ADEQ Arizona Department of Environmental Quality

THE ARIZONA WATER QUALITY INDEX

The Arizona Water Quality Index:
A Communication Tool for Water Quality Summaries

ADEQ has adopted the approach of the Canadian Water Quality Index, adapting it to Arizona's unique data assessment needs and the arid ecosystems and hydrologic regimes of the American Southwest. In following the Canadian model, Arizona is affirming the suitability of a baseline comparative model for its needs, wherein water quality benchmarks for variables serve as the baseline for data comparisons in index calculations. The WQI and associated tools described below gives ADEQ, interested partners, and the public new capabilities and insights into the status of our state's waterways.

Purpose and Value

An index is a metric that distills the complexity of data into an essence that can be quickly evaluated. The Arizona Water Quality Index (WQI) serves two purposes. The primary function is to apply rigorous scientific inquiry and analysis to water quality standards and other conditions within a body of water. The secondary function is as a communication tool, informing the general public, active stakeholders, decision-makers, and water quality analysts about water quality in the state.

The WQI combines the technical details of water quality ─ concentrations, loads, discharges and flow, water quality standards and designated uses ─ to arrive at one succinct and informative number that can then be analyzed statistically, historically and spatially. All variability across constituents is standardized and put on the same scale for analysis; a strong benefit that allows for asking and answering deeper questions about the data and enabling the user to draw conclusions which were previously obscure or unavailable. The WQI can also be used to evaluate change in water quality over time. If care is taken to ensure the technical details of the data sets are consistent in composition and durations, trends with statistical significance can be determined with a high degree of reliability.

The WQI also excels as a tool for succinct communication with the public and stakeholders. Active and engaged stakeholder involvement is crucial to realizing on-the-ground improvements in water quality. The prerequisite to stakeholder involvement is the establishment of a clear and common language in terms that stakeholders can easily understand, engaging their interest and ideally motivating them to contribute to improvement efforts. The WQI serves as that common language. It reduces the complexity of water quality data and analysis into a much simpler form for broad comprehension by all parties. In

addition to the WQI, ADEQ has developed two related indices – the analyte water quality index (AWQI) and the index stability score (ISS).

Water Quality Index

The WQI considers the:

- Percentage of distinct chemical parameters exhibiting exceedances relative to the population of distinct chemical parameters (scope),
- Percentage of water quality exceedances relative to the total population of individual water quality results (frequency), and
- Magnitude of excursions over the most restrictive water quality standard (amplitude).

Three essential elements must be in place for an index number to be generated:

- The method, consisting of the mathematical models/formulas subsequently presented,
- A data set of core parameters and any impairment analytes, and
- Water quality standards serving as the benchmarks by which these data are evaluated.

Measurements that are meeting water quality standards do not penalize the WQI. Where measurements are not meeting (exceed) water quality standards, the frequency, magnitude, and, scope of those exceedances are considered in the calculation.

Consistency in the composition of data sets is assured by limiting index calculation to data sets comprised of impairment analytes for the water of interest and Arizona's *core parameters*. Core parameters are a set of water quality variables established to ensure that the most important variables for each designated use (i.e., those with frequently observed exceedances, critical toxicity, and routinely sampled parameters) were considered in all assessment evaluations. The adoption of the core parameter data set as the WQI basis establishes a consistent framework for the employment of the WQI.

Arizona water quality standards generally serve as the basis for the criteria considered in the index calculations. An exceedance of the water quality standard decreases the index from a top score of 100 simultaneously in three distinct ways:

1. one of *n* water quality variables showing adverse water quality impacts in the *scope* term (F_1) of the calculation,
2. one of the total number of results in the data set showing adverse impacts in the *frequency* term (F_2) of the calculation, and
3. the magnitude of the exceedance is tabulated relative to the standard for the *amplitude* term (F_3) of the index calculation.

$$General\ WQI = 100 - \left(\frac{\sqrt{{F_1}^2 + {F_2}^2 + {F_3}^2}}{1.732} \right)$$

The index follows a modified and streamlined methodology specifically developed for it and thus may occasionally generate results that do not necessarily agree with the assessment status of the reach or water body.

Results are considered only once relative to the most stringent standard. Visit-specific hardness levels are considered for dissolved metals calculations, with each result compared to the standard applicable for the reported hardness value for that sample. Chronic standards are used for comparison for aquatic and wildlife uses of cold, warm, and effluent-dependent water streams or sites. Acute dissolved standards are used for comparison for the ephemeral aquatic and wildlife designated use.

Analyte Water Quality Index

The scope, frequency, and amplitude components as described in the WQI can be modified to yield an index number specific to a given analyte. This modification is called the Analyte Water Quality Index (AWQI). This approach is valuable in assessing the severity of individual impairments on the same 0 to 100 scale. The scope component of WQI calculation drops out, and the AWQI is determined only with the frequency and amplitude components. With preparatory calculations the same as used for the WQI for the retained sub-indices, the AWQI is then calculated:

$$AWQI = 100 - \left(\frac{\sqrt{{F_2}^2 + {F_3}^2}}{1.414} \right)$$

Where F_2 is restricted to the number of exceedances and results for the individual analyte alone and F_3, likewise, is calculated based on only the individual analyte being considered.

Index Stability Score

The Index Stability Score (ISS) provides a necessary adjunct to WQI and AWQI results. A noted limitation of WQI reporting in its first several years of existence was the inability of users to assess how much confidence to put into the number reported. A 100 reported for a site with two data points was given the same credibility as a 100 reported with a long historical record of water quality data. For example, many historical sites in Total Maximum Daily Load (TMDL) reach reporting had calculated WQIs of 90 or better based on three or fewer data points, giving a misleading positive impression of water quality in areas of known impairment. This lack of discrimination between the robustness of data sets posed a problem, since WQIs based on small data sets are extremely volatile and subject to wide fluctuations, even with minimal additional data. The ISS captures and reports on how stable or volatile a reported WQI may be.

The final ISS formula follows the model of the general WQI formula:

- Where C_1 is the Statistical Sufficiency sub-score , and
- C_2 is the Natural Variability sub-score, and
- C_3 is the Data Representativeness sub-score.

$$ISS = L_c * p_G * \frac{\sqrt{C_1^2 + C_2^2 + C_3^2}}{1.732}$$

The additional terms L_c and p_G comprise a restricting term to constrain index calculation for data sets smaller than ten records and a coefficient equal to the percentage of core parameter variables in the set respectively.

Like the WQI, the ISS is represented on a scale of 0 to 100. An ISS of 100 represents the highest possible score. It conveys high confidence of a stable and reliable score (i.e., not volatile), while 0 indicates no confidence should be placed in the score stability (extreme volatility). Indices that are stripped of their restricting terms for inadvisable use automatically revert to an ISS of 0. This precautionary action serves as a quality assurance and quality control (QA/QC) measure. As scores, there can be no expectation of reliability when using the values the index formula may generate.

Summary

There are several major features and advantages to using the WQI, including:

- A simple and easily understandable scale of 0 to 100, requiring only a general orientation as to what constitutes a top score.
- Scalability in terms of spatial application; when designated uses are consistent across all reaches, the WQI can be applied to a single site, a stream reach, or an entire stream.
- Wide temporal flexibility, as the WQI can be calculated for any period of interest, provided enough data is available to generate indices that satisfy data-adequacy criteria.
- Sub-metrics that can be captured and reported for subsidiary analyses (e.g., the percentage of data exceeding standards, whether all core parameters have been captured in a set, how much an average excursion exceeds the standard by, etc.).
- Creation and use of an analyte-specific WQI, with a modified mathematical basis, to assess the degree of severity of any individual variable's impairment.

For More Information

- The Arizona Water Quality Index: A Communication Tool for Water Quality Summaries | https://static.azdeq.gov/wqd/reports/wqi_18.pdf
- The Arizona Water Quality Index: Trends and Exploratory Data Analysis 1989 - 2019 | https://static.azdeq.gov/wqd/reports/wqi_20.pdf
- Index Stability Score: An adjunct tool for Water Quality Index Reporting | https://static.azdeq.gov/wqd/reports/index_20.pdf