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U.S. Department of Transportation

Federal Highway Administration

Quality Assurance in Materials and Construction

FINAL REPORT

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Executive Summary

This review is a product of the FHWA 2006, National Review Program (NRP). Quality Assurance (QA) was selected for review in 2006 because the program was ranked as one of the top five areas of interest for review by FHWA. Over the last 10 years an average of 75 percent of the Federal-aid program was affected by the QA program. The goals of this review are: to reduce risk in the quality assurance program; recommend improvements which allow Division Offices to evaluate, approve, and monitor State quality assurance programs with a high degree of confidence; and identify successful practices that will add value to this program at a national level.

This review looked solely at FHWA Division Offices and how they evaluate, approve, and monitor the State's QA program. Seven Division Offices were selected to participate in this review based on geographic diversity, program size, perceived risk, and use of contractor test results. This review focused on the six elements of a QA program: contractor quality control, agency acceptance, independent assurance, dispute resolution, laboratory accreditation and qualification, and personnel qualification/certification. In addition to these six elements, Divisions were asked if they considered their program to be effective and why.

From this focused direction and to accomplish the listed goals, the Team developed the following recommendations to assist the FHWA Division Offices in their oversight and stewardship responsibilities for the quality assurance program.

Recommendation #1: The FHWA senior management and Division Office leadership should develop Agency and individual performance objectives to increase accountability for the QA program equal to the level of investment and risk.

Recommendation #2*:* FHWA should identify strategies for addressing the limitations in the existing language of 23 CFR 637 such as:

- Being more applicable to all Federal-aid projects, regardless of system, class, or type;
- Addressing construction inspection more formally and clearly;
- Addressing acceptance of manufactured/certified materials; and
- Addressing alternate project delivery methods in the context of QA and the risk to public funds.

Recommendation #3: The FHWA Headquarters and the Resource Center should develop and implement an action plan to be adequately staffed and organizationally aligned to provide a single focal point that will provide timely program and technical advice to Division Offices/States on QA.

As a first step towards implementation of this recommendation, the Team suggests forming a task force with Headquarters, Resource Center, and Division representation to

study and recommend staffing or organizational changes that may be required to meet the needs of the Divisions.

Recommendation #4a: FHWA should develop a QA Manual of Practice to be a single point of reference document that would provide guidance and information to Division Offices.

Recommendation #4b: The FHWA should identify and/or develop a national network of QA talent to serve as a resource to others in the Agency.

Recommendation #4c: The FHWA should establish a QA Peer Review program using the existing Research Program peer reviews as a model.

Recommendation #4d: The FHWA should develop a comprehensive "QA 101" workshop that is built off of existing materials.

Recommendation #4e: The FHWA should implement a QA certificate program to recognize employees who have demonstrated a level of competence in QA and who can serve as Agency resources in the QA area.

Recommendation #5a: The FHWA should develop a question-based evaluation tool to evaluate the effectiveness of the six elements of a QA program and the program as a whole.

Recommendation #5b: The FHWA should develop risk-based evaluation tools to:

- Develop and assess appropriate testing frequencies and associated levels of risk for a variety of materials.

- Compare quality measures in a variety of "what if" scenarios (Percent Within Limits verses Absolute Average Deviation verses Conformal Index, and so on.)

- Assess variability of material tests conducted by contractor versus owner. (See discussion in Successful Practices section of report.)

The Federal Highway Administration has seen many changes over its long and successful history. As the Agency moves forward, FHWA needs to ensure that the strong commitment to stewardship and oversight of quality assurance programs is maintained with intensity similar to that of financial integrity and the Vital Few. Quality Assurance touches all materials and construction activities on a project and directly impacts the service life of a transportation facility. Implementing these recommendations would result in improved performance of transportation construction projects, more effective QA programs for State DOTs, improved oversight/stewardship by FHWA, and a more valid risk assessment process at the Division Office level. The recommendations contained in this report provide strategies to FHWA's leadership to address specific deficiencies. Correcting these deficiencies will reduce risk and exposure and provide a

valuable service to State DOTs, highway industry, and traveling public. The Team urges FHWA's leadership to accept the recommendations contained in this report.

Background

This review is a product of the FHWA 2006, National Review Program (NRP). The NRP provides program evaluation at the corporate level to enhance program effectiveness, ensure more program consistency, and identify successful practices across the Nation. The NRP is an annual program of reviews conducted by Teams comprising experienced FHWA personnel. Review topics are selected through an annual call followed by a solicitation for Team members from FHWA unit offices. Quality Assurance (QA) was selected for review in 2006 because the program ranked as one of the top five areas of interest for review by FHWA.

The role of the QA program is to ensure that the quality of the materials and construction incorporated on all Federal-aid highway projects on the National Highway System (NHS) are in conformity with the requirements of approved plans and specifications. The programs developed by the State Department of Transportations (DOTs), must adhere to 23 CFR 637, *Construction Inspection and Approval* (contained in Appendix A), and be approved by FHWA. These programs lay out systematic actions necessary to provide confidence that the material and workmanship incorporated into a project will satisfy given requirements.

Changes to this regulation occurred in 1980, 1987, 1995, and 2002. Prior to 1980, the regulation primarily addressed sampling and testing of material used in construction. This regulation also had a strong focus on quality and acceptability of material and FHWA oversight requirements. The 1987 change to the regulation clarified that States must perform all acceptance testing; further clarification was provided through two memorandums and a technical advisory (T 5080.11) issued by FHWA. In 1995, the regulations were rewritten to allow for the use of contractor test results in the acceptance decision and establish a systematic approach to quality assurance. In 2002, the regulation was updated to address design-build projects.

While the regulation changed FHWA's approach to the QA program there were several other factors that affect the status of the program today:

- Starting with the Intermodal Surface Transportation Efficiency Act (ISTEA) there have been sweeping changes to FHWA's role in the administration of Federal-aid projects. These changes have altered stewardship and oversight of the QA program.

- The FHWA underwent an organizational restructuring that eliminated the Regional Offices and created the Resource Center while also shifting responsibilities in Headquarters. This restructuring and shifting of responsibilities has altered the support structure for the QA program.

- State DOTs and FHWA have lost staff and expertise needed for the QA program. These losses have created a void in the execution and oversight of the QA program.

Purpose of Review

The purpose of this review was to independently evaluate the FHWA Division Offices' stewardship and oversight of the QA program. The goals for this review were:

- Reduce risk in the Quality Assurance Program.
- Recommend improvements which allow Division Offices to evaluate, approve, and monitor State quality assurance program with a high degree of confidence.
- Identify successful practices that will add value to this program corporately/nationally.

Quality assurance is a critical component of the States' construction programs. The FHWA Division Office's role in providing proactive QA stewardship is considered essential to the successful delivery of State construction projects. Over the last 10 years, an average of 75 percent of the dollars apportioned for the Federal-aid program have been obligated for projects which are affected by the QA program. Since the amount of money associated with the construction program is so large, it is inherently a high risk area. Quality assurance is the principal means by which the States verify construction, material, and product quality, and is therefore the primary method by which the FHWA and the States can control and reduce risk to the construction program.

The 2005 Financial Integrity Review and Evaluation Program (FIRE) established oversight procedures to ensure that Federal funds are properly managed and effectively used, that financial processes and transactions are reviewed, and that safeguards are in place to minimize fraud, waste, and abuse. Proper quality assurance procedures are one method of safeguard and are essential for providing the fiscal accountability and oversight required by the FIRE program. Quality assurance in the construction phase, and particularly in material quality, is necessary to ensure federal funds are properly managed and effectively used.

The FHWA's stewardship role reflects the Agency's responsibility to ensure that the Federal Highway programs are delivered in an efficient and effective manner. While States may assume certain project approval authorities, the FHWA is ultimately responsible for ensuring that the Federal Highway programs are delivered consistent with established requirements.

Quality construction is fundamental to meeting the mission of the FHWA, and quality assurance is the primary means by which the FHWA ensures that it has confidence in the quality of the highway products delivered. Achievement of the Agency's national objectives is dependent on highway improvements being constructed to a desired level of quality in order to ensure that they perform as intended. Completed construction projects represent tangible products by which the FHWA is measured in the delivery of its programs. The public and Congress ultimately define the success of these construction projects based on their performance.

Scope and Methodology of Review

Scope

As cited in 23 CFR 637, every Division Office is responsible for the approval of the State's quality assurance program. As part of the Office of Infrastructure's stewardship activities they have initiated a multi-year review focusing on the adequacy of State's quality assurance programs. Infrastructure's review concentrated on the quality assurance program as developed by the State focusing on regulatory compliance and technical assistance. The review has brought attention to the use of contractor test results in the acceptance decision.

In contrast to the Office of Infrastructure's review, this national review focused on how Division Offices evaluate and approve the State's quality assurance program and what criteria are considered in that approval. An additional focus of this review was the Division Office's monitoring of the State's implementation of the approved program. The foundation for this review is the six elements of a QA program. These six elements are considered to be the building blocks of an acceptable quality assurance program and served as the basis for the review of the Division Office's evaluation, approval, and monitoring of the quality assurance program and are discussed in more detail later in this report.

These six elements are outlined in various documents such as the *National Quality Improvement Task Force Report on QA Procedures for Highway Construction* (FHWA DP-89, June 1994) and the *AASHTO Implementation Manual for Quality Assurance* (February 1996). Although other documents may group these activities differently, it is helpful to define the quality assurance program using these six elements:

1. Contractor quality control
2. Agency acceptance
3. Independent assurance
4. Dispute resolution
5. Laboratory accreditation and qualification
6. Personnel qualification/certification

In order to have a better understanding of the content of this report, it is valuable to have a clear understanding of the definition of these elements. As the Team discovered during this review, the terms used for the six elements often have different meanings depending on the particular jargon used in each State. For the sake of clarity for this report, these six elements are further defined and described. It is important to understand that these six elements work together to ensure a complete effective QA program. If one or more of the six elements is missing from a Division Office's oversight, the program as a whole is significantly weakened and risk is increased.

1. Contractor Quality Control

Contractor quality control (QC) is a defined system specifically designed to allow the contractor to monitor, assess, and adjust the production or placement processes of specific materials to ensure that the final product will meet the level of quality specified. Quality control testing is different than the acceptance testing discussed in the section below; its purpose and function is to measure those quality characteristics and inspect those activities that impact the quality of the finished product at a time when corrective action can be taken if needed. These efforts and testing defined and performed by the contractor should be able to identify nonconforming material and prevent its incorporation into the final product. It also functions to identify proper control and provide a level of confidence that the work is being completed according to the established specifications.

The minimum contractor quality control activities should be defined in the construction contract as part of a plan utilized during construction. The activities of this plan include material testing requirements, inspection activities, corrective action when required, and management control to ensure that the work conforms to the contract requirements.

2. Agency Acceptance

Agency acceptance is defined as the process used by the Agency to evaluate and determine the degree of compliance of the final project with contract requirements. The Agency acceptance program is composed of elements that enable the State to determine the quality of the product as specified in the contract requirements. These activities include verification sampling, testing, and inspection. In some instances, this can also involve determining a quality-based pay factor for a given finished product. The Agency acceptance program should include inspection schedules, lot sizes, sample sizes, testing frequency, quality measure, pay factors, and acceptance limits. If contractor data is utilized in the acceptance decision the program would also include a validation method and risk evaluations.

3. Independent Assurance

Per 23 CFR 637, the purpose of independent assurance (IA) activities is to provide an unbiased and independent evaluation of <u>all</u> the sampling and testing procedures used in the acceptance decision. This system is designed to verify the quality of the data, not the quality of the material, which is being obtained during the course of highway construction. The IA samples evaluate the sampling and testing personnel and their associated equipment. Deficiencies in testing or equipment can be discovered by comparing IA test results. Through this process, the integrity of the system is monitored and therefore provides a level of confidence in the data that is obtained and used in the acceptance decision.

There are two methodologies for performing IA activities, project-based and systematic. Project-based is a more traditional approach in which the personnel on a specific construction project are evaluated by periodic IA samples and observations. The results of these tests would then be used

to determine if any discrepancies exist in the sampling and testing procedures of the people and equipment being utilized on the project. Results of project-based IA are reported as part of project materials certifications.

In the systematic approach, the IA sample is still utilized to determine any discrepancies in testing or equipment, however since it is not performed in concert with project activities it would become necessary to track the individual testing technicians and associated equipment. If a State elects to use the systematic approach to IA, the regulations require an annual report be submitted to the Division Office.

4. Dispute Resolution

Dispute resolution is a documented process that is used to resolve conflicts resulting from discrepancies between the State's and the contractor's test results. This type of resolution is very specific to addressing test results that are used in the acceptance decision and should not be confused with contract administration dispute resolution processes (partnering, mediation, arbitration, and so on).

This process may involve items such as test procedure review, sample retesting, comparison testing, and third-party testing. Regardless of specific process elements, the entire dispute resolution process should balance the risk of both parties and offer a consistent approach for all construction projects.

5. Laboratory Accreditation and Qualification

As part of 23 CFR 637, each State shall have a central laboratory accredited by the AASHTO Accreditation Program or a comparable laboratory accreditation program approved by the FHWA. In addition, all testing performed as part of the acceptance decision must be completed by a qualified laboratory. These laboratories include State laboratories that are not part of the AASHTO Accreditation Program, contractor laboratories, and vendor laboratories. It is necessary for the States to define and list the specific criteria that are used to determine the components of a qualified laboratory.

6. Personnel Qualification/Certification

As part of 23 CFR 637, all sampling and testing data to be used in the acceptance decision shall be performed by qualified sampling and testing personnel. The State needs to define the criteria that are used to determine these qualifications; in general the components include:

- Formal training,
- Hands-on demonstration,
- Written examination, and
- Periodic re-qualification.

This process will also document how the list of qualified personnel is maintained.

Methodology

To identify key states for this review the Team focused on the following criteria:

- Dollar size of Federal-aid program; small, medium, and large.
- Acceptance testing method; contractor testing versus Agency testing.
- Ranking of subject matter during the national review program solicitation; low, medium, or high.
- Geographic representation in each Director of Field Services area; North, South, and West.
- Participation in other recent national reviews.

The Division Offices selected for the review were Utah, Alabama, Pennsylvania, Wyoming, Illinois, District of Columbia, and Texas.

In addition to site selection, the Team also focused on the content of the questions to be asked during the review. The Team developed a four-part questionnaire that examined the six elements of QA, general oversight, staffing, and support and improvements needed in the program. The four parts of the questionnaire examined the Division Office, State DOT, consultant, and industry roles and responsibilities in the QA program. The Division Offices were given the option to provide the specific portion of the questionnaire to consultants and/or industry, if applicable. The interviews captured input from FHWA Division Administrators, FHWA program managers, and State QA leaders and program managers. The basis for the questionnaire was 23 CFR 637 and Technical Advisory (TA) T6120.3 (Appendix B). The questionnaire asked the Division Office how they administered the six elements of the program, if they considered each element and the overall program to be effective, and how they made this evaluation. A copy of the questionnaire can be found in Appendix C.

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The Team members for this review were:

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- Utah
- Alabama
- Pennsylvania
- Wyoming
- Illinois
- District of Columbia
- Texas

Observations and Recommendations

Observation #1: Agency emphasis and dedication of resources in the QA area is not commensurate with the level of investment and risk.

As noted in the Purpose of Review section of this report, over the last 10 years an average of 75 percent of the Federal-aid program was affected by the QA program. With organizational restructuring and the changes brought about by the legislation in the 1990's, FHWA's traditionally very strong role in QA shifted and other priorities emerged. As the Agency moves towards risk-based decision processes, the level of investment and the related risk in the materials and construction area dictate a re-focusing of FHWA's efforts in QA.

Prior to the 1990's, the Division Offices had direct oversight and responsibility for the majority of Federal-aid construction projects occurring at any given time. Area Engineers checked materials test results, delivery tickets, Independent Assurance results, quality of inspection, etc. Regional Office, and occasionally Headquarters, engineers would periodically review the Division Office activities and would conduct, or assist with, process reviews covering QA-related topics. This amount of hands-on involvement was indicative of the emphasis and resources the Agency devoted to QA, with the clear goals being the construction of high-quality, long-lasting projects and assuring the appropriate use of taxpayer funds.

When the ISTEA legislation brought about the concept of "exempt" projects, FHWA became less involved at the project level, which was to be complemented by increased involvement at the program level. Formal Agency goals and performance expectations in the QA area have been limited which has resulted in a lack of clarity for managers when they are distributing their available resources and also a lack of clarity for staff-level engineers as they assess what level of time and effort they should be devoting to QA activities. The closing of the Regional Offices and the reduction of reviews by the Headquarters Office has exacerbated this lack of clarity. Four of the seven Division Offices noted the need for more explicitly defining the role of QA in the context of the FHWA culture.

In 2002, safety, congestion mitigation, and environmental streamlining coalesced into FHWA's Vital Few. These quickly became high priority areas with a great deal of Agency resources devoted to achieving identified goals in each area. Performance expectations and managerial emphasis on the Vital Few are readily apparent at all levels of the Agency. Three Division Offices explicitly stated that QA is interwoven with the Vital Few and that having solid QA programs at the State level, supported by appropriate levels of FHWA QA activities, significantly supports the accomplishment of the goals of the Vital Few. This theme was echoed throughout each of the reviews and is supported by the Team. Increasing the emphasis on QA by establishing performance expectations at all levels of the Agency will enhance Vital Few activities and will also support the accomplishment of several goals included in the FHWA Strategic Implementation Plan.

In recent years, the mantra of "Get In, Get Out, and Stay Out" has been promoted to demonstrate the public's desire for longer-lasting highway projects. As traffic volumes continue to increase,

and the associated user costs of construction congestion continue to spiral upward, the need for longer-lasting facilities is paramount. Tremendous amounts of research funding has been dedicated to developing improved materials such as Superpave hot-mix asphalt, high performance concrete, and high performance steel. Without proper acceptance testing and inspection, the public will not fully realize the increased service life that these improved products are capable of providing.

A 2006 national appraisal and evaluation[1] performed by FHWA's Office of Infrastructure of 20 State pavement preservation programs found that in nearly all of the States reviewed, pavement design lives are not being achieved in practice. In fact, it is very common to find both flexible and rigid pavements that last only a fraction of their design lives. The Pavement Preservation Report did not identify the factors that may have accounted for the shortened longevity of new pavements, but it's reasonable to assume that one of the contributors is insufficient emphasis on proper quality assurance procedures during construction. This truly is an area where "back to the basics" offers ample benefits. A decrease in QA emphasis at the Federal level leads to a decrease at the State level which, inevitably, leads to lower quality projects and continued erosion of the transportation infrastructure.

One theme that emerged during our interviews was the topic of regulatory compliance. As contemplated in 23 CFR 637, the goal of a QA program should be to effectively provide assurance that the quality of the finished product is what it should be; compliance with the regulation is also a priority. It is currently possible to have a QA program that is effective but does not comply with the regulation. Conversely, it is also possible to have a QA program that is compliant with the regulation but is not effective. The Team believes that a clear managerial message about QA, including performance expectations, will lead to States and Division Offices being more apt to comply with the intent of the regulation in developing and implementing effective QA programs.

As FHWA and the States have sought out new ways to maximize efficiency in delivering the highway program, new areas of risk have arisen. In 1995, 23 CFR 637 was re-written to allow contractor test data to be used in the acceptance decision. While the regulation and Technical Advisory 6120.3 identify the need for controls to be in place, the overall concept increases the risk to public funds. Thirty-four States now use contractor test results in the acceptance decision. Many of these States are using these results not only for pass/fail acceptance but also when determining pay factor adjustments; essentially, contractor data are being used to determine incentive or disincentive payment. This is made even more significant by the fact that these pay adjustments are most often applied to hot mix asphalt, concrete, and earthwork items, often representing the highest percentage of cost on a project.

Using contractor test results in the acceptance decision can be particularly appealing to States facing a loss of expertise due to retirements and personnel reductions driven by budget issues at the State level. State DOT managers may feel they are able to reduce their workload by shifting the testing burden onto the contractors. However, States are increasing the risk to Federal-aid funds by not establishing sufficient controls, as envisioned in the regulations. In 2000, the Office

[1] Pavement Preservation Technical Assistance Appraisal and Evaluation of State Programs – Interim Report, Federal Highway Administration, Washington, D. C., Draft December 2006.

of Infrastructure initiated a series of reviews of State DOT QA programs with 3-4 States reviewed each year.[2] Significantly, the Infrastructure reviews found that many State systems used to validate contractor test data need to be strengthened. The reviews noted many critical deficiencies for using contractor test data, such as the lack of independent sampling for verification tests, inadequate statistical comparisons of test results, and insufficient State control of test samples, sampling locations, and testing data. Of the 15 States reviewed that used contractor test data in the acceptance decision, only 5 were found to have "reasonably good" systems in place to validate the contractor test data. The inherent risk is obvious since the procedures and controls envisioned in the regulations are not in place.

With seventy-five percent of the Federal-aid dollars exposed, the potential for and the risk of fraud is substantial. FHWA has seen an increase in suspension and debarments in the last few years related specifically to materials.[3] From 1996 through 2004 FHWA had processed a total of three materials related suspension and debarment actions. In 2005 alone, there were 2 of these types of actions processed and in 2006 this figure had risen to 6. In addition in 2006, 3 cases have been settled without suspension or debarments and negotiations are currently underway on one case settlement that would result with no debarment or suspension. These are clear indicators of risk exposure for FHWA and the associated funds.

The recent, highly publicized, issues on the Boston Central Artery/Tunnel project are indicative of the level of risk and the potential consequences of short-comings in QA systems. The consequences go beyond the exposure of funds noted above. The fatality that resulted as a result of the partial collapse of a tunnel ceiling has shaken the public's trust. The indictment of six individuals related to substandard quality concrete being provided throughout the project has further damaged the public's faith in Government's ability to effectively monitor construction projects and assure effective use of taxpayer funds.

Each of the issues discussed in this section demonstrates the need to increase FHWA's emphasis on QA. The FHWA management has been successful at establishing a focus on the Vital Few and FIRE through the messages they deliver to all employees and, every bit as importantly, by the establishment of performance objectives and accountability throughout the Agency. The QA is key to the accomplishment of FHWA goals and the Agency needs to take a similar approach to QA as it has to the Vital Few and FIRE.

Recommendation #1: The FHWA senior management and Division Office leadership should develop Agency and individual performance objectives to increase accountability for the QA program equal to the level of investment and risk.

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[2] Quality Assurance Stewardship Review - Summary Report for Fiscal Years 2003 Through 2005, Federal Highway Administration, Office of Pavement Technology, Washington, D.C., http://www.fhwa.dot.gov/pavement/materials/stewardreview2006.cfm, 2006.

[3] This information has been derived from a summary based on a review by the Federal Highway Administration, Office of Infrastructure of the administrative records and FHWA Notices N2000.485 to N2000.582, Federal Highway Administration in Washington DC.

Observation #2: Existing QA regulations do not address areas of concern to Division Offices and States.

Throughout the course of this review, all seven Division Offices and all seven States indicated a need to refine the regulation to address current needs and issues.

During our interviews, there was a great deal of discussion about the regulation and its application. The areas where Division Offices and States see a need for refinement of the regulation can be consolidated into four primary topics:

- The limited applicability of the current regulation;
- The need to incorporate construction inspection into 23 CFR 637;
- The need for the regulation to address acceptance of manufactured/certified materials; and
- The need for additional regulatory language addressing project delivery methods other than the traditional design-bid-build.

The limited applicability of the current regulation

The current regulation was issued in 1995 during a time when FHWA was seeking to define the scope of Federal interest in the highway program in the post-Interstate era. The Agency, and the enabling legislation, focused FHWA's Title 23 activities on the National Highway System (NHS) and 23 CFR 637 was developed with that in mind. The regulation was issued and is applicable only to projects on the NHS; there are no regulatory requirements for QA on non-NHS projects. Division Offices and States perceive this as an inconsistency as they tend to adhere to the idea that "a Federal dollar is a Federal dollar" regardless of where it is spent and FHWA is accountable for all funds it administers. This perspective is supported by the improper payments standards set forth in FIRE. The audit procedure calls for proper documentation of both the quantity and quality of what is paid, regardless of whether the project is on the NHS or not.

Significantly, all seven States we reviewed utilize the same requirements for all projects, i.e. the State implements a single QA program for all projects. It is notable that States developed their current QA programs at a time when they were under less pressure to reduce staffing and to continually "do more with less" than they are today. The fact that States uniformly chose to implement one program for all their projects further supports the idea that "a Federal dollar is a Federal dollar" regardless of where it is spent.

As States become more and more pressed to deal with budget cutbacks and staffing reductions, they may be tempted to relax their requirements and, therefore, increase the risk for projects off the NHS. This sentiment is borne out in two of the States we visited. In the first, the Division Office and State said that local agencies were pressuring the State legislature to force the State

DOT to relax/eliminate its QA requirements for locally administered projects. They were using the fact that the regulations did not require QA for their projects as leverage, stating that since QA is not required by Federal regulation it is not needed and they should not be held to that standard on their projects. With the acknowledged level of risk that already exists with locally administered projects, the fact that the regulation only applies to the NHS should not be used as justification to develop an alternate, presumably less rigorous, QA Program for projects off the NHS. This would increase the risk to the public and increase the likelihood that an acceptable level of quality is not obtained for the money spent. Again, the requirements set forth in FIRE do not support the argument being advanced by those local agencies. As noted, FIRE requirements do not distinguish between NHS and non-NHS projects.

In the other State, an upper management State DOT official opined, *With all that is going on nationally, QA is an area that FHWA cannot afford to back off of; if anything, the effort needs to be increased.* This comment builds off the same message we received from the first State. The official was referring to the budget pressures and cutbacks in staffing that many States are facing and the temptation of State DOT upper management to proceed with the same position taken by the local agencies in the previously mentioned State. As these budget and personnel pressures continue to increase, State DOTs may look to reduce QA on non-NHS projects. If this occurs, this will increase the risk on projects, serve to further erode the highway infrastructure, and lead to the loss of public trust as noted under Observation 1.

The concluding issue on this topic is the conflict of interest provisions in 23 CFR 637.209(c). As with the rest of the regulation, these provisions apply only to the NHS. In response to the aforementioned budget cuts and staffing reductions, States are making more use of consultants to perform QA activities. In recent years, many States have added specific contractor quality control requirements to their specifications; this has led to contractors also increasing their reliance on consultants. These trends are likely to increase in the future; the result is that conflicts of interest will become an increasingly important issue. If the applicability of the regulation is not expanded, the conflicts of interest that are specifically prohibited on the NHS will inevitably occur on projects off the NHS. By their very nature, conflicts of interest increase risk and are not in the public interest.

The need to incorporate construction inspection into 23 CFR 637

This topic was mentioned by each Division Office and each State; although there was consensus that construction inspection needs to be addressed, there were a variety of opinions on how it should be addressed. This topic was an item in the 1994 FHWA 23 CFR 637 Quality Assurance Procedure for Construction, Notice of Proposed Rulemaking, but was not fully incorporated into the final rule and is still a major issue encountered in the present day QA program. The NPRM placed more emphasis on the requirement for construction inspection. It stated, “The SHA shall inspect the product or construction or both for attributes that are detrimental to the performance of the finished product.” In the final rule, the reference to construction inspection was deleted. This omission has resulted in confusion as to whether the “specific attributes to be inspected” includes construction inspection.

During the review, some Division Offices and State DOT commented that the regulations should focus on adequate levels of inspection, i.e. staffing levels and items requiring inspection, while others felt the regulation should focus on the qualifications of inspectors, similar to how the current regulation treats those performing acceptance sampling and testing. All Division Offices were in agreement that there is confusion and uncertainty as to whether or not construction inspection is a part of the current regulation.

In 23 CFR 637 "Construction Inspection and Approval," the word "Inspection" is notably mentioned in two places:

> 637.203
> *Definitions. Acceptance Program. All factors that comprise the State transportation department's (STD) determination of the quality of the product as specified in the contract requirements. These factors include verification sampling, testing, and inspection and may include results of quality control sampling and testing.*
>
> 637.207 (c) (1) (i) (C):
> *Identification of the specific attributes to be inspected which reflect the quality of the finished product.*

The Federal-Aid Policy Guides (FAPG) transmittal 36, dated July 19, 2006, provides a non-regulatory supplement to 23 CFR 637. Under 2 (a), it reads: "The State's acceptance program should provide a reasonable level of inspection to adequately assess the specific attributes which reflect the quality of the finished product. Acceptance inspection should include inspection of the component materials at the time of placement or installation, as well as the workmanship and quality of the finished product."

This language, taken in concert with the title of the regulation, seemingly makes it clear that inspection is a part of the existing regulation, yet the confusion is readily apparent throughout both FHWA and the States. This issue has been discussed and debated numerous times at the FHWA meetings held in conjunction with the AASHTO Subcommittee on Construction meeting.

There are several other entities, both within FHWA and in other organizations that are currently examining this issue. These organizations include: FHWA Office of Asset Management, FHWA Office of Pavement Technology, the aforementioned AASHTO Subcommittee on Construction, AASHTO Subcommittee on Materials, and the Transportation Curriculum Coordination Council.

Revising the regulation to address construction inspection will not only help resolve the confusion, and concurrent inconsistent application of the regulation, but will help raise the overall emphasis on QA, as called for under Observation #1. A more straightforward approach to construction inspection requirements should also promote the concept that inspection and materials testing are both necessary components of an acceptance program. Having that concept firmly established should help prevent further erosion of QA programs at the State and local level resulting in better-quality, longer-lasting projects, thereby facilitating the achievement of several Agency goals.

The need for the regulation to address acceptance of manufactured/certified materials

While existing data is not available to determine a specific amount of funds involved, a substantial amount is spent on manufactured/certified materials. The existing regulation is written around the acceptance of project-produced materials, e.g. soils and aggregates, hot mix asphalt pavement, and concrete, while remaining silent on the use of manufacturer's certifications for acceptance. Six of the seven Division Offices and States noted this as an issue and expressed a desire for the regulation to address it.

States have different practices and procedures for accepting products based on manufacturer's certifications; one State we reviewed had a very well-developed process that included periodic testing and formal evaluation of field performance for these materials while other States had virtually no process at all. One State noted that once a product was placed on the Approved Materials List, barring a major documented failure it would remain on the list because periodic testing was not performed and field evaluation of product performance was not done. Given the amount of funds involved in these materials, this broad variation is evidence of the need for a clearer regulatory position.

The 23 CFR 637.205(a) states that each State's QA Program must "be approved by FHWA." Materials acceptance is an integral part of a QA Program and the regulation focuses on the acceptance of project-produced materials. Manufactured/certified materials constitute a significant expenditure of funds; one State observed that 10 percent of their funds are spent on these materials. However, there is no regulatory language allowing or disallowing the use of manufacturers' certifications to be used as a basis for acceptance. The Team supports the development of regulatory language to address these materials; this is appropriate given the amount of funds expended on these items.

The need for additional regulatory language addressing project delivery methods other than the traditional design-bid-build

As States and FHWA look for ways to maximize the efficiency of the Federal-aid dollar, alternative project delivery methods are becoming increasingly more commonplace. The regulation was developed at a time when warranties and design-build contracting were being newly applied on Federal-aid contracts. With the passage of time, these have become more commonly used and we are now seeing new delivery methods such as design-build-operate-maintain, design-build-warranty, and public/private partnerships being used.

The regulation does address design-build contracting. One Division Office and State did not feel the regulation considers allowing reduced QA requirements coincident with reduced risk of public funds. Regulatory modifications should be made to differentiate between the various project delivery methods and their impact on QA and, ultimately, the risk to the public. By way of example, Texas is pursuing a public/private partnership project funded primarily with private funds. The private entity will design, build, operate, and maintain the facility for 40 years, at which point it will be turned over to the Texas DOT. Clearly, the risk to public funds on this

project is minimal in comparison to the typical design-bid-build project contemplated in the regulation. As FHWA proceeds with risk-based decision making, this is an area where the regulations can be used to support those processes.

Recommendation #2: FHWA should identify strategies for addressing the limitations in the existing language of 23 CFR 637 such as:

- ***(a)*** Being more applicable to all Federal-aid projects, regardless of system, class, or type;
- ***(b)*** Addressing construction inspection more formally and clearly;
- ***(c)*** Addressing acceptance of manufactured/certified materials; and
- ***(d)*** Addressing alternate project delivery methods in the context of QA and the risk to public funds.

Observation #3: The QA functions are distributed within FHWA Headquarters and the Resource Center in a way that does not allow for a focused QA approach. There is confusion in the Division Offices as to who to contact with QA issues since there is not a clear understanding if this is a program or technical issue or how the organizational structure supports QA.

Prior to 2000, FHWA's staffing levels were more robust and the organizational structure for QA was more clearly defined. As mentioned under Observation 1, the Division Office area engineer was supported by someone in the Division Office who worked in the QA area, either full-time or as a collateral duty. Additionally, the Regional Office with clearly defined responsibilities in QA provided additional support to the Division Office. Headquarters' QA functions were closely aligned with program delivery in the Materials Branch under the Construction and Maintenance Division. Today there is not clear alignment of Agency support roles and responsibilities.

In 1998, the Regional Offices closed and FHWA established the Resource Center offices to provide technical support and assistance to the Division Offices. In the late 1990's, Headquarters also underwent organizational realignment to better fit with the Agency's new business model. With Division Offices now operating under the revised Agency structure, it has become clear that QA is an area that has lost organizational clarity as the previous clear-cut lines of responsibility have become splintered. This has resulted in Division Offices not being able to efficiently get additional guidance or answers to their questions. In many cases, time is critical when Division Offices are seeking answers to QA-related questions and the lack of ability to easily obtain answers has proven frustrating to Division Offices and States. Five of seven Divisions commented that there is a need for a more cohesive structure in Headquarters and the Resource Center to provide support to the field in the QA area.

In a May 3, 1999, memorandum regarding Quality Management, the Office of Infrastructure defined how the QA program area would be handled at the Headquarters level under the revised Agency structure. This memorandum noted that QA is a very broad subject area that cannot be pigeon holed in a single segment of the Agency. The memo stated, "Overall direction…rests in the Office of Asset Management…Various technical topic areas have been separated among the technology offices." The memo went on to identify specific functions and assign them to "lead offices."

While the memorandum may have provided some initial clarity, over time FHWA has deviated from the direction of the memo. There are several aspects that may now contribute to the lack of clarity rather than resolve it:

- The memo assigns the overall direction to the Office of Asset Management yet the perception at the Division level is that because the regulatory responsibility for 23 CFR 637 resides in the Office of Pavement Technology, QA in general does as well;

- Over time, the lines of delineation for topic areas identified in the memo have become distorted and the associated lead offices roles have become unclear. One example is statistical analysis, control, and comparison was assigned to the Office of Asset Management when, in practice today, this function is largely handled by the Office of Pavement Technology;

- When the memo was issued, the Resource Center was relatively new and did not have a defined role in the QA area, consequently, the memo did not identify whether FHWA considers QA to be a technical or program issue and what role the Resource Center should play. One Division Office told the Team that they would not contact the Resource Center for any QA-related issues because they viewed QA as a program issue, not a technical one. This is in stark contrast to the letter of thanks written by a Division Office, as shown on the Resource Center's website, to a member of the Resource Center Pavements and Materials Team, thanking him for his assistance with "QC/QA specs." Additionally, when reviewing FHWA's online resources, QA is specifically noted as an area of responsibility under the Resource Center Pavements and Materials Team and several QA functions are noted areas of responsibility of the Resource Center Construction and Project Management Team. Clearly, there are some missing links in the information and resource chain.

Five of seven Divisions mentioned problems either getting timely responses to questions or even knowing where to go for information; the Team verified some of the concerns expressed. Given the reduction in personnel in the QA area, Division Offices are likely to seek answers on FHWA websites. The Team examined various FHWA websites looking for information on QA. Our experience in doing this was less than satisfactory and substantiates the Division Offices' concerns. The QA is scattered throughout several web pages including those of the Office of Asset Management and the Office of Pavement Technology with some limited additional information available on the Resource Center Construction and Project Management Team's site. We found it difficult and confusing to navigate the FHWA sites in search of answers.

Given the issues discussed in the introduction and under Observation #1, the Team feels it is imperative that the Agency develop an approach to be more responsive to the Division Offices.

Recommendation #3: The FHWA Headquarters and the Resource Center should develop and implement an action plan to be adequately staffed and organizationally aligned to provide a single focal point that will provide timely program and technical advice to Division Offices and States on QA.

As a first step towards implementation of this recommendation, the Team suggests forming a task force with Headquarters, Resource Center, and Division representation to study and recommend staffing or organizational changes that may be required to meet the needs of the Division Offices.

Observation #4: Division Offices have a lack of understanding of the six elements of QA and application of the elements in evaluating, approving, and monitoring a State's QA program.

Although this effort was not a compliance review, one of the objectives was to assess how Division Offices were evaluating, approving, and monitoring their State's QA program. In doing so, the Team developed its review guidelines to mirror each of the six elements of a QA program (contractor quality control, agency acceptance, independent assurance, dispute resolution, laboratory accreditation and qualification, and personnel qualification/certification) and assess each one independently. During the interviews, this invariably led to discussions about whether or not elements of the program were in compliance with the regulations and/or Technical Advisory T6120.3. The Team did not view this as a negative consequence, in fact, quite the opposite. This often led to a healthy and vigorous exchange of viewpoints and ideas between Team members and Division Office management and staff.

While it is not appropriate to dwell on the specifics, it is appropriate to present some data related to the magnitude of the issue. Of the seven Division Offices we interviewed, the opinion of the Team was that none of these programs were in full compliance with the QA regulation and/or guidance; this does not necessarily mean the programs were not effective. One Division Office stated very plainly that they were aware their program may not have been following the regulations and guidance in their entirety. This Division Office felt their program was very effective but they had no method of measurement or documentation (see Observation #5). In five States, the Independent Assurance Program was either not complete or not properly implemented; of the four States that utilized contractor test results for acceptance, none were validating the contractor data in accordance with the regulation and/or Technical Advisory; four States were not properly using dispute resolution for materials testing discrepancies; two States lacked laboratory qualification requirements; and one State did not require technician recertification.

During the course of our interviews, it became evident that five of the seven Division Offices had not looked at all the elements of their State's QA programs in many years. It was also apparent to Team members that some Division Offices were unaware of what the six elements of a QA program were.

With FHWA moving towards risk-based decision making, it is imperative that those individuals assessing risk in a given program area have an in-depth understanding of that program. Without a thorough knowledge and understanding of what a QA Program is, the results of any subsequent risk assessment are dubious at best. As an example, the Team opines that no Division Office should have a risk assessment rating of low, for impacts based on the volume of Federal-aid dollars that are impacted by the QA program; yet there are Division Offices that rated this low for impact.

In looking at how to improve the Agency knowledge base, the views of the Division Offices interviewed, and the Team, converged on three primary areas: (1) Agency resources; (2) training resources; and (3) FHWA QA Certificate.

Agency resources

As noted in previous sections of this report, Agency staffing in QA has been reduced in recent years. With the concurrent change in emphasis areas, employee turnover, and a change in how new employees are brought into FHWA, a gap in the level of knowledge in QA at the Division Office level exists. Prior to the mid-1990s, FHWA engineers went through a training program that included significant exposure to QA and related issues. Typically, the first position an engineer held upon completing the training program was an Assistant Area Engineer where skills in QA were further developed. This is no longer the model in use; the current Professional Development Program does not require a new hire to spend time becoming exposed to QA. Also complicating this issue is that a majority of new employees are mid-career hires who are hired into a specific position and may have no exposure to QA. Consequently, newer employees do not have the background in QA that existed in the past.

There were Division Offices and States that felt they lack the ability, understanding, or awareness of the skills needed to evaluate their programs. For example, information provided in Technical Advisory 6120.3 speaks to the intricacies of the use of contractor test results in the acceptance decision. This will be discussed further in Observation 5, but the fact remains that Division Offices and States believe that they are inadequately trained and equipped to handle the mathematical rigor necessary to perform the analysis.

Throughout FHWA there are a variety of staffing models used in Division Offices and some lend themselves more towards maintaining QA expertise than others. Some offices have a single engineer whose primary function is QA and that person serves as a resource and provides guidance to others in the Division Office. Other Division Offices treat QA as a collateral duty that may rotate periodically among Division Office staff. The QA is an area that takes time, passion for the topic, and hands-on work to develop expertise. While it is likely that not many Division Offices will have an individual with expert-level skills, there remains a need for knowledge in QA topics. This knowledge will assist Division Offices in both assessing overall risk in the Federal-aid program and for working with their State DOT to manage the program. Successful QA program management will accomplish the goal of quality projects constructed in accordance with Federal requirements.

There are several ways to augment the skills and resources that exist in the Division Offices. First, developing an up-to-date Manual of QA Practice would provide Division engineers, and others across the Agency, with a single point of reference for information related to QA. This manual would include all current information on QA including the non-regulatory supplement, policy memoranda, Technical Advisories, website addresses, and would also include references to other sources of information such as NCHRP syntheses and TRB reports. Ideally, this manual would also be available online which would help address the issue of confusing FHWA web links as discussed in Observation #3.

Another way to maximize the use of existing Agency resources is to establish an identified network of agency specialists in QA who can serve the agency in a capacity beyond their existing office. Although the issue of reduced QA staffing is very real, the Agency does have individuals who are experienced in QA. Several of these individuals work in Division Offices

which may be seen as desirable from the standpoint of another Division Office seeking guidance on an issue involving working with the State. Establishing a network of this type would also help to address the confusion that exists at the Division level regarding the role of the Resource Center and various Headquarters Offices in QA, as discussed in Observation #3. Once this network was established, and publicized, Division Offices and others in the Agency or at the State level would have a ready reference to use when seeking help with a variety of efforts such as a process review, specification assistance, or resolution of specific issues.

Building off this idea is the concept of sharing existing employees with expertise in QA in a way that specifically improves Agency competence in QA. As FHWA wrestles with this overall concept, the Agency could use the existing peer review model that exists in the research area and apply that to QA. Using the above-mentioned identified pool of talent in the Agency, a designated number of peer reviews could be conducted each year; if desired, these could be done in conjunction with the current reviews of State QA Programs being conducted by the Office of Infrastructure. While not specifically discussed with the Division Offices during the interviews, based on the discussions, the Team's opinion is the Divisions would welcome peer reviews of this type.

Training resources

Historically, FHWA training in "QA" has focused on the technical aspects of the materials and the associated construction techniques. Some examples are the FHWA Materials Course for Field Engineers, Materials Control and Acceptance Quality - Assurance Course, and the six-week materials course "Highway Materials Engineering," currently presented annually at the University of Nevada-Reno. Over the last several years these classes have shown a continuous decline in attendance. The attendance for the Materials Course for Field Engineers was so low that the course is no longer offered. In the last several years, the Office of Pavement Technology has developed and presented training in statistical acceptance concepts. These seminars/workshops are very good but they are limited in scope and do not address QA from a programmatic perspective.

The FHWA, and States, would benefit significantly from a training course that looks at QA more holistically and covers each element of a QA Program. All seven Divisions requested training in the basics of a QA program and its six elements. As an example, the New England Transportation Technician Certification Program (NETTCP) has a QA Technologist course that currently is the closest thing to providing a full programmatic view of quality assurance. This course was designed to certify State and contractor practitioners in QA concepts as they relate to production of highway materials and the subsequent determination of quality level attained.

The NHI is in the process of modifying the NETTCP course to make it appropriate for a national audience. This course is expected to rollout this year. This NHI course could be used as a base to develop a product that meets the needs of the FHWA audience. We envision the final product being a "QA 101" training course that would detail the responsibilities of Division Office specialists, generalist engineers, and potentially to Division Office management as well. The workshop would present QA terminology in an effort to resolve the widespread confusion in terms that exists along with explaining each component of a QA program and presenting some

best practices for each. The 23 CFR 637 and its associated supporting guidance could also be discussed in detail.

FHWA QA Certificate

As we discussed the issue of the Agency's knowledge base during the Division Office interviews, the concept of FHWA-certified QA employees was raised or supported by five of seven Division Offices. A certificate program would support several items discussed in this section. Specifically, it would:

- Provide motivation for employees to enhance their existing QA knowledge;
- Help identify the existing knowledge base in FHWA and help maintain the integrity of a nationwide database;
- Identify potential members of QA Peer Review Teams;
- Provide a pool of potential instructors to draw from for a QA 101 course; and
- Raise the overall Agency emphasis on QA as called for in Observation #1.

In the September 2006 FHWA all-employee videoconference, Executive Director Bud Wright expressed his support for the establishment of core competencies and baseline knowledge and the verification of these competencies through certification. Given the significance of QA, it is a logical choice to be a topic area for FHWA to explore this approach.

In summary, each of the recommendations listed below will help to raise the overall Agency knowledge and skill level in the QA area. Increased consistency, improved networking, improved communication of best practices, improvement in QA programs nationwide, and, ultimately, better quality projects for the traveling public are all likely to follow.

Recommendation #4a: The FHWA should develop a QA Manual of Practice to be a single point of reference document that would provide guidance and information to Division Offices.

Recommendation #4b: The FHWA should identify and/or develop a national network of QA talent to serve as a resource to others in the Agency.

Recommendation #4c: The FHWA should establish a QA Peer Review program using the existing Research Program peer reviews as a model.

Recommendation #4d: The FHWA should develop a comprehensive "QA 101" workshop that is built off of existing materials.

Recommendation #4e: The FHWA should implement a QA certificate program to recognize employees who have demonstrated a level of competence in QA and who can serve as Agency resources in the QA area.

Observation #5: Divisions could not assess the effectiveness of the six elements of the program.

One of the stated objectives of this review was to assess how Division Offices were reviewing, approving, and monitoring their State's QA program. As previously noted, the Team's review guidelines were set up to address this for each of the six elements of QA. For several elements when we asked how the Division Office was evaluating the QA program, they responded by asking Team members how to properly evaluate the elements. All Division Offices stated that tools are needed to provide guidance in evaluating QA programs; they further noted that determining if a program complies with the regulation is different from determining if a program is effective. The effectiveness of parts of the program are not being adequately assessed; this is directly linked to the knowledge gap discussed in Observation #4 and the lack of a tool to assess the effectiveness of the elements of the program.

The regulation requires the Division Administrator to approve the State's QA program. Throughout the review, we were made aware of the significant benefit of continued Division Office monitoring and evaluation of specific elements of the program and how those efforts led to improvements. There are numerous examples to illustrate this including:

- The Utah Division's detailed joint QA review with Utah DOT resulted in reassessment of the overall QA program in Utah and developed an action plan to make long-term improvements to their program.

- The Alabama Division Office attended the technician certification classes and raised concerns about the course materials. This resulted in a new vendor being selected and the courses being substantially revised;

- The Texas and Pennsylvania Division Offices encouraged a statistical review to prevent the State from lowering the testing frequency on project produced materials;

- The Illinois Division Office makes multiple presentations at industry forums to promote compliance with QA programs and make industry aware of changes resulting from the numerous reviews conducted by the Division Office.

- The Washington, DC Division Office performed a joint review with the Office of Infrastructure, the Resource Center, and the District that resulted in revisions to testing frequency, IA program, and technician qualification program; and

- The Wyoming Division Office coordinated with the State to develop four standard quality control plans that are included in the specifications.

This topic area is a logical follow-on to the items discussed throughout this report. As performance expectations are set and the awareness and knowledge of QA is raised, FHWA staff will need tools and methods to properly evaluate QA programs from a more holistic viewpoint and will also look for characteristics exhibited by outstanding programs. Some of the existing guidance contains discrete aspects (e.g., the FAPG, dated July 19, 2006, Transmittal 36, describes what characteristics an acceptable technician certification program should contain) but additional tools/evaluation techniques and methods are needed. As FHWA increases its use of risk-based processes, several potential tools lend themselves to a risk-based approach for program comparison and evaluation.

Division Offices mentioned several topics where they felt tools would be especially useful:

- Evaluating testing frequencies and risk for various materials for use by Division Offices when approving material test frequency guides;
- Evaluating different quality measures under a variety of "what if" scenarios, i.e. percent within limits (PWL) versus average absolute deviation versus conformal index and so on;
- Acceptance of small quantities;
- Acceptance of manufactured/certified materials;
- Overall evaluation of buyer's and seller's risk; and
- Evaluation of contractor quality control programs.

These tools are focused and we see them as parts of an overall package that should be developed to guide Division Offices in their evaluations of QA programs.

As States face the continued pressure from their governing bodies and face continued budget tightening, there is considerable need for Division Offices to stay engaged in their State's QA program. Providing the tools necessary to evaluate the overall effectiveness of their program will help assure that Division Offices serve as an integral part of the QA process.

Recommendation #5a: The FHWA should develop a question-based evaluation tool to evaluate the effectiveness of the six elements of a QA program and the program as a whole.

Recommendation #5b: The FHWA should develop risk-based evaluation tools to:

- Develop and assess appropriate testing frequencies and associated levels of risk for a variety of materials.
- Compare quality measures in a variety of "what if" scenarios (Percent Within Limits versus Absolute Average Deviation versus Conformal Index, and so on.)

- Assess variability of material tests conducted by contractor versus owner. (See discussion in Successful Practices section of report.)

Conclusions

Quality Assurance is an area of significant risk for the Agency. The QA was selected for review because the program was ranked by the Agency as one of the top five concerns and this review validates that observation. The role and structure of FHWA has changed since ISTEA; leading to a lack of focus in the QA area. Division Offices and State DOTs interviewed by the Team expressed a strong desire for FHWA to play a lead role in the QA area. They expressed concern that a lack of appropriate emphasis by FHWA will reduce performance of transportation projects resulting in a continued decline of confidence by the public and also expose FHWA to negative findings from outside review agencies. It is imperative that the FHWA reestablish a strong commitment to stewardship and oversight of the quality assurance program.

Quality Assurance touches all materials and construction activities on a project and directly impacts the service life of a transportation facility. Over the last 10 years an average of 75 percent of the Federal-aid program was affected by the QA program; for fiscal year 2006 this amounted to approximately $26.5 billion. The Team was charged to review Division Offices with the goals of recommending improvements, identifying successful practices, and reducing the risk in this program. Based on this review, the Team offers several recommendations that will improve and strengthen the QA program: to ensure that agency emphasis is commensurate with the level of risk in the program; modify the existing regulations; develop an aligned Agency structure; increase Agency knowledge and skills in QA; and provide tools to facilitate Division Office assessments of State QA programs.

The Team strongly believes that by implementing these recommendations the result will be improved performance of transportation construction projects; more effective QA programs for State DOTs; improved oversight/stewardship by FHWA; and increased confidence by FHWA and State DOTs that the identified risk is acceptable in the QA area.

Successful Practices

The Alabama Division Office successfully used QL-PAY as an analytical tool to test the validity of contractor and State DOT test data. A bias was uncovered that resulted in higher pay for the contractor when using contractor test data rather than the State test data.

A description of the process used by the Alabama Division Office is included as Appendix D.

Appendix A

Title 23 Part 637—Construction Inspection and Approval

Authority: Sec. 1307, Pub. L. 105–178, 112 Stat. 107; 23 U.S.C. 109, 114, and 315; 49 CFR 1.48(b).
Source: 60 FR 33717, June 29, 1995, unless otherwise noted.
Editorial Note: Nomenclature changes to part 637 appear at 67 FR 75934, Dec. 10, 2002.

Subpart A [Reserved]

Subpart B—Quality Assurance Procedures for Construction

§ 637.201 Purpose.

To prescribe policies, procedures, and guidelines to assure the quality of materials and construction in all Federal-aid highway projects on the National Highway System.

§ 637.203 Definitions.

Acceptance program. All factors that comprise the State transportation department's (STD) determination of the quality of the product as specified in the contract requirements. These factors include verification sampling, testing, and inspection and may include results of quality control sampling and testing.

Independent assurance program. Activities that are an unbiased and independent evaluation of all the sampling and testing procedures used in the acceptance program. Test procedures used in the acceptance program which are performed in the STD's central laboratory would not be covered by an independent assurance program.

Proficiency samples. Homogeneous samples that are distributed and tested by two or more laboratories. The test results are compared to assure that the laboratories are obtaining the same results.

Qualified laboratories. Laboratories that are capable as defined by appropriate programs established by each STD. As a minimum, the qualification program shall include provisions for checking test equipment and the laboratory shall keep records of calibration checks.

Qualified sampling and testing personnel. Personnel who are capable as defined by appropriate programs established by each STD.

Quality assurance. All those planned and systematic actions necessary to provide confidence that a product or service will satisfy given requirements for quality.

Quality control. All contractor/vendor operational techniques and activities that are performed or conducted to fulfill the contract requirements.

Random sample. A sample drawn from a lot in which each increment in the lot has an equal probability of being chosen.

Vendor. A supplier of project-produced material that is not the contractor.

Verification sampling and testing. Sampling and testing performed to validate the quality of the product.

§ 637.205 Policy.

(a) *Quality assurance program.* Each STD shall develop a quality assurance program which will assure that the materials and workmanship incorporated into each Federal-aid highway construction project on the NHS are in conformity with the requirements of the approved plans and specifications, including approved changes. The program must meet the criteria in §637.207 and be approved by the FHWA.

(b) *STD capabilities.* The STD shall maintain an adequate, qualified staff to administer its quality assurance program. The State shall also maintain a central laboratory. The State's central laboratory shall meet the requirements in §637.209(a)(2).

(c) *Independent assurance program.* Independent assurance samples and tests or other procedures shall be performed by qualified sampling and testing personnel employed by the STD or its designated agent.

(d) *Verification sampling and testing.* The verification sampling and testing are to be performed by qualified testing personnel employed by the STD or its designated agent, excluding the contractor and vendor.

(e) *Random samples.* All samples used for quality control and verification sampling and testing shall be random samples.

§ 637.207 Quality assurance program.

(a) Each STD's quality assurance program shall provide for an acceptance program and an independent assurance (IA) program consisting of the following:

(1) Acceptance program.

(i) Each STD's acceptance program shall consist of the following:

(A) Frequency guide schedules for verification sampling and testing which will give general guidance to personnel responsible for the program and allow adaptation to specific project conditions and needs.

(B) Identification of the specific location in the construction or production operation at which verification sampling and testing is to be accomplished.

(C) Identification of the specific attributes to be inspected which reflect the quality of the finished product.

(ii) Quality control sampling and testing results may be used as part of the acceptance decision provided that:

(A) The sampling and testing has been performed by qualified laboratories and qualified sampling and testing personnel.

(B) The quality of the material has been validated by the verification sampling and testing. The verification testing shall be performed on samples that are taken independently of the quality control samples.

(C) The quality control sampling and testing is evaluated by an IA program.

(iii) If the results from the quality control sampling and testing are used in the acceptance program, the STD shall establish a dispute resolution system. The dispute resolution system shall address the resolution of discrepancies occurring between the verification sampling and testing and the quality control sampling and testing. The dispute resolution system may be administered entirely within the STD.

(iv) In the case of a design-build project on the National Highway System, warranties may be used where appropriate. See 23 CFR 635.413(e) for specific requirements.

(2) The IA program shall evaluate the qualified sampling and testing personnel and the testing equipment. The program shall cover sampling procedures, testing procedures, and testing equipment. Each IA program shall include a schedule of frequency for IA evaluation. The schedule may be established based on either a project basis or a system basis. The frequency can be based on either a unit of production or on a unit of time.

(i) The testing equipment shall be evaluated by using one or more of the following: Calibration checks, split samples, or proficiency samples.

(ii) Testing personnel shall be evaluated by observations and split samples or proficiency samples.

(iii) A prompt comparison and documentation shall be made of test results obtained by the tester being evaluated and the IA tester. The STD shall develop guidelines including tolerance limits for the comparison of test results.

(iv) If the STD uses the system approach to the IA program, the STD shall provide an annual report to the FHWA summarizing the results of the IA program.

(3) The preparation of a materials certification, conforming in substance to Appendix A of this subpart, shall be submitted to the FHWA Division Administrator for each construction project which is subject to FHWA construction oversight activities.

(b) In the case of a design-build project funded under Title 23, U.S. Code, the STD's quality assurance program should consider the specific contractual needs of the design-build project. All provisions of paragraph (a) of this section are applicable to design-build projects. In addition, the quality assurance program may include the following:

(1) Reliance on a combination of contractual provisions and acceptance methods;

(2) Reliance on quality control sampling and testing as part of the acceptance decision, provided that adequate verification of the design-builder's quality control sampling and testing is performed to ensure that the design-builder is providing the quality of materials and construction required by the contract documents.

(3) Contractual provisions which require the operation of the completed facility for a specific time period.
[60 FR 33717, June 29, 1995, as amended at 67 FR 75934, Dec. 10, 2002]

§ 637.209 Laboratory and sampling and testing personnel qualifications.

(a) Laboratories.

(1) After June 29, 2000, all contractor, vendor, and STD testing used in the acceptance decision shall be performed by qualified laboratories.

(2) After June 30, 1997, each STD shall have its central laboratory accredited by the AASHTO Accreditation Program or a comparable laboratory accreditation program approved by the FHWA.

(3) After June 29, 2000, any non-STD designated laboratory which performs IA sampling and testing shall be accredited in the testing to be performed by the AASHTO Accreditation Program or a comparable laboratory accreditation program approved by the FHWA.

(4) After June 29, 2000, any non-STD laboratory that is used in dispute resolution sampling and testing shall be accredited in the testing to be performed by the AASHTO Accreditation Program or a comparable laboratory accreditation program approved by the FHWA.

(b) Sampling and testing personnel. After June 29, 2000, all sampling and testing data to be used in the acceptance decision or the IA program shall be executed by qualified sampling and testing personnel.

(c) Conflict of interest. In order to avoid an appearance of a conflict of interest, any qualified non-STD laboratory shall perform only one of the following types of testing on the same project: Verification testing, quality control testing, IA testing, or dispute resolution testing.

Appendix A to Subpart B of Part 637—Guide Letter of Certification by State Engineer

Date Project No.

This is to certify that:

The results of the tests used in the acceptance program indicate that the materials incorporated in the construction work, and the construction operations controlled by sampling and testing, were in conformity with the approved plans and specifications. (The following sentence should be added if the IA testing frequencies are based on project quantities. All independent assurance samples and tests are within tolerance limits of the samples and tests that are used in the acceptance program.)

Exceptions to the plans and specifications are explained on the back hereof (or on attached sheet).

Director of STD Laboratory or other appropriate STD Official.

Appendix B

Technical Advisory T6120.3

U.S. Department
of Transportation
**Federal Highway
Administration**

Technical Advisory

Subject
Use of Contractor Test Results in the Acceptance Decision, Recommended Quality Measures, and the Identification of Contractor/Department Risks

Classification Code	Date	Office of Primary Interest
T 6120.3	**August 9, 2004**	**HIPT-10**

Par.

13. Can contractor split sample test results be used in the acceptance decision?
14. What are the recommended quality measures?
15. What quality measures are not recommended?
16. What are contractor and department risks?
17. Are there any conflicts between American Association of State Highway and Transportation Officials (AASHTO) quality assurance publications and FHWA regulations?
18. Are there any reference materials on quality assurance, risks, and statistics?

1. **What is the purpose of this Technical Advisory?** This Technical Advisory provides guidance and recommendations for the use and validation of contractor's test results for acceptance, the use of quality measures, and the identification of contractor and department risks.
2. **Does this Technical Advisory supersede other Federal Highway Administration (FHWA) guidance?** Yes. This Technical Advisory supersedes previous guidance provided in the following:
    a. *Memorandum from Director, Office of Engineering, to Regional Administrators,* "INFORMATION: Quality Assurance Procedures for Construction - 23 CFR 637 - Sampling for Verification Testing," March 28, 1997.
    b. *Memorandum from Chief, Highway Operations Division, to Regional Administrators, Division Administrators, Federal Lands Highway Program Administrator,* "INFORMATION: Quality Assurance Guide Specification and Implementation Manual for Quality Assurance," August 2, 1996.
3. **What is FHWA's policy on the use of contractor's quality control test results for acceptance?** The FHWA policy on the use of contractor's quality control test results for acceptance requires validation of all data not generated by the State transportation department (STD) or its designated agent if used in the acceptance decision. The requirements are codified in Title 23 Code of Federal Regulations Part 637 Subpart B (23 CFR 637B), located at http://wwwcf.fhwa.dot.gov/exit.cfm?link=http://www.access.gpo.gov/nara/cfr/waisidx_03/23cfr637_03.html. (Note that the use of STD is in line with 23 CFR 637 B, as of April 1, 2003. In this Technical Advisory, all references to State Highway Agency (SHA) or "agency" have been replaced with STD or "department.")
4. **Is there any existing FHWA guidance regarding 23 CFR 637B, the use of quality measures, and the identification of contractor and department risks?** Yes. Existing FHWA guidance is provided in the following:

a. *FHWA Materials Notebook: Chapter 1 - Materials Sampling and Testing* 23 CFR 637, "23 CFR 637 ACTION: Final Rule and Questions & Answers on the Regulation," http://www.fhwa.dot.gov/pavement/materials_notebook/1sec1.htm.
b. *Publication No. FHWA-RD-02-095* "Optimal Procedures for Quality Assurance Specifications" (see paragraph 18b), http://www.tfhrc.gov/pavement/pccp/pubs/02095/.
c. *Memorandum from Chief, Highway Operations Division, to Resource Center Directors, Division Administrators,* "INFORMATION: Laboratory Qualification," October 9, 1998, http://www.fhwa.dot.gov/pavement/labqual.htm.
d. *Memorandum from Chief, Highway Operations Division, to Resource Center Directors, Division Administrators, Acting Federal Lands Highway Program Administrator,* "INFORMATION: Technician Qualification," July 17, 1998, http://www.fhwa.dot.gov/pavement/techqual.htm.

5. **What is the background on quality assurance and quality assurance specifications?**
   a. One of the fundamental concepts in quality assurance (QA) specifications is the separation of the functions of quality control (QC) and acceptance. In QA specifications, the contractor is responsible for the QC and the STD is responsible for obtaining and conducting verification tests and making the acceptance decision. Although QA is a combination of QC and acceptance, the separation of these two functions is important.
   b. Due to the evolutionary nature of QA specifications, QC and acceptance functions often have been combined or intermingled. This has been a major source of confusion. The intermingling of QC and acceptance can be traced to the first statistically based specifications that were used at a time when STDs had technicians at the contractor's materials plants. The STD technicians did testing and determined when the product was acceptable. Contractors rarely did their own QC testing, and they often made changes to the process when necessary based on the STD's test results. Although QC was often recognized as a separate item from acceptance, in reality, little separation occurred.
   c. With the downsizing that took place within many STDs in the 1990s, inspection and testing personnel positions were reduced significantly and many technicians were removed from the contractors' materials plants. Although STDs often took it upon themselves to control most aspects of production and construction, reductions in staff made it more important to assign QC where it rightfully belonged so the STD could focus on acceptance testing and inspection. This resulted in

the contractor having to conduct the QC tests and the STD examining options for requiring more of its functions to be undertaken by the contractor. Many STDs found ways to include contractor test results in the acceptance decision, and some have questioned why the regulations prohibit the contractor from conducting acceptance testing.

d. The Federal regulations on sampling and testing of materials for construction appear in 23 CFR 637B (see paragraph 18a). These regulations were revised on June 29, 1995. This revision included clarification on the use of contractor test results in an acceptance program. The regulations most recent revision occurred in the *Federal Register* on December 10, 2002.
e. Further evolution of QA specifications has introduced the use of incentive/disincentive provisions and pay adjustment systems that utilize pay factors to adjust the amount paid to a contractor based on the level of quality of the product provided. Several different statistical quality measures were developed and used in order to determine this level of quality. Some examples of quality measures are: percent within limits, percent defective, average deviation, average absolute deviation, conformal index, and moving average. Some of these quality measures have been implemented without fully understanding how they apply to acceptance or whether they conform to sound statistical principles.
f. Statistical QA specifications and acceptance procedures have been implemented without fully understanding the risks involved to both the STD and the contractor. The acceptable level of STD risk and contractor risk is a subjective decision that often varies between departments. It is estimated that few departments have developed and evaluated the risk levels associated with their acceptance plans.
g. State planning and research pooled fund study SPR-2(199) "Optimal Acceptance Procedures for Statistical Construction Specifications" was conducted in order to investigate the current use of QA specifications and provide recommendations for statistically sound QA procedures and balancing of risks. The pooled fund study was administered by FHWA and the results provided in publication no. FHWA-RD-02-095, "Optimal Procedures for Quality Assurance Specifications" (see paragraph 18b). This publication provides a guide for developing new or modifying existing acceptance plans and QA specifications.

6. **Where can I find definitions for the terms used within this Technical Advisory?** The definitions for terms used in this Technical Advisory are taken from the following sources (listed in order of precedence), unless otherwise specified:

a. 23 CFR 637 (see paragraph 18a).
b. AASHTO R10 (see paragraph 18e).
c. Transportation Research Board (TRB) Circular (see paragraph 18f).

7. **Do any of the terms need additional explanation?** Some additional explanations of terms are provided below:
    a. **Difference Two-Sigma Limit (D2S Limit).** The D2S method compares the contractor and department results from a single split sample. The D2S Limit indicates the maximum acceptable difference between two test results obtained on test portions of the same material (and thus, applies only to split samples), and it is provided for single and multi-laboratory situations. It represents the difference between two individual test results that has approximately a five percent chance of being exceeded if the tests are actually from the same population. The value provided by this procedure is contained in many AASHTO and American Society of Testing and Materials (ASTM) test procedures and is typically listed in the precision and bias statement as "Acceptable Range of Two Test Results" at the end of each test procedure.
    b. ***F*-test.** The *F*-test provides a method for comparing the variances (standard deviations squared, σ^2) of two sets of data by assessing the size of the ratio of the variances. The hypothesis is that the department's tests and the contractor's tests are from the same population and the variability of the two data sets are equal. The intent is to determine whether the differences in the variability of the contractor's tests and the department's tests are larger than might be expected by chance if they came from the same population. The calculated *F*-value is then compared to the critical value (F_{crit}) obtained from a table of *F*-values at a chosen level of significance (α). The *F*-test can be used to compare either an equal or unequal number of contractor vs. department sample sizes.
    c. **Operating Characteristics (OC) Curves**
        1. (1) OC curves for statistical tests. OC curves can be developed to indicate the probability of rejecting a hypothesis. This type of curve shows the relation between the probability of rejecting a hypothesis that a sample belongs to a given population with a given characteristic and the actual population value of that characteristic. OC curves can also be developed to show either the probability of not detecting a difference, or detecting a difference, versus the actual difference between the two populations being compared. There are also OC curves available to provide guidance regarding the number of tests needed to achieve a certain probability of detecting a given difference when one actually

exists. OC curves that plot the probability of detecting a difference are sometimes called power curves because they plot the power of the statistical test procedure to detect a given difference.

2. (2) OC curves for acceptance plans. OC curves can also be a graphical representation of an acceptance plan that shows a relationship between the actual quality of a lot and either (a) the probability of its acceptance (for accept/reject acceptance plans), or (b) the probability of its acceptance at various pay levels for acceptance plans that include pay adjustment provisions.

d. **Paired *t*-test.** The paired *t*-test compares contractor and department results from an equal number of split samples. When it is desirable to compare more than one pair of split sample test results, the *t*-test for paired measurements can be used. This test uses the differences between pairs of tests and determines whether the average difference is statistically different from zero. Thus, it is the difference within pairs, not between pairs, that is being tested. The calculated *t*-value is compared to the critical value (t_{crit}) obtained from a table of *t*-values at a specified level of significance and with n-1 degrees of freedom (see *t*-test in paragraph 7e).

e. ***t*-test**

1. (1) The *t*-test provides a method for comparing the means of two independent data sets and is used to assess the degree of difference in the means. The null hypothesis is that the department's tests and the contractor's tests are from the same population, and the means of the two data sets are equal. The desire is to determine whether it is reasonable to assume that the contractor's tests came from the same population as the department's tests. The *t*-test can be used to compare either an equal or unequal number of contractor vs. department sample sizes.
2. (2) Since the values used for the *t*-test are dependent upon whether or not the variances are assumed equal for the two data sets, it is necessary to test the variances (*F*-test) before the means (*t*-test). If it is determined that the variances are assumed to be equal ($F<F_{crit}$), then the *t*-test is conducted based on the two sample sets using a pooled estimate for the variance and pooled degrees of freedom. If the sample variances are determined to be different ($F\geq F_{crit}$), then the *t*-test is conducted using the individual sample variances, the individual sample sizes, and the effective degrees of freedom. The calculated *t*-value is compared to the critical value (t_{crit})

obtained from a table of *t*-values at a specified level of significance.

8. **What are the requirements for the use of independent samples?** The regulation 23 CFR 637B requires the use of independent samples for verification sampling and testing in the acceptance program. In order to be considered independent, each sample must contain independent information reflecting all sources of variability associated with the material, process, sampling, and testing in the test results. This does not prevent split samples from being used in the acceptance decision if the data is used properly to provide validation of independent data (see paragraph 13). Some clarification of using contractor performed sampling for verification sampling and for use in the acceptance decision is found in paragraphs 9 through 13.
9. **Who is required to perform verification sampling and testing?**
    a. The regulation requires STD personnel or their representatives to perform the verification sampling and testing. The regulation also specifically indicates that verification sampling and testing cannot be performed by contractor employees. However, there are situations where labor regulations, hazardous conditions, and liability issues may dictate some contractor involvement in verification sampling. In these situations, the involvement of contractor personnel should be limited so that they are not deemed to be in control of the sampling.
        1. (1) The STD can use the services of the contractor's personnel to assist in obtaining independent verification samples when the following requirements are adhered to:
            1. (a) The verification sample location or time has been randomly selected by the STD and is only given to the contractor immediately prior to sampling.
            2. (b) The contractor's personnel are used only to provide labor to assist in physically obtaining the verification sample of the material.
            3. (c) The STD is present to witness the taking of the verification sample.
            4. (d) Both the STD witness and contractor labor are qualified sampling personnel.
            5. (e) The STD witness controls the sampling process by choosing the location or timing and directing the taking of the verification sample.
            6. (f) The STD witness immediately takes possession of the verification sample.
        2. (2) STD verification sample independence and the intent of 23 CFR 637B are maintained when the above requirements are met. However, these situations should be the exception and

not the rule. The verification sampling is expected to be performed entirely by STD personnel or their representative in the majority of situations.

b. Verification testing is required to be performed by the STD or its designated agent, excluding the contractor or vendor; therefore, verification testing cannot be based on contractor performed testing witnessed by the STD.

10. **What are the validation procedures performed on independent samples?** When comparing two data sets, such as department and contractor test results, it is important to compare both the variances and the means. The tests most often used are the *F*-test (comparison of variances) and the *t*-test (comparison of means), which are used together. A procedure that compares a single department test with 4 to 10 contractor tests is sometimes used but not recommended.

a. The *F*-test and *t*-test are the recommended methods because they have more power to detect actual differences than the method that relies on a single department test for the comparison. If either the *F*-test or the *t*-test show a significant difference ($F \geq F_{crit}$ or $t \geq t_{crit}$), it is questionable whether the data does truly come from the same population.

1. (1) The computational method used for the *t*-test differs depending on if the variances are found to be either equal or not equal. There is a *t*-test that corresponds with finding a difference in variances, $F \geq F_{crit}$ (see paragraph 7e). This has lead to instances of incorrectly validating test results by finding no differences in the means ($t < t_{crit}$) after finding differences in the variances ($F \geq F_{crit}$). When a difference in the variances is identified then the test results have not been validated, even if no difference in the means has been identified.
2. (2) The source of the difference should be identified if it is determined that a significant difference is likely between either the variances or the means. The identification of a difference between either variances or means is simply a notice that a difference exists. Therefore, the source of the difference must still be determined.

b. The method of comparing a single department test to a number of contractor tests should not be used. Although simple, it suffers from the fact that only a single department test is used when making the comparison. Any comparison method that is based on a single test result is not effective in detecting differences between data sets. This is due to the high variability that is associated with individual values, as compared with mean values.

11. **What are the test method comparison procedures performed on split samples?**
    a. The comparison of a single split sample by using the D2S limits is simple and can be done for each split sample that is obtained. However, since it is based on comparing only single data values, it is not very powerful for identifying differences when they exist. Thus, it cannot detect real differences unless the results are far apart. The appeal of the D2S method lies in its simplicity rather than its power.
    b. Due to D2S method limitations, it is recommended that the paired *t*-test (see paragraph 7d) be used on the total accumulated split sample results to allow for a comparison with more discerning power. If either of these comparisons indicates a difference, then an investigation to identify the cause of the difference should be initiated.
12. **When should split samples be used?** The split sampling, testing, and comparison procedures (see paragraph 11) are primarily used as a function of an Independent Assurance (IA) program as outlined in 23 CFR 637B. The use of split samples in the IA program provides a check on testing equipment and procedures. The evaluation of split samples helps to identify where the cause of any differences may occur by isolating the testing components. This complements the QA program and ensures credibility of the testing program.
13. **Can contractor split sample test results be used in the acceptance decision?**
    a. In order for contractor split sample test results to be used in the acceptance decision, the contractor's test results used in the acceptance decision must be independently validated by the STD. The validation is not required if the STD conducts all of the verification sampling and testing and does not wish to use the contractor's test results in the acceptance decision.
    b. The contractor performs QC testing using independently obtained samples. The STD can perform verification testing using its half of the split samples when sampled as required in paragraph 9. The validation is accomplished by comparing the STD verification tests with the contractor's independently sampled QC tests (see Figure 1). The contractor's splits of the verification samples cannot be used for validation purposes because they are not independent of the STD samples. If both sets of split samples are used the only component of variability that can be compared is the testing variability. The split sample components of variability associated with materials, process, and sampling are the same, having come from the same location and sampler.

c. The contractor may or may not test their portion of the split sample. The validation procedure is the same in either case because the contractor's split samples cannot be used for validation (see Figure 1).
d. When the STD uses contractor personnel as labor to take verification samples as required in paragraph 9 and the STD then performs verification testing on these samples, the verification test results may be considered independent of the contractors test results. They may be considered independent because they have been sampled with control by the STD, independently tested, and independently compared to the contractor's independent QC test results (test results that do not include the contractor's set of split samples). Again, in order to be considered independent the two sets of samples must each contain the variability associated with the material, process, sampling, and testing.
e. If the contractor's independently sampled QC test results are validated by the STD verification test results, then the material can be accepted based on either:
    1. (1) The total test results provided by the contractor that combine their independent QC test results and their split of the verification sample test results (see 2.1 in Figure 2),
    2. (2) A combination of independent contractor QC test results excluding their split sample test results and the STD verification split test results (see 2.2 in Figure 2), or
    3. (3) Only the contractor independent QC test results, excluding all split sample test results (see 2.3 in Figure 2).
f. The STD test results from their split portion of the verification samples and the contractor test results from their split portion of the of the verification samples cannot be combined for the acceptance decision (see 2.4 in Figure 2). If the two sets of split test results are combined, they are no longer independent and the population of the contractor's independent test results will be biased and result in an invalid comparison. In essence, a double counting of test results would occur if the two sets of split test results were combined. This is true even though the two sets of test results may have different values.
g. A scenario may exist where all samples are taken by the STD and split between the STD and contractor. In this scenario the STD only performs verification tests on a specified percentage of all the split samples they have in their possession. It is important to note, the validation must still be performed on independent sample data. Again, this is accomplished by comparing the STD verification test results with the contractor's independent test results. The

contractor's independent test results cannot include the split tests that match with the STD verification tests.

1. (1) For example, if 11 samples were split, the contractor tests all 11 samples and the STD tests only 3 samples, the 3 STD test results would be compared against the contractor's remaining 8 test results. Independence of the two sets of data is maintained by excluding the contractor's three test results that match the STD test results.
2. (2) In essence, the validation shown in Figure 1 has occurred when the STD does not test all of the split samples that are in its possession. By taking possession of all the split samples, the STD does have additional material for an investigation if the contractor's results do not validate or for use in a dispute resolution system.

h. Although split samples have physically been taken, it is the method which the data from these samples is analyzed that allows independent validation and their use in the acceptance decision. The independent validation is accomplished by validation procedures performed on independent samples (see paragraph 10), not by test method comparison procedures performed on split samples (see paragraph 11).

14. **What are the recommended quality measures?** The percent within limits (PWL) or percent defective (PD) are the recommended quality measures to be used. It is necessary to measure both the center and spread when characterizing a lot of material. These quality measures use the mean and standard deviation to measure center and spread and then estimate the percentage of the lot that is within, PWL, or outside of, PD, the specification limits. Since PD and PWL can easily be converted to one another simply by subtracting from 100, they are equivalent quality measures. The preference on which of the two quality measures to use, PWL or PD, is typically based on the department's preference to highlight how much of the material meets the requirements as described with PWL, rather than how much is defective as described with PD.

15. **What quality measures are not recommended?**

a. The average deviation from the target value should not be used as the quality measure for QA acceptance plans. This approach often encourages the contractor to manipulate its process during the production of a lot. In effect, the contractor increases process variability by making frequent adjustments to the process in order to get the average of the test results to be at or near the target value.

b. The average absolute deviation (AAD) from the target value should not be used as the quality measure for QA acceptance plans. To avoid the problem of over-adjusting the process in response to early

test results, the average absolute deviation from the target has been used instead of the average deviation. By taking the absolute value of the deviation from the target, the contractor cannot benefit by any strategy other than aiming for the target value. However, the variability of the material may not be adequately measured. Very different sets of test results can give identical AAD values. Not only must it be questioned if equal pay is appropriate for these widely different conditions, the use of AAD fails to document these differences that should be used for future modifications of the specification. Specifically, the means and populations may vary considerably for different sets of test results that can give identical AAD values. These mean and variability differences are disregarded with acceptance based on AAD.

c. The conformal index (CI) should not be used as the quality measure for QA acceptance plans. The CI is very similar in practice to the AAD and has the same disadvantages of not being appropriate for a one-sided specification and potentially having the same CI value for very different test results.
d. The moving average should not be used as the quality measure for QA acceptance plans. The moving average was developed as a QC measure and not developed for use as an acceptance approach. The use of the moving average is not consistent with the use of lot-by-lot acceptance. When acceptance is based on a lot, it is assumed that the various lots are independent of one another. Since each individual test result appears in several moving average calculations, the moving averages are correlated and the results of one average are not independent of the next; therefore, it is difficult to determine when or where a lot begins or ends. In addition, it is not easy to determine pay factors on a lot-by-lot basis since the successive moving averages are correlated and individual lots are not well defined. As a result, acceptance procedures based on moving averages often result in production shut downs and plant adjustments rather than determining appropriate pay factors for specific production lots.

16. **What are contractor and department risks?**

a. The two types of risks discussed in this section are the seller's (contractor) risk (α) and the buyer's (department) risk (β). The acceptable level of α and β risks is a subjective decision that can vary from department to department. A properly developed QA acceptance plan takes these risks into consideration in a manner that is fair to both the department and contractor. Too large a risk for either party undermines credibility.

1. (1) Table 1 of the AASHTO Material's Specification R 9-97(2000), "Acceptance Sampling Plans for Highway Construction" (see paragraph 18d), has suggestions for risk levels for both the seller and buyer that range from 0.001 (0.1 percent) to 0.200 (20 percent). It should be noted that large sample quantities, on the order of 10 to 20 or more, are needed to achieve some of the risk levels provided in this table. Larger sample quantities will provide this lower level of risk to both the department and contractor. The selection of the number of samples required by a department may need to be modified based on an analysis of risks.
2. (2) The sample size is the number of test results used to judge the quality of a lot, and therefore it is directly related to the lot size. One reason to use larger lot sizes is the potential resultant increase in sample size. This tends to provide a much lower level of risk to both the contractor and department. However, an assumption that all of the material and construction processes remain consistent throughout the lot is required. Small lot sizes may not be compatible with large sample sizes due to a large amount of required testing. Larger sample sizes can be used with large lot sizes to decrease risks of making incorrect acceptance decisions. However, the possibility of combining materials from different populations must be taken into consideration. The final decision regarding sample size per lot cannot be made until an evaluation of risks has been completed. An attempt should be made to balance the risk between the contractor and department while holding the risk to a reasonable level. This means that a large number of samples may be required. If the risks cannot be held to a reasonable level for both, the department may have to accept a disproportionate level of risk.

b. The α and β risks are very narrowly defined to occur at only two specific quality levels. The α risk is the probability of rejecting material that is exactly at the acceptable quality level (AQL), while β is the probability of accepting material that is exactly at the rejectable quality level (RQL). Therefore, they do not provide a very good indication of the risks over a wide range of possible quality levels that a contractor may operate. It is necessary to construct an OC curve that illustrates the probability of acceptance for any quality level for the acceptance plan under consideration (see Figure 3) to evaluate how the acceptance plan will actually perform in practice. Another step that is necessary to fully evaluate the risks for a pay

adjustment acceptance plan is to plot OC curves associated with receiving various pay factors (see Figure 4).

c. The concept of α and β risks derives from statistical hypothesis testing where there is either a right or wrong decision. When α and β risks are applied to materials or construction, they are only truly appropriate for the case of a pass/fail or accept/reject decision. This may lead to considerable confusion if an attempt is made to apply them to the pay adjustment case.
    1. (1) The evaluation of risks becomes more complicated when the acceptance system includes pay adjustment provisions. The α and β risks discussed do not fully incorporate the concept of pay adjustments. By itself, the α risk, defined as the probability that an acceptance plan will incorrectly reject acceptable quality material or construction, cannot reflect the fact that the material or construction may be accepted at any of the possible pay adjustments (full pay, increased or decreased pay). When working with a pay adjustment system, the contractor's risk may also be interpreted as the probability of acceptable material or construction being accepted at less than 100 percent pay. In order to avoid confusion in the terms when the contractor's risk is used in this manner, the risk is here called a_{100}. However, it is computed in the same manner as α at the AQL. In addition, the β risk, defined as the probability that the owner incorrectly accepts rejectable quality material or construction, cannot reflect the impact of pay adjustments on determining the department's risk. When working with a pay adjustment plan, the department's risk may also be interpreted as the probability of accepting rejectable quality material or construction at 100 percent pay or greater. In order to avoid confusion in the terms when the department's risk is used in this manner, it is here called β_{100}. There are α and β type risks (α_{PF} and β_{PF}) associated with any given level of pay adjustment or pay factor (PF) from zero through the bonus chosen by the STD. For example, at a pay factor of 0.90 (90 percent payment) the alpha and beta risks can be represented by α_{90} and β_{90}. Likewise, at a pay factor of 1.05 (bonus of 5 percent) alpha and beta can be represented by α_{105} and β_{105}.
    2. (2) The use of α and β risks alone to evaluate pay adjustment acceptance plans is simply not sufficient. When developing a pay adjustment system the contractor's risk α_{PF} and the department's risk β_{PF} must also be considered for the entire range of risks associated with the system. If only one level of

risk is evaluated alone, for example at 100 percent pay, some other risks associated with the system may be too high. Making any change to the system will change all risks involved.

d. An additional method to properly evaluate the risks when pay adjustments are added to the acceptance decision is the expected pay (EP) curve (see Figure 5). The EP curve has the advantage of combining all of the possible levels into a single expected or long-term average pay for each given level of quality.
e. The EP curve can also be used to ensure that a department's acceptance plan will pay 100 percent for material that is accepted at the AQL. It is generally agreed that the average pay for AQL material should be 100 percent. An average pay of 100 percent cannot be achieved unless a bonus is allowed. If the department's pay equations or tables are not properly developed, the average pay factor may be above or below 100 percent at the AQL. This would result in the contractor either being underpaid or overpaid on average. If this is the case, the department should determine if an expected pay other than 100 percent is acceptable for AQL material.
f. While the average expected pay shown with an EP curve should be used in addition to considering α and β type risks, the use of EP curves alone is also not sufficient to fully evaluate an acceptance plan. The EP alone is not a complete measure of the likelihood that any individual lot will receive a correct pay factor. The variability of the individual pay factors about the EP curve must also be considered.
g. When a price adjustment acceptance plan is used, it is essential that the department develop an EP curve and multiple OC curves for the probability of receiving various pay factors over the total range of quality levels in addition to considering all levels of α and β type risks. Both OC and EP curves must be developed and analyzed to show how an acceptance plan was designed to function. In all cases, when pay adjustments are used in the acceptance decision, the OC curves should be constructed to confirm that the acceptance procedure is working as desired and, in particular, that the average pay factor at the AQL is 100 percent. The department may also want to look at computer simulation histograms of individual pay factors to obtain a picture of how much variability is associated with the pay factor determination.
h. It is important to note that for PWL or PD acceptance plans, computer simulation is almost always used to develop α and β risks, OC and EP curves. The OCPLOT computer program that was developed as a part of FHWA Demonstration Project No. 89 (see

paragraph 18j) is able to develop OC and EP curves, run simulations on the effect of the variability of the individual lot pay factors on the final pay factor determination, and create histograms. This program can be found on the Federal Highway Administration Office of Pavement Technology website at http://www.fhwa.dot.gov/pavement/qasoft.htm.

17. **Are there any conflicts between American Association of State Highway and Transportation Officials (AASHTO) quality assurance publications and FHWA regulations?**
    a. The companion reports "AASHTO Implementation Manual for Quality Assurance" (see paragraph 18h) and "AASHTO Quality Assurance Guide Specification"(see paragraph 18i) were published in February 1996 as reports of the AASHTO Highway Subcommittee on Construction. The Guide Specification is not an official AASHTO Specification and the Implementation Manual is not an official guide or voluntary standard because they have not been balloted and approved by the AASHTO Standing Committee on Highways and the AASHTO Board of Directors.
    b. These reports provide uniform guidance to develop and implement quality assurance standard specifications. While these reports substantially follow 23 CFR 637B, some differences exist.
        1. (1) One significant difference is that the reports provide for the use of either paired split (see paragraph 11) or independent (see paragraph 10) sample data comparisons for validation of contractor test results, while 23 CFR 637B allows only independent sample data for validation (see paragraph 8). The use of a paired split sample data comparison only verifies the test procedures and equipment, not the quality of the material (see paragraph 12). The use of independently obtained and tested samples assesses material, process, sampling and testing variability. Therefore, an acceptance program that uses paired split sample comparisons or witnessed tests for validation does not ensure the material quality and does not meet the requirements or intent of 23 CFR 637B.
        2. (2) On the other hand, the use of split samples in the IA program provides a check on testing equipment and procedures. This complements the QA program and ensures the credibility of the testing program. The Implementation Manual offers the option of using either split or independent samples for IA. This does not agree with the regulation that IA testing may only be performed on split samples or proficiency samples. There is value to both split and independent

samples; however, they do not provide interchangeable information.

18. **Are there any reference materials on quality assurance, risks, and statistics?** Yes. The following references apply to quality assurance, risks, and statistics.
    a. "23 CFR Part 637," *Subpart B - Quality Assurance Procedures for Construction*, Federal Highway Administration, Federal Register, Washington, DC, April 2003, http://www.access.gpo.gov/nara/cfr/waisidx_03/23cfr637_03.html.
    b. "Optimal Procedures for Quality Assurance Specifications," *Publication No. FHWA-RD-02-095*, Federal Highway Administration, Washington, DC, April 2003, http://www.tfhrc.gov/pavement/pccp/pubs/02095/.
    c. *StatSoft, Inc., Electronic Statistics Textbook*, StatSoft, Tulsa, OK, 2003, http://wwwcf.fhwa.dot.gov/exit.cfm?link=http://www.statsoft.com/textbook/stathome.html.
    d. "Acceptance Sampling Plans for Highway Construction," *AASHTO Standard Specifications for Transportation Materials and Methods of Sampling and Testing, Part 1B Specifications: R 9-97 (2000)*, American Association of State Highway and Transportation Officials, 22nd Edition, 2002. (This is currently being evaluated and rewritten under the guidance of NCHRP Project 20-07, Task 164.)
    e. "Definition of Terms for Specifications and Procedures," *AASHTO Standard Specifications for Transportation Materials and Methods of Sampling and Testing, Part 1B Specifications: R 10-98 (2002)*, American Association of State Highway and Transportation Officials, 22nd Edition, 2002.
    f. "Glossary of Highway Quality Assurance Terms," *Transportation Research Circular No. E-C037*, Transportation Research Board, Washington, DC, April 2002, http://wwwcf.fhwa.dot.gov/exit.cfm?link=http://trb.org/news/blurb_detail.asp?id=621.
    g. *Introduction to Statistical Quality Control, Fourth Edition*, Douglas C. Montgomery, ISBN 0471316482, John Wiley & Sons, November 2000.
    h. *AASHTO Implementation Manual for Quality Assurance*, AASHTO Construction/Materials Quality Assurance Task Force of the AASHTO Highway Subcommittee on Construction, American Association of State Highway and Transportation Officials, February, 1996.
    i. *AASHTO Quality Assurance Guide Specification*, AASHTO Construction / Materials Quality Assurance Task Force of the

AASHTO Highway Subcommittee on Construction, American Association of State Highway and Transportation Officials, February, 1996.

j. "Quality Assurance Software for the Personal Computer, Demonstration Project 89," *Publication No. FHWA-SA-96-026*, Federal Highway Administration, Washington, DC, May 1996, http://www.fhwa.dot.gov/pavement/qasoft.htm.

k. *Statistical Quality Control, Seventh Edition*, Eugene Grant and Richard Leavenworth, ISBN 0078443547, McGraw-Hill, January 1996.

l. *Quality Control and Industrial Statistics, Fifth Edition*, Acheson J. Duncan, ISBN 0256035350, McGraw-Hill, October 1994.

m. *Report on Limits of Use of Contractor Performed Sampling and Testing in Federal Highway Administration Programs*, Robert Bohman, et al, Federal Highway Administration, March 1993.

n. *Materials Control and Acceptance - Quality Assurance*, NHI Course Number 134042A, Federal Highway Administration, National Highway Institute, http://www.nhi.fhwa.dot.gov/.

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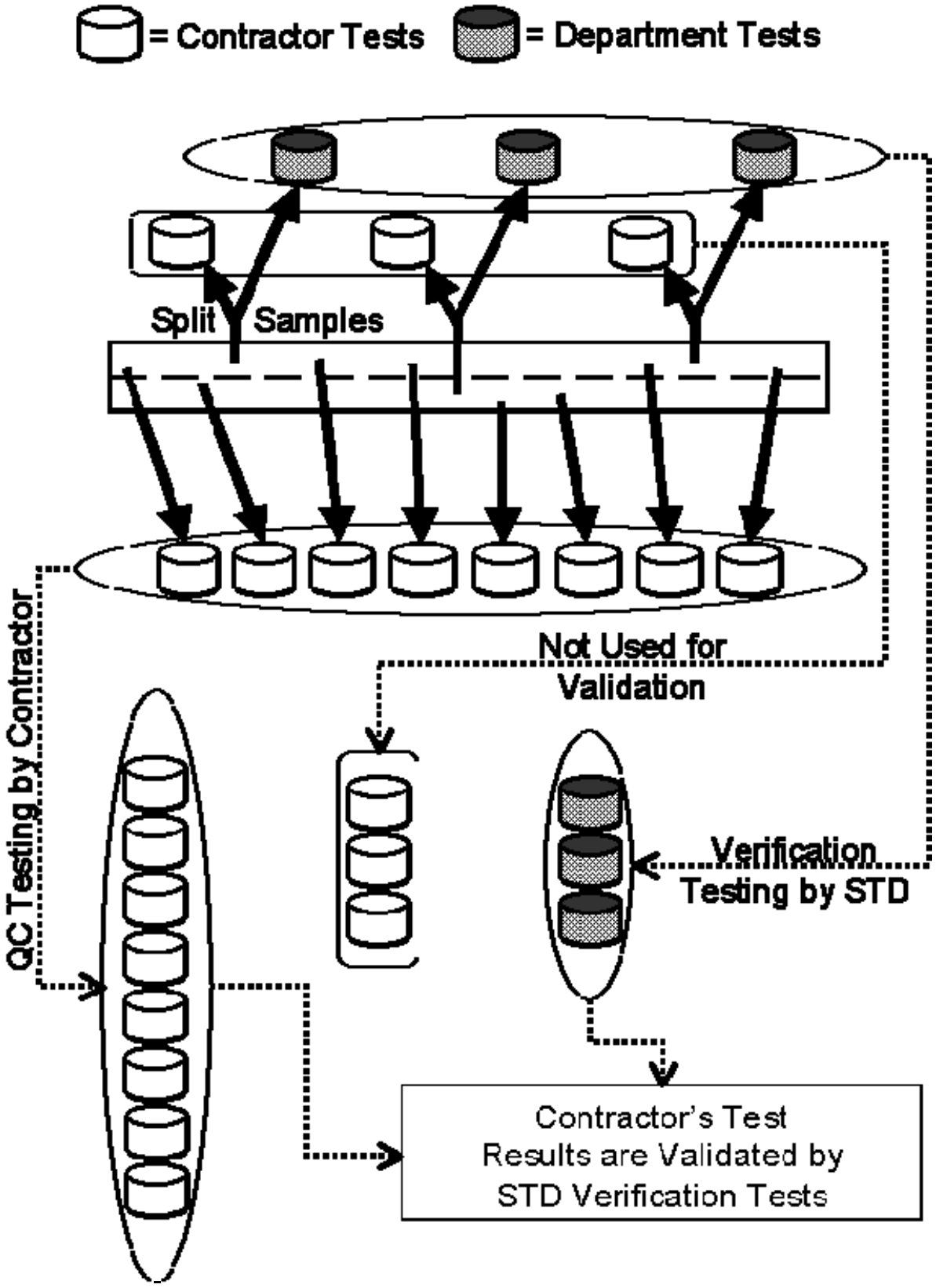

Figure 1 - Validation of Contractor's Tests

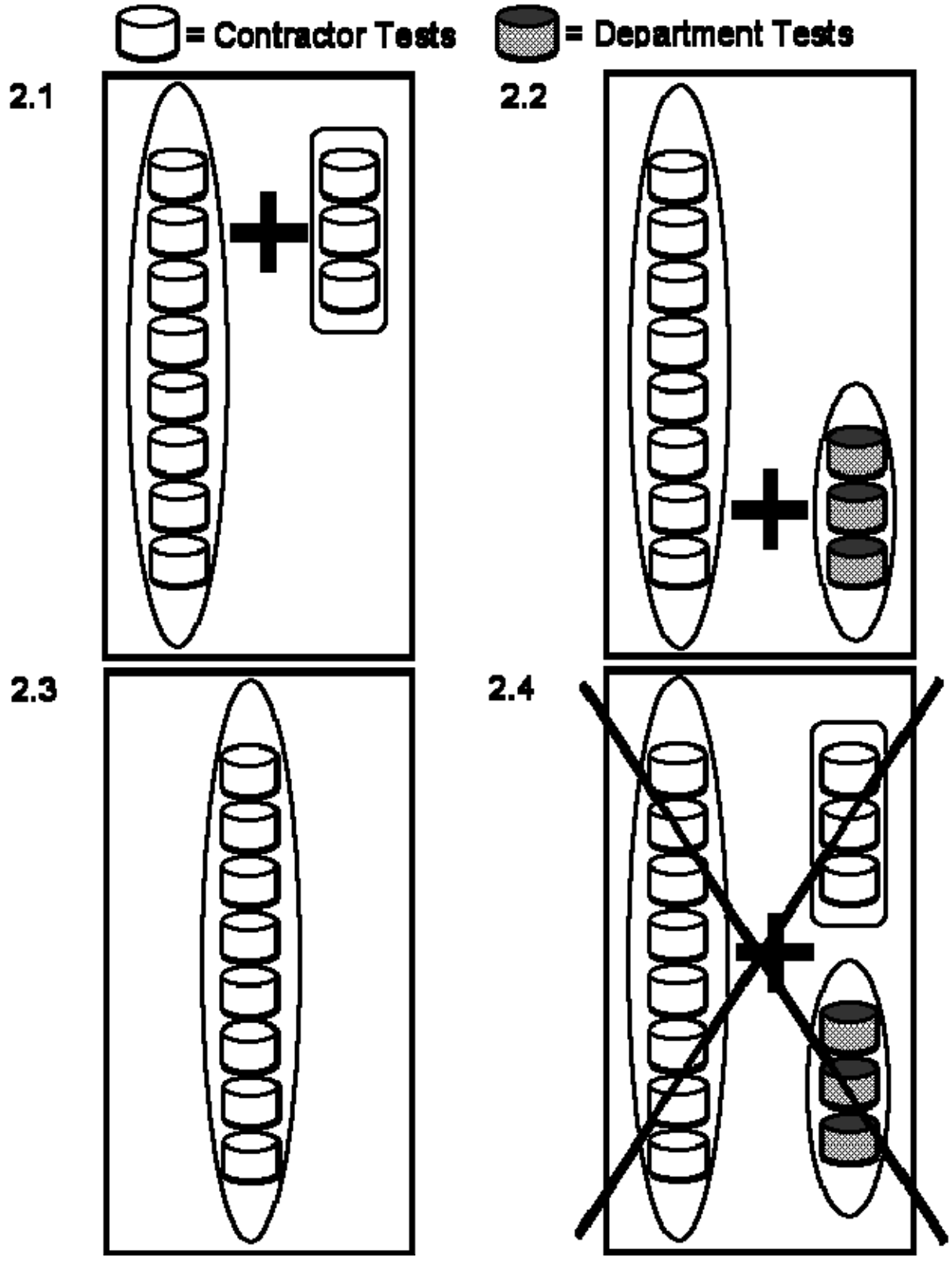

Figure 2 - Acceptance Based on Combined Test Results

(Using Sampling Plan in Figure 1)

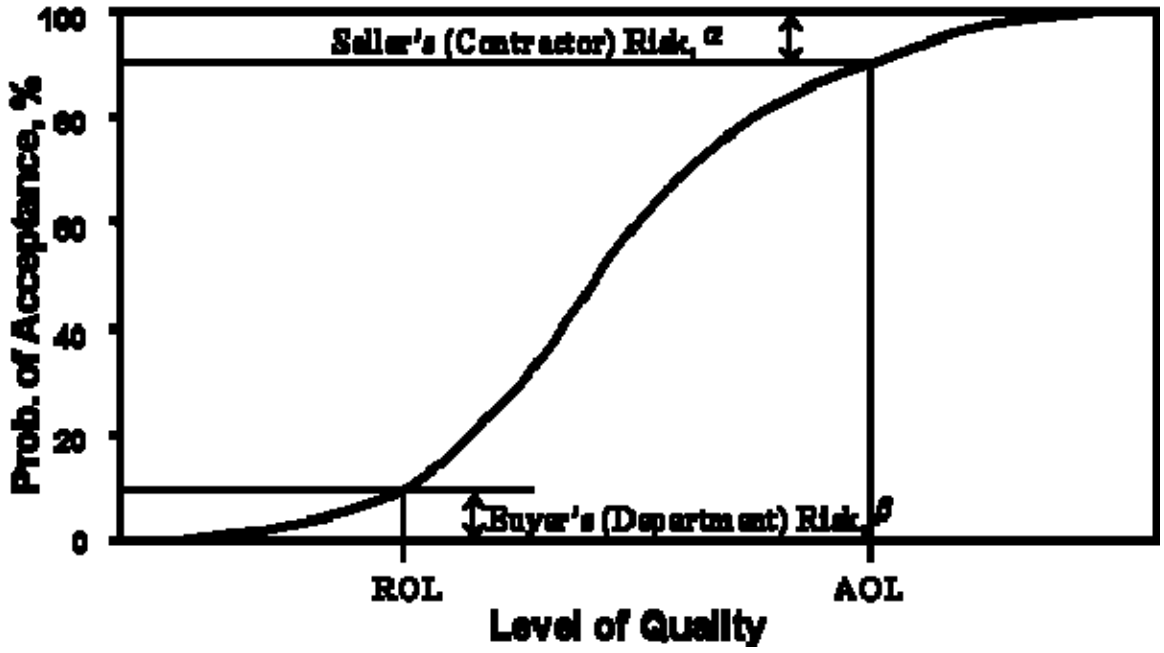

Figure 3 - Typical Operating Characteristic (OC) Curve for an Accept/Reject Acceptance

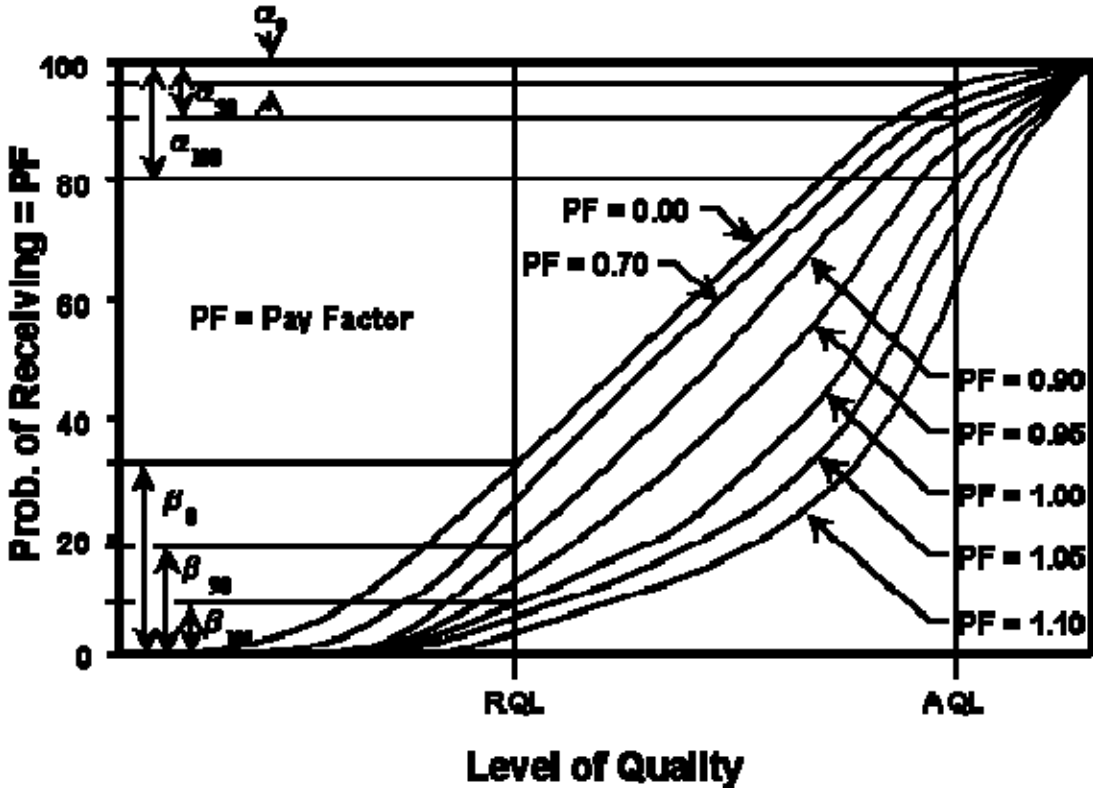

Figure 4 - Typical Operating Characteristic (OC) Curves for an Acceptance Plan with Pay Adjustments

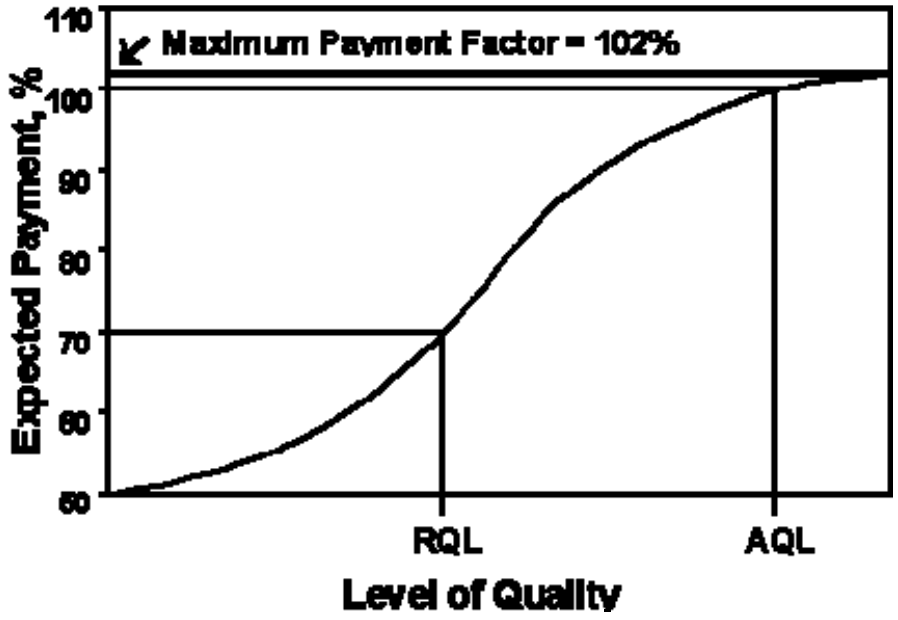

Figure 5 - Typical Expected Pay Curve

Appendix C

Questions for Division Office

1. General: For DA/ADA Meeting

1.1. What are your goals for the QA program? What does the Division Office hope to accomplish with this program?

1.2. Stewardship

1.2.1. Who has the responsibility for the stewardship of the QA Program?

1.2.2. What is the background and training of this individual in quality assurance?

1.2.3. How long have they been responsible for the QA program?

1.2.4. Does this individual have approval authority for the QA program?

1.3. Staffing

1.3.1. Discuss the QA role of others in your office.

1.3.2. Has anyone in the Division attended any training in topic areas covered by QA? What training was attended?

1.3.3. In general, do you feel that your staff are adequately trained and of sufficient quantity to play a significant role in the QA Program?

1.3.4. How are QA program activities incorporated or reflected into individual performance plans?

1.3.5. What commitment of resources is captured in the Individual Performance Plan (planned hours, percentage of effort, GOE)?

1.4. Risk Assessment

1.4.1. Has the Division Office conducted a risk assessment in the Material Quality Assurance area? If so, what was the score? How did this rank within your Division Office?

1.4.2. Did the Division Office develop risk statements in the Materials Quality Assurance area? If so, what are they?

1.4.3. Explain any concerns with the QA program in your State.

1.5. Project Performance

1.5.1. Explain any concerns with the performance of construction projects in your State and are they related to the QA program.

1.5.2. If you have premature failures, is there a formal means to address these failures and prevent their reoccurrence?

1.6. How does the interaction take place between the Division Office and STD in the area of development and continuous reevaluation and refinement of quality assurance programs?

1.7. How does the Division Office evaluate the overall effectiveness of the State's Quality Assurance Program?

1.8. Have Division Office efforts led to changes/improvements in the Quality Assurance Program?

2. General (for staff):

2.1. Guidance

2.1.1. What guidance is the Division Office using on QA Program issues?

2.1.2. How was this guidance used?

2.1.3. What would you change about existing guidance?

2.1.4. What additional guidance would be helpful?

2.2. Approval

2.2.1. How are the STD's QA Program requirements documented? (Agency Construction Manual, Materials Manual, other documents, etc.)

2.2.2. When was the last formal approval of the State's quality assurance program? Is this program approved in whole or by parts?

2.2.3. What was the form of the approval? (written letter, verbal, other)

2.2.4. Is a review/approval of the program conducted by the Division Office and if so what period is used?

2.2.5. Does the State periodically amend the Program?

2.2.6. Explain the amendment approval process.

2.2.7. Does your QA program differentiate between State Oversight and FHWA Oversight projects?

2.2.8. Does your QA program differentiate between NHS and non-NHS projects?

2.2.9. Does your QA program differentiate between Federal-aid and non-Federal-Aid projects?

2.2.10. Does your QA program differentiate between State administered and LPA administered projects?

2.3. Emphasis

2.3.1. Is the QA Program an emphasis area at the staff level?

2.3.2. Does the Division Office management ask you questions about the QA program? Does it fall within the Division Offices top priorities?

2.3.3. Explain the Transportations Engineer's role in the QA program.

3. Contractor Quality Control (QC) – Process Control

3.1. Explain the State requirements for contractor QC and how QC test results are used.

3.2. Is the Division Office satisfied that the State's QC requirements provide adequate control of the production process? Does this match with project performance?

3.3. Is the contractor required to have qualified/certified testers and laboratory facilities?

3.4. How are the contractor's QC activities verified? Are reviews and supervision of such work documented?

3.5. QC Plans

3.5.1. Are formal QC Plans required? If they are required, what items are they applied to and how are they used?

3.5.2. Are they approved by the State?

3.6. Does the QA Program require other contractor QC submittals during project construction (e.g. control charts, etc.)? If so, are these being used effectively by contractors to monitor construction activity?

3.7. Have there been issues/problems with QC? If yes, please describe.

3.8. What role does the Division Office play in evaluating contractor QC performance?

3.9. How does the Division Office evaluate the overall effectiveness of the contractor quality control?

4. Agency Acceptance

4.1. What role does the Division Office play in the development of the State's acceptance process?

4.2. Inspections and Testing - Acceptance consists of inspection and testing.

4.2.1. What criteria does the Division use to evaluate the State's balance between inspection and testing?

4.2.2. Explain the State's process for determining appropriate inspection levels, including both staffing and qualifications, for projects. Has this process been approved by the Division Office?

4.2.3. How does the Division Office determine that projects are adequately inspected?

4.3. Approved Sources/Approved Materials

4.3.1. Does the State have an "Approved Sources/Approved Materials" list?

4.3.2. Has the Division approved the process for maintaining this listing? How does the Division Office monitor this list?

4.4. Project Produced Material

4.4.1. Has the Division Office approved the State's testing regime for project-produced materials (asphalt, concrete, gravel, etc)?

4.4.2. What basis was used to determine appropriate tests, frequencies, and acceptance criteria?

4.4.3. Describe your State's process for acceptance of small quantities or non-critical items.

4.4.4. How does the Division Office monitor project-level testing to assure the State operates in accordance with the approved procedures?

4.4.5. If a project deviates from approved procedures, is the Division Office consulted/advised by the State?

4.4.6. Who makes the participation decision in these circumstances?

4.5. Contractor Test Results

4.5.1. Does the State use contractor test results in the acceptance decision? If No, skip to question 4.6

4.5.2. How are the contractor's results verified? Are reviews and supervision of such work documented?

4.5.3. Have there been problems in this area? If yes, how were they identified and what role did the Division Office play in their resolution?

4.5.4. Has the State's process for verifying the contractor test results been approved by the Division Office?

4.5.5. Does your process follow TA 6120.3? If not, what process are you using?

4.5.6. Do you have suggestions for improving TA 6120.3?

4.5.7. Was the guidance in “Evaluation of Procedures for Quality Assurance Specifications” FHWA-HRT-04-046 and “Optimal Procedures for Quality Assurance Specifications” FHWA-RD-02-095 used in setting up your acceptance program?

4.6. Have Division Office efforts led to changes/improvements in the Acceptance Program?

4.7. How are project Materials Certificates reviewed by the Division?

4.8. How does the Division Office evaluate the overall effectiveness of the State’s Acceptance Program?

5. Agency Independent Assurance (IA)

5.1. Describe your States IA program.

5.2. Has the Division Office approved the IA Program? If yes, what criteria were used?

5.3. How often does the Division Office evaluate the IA Program?

5.4. If systematic IA is used, does the Division Office receive an annual report from the State? Is the report formally approved?

5.5. IA Contractor Testing

5.5.1. If contractor test results are used in the acceptance decision, how are contractors evaluated by IA?

5.5.2. Have there been problems with this? If yes, what role has the Division Office played in identifying and resolving the problems?

5.5.3. Is the Division Office comfortable with the process of IA evaluation of contractor testing?

5.6. Have there been problems in the area of Independent Assurance? If yes, how were they identified and what role did the Division Office play in their resolution?

5.7. How does the Division Office evaluate the overall effectiveness of the State's Independent Assurance Program?

6. Dispute Resolution for Material Test Results

6.1. Does your State offer dispute resolution for materials test results to the contractor? If no, why not? If yes, describe the system.

6.2. Do you feel your system offers a balanced approach and appropriately balances risk between the State and the contractor?

6.3. What criteria were used in approving the dispute resolution system?

6.4. How does the Division Office monitor dispute resolution and have any changes/improvements occurred because of Division Office monitoring activities?

6.5. How does the Division Office evaluate the overall effectiveness of the State's Dispute Resolution Program?

7. Laboratory Accreditation and Qualification

7.1. How does the Division Office monitor the State's central laboratory accreditation?

7.2. Does the State have other testing facilities other than the central lab? Are these labs accredited or qualified?

7.2.1. If yes, how are these facilities deemed "qualified?"

7.2.2. Has the Division Office approved this process and how is it monitored?

7.3. What sources of information has the Division Office used to develop its laboratory monitoring program/process (regulations, TA's, past experience, etc).

7.4. How does the Division Office evaluate the overall effectiveness of the State's Laboratory Accreditation and Qualification Program?

8. Personnel Qualification/Certification

8.1. Describe how personnel qualified/certified, as required by the regulations?

8.2. Describe the Division Office role in any regional or in-house certification program the State may have.

8.3. What criteria did the Division Office use when approving the qualification/certification program or its modifications?

8.4. Has the Division Office approved deviations from FHWA policies or guidance in this area? If yes, briefly explain the deviation.

8.5. How does the Division Office evaluate the overall effectiveness of the State's Personnel Qualification/Certification Program?

9. Support and Improvements

9.1. Is the Division Office provided adequate support that it needs to manage/improve the QA program by the following: If not, indicate what improvement you would like to see changed/developed/implemented.

9.1.1. Office of Infrastructure?

9.1.2. Resource Center?

9.1.3. Other Division Offices?

9.1.4. Existing regulations?

9.1.5. Existing technical advisories, checklists, and/or guidance?

9.1.6. Existing training opportunities?

9.1.7. Computer programs or other tools to evaluate the State's program?

9.2. How can the evaluation, approval, and monitoring process of the QA program be improved at the Division Office level?

9.3. How can FHWA leadership (headquarters) improve the QA Programs at the Division Office level?

9.4. Any concluding comments from the Division Office or thoughts on the review?

Questions for State Transportation Agency

STA-1. In the Quality Assurance area, are FHWA's requirements clear to you? If not, provide examples needing clarification.

STA-2. Describe your interaction with the Division Office in the QA program.

STA-3. What are your expectations concerning Federal stewardship of the FHWA QA program?

STA-4. Do you receive the information you need to administer QA on the Federal-aid program? Can you provide specific examples?

STA-5. How can FHWA be a better partner in the QA area? What would you like us to take back with us to communicate to our management?

STA-6. Do you jointly review the QA program with your local Division Office on a regular basis?

STA-7. How do you work with the Division Office in the approval/amendments to your QA program?

STA-8. If there are concerns with adequate testing, Federal participation, or potential fraud how do you work with the Division Office to resolve this issue?

STA-9. What are the biggest challenges facing your organization in the administration of the QA program on the Federal-aid program?

STA-10. Do you contact any FHWA personnel outside of your local Division Office for assistance with QA issues? If yes, please explain.

STA-11. Have you discussed the Division Office's risk assessment of the QA program?

STA-12. What tools/training could FHWA provide that would be useful to you?

STA-13. Is there anything else you would like to add?

Questions for Consultants

C-1. Describe the role of consultants in the QA program.

C-2. Describe your interaction with FHWA Division Office in the QA program.

C-3. Do you consider the FHWA Division Office a resource in this area?

C-4. How would you improve FHWA's QA program requirements?

C-5. How do you assure your staff are properly trained and qualified to meet FHWA's QA requirements?

Questions for Industry

I-1. Describe the role of consultants in the QA program.

I-2. Describe your interaction with FHWA Division Office in the QA program.

I-3. Do you consider the FHWA Division Office a resource in this area?

I-4. How would you improve FHWA's QA program requirements?

I-5. How do you assure your staff are properly trained and qualified to meet FHWA's QA requirements?

Appendix D

Use of a Statistical Evaluation of Project Test Results to Monitor the Overall Process

Although many practices were noted during this review involving State DOTs, the Team is highlighting one practice noted in the Alabama Division. This practice involved the Alabama Division Office personnel proactively implementing the intent of TA 6120.3 to investigate a concern with their QA program.

Most process reviews focus on verifying compliance with specifications, regulations, and good practice. Another type of review is to take the data acquired on projects and analyze it to monitor the overall process.

The Alabama Division Office has performed three reviews by analyzing asphalt test results. The Alabama Division Office requested copies of all asphalt test results on numerous projects throughout the State. They then entered the data into the computer and analyzed it using established statistical methods. For these reviews all of the test results for each asphalt mix were evaluated together.

One component of the review was comparing the overall quality of the material accepted to the pay factors established by the contract specifications. For each asphalt mix, the Division Office performed a quality level analysis to determine the percent of material that was within certain evaluation ranges. This was done to determine if the existing contract methods for determining pay factors for material quality were reasonable. For laboratory air voids the Division Office calculated the percent of material between 3 percent and 5 percent air voids. They found that 17 of 25 mixes evaluated had more than 25 percent of the material outside of a 3 percent to 5 percent acceptance range. They also found that the contract method of evaluating the quality of the material had awarded a bonus to 16 of these mixes.

Another component of the review was comparing the contractor's test results with the Agency's test results. This comparison was on a mix basis, not a lot by lot basis. According to the contract, the results were compared on the project using a sample by sample comparison. By statistically comparing all the results for each mix a recurring bias that is undetectable on a sample by sample comparison becomes apparent. In this analysis, 18 of the 23 mixes evaluated failed either the t-Test or the F-test at 99 percent confidence.

For the initial review, the Division Office used QL-PAY, a computer program used by Federal Lands to establish pay factors based on percent-within-limits (PWL) and statistically compare two sets of test results using the t-test and F-test. This program can be obtained by contacting any of the Federal Lands Offices. For the follow-up review, they used an Excel spreadsheet that utilized the t-test and F-test functions built into Excel. The spreadsheet only performs the t-test and F-test; it does not perform a quality analysis. The spreadsheet has since been enhanced by the Resource Center to be more user friendly. A copy of the spreadsheet can be obtained from the Resource Center by contacting Rob Elliott or Tom Harmon.

This type review is a very effective tool the FHWA Division Office can use to monitor the effectiveness of the State's QC/QA procedures. The data can be analyzed at various levels; mix, project, district, contractor or statewide. This is a good way to verify if there are problems that the State's materials quality control and quality assurance system is not catching. It is also a way to assess the quality of the material being accepted.

For further information on this successful practice, contact Mr. Steve Mills, Operations and Pavements Engineer, Alabama Division Office.