA ITEM EVALUATION

A. Accompany inspection teams in field: The major flaw with this method is that the presence of the QA review team probably will influence the inspector's attitude and performance. This would not be representative of the day-to-day operations. The major advantage is that the QA evaluation can be made with fewer resources than can an independent review, and there is the opportunity to test the inspector's knowledge by asking questions. The method is thought to be more appropriate for district office quality control than central office quality assurance and is appropriate to identify performance differences between districts.

*B*4. Independent field inspection and complete documentation (previous documentation not available): This is considered to be the most effective method of verifying the inspection and field documentation; however, it is also the most expensive. Not only will it take considerably more time and resources to recreate all the inspection and inventory documentation but an additional trip to the bridge will often be required to resolve differences. QA Level 4 uses this approach.

*B*3. Independent field inspection—document only deviations (previous ratings available): This is an acceptable alternative to the previous method. The QA team takes the current BMS printout to the bridge, but to avoid being influenced team members do not look at the ratings until after completing a separate condition evaluation. They provide documentation only on the ratings that differ significantly from the district's ratings. The approach is part of Levels I, II, and III, the difference being the number of inspection items subject to QA.

C. Computer edits districts' BMS data: A carefully conceived computer edit of inventory and inspection data entered by the district for each bridge is a relatively inexpensive method of identifying erroneous and contradictory information. It is currently performed by BMS Division but requires modifications to fit the desired level. This method identifies contradictions in entered data but does not determine or verify the actual situation in the field.

D. Partial inspection based on report review—document only deviations (previous report available): This is a method used by some districts for quality control. They look for unusual condition changes or very low ratings when reviewing the reports. The items are then evaluated in the field to verify the rating. This is not practical for QA because it requires an initial review of all the reports. The QA field evaluations would then be scattered throughout the state. Other objections are that the evaluations would be slanted toward problem bridges and the evaluation would not determine the thoroughness of the inspections. An inspector could get by with a poor job as long as the ratings did not change. This approach is not recommended.

E. Evaluate certain items based on sensitivity: Resources do not permit a complete check of all the information contained in the inspection and inventory file for each QA evaluation. Some information is more sensitive than others in considerations such as sufficiency or load rating. QA Levels II, III, and IV include this method for selecting inspection items in the inventory evaluation.

F. Evaluate certain teams or districts based on performance history: An important objective of the QA program is to provide an accurate picture of the overall bridge safety inspection program; the sampling technique therefore should provide a representative group of bridges. This method would not do that, and it is not recommended.

G. Evaluate inspection file: The file normally contains backup data for the load rating analysis, posting recommendation, and maintenance work orders. The file also contains detailed reports of the periodic inspection findings. QA Levels I, II, III, and IV include a different level of file quality evaluation of all the bridges selected for the field review.

H. Evaluate backup procedures: It is difficult to evaluate the various data in the file without understanding the procedures that generate and use the information. QA Levels II and IV include an evaluation of the office planning and follow-up procedures related to the bridge safety inspection program.

I. Verbally question individuals involved in supervising district inspection program: The districts are unique and have special requirements of their inspection program. A standardized questionnaire is helpful to document the organizational structure, procedures, and personnel capability found in each district. This and the previous method will often overlap. It is also included in QA Levels III and IV.

J. Accompany district personnel during quality control visits: Each district has an approved QC plan for bridge safety inspection. An objective of QA is to monitor compliance with the QC plan. The district QC plans include field visits by the different levels of supervisors responsible for the program. The visits are often spontaneous or combined with other responsibilities. Although it might be useful, it is not practical to include on-site monitoring of these visits as part of the QA concept. The review of this activity is, therefore, restricted to verification by asking questions during office interviews included in QA Levels III and IV. The effectiveness of the district QC efforts will be evidenced by the results of the other QA activities. Therefore, this is not a practical QA work item.

Table 2 includes items *K* and *L*, which were added after this appraisal was made.

ACKNOWLEDGMENTS

Other members of the project team contributed substantially to the development of information contained in this report. Notable are Leonard E. Schwartz, Project Manager, Bridge Maintenance Systems Division, Bureau of Bridge and Roadway Technology, Pennsylvania Department of Transportation; and Thomas H. Suthers, QA Team Leader, Wilbur Smith Associates, BTML Division (WSA/BTML). The following individuals contributed in an advisory capacity: Roland Berger, WSA/BTML; Martin Rissel, WSA/BTML; Robert Nickerson, Federal Highway Administration; William Moyer, Gary Hoffman, Steve Simco, Joseph O'Melia, Charles Mergl, Roland Cope, and Robert Paul, all of PennDot; and Neal Wood, Pennsylvania Turnpike Commission.

Publication of this paper sponsored by Committee on Structures Maintenance.