The National Highway Runoff Data and Methodology Synthesis

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ABSTRACT

This report describes the National Highway Runoff Data and Methodology Synthesis (NDAMS) project, and provides an overview of the project's findings and conclusions. The project cataloged over 2,600 reports relevant to the study of highway and urban runoff and reviewed the quality of data in 252 reports (34 literature review or summary reports and 218 detailed reports). These reviews represent nearly 10 percent of all reports in the NDAMS bibliographic database and more than 50 percent of the reports in the database designated as highway runoff reports. The metadata reviews indicate that much of the available data are not sufficiently documented for inclusion in a technically defensible regional or national dataset. Few reports document the information and data necessary to establish the quality or representativeness of research results for regional or national synthesis. Even fewer reports meet multiple documentation criteria. Furthermore, research indicates that technical issues involved with the collection, processing, and analysis of suspended sediments, trace elements, and organic compounds raise doubts about the veracity of many datasets. Therefore, efforts to coordinate environmental-research projects should include an electronic system to facilitate information exchange that incorporates consistent sampling protocols, national data-documentation standards, and a technical audit process designed to ensure that data meet documentation and data-quality requirements. Such a system is necessary to produce data that meet local, regional, and national information needs.

INTRODUCTION

The Federal Highway Administration (FHWA) and State transportation agencies are responsible for determining and minimizing the effects of highway runoff on water quality, while planning, designing, building, operating, and maintaining the Nation's highway infrastructure (***1,2,3***). Increasingly, regulatory agencies are using the estimated characteristics of the different nonpoint sources in a given watershed to determine and apply a total maximum daily load (TMDL) for receiving waters (***4***). TMDL assessments and other water-quality initiatives have increased efforts by Federal and State regulatory agencies to quantify and regulate sources of nonpoint-source pollution. In many cases, transportation agencies are required to implement best management practices (BMPs) to minimize the potential effect of highways as a nonpoint source of runoff constituents (***5***). The objectives and monitoring goals of highway runoff studies conducted during the last 30 years have been diverse, because the transportation community must address numerous questions about the characteristics and impacts of highway runoff (***1,2,3***). Data from different highway runoff studies have been combined to characterize runoff quantity, quality, and processes; develop information for the design, implementation, and assessment of BMPs; develop information for regulatory or legal needs; and assess and predict the potential for environmental effects from runoff. These diverse study objectives and monitoring goals impose different data and information requirements (***1,3***).

Environmental datasets are not repeatable in the sense that one may not recreate controlled conditions as is expected for laboratory work. To create defensible environmental datasets one must completely document the sampling location, site characteristics, weather conditions, stormwater flows, and the protocols used during the monitoring period (**1,6,7**). The quality and quantity of environmental data required to support a decision, however, can vary greatly depending on the nature and scope of the problem and the regulatory environment. For example, sampling as few as four or five storms of each type (rain, snow, and mixed) may indicate the order of magnitude of event mean concentrations (EMCs) at a given site, but sampling more than 15-20 storms at each site is necessary to provide an accurate estimate of the average EMC for a given site (***8***).

As study objectives and monitoring goals increase in complexity, data requirements and collection costs increase (***1,6***). Data-quality objectives (DQOs) define the type, quantity, and quality of information necessary to meet environmental monitoring goals and objectives. The U.S. Environmental Protection Agency (USEPA) DQO process is designed to help weigh the costs of data acquisition against the consequences of a decision error caused

by inadequate input data and to define criteria that will be used to establish an appropriate data-collection design (***9***). The nature and scope of the problem and the regulatory environment determine the quality and quantity of environmental data required to support a decision. For example, datasets that are admissible as legal evidence must contain enough information to withstand any reasonable challenge to their quality and veracity (***1***). Current (2002) USEPA data-evaluation criteria require that all data used in regulatory decision-making processes be verified (the data are collected in accordance with approved protocols) and validated (the data quality is documented, the data meet established DQOs, and that documentation is sufficient to allow evaluation in terms of other DQOs) to ensure the defensibility of data and decisions made with the data (***10,11***).

Qualitative assessments, quantitative studies, and predictive studies need definitive goals and an associated set of DQOs. Qualitative assessments, such as reconnaissance studies, provide order-of-magnitude estimates of runoff quality and (or) associated environmental effects. Quantitative studies provide more exact and defensible information that can be used to compare data populations from different sites on the basis of site-specific characteristics. Predictive studies produce data and information needed to develop quantitative predictive equations to estimate the quality of runoff and associated effects at unmonitored sites, with an associated assessment of the uncertainty in the predictions. The primary objective of a regional or national synthesis of runoff quality, however, is to quantitatively predict runoff quality and the potential for adverse effects in the environment at unmonitored sites across the country on the basis of readily obtainable site-specific information and data. Therefore, a national synthesis requires robust DQOs to ensure maximum utility of datasets for the scientific, engineering, and regulatory needs of transportation agencies. Within this context, the FHWA must establish that the available data and procedures used to collect and interpret the data are valid (useful for intended purposes), current, complete, and technically supportable (***1,3***).

The information needs and regulatory requirements that face transportation decisionmakers necessitate an evaluation of the available highway-runoff research results with respect to the DQOs for a regional or national synthesis of information and data. In order to distinguish between real intersite differences and sampling artifacts, standards for quality assurance and quality control (QA/QC), comparability, and documentation must be higher for a national synthesis than for a local monitoring program (***1,3***). Comprehensive national standards may add to monitoring costs on a case-by-case basis, but experience indicates that monitoring activities need to be improved

and integrated to more effectively and economically meet the full range of local, regional, and national information needs (***7***). It is beyond the scope of the NDAMS project to establish DQOs for the Federal and State transportation agencies, regulatory agencies, and other public and private stakeholders. It is incumbent upon decisionmakers and regulators to determine the DQOs necessary to address each issue, but some basic aspects of data documentation (such as methods and QA/QC documentation) are considered necessary for all valid current and technically defensible highway runoff studies (***1,3***). A single quantitative set of DQOs, however, might either be too restrictive, disqualifying datasets (that are appropriate for a given use), or too vague, precluding useful predictive interpretations. In order to address these concerns, the U.S. Geological Survey (USGS), in cooperation with the FHWA, initiated a National Data and Methodology Synthesis (NDAMS) to catalog available information and evaluate a sample of this information to determine if available reports sufficiently document the basic information, explanatory variables, and data-quality indexes necessary to meet various DQOs that may be applicable to different runoff issues (***1,3***).

This report provides an overview of the NDAMS project, a discussion of project results, and an examination of research needs identified by the project. The overview of the project briefly describes the methods used to catalog and evaluate available runoff-quality information. The discussion of project results describes major findings of the data-quality review process. Results of the data-quality review process are described in terms of research needs and potential DQOs for a regional or national synthesis of runoff-quality data from the population of reviewed reports (rather than characteristics of individual reports) because the NDAMS is an assessment of all available data rather than a critique of the work of individual studies and programs. Research needs identified in a series of "expert chapters" (***1***), and in the results of the data-quality review (***3***) also are discussed.

OVERVIEW OF THE PROJECT

During the NDAMS project, the USGS developed criteria for evaluating runoff-quality studies, compiled a catalog of relevant literature, reviewed a sample of the available literature, and interpreted the results of this review process. Uniform criteria for evaluating runoff-quality studies were necessary to establish data quality. A catalog of relevant literature was necessary to establish the population of available documents. The review of the literature and subsequent interpretation thereof was necessary to determine if available information is valid, current, and technically defensible for regional or national synthesis of runoff data.

The USGS, in cooperation with the FHWA assembled a team of subject-matter experts to examine technical issues associated with the collection, processing, interpretation, and documentation of data that would be valid, current, comparable, and technically defensible for individual studies and for subsequent regional or national synthesis of runoff data. Experts from within the USGS Water Resources and Biological Resources Disciplines combined their input with that from State and Federal environmental and transportation agencies to establish key issues and data-evaluation criteria based upon the current state-of-the-art. They produced a series of reports (each concerning one aspect of highway-runoff investigations) that document data-evaluation criteria that were used to produce the NDAMS program review sheets (***12***). These reports document criteria for monitoring the quality of runoff including: basic information and data quality (***13***), precipitation and runoff flow (***14***), the geochemistry of runoff (***15***), sediments in runoff (***16***), trace elements in runoff (***17***), organic chemicals in runoff (***18***), the potential ecological effects of runoff (***19***), monitoring atmospheric deposition (***20***), QA/QC (***21***), and interpreting runoff data using appropriate statistical techniques (***22***). These 10 “expert chapters” were released as limited distribution open-file reports and made available on the NDAMS Web site (***23***) pending publication of all 10 expert chapters as Volume I of the NDAMS project FHWA report series (***1***). These reports also are available in electronic format on the CD-ROM accompanying volume II of this series (***2***).

A literature search was done to catalog literature relevant to the study of highway runoff. As reports were collected and citations were verified, pertinent information was entered into a database. More than 2,600 reports and more than 1,300 abstracts or summaries were cataloged in the bibliographic database during the study. Abstracts are provided for almost all reports without copyright restrictions, such as reports published by government agencies and journal articles documenting government sponsored research (***1***). Summaries were written for

reviewed reports that may have copyright restrictions, such as journal articles describing research not funded by government agencies. An abstract or summary is available for about 50 percent of the 2,600 reports. This database, and a number of other products from the study, are available on the CD-ROM accompanying Volume II of the NDAMS project FHWA report series (***2***). An on-line searchable version of the bibliographic portion of the database is available on the NDAMS Web site (***23***).

The data-evaluation criteria and the catalog of relevant literature were used as tools to select reports for the metadata review. Generally, publications presenting the results of highway-runoff water-quality investigations were selected for review in reverse chronological order. These reports were reviewed using the NDAMS program review sheets following standard methods (***2,12***) to document metadata necessary to establish the published information as valid, current, and technically supportable (***1,13***).

During the project, 252 reports were reviewed, and for each report pertinent information was recorded in the "basic report metadata" component of the database, including basic report information, the classes of chemical constituents sampled, the sampling matrixes, and the hydrologic and physical focus of each investigation. Published literature reviews and summary reports were included in the evaluation of available information in this level of the database because they often are a valuable source of general information, they provide references for sources of detailed information, and they provide perspectives for the potential use of original data in regional or national synthesis efforts. Detailed information and metadata were not recorded for literature reviews and summary reports because these reports generally do not document enough details about the data-collection programs to evaluate the quality of information in the original interpretive studies that they summarize.

Reports that document details from runoff-quality investigations received a full data-quality evaluation. Metadata from 218 detailed reports were fully documented in the database. “Detailed report metadata” included documentation methods, temporal information, site location and characteristics, sample collection and processing methods, specific water-quality constituents of concern, flow-monitoring methods, field and laboratory QA/QC methods, and uncertainty analyses (***2***). Metadata was recorded on the appropriate review sheet when subject information was documented clearly in the reviewed report.

Results of the review process were entered as standardized metadata tables within the bibliographic database to facilitate use for current and future runoff-quality investigations (***2***). The experience and knowledge of the reviewers were used to translate the results of the review process using the NDAMS review sheets into standard responses that would lead to consistent and objective interpretations of available data in published reports. Whenever possible, narrative descriptions in the review sheets were condensed into yes-no questions (or yes-no variants that would include responses for "not applicable" or "unknown" where appropriate), standard multiple-choice questions, or extendable lists of appropriate responses. For example, the reviews included a search for information about the sampling materials (such as equipment, bottles, and preservatives), but examination of review results indicated that this information was not typically available, and when available, was not described in a consistent manner among the reviewed reports. Therefore, the response was simplified to a "yes" or "no" for this question about sampling materials. Information in the review sheets also was converted to database inputs by means of standard lists. These lists ensured that the data could be entered repeatably, and that information recorded in the database could be aggregated and classified for interpretation.

Results of the metadata-review process form the basis for evaluating available highway-runoff research data in terms of regional or national information needs (***3***). Documentation of general information and metadata, runoff-quality constituents, explanatory variables, and data-quality information all are necessary for integrating a valid, current, comparable, and technically defensible dataset. The metadata review process documented the availability of this information in individual research reports. The information and metadata generated by the NDAMS review process, however, are considered in terms of the population of available data. Results are presented in terms of the proportion of reviewed reports that meet basic verification and validation requirements, meet potential DQOs, and are distributed among different regions representing geographic explanatory variables (***3***).

DISCUSSION

The NDAMS project was designed to identify publicly available information relevant to the study of the quality of highway runoff and to assess the suitability of this information and data for a predictive regional or national runoff model. The study goals and related DQOs determine the suitability of a given dataset. For example, a primary goal of runoff studies has been to "characterize highway runoff." In this quest, different studies have measured runoff on the pavement, in a drainage system, within a structural BMP, and at the outfall to receiving waters (***2***). Sedimentation and geochemical processes affect the concentration and speciation of constituents as runoff flows from the pavement through drainage structures and BMPs to receiving waters (***1,15,17***). These effects are expected to vary widely from site to site depending on the physical, chemical, and hydraulic characteristics of the runoff, the pavement, and the drainage structure at each site (***1,15,17***). Also, samples collected in drainage structures commonly include runoff from shoulders and median strips, which may have different chemical characteristics than pavement runoff. As such, studies that characterize runoff collected on the pavement would be expected to provide the most consistent results for prediction of pavement runoff-quality with a minimal number of sites and samples. Therefore, if the defined problem and decision is to characterize the quality of pavement runoff for national synthesis, then studies that collect samples on the pavement or at the entrance to catchbasins set in the pavement would be most appropriate. If, however, the problem and (or) the decision is focused on the performance of BMPs or the potential effect of runoff quality on receiving waters, then samples collected from drainage structures and at the outfall to receiving waters are necessary. Data from more sites and analysis of more samples at each site would be necessary to achieve the same level of uncertainty for these expanded goals, because the differences in site characteristics, in flow paths, and in processes that affect runoff quality in drainage structures along these flow paths could mask relations between highway characteristics and measured runoff quality (***1,22***). DQOs for runoff studies also must address the type of runoff constituents and the sampling matrix to be measured to meet program goals. For example, if the question is regulatory compliance, then concentrations in water samples may be sufficient. If, however, the question is about the actual effect of runoff quality on aquatic communities in receiving waters, then sediment chemistry and direct biological measurements may be necessary (***1,19***).

Results of the metadata review provide information to evaluate the suitability of available data to meet different study goals and DQOs. For example, the sampling matrix and the class of constituents analyzed in each

TABLE 1 Contingency table indicating the percentages of the 252 reports reviewed that document sampling of one or more matrixes and analysis of one or more constituent classes

[**Constituent class:** TE, trace elements; SS-sediment and solids; OC-organic compounds. **Analysis matrix:** Biological tissue samples would not be analyzed for sediment concentrations but concentrations of trace elements in biological tissues may, for example, be interpreted in terms of the grain-size distribution of bottom sediment collected with benthic organisms]

	Analysis Matrix							
Constituent Class	Unspecified	Water	Sediment	Biota	Water and Sediment	Water and Biota	Sediment and Biota	Water, Sediment and Biota
TE	74	64	33	16	25	10	12	8
SS	67	62	30	10	25	7	9	6
OC	62	54	20	7	16	6	5	4
TE and SS	56	52	26	10	21	7	9	6
TE and OC	46	44	16	6	15	5	4	4
SS and OC	44	43	15	4	14	4	3	3
TE, SS, and OC	39	38	14	4	13	4	3	3

matrix may be considered as part of DQOs established for creating a predictive model to assess relations among runoff quality, accumulation of runoff sediments in receiving waters, and measured biological responses. Concentrations of constituents from analyses of different sample matrixes are not directly comparable, so each matrix must be sampled and analyzed to provide the necessary information (***1,17,18***). The availability of runoff-quality information documenting sampling of one or more matrixes and analysis of one or more constituent classes as a percentage of the 252 reviewed reports are indicated in contingency table (**table 1**). Most of the reviewed reports document analysis of trace elements (about 74 percent), sediment and solids (about 67 percent), and (or) organic constituents (about 62 percent) in one or more environmental sampling matrixes. Only about 3 percent of the 252 reviewed reports, however, include analysis of all three constituent classes from all three matrixes. Furthermore, **table 1** does not necessarily indicate that all constituent classes were analyzed for each matrix, only that the subject reports included data for one or more constituent classes in each matrix (for example, see the headnote on **table 1**). Therefore, the number of studies included in the NDAMS review that meet a given set of DQOs decreases as information needs expand.

The geographic distribution of data also is an important consideration for the development of a regional or national model. Variation in runoff fluxes and the potential effect of highway runoff on the local aquatic environment are expected to correlate with regional factors such as climate, hydrology and physical habitat, as well as with site-specific factors such as traffic volume, extent of pavement, and right-of-way characteristics (***1,22***). For example, the application of road salts and friction materials in cold areas may increase substantially annual loads of dissolved and suspended solids, and may alter local geochemical and ecological processes (***1,15***). Organics may degrade and volatilize at substantially faster rates in regions with higher annual temperatures than in colder regions (***1,18***). Furthermore, atmospheric deposition--and related effects on runoff quality--varies substantially from site to site within the conterminous United States (***1, 20***). If the distribution of highway runoff sampling sites in **table 1** are examined in terms of their geographic distribution among the 15 rain zones defined by the USEPA for storm sampling (***25***) then the regional availability of data can be assessed. **Figure 1** indicates the geographic availability of information from reports documenting sampling and analysis of the (A) water, (B) sediment, (C) biological, and (D) all three matrixes (without regard for constituent class) at highway-runoff monitoring sites in the conterminous United States and southern Canada. These maps indicate that water-quality-sampling efforts have been the primary focus of most highway-runoff reports, and that there also is geographically diverse sediment and biological data.

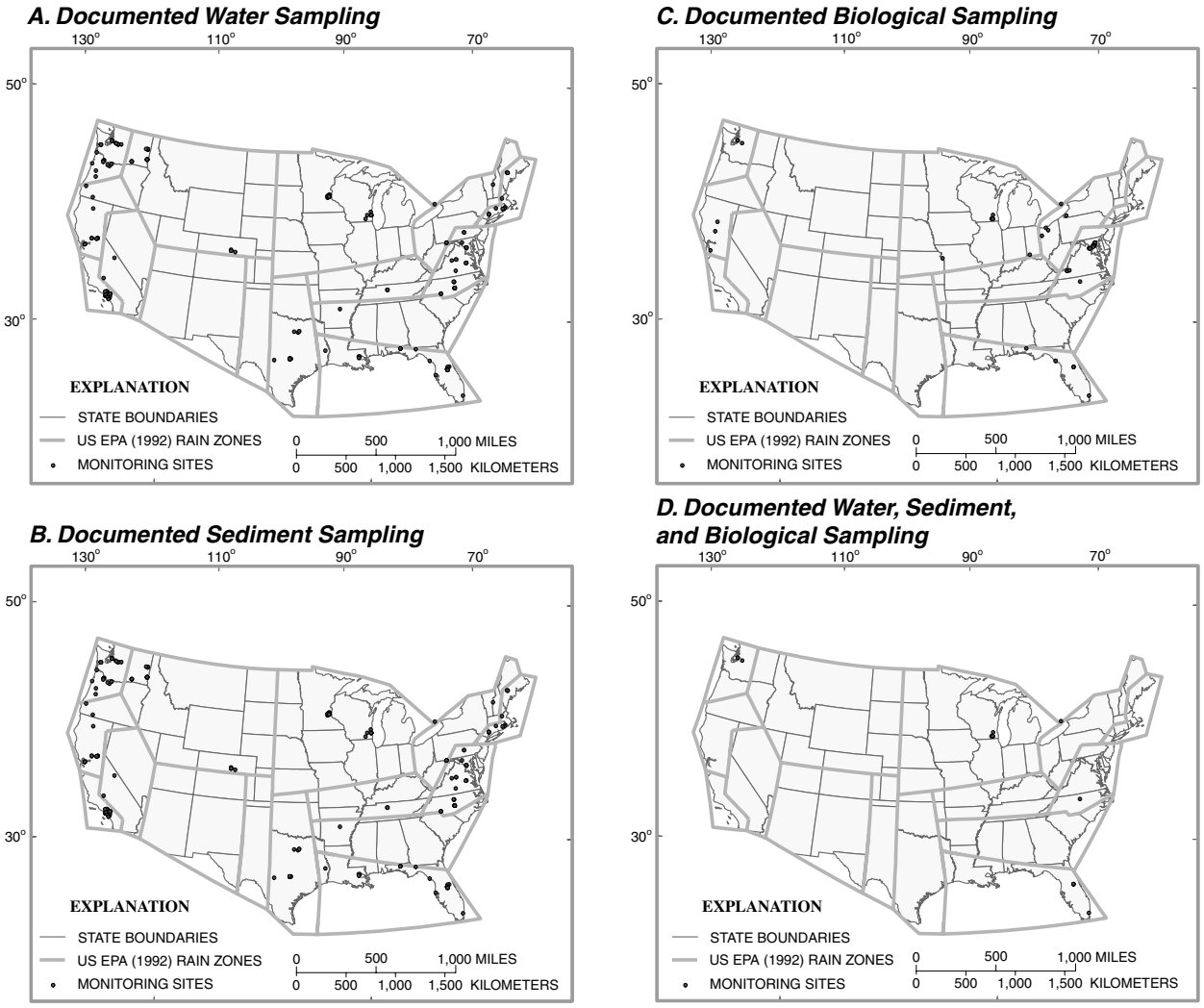

FIGURE 1 Distribution of highway sites with documented (A) water-sampling data, (B) sediment-sampling data, (C) biological-sampling data, and (D) water-, sediment-, and biological-sampling data cataloged in the NDAMS review among the USEPA (1992) rain zones in the conterminous United States.

Few reports, however, document sampling and analysis of water, sediment, and biological matrixes; information that may be necessary for understanding how runoff quality affects biota in receiving waters (***1, 19***).

Because of increasingly stringent data-quality requirements, the quality of data is as much a concern as the availability of data (***1,3***). The USEPA data verification and validation process includes a retrospective analysis of all the protocols used, each piece of data collected, and statistical analysis of environmental data and supporting quality-control data (***1***). A data-quality audit is considered necessary by the USEPA to establish that

* the data can be replicated by the original data collector,
* there is sufficient documentation of all procedures used in the data-collection effort to allow for repetition of the effort by a person or team with technical qualifications similar to those of the original data collector,
* there is sufficient documentation to verify that the data have been collected and reported according to these procedures and that documentation is sufficient to allow a potential user to determine the quality and limitations of the data, and
* the data are of sufficient quality for their intended use with respect to the expected bias, precision, accuracy, comparability, completeness, representativeness, and other performance criteria (***10***).

Similarly, a review of the comparability of water-quality data collected by Federal, State, and local monitoring organizations determined that, to be useful, data must be representative of the system under study, available for public use as original data, collected from a readily located sampling site, associated with sufficient QA/QC documentation, and available in useful computer files (to increase reliable compilation and manipulation of large volumes of data) (***26***).

The NDAMS metadata-review statistics indicate that the population of available highway-runoff reports commonly does not have sufficient documentation to initiate the verification and (or) validation process. For example, only about 45 percent of reviewed reports document collection of precipitation and flow data, even though these data are necessary for basic hydrologic characterization of a study site, for implementing a flow-weighted composite-sampling system, and for predicting concentrations and loads at unmonitored sites with the data collected (***1,14,22***). Few reports also document information necessary for interpretation and use of concentration data (***1,3, 13,21***). For example, about 38 percent of the 218 detailed reports identify the laboratory(ies) used for sample analysis (only about 20 percent of the 151 reports with sediment data identify the sediment laboratory used) and

only 16 percent indicate that the laboratory was certified by an independent organization. Also, fewer than half of the reports document any laboratory, field, or laboratory and field QA/QC activities. Fewer than 10 percent of the 218 detailed reports document existence of a quality plan, a published quality plan, or an internal or external audit, which are considered to be fundamental components of a quality system (***21***). Furthermore, chemical detection limits, which are necessary for interpretation of trace-element (***17***), and organic (***18***) constituent data, were not documented for 74 percent of the 162 reports with trace-element data, 82 percent of the 131 reports with organic-compound data, and 44 percent of the 27 reports with pesticide and (or) herbicide data. Many individual examples, therefore, indicate that the population of available reports does not document the information necessary for regional or national synthesis.

Availability of reliable runoff-quality data in an electronic format is necessary to facilitate future use and interpretation of data collected (***1,3,7,22,26***). For example, the 1990 FHWA model study (**27**) and the Canadian Ministry of Transportation's synthesis of runoff data (***28***) both indicate that efforts toward interpretation of highway-runoff data involved substantial difficulties in the collection, examination, quality assurance, quality control, and computer entry of historical runoff-quality data. Conversely, researchers were able to assemble a much larger National Urban Runoff Program (NURP) dataset from the USGS and the USEPA with less effort because these programs were supported by QA/QC measures and the data were stored in readily available national water-quality databases (***22,29***). QA/QC in the data entry and archiving process is therefore as important as QA/QC in the data collection process (***1,21***). Furthermore, the USEPA data-validation and verification process now requires that data and supporting documentation must be available in an electronic database for this USEPA review process (***3,10***). In comparison, about 12 percent of the 252 reviewed reports indicate that original data are available in an electronic format; only about 5 percent indicate the documentation of QA/QC measures and the availability of electronic data.

Although individual data elements are important, it also is necessary to evaluate the suitability of the available information in terms of a combination of data elements necessary to utilize any given dataset. For example, knowledge of a measure of traffic volume (such as the average daily traffic), water-quality data from more than 15 independent storms (***8***), and measurements of the storm total and precipitation intensity at a test site may be used to predict concentrations and loads of constituents in runoff at similar sites (***1,22***). Although each of these criteria is documented in more than 20 percent of the 218 detailed reports, only about 8 percent of these reports include all three criteria (**fig. 2A**). Furthermore, when the documentation for these selected explanatory variables is examined, only 3 percent also have laboratory or field QA/QC documentation (**fig. 2B** and **fig. 2C**, respectively) and fewer than 2 percent have laboratory and field QA/QC documentation (**fig. 2D**).

The research to define the information and data necessary to document data for regional or national synthesis indicates that a number of unresolved technical issues also substantially affect the transferability and technical defensibility of many available runoff-quality datasets. The following examples highlight some of these findings, which are discussed in detail within the results of the NDAMS study (***1,2,3***). Many runoff-quality studies include only the contaminants of concern. The effect of local geochemical conditions on the environmental distribution of these contaminants, however, may preclude regional or national synthesis unless datasets also define the geochemistry of precipitation, runoff, sediments, and receiving waters (***1,15***). Accurate measurement of suspended sediment concentrations and loads is crucial for assessing runoff quality, the potential effect of runoff in receiving waters, and for determining the effectiveness of BMPs. Recent research indicates that analyses of samples by the total suspended solids (TSS) method commonly used to measure sediment concentrations in runoff tends to underrepresent the actual suspended-sediment concentration (SSC), and that relations between TSS and SSC are not transferable from site to site even when grain-size distribution information is available (***1,16***). Therefore, it may be necessary to analyze water samples using the suspended-sediment concentration method (***16***). Investigation of trace element (metals) monitoring methods indicates that trace-element datasets are considered suspect unless sampling protocols are documented fully and there is sufficient QA/QC information available to prove that measured concentrations represent environmental conditions rather than artifacts of the sampling and analysis process (***1,17***). A review of methods and data from organic-chemical monitoring studies indicates that substantial loads of organic chemicals may be undetected in dissolved and whole-water samples because many of these chemicals are

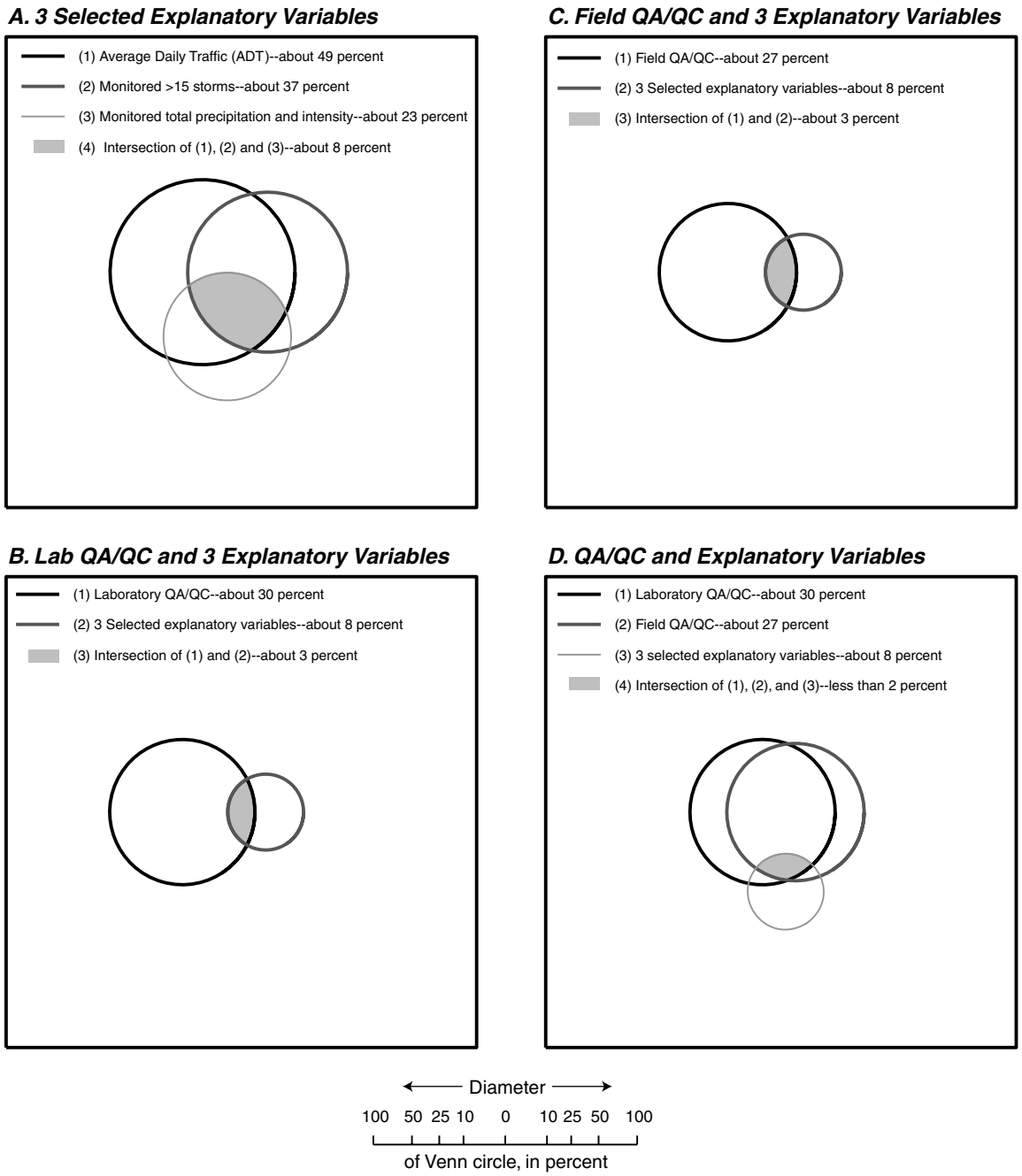

FIGURE 2 Percentages of the 218 detailed reports that document basic report information including: (A) three selected explanatory variables, (B) laboratory QA/QC and three selected explanatory variables, (C) field QA/QC and the three selected explanatory variables, and (D) laboratory QA/QC, field QA/QC, and the three selected explanatory variables.

hydrophobic and detection limits for analysis of whole-water samples are too high to reliably quantify concentrations and loads of these compounds (***1,3,18***). The USGS currently collects, concentrates, and analyzes suspended sediments from runoff to quantitatively measure organic chemicals in runoff because of these limitations (***24***). Review of atmospheric monitoring methods also indicates a number of potential problems with the collection and interpretation of atmospheric deposition data that affect local interpretation of runoff loads and regionalization of point data (***1,20***). Review of methods and data from studies of the environmental effects of runoff in receiving waters indicates that highway runoff generally is not acutely toxic. Biological tissue analysis and community assessments, however, indicate that elevated concentrations of highway-runoff constituents were measured in tissues of species associated with aquatic sediments, and there are decreases in the diversity and productivity of aquatic ecosystems at sites where highway-runoff sediments accumulate (***1,19***). Furthermore, many trace elements and organic chemicals may not be quantified in whole-water samples at current chemical detection limits, but may be accumulating in runoff sediments deposited in receiving waters (***1,17,18***). Therefore, studies of runoff sediment loads and sediment quality may better define potential effects of runoff on aquatic communities in receiving waters than would studies of total (whole water) runoff loads and runoff quality.

It may be argued that any number of the individual elements included in the review is not absolutely necessary for regional or national synthesis. Evaluation of many individual documentation elements, however, indicates that the available literature does not properly document research to a degree that would establish that available data are valid, comparable, or technically defensible for regional or national synthesis. Furthermore, when individual metadata requirements are combined (as in fig. 2), the proportion of available reports that meet these multiple criteria quickly decreases to the point at which regional or national synthesis is not possible.

The lack of a substantial body of valid, current, and technically defensible information in the available literature points to the need for national standards (***3***). Collection and documentation of information necessary for regional, national, or expanded use of any given dataset typically requires more resources than those required for local regulatory or information needs. The need for additional documentation efforts, however, may not be justifiable within the local context unless regional or national information requirements are specified by organizations and agencies sponsoring or conducting this runoff research. The Transportation Research Board (***30***), recognizing the need for data and information, indicated that unless standards are established, the continuation of nonuniform approaches to data collection and documentation will preclude the development of valid conclusions when different datasets are integrated for regional or national interpretation. Necessary standards may include:

* requirements that all information and data are collected within a quality system to document verification and validation of all data with internal and external technical audits;
* protocols for collection, processing, and analysis of environmental samples;
* documentation standards for laboratory and field methods, materials, analytical detection limits, site characteristics, and other explanatory variables;
* documentation standards describing the type and format of data to be saved in electronic format; and methods for posting all runoff-research reports on the Internet in a centralized location.

Development of these standards by the transportation community may, at first, appear to be an overwhelming requirement. The expert chapters produced by the NDAMS project, however, identify many of the technical issues that must be defined for highway runoff studies (***1***). Also, applicable standards are being developed within the water-resources-research community (***6,7,8,25***). The transportation community, therefore, may benefit by adopting or adapting existing standards and by participation in wider efforts toward the development or implementation of methods, protocols, and electronic datasets.

CONCLUSIONS

Review and analysis of the metadata collected for the NDAMS project indicates that much of the available data are not sufficiently documented for inclusion in a technically defensible regional or national dataset. Results of the metadata-review process indicate that few reports document enough of the information and data necessary to establish the quality or representativeness of research results. Also, the number of reports that meet criteria for documentation of project data are diminished substantially when multiple criteria are applied. Furthermore, various technical issues raise doubts about the veracity of existing suspended-sediment, trace-element, and organic-compound data. The fact that a project's data may not meet criteria for regional or national synthesis, however, does not mean that the data are not useful for meeting that project's goals. To meet national or regional objectives, it is necessary to establish systematic data-quality objectives, an integrated quality system, and standard protocols for sample collection, processing, analysis, documentation, and publication to ensure that resources expended to meet environmental research needs are used efficiently and effectively. To this end, the transportation community can adopt, adapt, and participate in the development and application of standard methods for data collection, processing, and distribution. Integration of Federal, State, and local regulatory, data-collection, and research programs within a system to facilitate information transfer will provide an economy of scale by making research results available to the entire research community. National standards and a technical audit process are necessary, however, to ensure that data in this system meet documentation and data-quality requirements.

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