

Principles and Best Practices for Post-Election Tabulation Audits

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Executive Editors**

Lynn Garland

Mark Lindeman
Senior Science and Technology Policy Officer, Verified Voting

Neal McBurnett
Independent Election Auditing Consultant and Developer

Jennifer Morrell
*Consultant
Former Deputy of Elections, Arapahoe County, Colorado
Former Election Director, Weber County, Utah*

Marian K. Schneider
*President, Verified Voting
Former Special Advisor to Governor Tom Wolf on Election Policy
Former Deputy Secretary for Elections and Administration, Pennsylvania Department of State*

Stephanie Singer
*Consultant, Verified Voting
Former Chair, Philadelphia County Board of Elections*

**** affiliations for identification purposes only**

These principles and best practices were written to guide the regulation and design of high-quality post-election audits. They were developed by an ad hoc group including former election officials, public advocates, computer scientists, statisticians, and political scientists. This version of the principles and best practices updates a previous version written in 2008 by Mark Lindeman, Mark Halvorson, Pamela Smith, Lynn Garland, Vittorio Addona, and Dan McCrea.

Table of Contents

Introduction 4
Principles for Tabulation Audits 7
Best Practices for Tabulation Audits 8
 1. EXAMINATION OF VOTER-VERIFIABLE PAPER BALLOTS..... 8
 2. TRANSPARENCY 9
 3. SEPARATION OF RESPONSIBILITIES 11
 4. BALLOT PROTECTION 12
 5. COMPREHENSIVENESS 13
 6. APPROPRIATE STATISTICAL DESIGN 14
 7. RESPONSIVENESS TO PARTICULAR CIRCUMSTANCES 16
 8. BINDING ON OFFICIAL OUTCOMES 17
 9. INVESTIGATING DISCREPANCIES AND PROMOTING
 CONTINUOUS IMPROVEMENT 18
APPENDIX: Audit Practicalities 19

Introduction

This document is meant to provide guidance to relevant legislative bodies, state and local election administrators and vendors.

Why Audit Elections?

A healthy democracy requires widespread trust in elections. In particular, people need to be sure that the official election outcomes match the will of the voters.¹ Election audits that examine voted ballots provide direct evidence that the people who take office and the ballot measures enacted were in fact chosen by the voters.²

Audits differ from recounts. Audits routinely check voting system performance in contests regardless of how close margins of victory appear to be.³ Recounts repeat ballot counting in special circumstances, such as when preliminary results show a close margin of victory. In most cases, audits require checking a small fraction of ballots, while a recount requires checking all ballots. Ideally, a post-election audit can lead to a full recount if necessary to correct the reported outcome.

Voices from across the political spectrum agree that we should be auditing our election outcomes. According to a 2018 Senate Intelligence Committee report, “States should consider implementing more widespread, statistically sound audits of election results. Risk-limiting audits, in particular, can be a cost-effective way to ensure that votes cast are votes counted.”⁴ The bipartisan Presidential Commission on Election Administration recommended that audits “must be conducted after each election, as part of a comprehensive audit program,” and specifically endorsed risk-limiting audits.⁵ The National Academies of Science, Engineering, and Medicine’s 2018 consensus study report on election security similarly recommended audits that “include manual examination of statistically appropriate samples of paper ballots cast,” and advocated implementing risk-limiting audits.⁶

¹ We will use “outcome” to refer not to specific vote totals, but to the legal and official consequences of an election, such as: which candidate will take office (outcome of a general election); whether a government will issue a bond (outcome of a ballot question).

² See *Evidence-Based Elections*, P.B. Stark and D.A. Wagner, IEEE Security and Privacy, Special Issue on Electronic Voting, 2012.
<http://statistics.berkeley.edu/~stark/Preprints/evidenceVote12.pdf>

³ We will use “contest” to refer to any ballot item (such as an election to public office or a ballot initiative) – not to a challenge to the results, as in some states.

⁴ <https://www.intelligence.senate.gov/publications/russia-inquiry>

⁵ <http://web.mit.edu/supportthevoter/www/files/2014/01/Amer-Voting-Exper-final-draft-01-09-14-508.pdf>

⁶ National Academies of Science, Engineering, and Medicine, *Securing the Vote: Protecting American Democracy* (National Academies Press, 2018), available at <https://www.nap.edu/catalog/25120/securing-the-vote-protecting-american-democracy>

About Tabulation Audits

Nearly all US votes today are counted by computerized voting systems. Such voting systems have produced outcome-changing errors through problems with hardware, software, and procedures.⁷ Errors can also occur in hand counting of ballots or in the canvassing of results. Even serious errors can go undetected if results are not audited effectively.

Well-designed and properly performed post-election tabulation audits provide solid public evidence for the initial outcome when it is correct – and an opportunity to recover gracefully when it is not. Good tabulation audits create resilience against damage from human error, system flaws or malicious interference, and should be applied routinely to any voting system.

A tabulation audit checks that the outcome of the election reflects the selections of the voters, as expressed on the ballots accepted for counting by the election authority. By “tabulation audit,” we mean more than just resumming numbers that represent votes. A tabulation audit also includes the separate, preliminary step of determining voter intent (did this voter vote for this choice in this contest?) from the marks on the ballot.

Tabulation audits involve people (auditors) physically examining and interpreting votes on paper ballots that people (voters) have had the opportunity to verify, and using those interpretations to check the computer (voting system) results. The benchmark of tabulation accuracy is what an accurate hand count of all ballots accepted for counting by the election authority would reveal. Additional measures, including additional audits, are needed to check that ballots have been appropriately accepted or rejected, and that the ballots have been preserved unchanged – no ballots added, removed, or altered. Many other aspects of election administration also can benefit from routine auditing, although we do not discuss such audits here.

⁷ In Wisconsin in 2016, the recount found that the Optech Eagle voting machines miscounted votes because they did not detect some of the inks or pencils used by the voters. (https://host.madison.com/wsj/news/local/govt-and-politics/state-to-end-use-of-ballot-counting-machine-that-had/article_7a087f85-8894-5foe-9d16-19920b3065ee.html) In Rhode Island in 2016, the voting machines’ initial result selected the wrong winner because “the scanners were only programmed to record one ballot style when a second was actually sent to the polling station. The initial unofficial results... were so lopsided that election officials questioned the outcome, and discovered the discrepancy.” (<http://www.providencejournal.com/news/20170914/vote-tally-audits-criminal-sentencing-overhaul-on-ri-lawmakers-agenda>) In Pottawattamie County, Iowa, in the June 2006 primary election for County Recorder, the original optical scan count showed challenger Oscar Duran defeating the incumbent, John Sciortino. A hand count showed that Sciortino actually had won handily; the scanners had been misprogrammed.

Best Practices for Tabulation Audits

1. EXAMINATION OF VOTER-VERIFIABLE PAPER BALLOTS

Audits require human examination of voter-marked paper ballots — the ground truth of the election. Voter-marked paper ballots may be marked by hand or by ballot marking device. Audits cannot rely on scanned images or machine interpretations of the ballots to accurately reflect voter intent.

- a. Paper ballots, whether marked by hand or by a ballot marking device, are easy for both voters and auditors to read or verify. They are durable and easy to handle during an audit.
- b. Ballots are designed to reduce ambiguity and to reliably reflect the intent of the voters. Care is taken to urge voters to confirm that the paper ballot reflects their votes as intended, whether they mark their ballots by hand or using a ballot marking device.
- c. The audit treats as authoritative only marks on paper that the voter could verify. It does not rely upon the accuracy of barcodes (including QR codes),¹⁰ images of ballots, electronically transmitted ballots, remade ballots or other unverified products of the election system. See box on page 9.
- d. The auditors do not know the machine interpretations or counts of the ballots they are auditing.

¹⁰ If some voters may verify their votes by “reading” barcodes (including QR codes) instead of human-readable marks or text, the implementation must allow voters to do so without relying upon any component of the voting system, and auditors, in addition to auditing the human-readable marks on ballots selected for audit, should also check that the barcoded information matches the human-readable marks.

- e. Human auditors interpret voter intent as recorded on the paper ballots, although technology may be used to assist and augment audits. Since audits help ensure the “software independence” of the election results,¹¹ care is taken to ensure and document software independence of the audit itself: no undetected change or error in any technology system used to assist with the audit will be able to cause an undetected change in the audit outcome. In no case is the vote-tabulating system a trusted component of the audit process. In particular, the ballot manifest must be created or verified independent of the voting system.¹²

Barcodes cannot be used for tabulation audits because the voters can neither interpret nor verify them. However, there may be other appropriate uses for barcodes in the election process, such as machine tabulation.

Images of ballots cannot be relied upon for tabulation audits, because the voter has no opportunity to verify the images and because images and other electronic evidence “can be altered by compromised or faulty hardware or software.”¹³ Images also may not match the paper ballots due to dust in the scanners, scratches in lenses, creases in paper ballots, voter marks in non-detectable ink and other causes. Using software to examine the images of the ballots can provide useful information. But software retabulation based on images cannot be considered a tabulation audit and will not offer robust assurance that the outcomes are correct.

Electronically transmitted ballots cannot be used for tabulation audits, because the paper ballots representing those submissions by electronic means such as fax, email or other internet delivery mechanisms have not been verified by voters. Electronically transmitted ballots are subject to many threats, including modification during transmission. These ballots must be accounted for in the audit calculations, but they cannot provide positive evidence for any particular election outcome. In other words, the audit will take into account the number of such ballots, but it will not assume that their indicated votes are accurate. See also Best Practice 5a.

Remade (or duplicated) ballots cannot be verified by the voter, so only the originals can be used in the audit.

¹¹ See Ron L. Rivest, *On the notion of “software independence” in voting systems*. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 366(1881):3759–3767, 2008.
(<http://rsta.royalsocietypublishing.org/content/roypta/366/1881/3759.full.pdf>)

¹² Small jurisdictions may be able to achieve this independence by hand; larger jurisdictions may need to use precision scales or other mechanical devices.

¹³ National Academies of Science, Engineering, and Medicine, *Securing the Vote: Protecting American Democracy* (National Academies Press, 2018), available at <https://www.nap.edu/catalog/25120/securing-the-vote-protecting-american-democracy>

2. TRANSPARENCY

Elections belong to the public. The public must be able to observe the audit and verify that it has been conducted correctly, without interfering with the process.

- a. Detailed auditing procedures are developed and published well in advance of elections, with reasonable opportunities for public comment. These include procedures for selecting contests and audit units, cataloguing the paper records and counting the votes. Similarly, algorithms used to determine when more units need to be audited and when the audit can end are published and subject to public comment.
- b. The public is given sufficient notice and access to observe key parts of the audit. The public is offered access to evaluate evidence of ballot protection, from ballot retrieval through manual examination, with reasonable opportunities for public comment. The public has sufficient access to witness the random drawing, ballot retrieval, and other audit procedures, and to verify that voter marks are interpreted correctly on the audited ballots. Election officials have the authority to prevent the public from hampering the proceedings.
- c. The public is provided with all necessary information to replicate all decisions and calculations made in support of the audit.¹⁴ The tabulated vote subtotals by audit unit (if such subtotals are used in the audit) and overall totals are published (presumably on the official elections website) or committed¹⁵, before the random selection of audit units, as is the ballot manifest that details how the ballots are stored. Other necessary information includes, when applicable, the random seed(s), the pseudorandom number generator (see footnote 23), the procedure for converting random numbers to audit units, and the auditors' interpretations recorded during the audit.
- d. Final audit results are reported to the public immediately and posted on the official elections website.
- e. Ideally, a public archive of the audit documents, reports and results is maintained indefinitely in the case of electronic records and for at least as long as the election certification documents in the case of paper records.

¹⁴ See Verified Voting's *Checking the Paper Record: A Guide for Public Oversight of Tabulation Audits* (<https://www.verifiedvoting.org/wp-content/uploads/2018/09/Checking-The-Paper-Record-Tabulation-Audit-Oversight-Guide.pdf>).

¹⁵ From the public's point of view, when voting system interpretations of individual ballots (or ballot "cards") are being compared to audit interpretations, it is most straightforward to publish cast vote records that report voting system interpretations of each vote on each ballot or card. In cases where protection of voter anonymity makes the straightforward approach problematic, cryptographic methods can be employed to commit the cast vote records while preserving anonymity. Note, however, that more complicated schemes create an additional barrier to public verification.

3. SEPARATION OF RESPONSIBILITIES

Neither the policy and regulation setting for the audit, nor the authority to judge whether an audit has satisfied those regulations, shall be solely in the hands of any entity directly involved with the tabulation of the ballots or the examination of ballots during the audit.

- a. Where state or local election officials are directly involved in ballot tabulation or handling ballots during an audit, some other entity or entities establishes the high-level audit policies — such as how to determine the contests and number of audit units to be audited, and how to select the particular audit units. This entity might be the legislature, an existing state agency (e.g., the Department of State or the Auditor's Office), or a new independent commission.
- b. When an official directly involved with the audit is a candidate for election, that official considers recusal from audit-related duties to the extent possible.
- c. Both high-level audit policies and detailed procedures are determined in consultation with the officials who directly participate in the tabulation and auditing of ballots.

6. APPROPRIATE STATISTICAL DESIGN

Audits should produce and scientifically assess evidence about tabulation accuracy while making efficient use of available resources. A risk-limiting audit (RLA) with a small risk limit assures a large chance that an incorrect outcome will be detected and corrected.

- a. Audit design considers current procedures and equipment²² (e.g. post-election deadlines and whether the voting system supports particular methods of auditing), the variety of contests to be audited, and priorities for how rigorously to audit the various contests. Matching anticipated workload with available time and resources can involve subtle choices and long-term planning.
- b. Statistical experts knowledgeable about post-election audits participate alongside stakeholders in designing the audit process.
- c. Audit units are selected using appropriate publicly verifiable random sampling methods.²³
- d. Risk-limiting audits are implemented as widely as is considered feasible given the current equipment. (See box on page 15 for information on RLAs.)
- e. RLAs of contests that span multiple jurisdictions, such as governor or mayor of a city that crosses county lines, are coordinated across jurisdictions or at the state level.
- f. If audits that are not risk-limiting are combined with, or used instead of, RLAs, they use valid risk-measuring designs, in order to assess the strength of the audit evidence that the reported outcomes are correct.
- g. In comparison audits (see appendix), audit units are defined to be as small as the voting equipment supports: single ballots (or cards) are most efficient; smaller batches are preferable to larger batches; individual voting machines are preferable to entire precincts; and individual early voting machines daily totals are preferable to entire early voting sites.
- h. If auditing begins before all the ballots have been tabulated (which may be reasonable, e.g., when absentee or provisional ballots are processed late in the canvass), care is taken to incorporate the later-tabulated ballots completely and correctly into the audit process.

- i. Criteria are specified for the circumstances under which additional audit units should be audited, and how many — or, if applicable, under what circumstances a full hand count should be conducted.

Risk-limiting audits are designed to ensure strong audit evidence that a reported outcome is correct — if the outcome is indeed correct. (“Outcome” refers to consequence, such as who won; see footnote 1. The “correct outcome” means whatever a full hand count would show.) If a full hand count would show a different outcome than the initial tabulation, RLAs have a large chance of leading to a full hand count that corrects the reported outcome.²⁴ The corresponding predetermined small maximum chance that an RLA of an incorrect outcome will *not* lead to a full hand count is called the risk limit. Beyond providing high assurance in specified contests, RLAs can reduce overall audit burden by allocating more resources to closer contests where more checking is needed to validate outcomes.

Risk-limiting audits of some contests can be combined with non-risk-limiting audits of others. For instance, a state could decide to audit all statewide contests to a 5% risk limit, all congressional and state legislative contests to a somewhat higher risk limit, and other contests (1) as they happen to appear on ballots already selected for audit (“opportunistic auditing”), (2) through some random selection of additional contests to audit, not necessarily to a risk limit, or (3) for a fixed number of ballots or a percentage of ballots.

The sample size for an RLA will depend on the audit method (see appendix), the margin of victory, and other factors, including what the audit finds as it progresses. Smaller margins of victory require auditing more audit units to attain a given risk limit; smaller risk limits require auditing more audit units. Small contests typically require auditing a larger *fraction* of ballots than large contests.

²² Some principles for voting system design relevant to audits are available at Verified Voting (<https://www.verifiedvoting.org/voting-system-principles/>).

²³ One sound approach is to have many stakeholders and observers make a total of 20 rolls of ten-sided dice to generate a random “seed” for a well-designed pseudo-random number generator (PRNG). Statistical experts should be consulted on the specifics of mapping the sequence(s) of random numbers to particular audit units.

²⁴ RLAs are designed never to overturn a correct outcome: Only a full hand count can change an outcome.

7. RESPONSIVENESS TO PARTICULAR CIRCUMSTANCES

Audit processes must include a way to respond to circumstances that come to light affecting particular devices, ballots or contests.

- a. Factors such as major election-day problems or preliminary results that deviate significantly from historical voting patterns might focus interest in particular sets of ballots, “targeted samples.” Such targeted samples may be selected by candidates, issue committees, parties, election administrators, or others as provided by regulation.²⁵
- b. A requested targeted sample may be used either in conjunction with a random audit, or by itself for a contest not selected for audit.

²⁵ One way to contain the cost of targeted samples is to require that the requesting candidate or group pay for additional ballots to be audited. Such a law was passed in Minnesota in the 2008 legislative session; under this law, the requesting candidate is refunded by the jurisdiction conducting the recount if the recount leads to the initial result being overturned.

8. BINDING ON OFFICIAL OUTCOMES

Audits, including any full hand counts that result, must be completed in time to change official outcomes if hand counts so indicate.

- a. Because audits can lead to 100% hand counts, audit and recount provisions should be appropriately harmonized.
- b. The election calendar may have to be adjusted to provide time to complete the audit before results are finalized.

9. INVESTIGATING DISCREPANCIES AND PROMOTING CONTINUOUS IMPROVEMENT

The data gathered from post-election audits should be analyzed and used to continuously improve voting processes.

- a. All discrepancies are recorded, their causes are investigated, and they are categorized by apparent cause — regardless of whether they raise doubts about outcomes. The broad categories include: (1) Machine and election process errors (e.g. ballot programming error, lens scratch, ballot crease interpreted as a mark); (2) Audit errors (e.g. wrong ballot retrieved, miscount in audit); (3) Computer misinterpretations of voter intent (e.g., mark in target area not intended as vote, overvote intended as a correction).
- b. The discrepancies found are compared to historical results. Recommendations to reduce future discrepancies are developed and implemented.
- c. Suggestions and action plans are developed for reducing future discrepancies, including better ballot design and instructions, improved training for officials conducting the initial tabulation or the audit, etc.

APPENDIX: Audit Practicalities

Election traditions, laws, administrative structure and voting systems vary widely, and they all affect tabulation audits. As more jurisdictions institute audits, or transition from traditional percentage audits to risk-limiting audits, it is helpful to consider the interplay between various logistical and administrative choices and the audit process. The purpose of this appendix is to present some logistical details of the audit process, in order to ease the integration of audits into existing election law, policy and administration. This discussion is selective, not comprehensive.

Audits generally use one of three broad methods:²⁶

Batch-level comparison: Presently, most audits are *batch-level comparison audits*, where some batches (often corresponding to individual precincts or voting machines) are randomly selected. The votes in each selected batch are audited by hand, and the audit counts are compared to the reported tabulation subtotals for the selected batches, as published before the random sample is drawn. Auditors must check that the batch subtotals — including all batches, not just the selected batches — add up to the reported vote totals. (See best practice 2b and its footnote.)

Ballot-level comparison: More efficient, when feasible, is a *ballot-level comparison audit*, in which a sample of individual ballots (or ballot cards) are sampled, audited, and compared to how each ballot was interpreted by the voting system. Today, many voting systems do not support ballot-level comparisons, but most recently developed systems do in central count situations. To support a ballot-level comparison audit, a voting system must produce a cast vote record (a record of the machine interpretation of the vote selections in every contest) for each ballot, with enough information to pair the cast vote record with the physical ballot from which it was created. Auditors must check that the vote totals calculated from the cast vote records match the reported vote totals.

Ballot polling: In *ballot-polling audits*, individual ballots are sampled and audited, and the audited vote totals are used to assess the correctness of the outcome, much as an election poll predicts outcomes. Ballot polling does not directly identify misinterpreted ballots or batches, and therefore cannot be used, in general, to pinpoint system or process problems. But in some cases it is the easiest method for verifying that specific contest outcomes — for instance, who won, or whether a referendum passed — are correct.

There are three common ways to determine the sample size of the audit:

- Fixed percentage: Select a fixed percentage of units to audit.²⁷

²⁶ These methods are described in more detail in A Gentle Introduction to Risk-Limiting Audits (<https://www.stat.berkeley.edu/~stark/Preprints/gentle12.pdf>).

²⁷ For instance, in New York, each county audits 3% of its voting machines or systems.

- Tiered: The percentage or number of units to audit varies depending on the margin of victory: the smaller the margin of victory, the more ballots to audit.²⁸
- Risk-limiting: The sample size depends on (among other things) the margin of victory, the set risk limit, and what the audit finds.²⁹

Risk-limiting audits are designed to examine enough ballots to provide strong evidence that outcomes of contests are correct – or to correct the outcomes, via full manual recounts, if they are wrong. (In practice, risk-limiting audits can audit larger samples than the risk limit would require, producing additional evidence about vote tabulation accuracy.) Other methods may audit far fewer, or far more, ballots than necessary to check particular outcomes. Some implementations of these methods provide rules for expanding the audits based on the results, which *could* lead some incorrect outcomes to be corrected. Many implementations provide no means to correct incorrect outcomes.

For batch-level comparison audits, for efficiency, the audit units should be as small as possible. For polling-place counted ballots, this means using the smallest unit available where the group of ballots can be associated with a reported result. This unit may be a precinct, an individual voting machine, or an individual voting machine on a particular day of early voting. It also is possible to audit arbitrary batches of ballots, in which case complete subtotals for every batch must be reported prior to the audit.

Ballots sometimes consist of multiple cards (sheets of paper). For auditing purposes, separate cards of a ballot from an individual voter do not need to be kept together and they are often best audited independently.

Sorting can sometimes lead to efficiencies. For example, sorting centrally counted ballots by precinct or ballot style, to separate out contests such as mayor of a small town which appear on only a small fraction of the ballots, can permit a risk-limiting audit to use a smaller sample size. If the audit relies on the sorting, then the sorting must be done – or confirmed – independently of the tabulation system.

Voting systems that imprint an identification number onto voted ballots as they are scanned can make a ballot-polling or ballot-level comparison audit more efficient by cutting down on the time it takes to confirm that the ballots pulled for examination are indeed the ballots determined by the random sampling. In some cases, such as in-precinct voting, where ballots may get shuffled, imprinting may be the only way to efficiently match a ballot to the CVR. Any imprinting needs to preserve ballot anonymity.

Auditing contests that combine results from separate jurisdictions – contests such as governor or US Senate or a ballot question in a town that is split between jurisdictions – requires cooperation and coordination between jurisdictions. Uniformity of process and voting technology across jurisdiction lines can simplify and smooth the audit.

²⁸ For instance, in New Mexico, the sample size ranges from 4 to 165 precincts depending on the reported margin: <https://law.justia.com/codes/new-mexico/2016/chapter-1/article-14/section-1-14-13.2/>, Table 1.

²⁹ As of August 2018, Colorado has mandated and implemented risk-limiting audits statewide; Rhode Island has mandated risk-limiting audits, but not implemented them. For details on these and other state audit requirements, you can consult Verified Voting's State Audit Law Database at <https://www.verifiedvoting.org/state-audit-laws/>.

Risk-limiting audits are generally conducted in one or more rounds. There is no hard and fast rule for choosing the number of ballots to be audited in each round. The larger the number of ballots, the more likely the audit will end in that round. Conversely, the smaller the number of ballots in each round, the less likely the audit will examine more ballots than strictly necessary. Logistics of ballot retrieval and coordination between different jurisdictions are worth considering as the choice is made. In unusual cases, it may at some point be easier to conduct a full hand count than to expand the random audit sample.



