Real-time QA/QC

Continuous Quality of the LiquID Station

This document outlines ZAPS Technologies' strategy for managing non-process variability and demonstrates how these automated processes work over both long and short timeframes to maintain reliable, repeatable, real-time data. Our quality management chain forms a quality assurance scaffolding that supports every LiquID™ station HMA reading. These processes are ongoing, integrated readings which are used to evaluate station performance, identify external issues impacting data continuity and evaluate the quality of maintenance being performed. This active management process for handling variability extends from our instrument design process through the minute-by-minute generation of real-time water quality data.

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Abstract

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ZAPS Technologies, Inc.

ZAPS Technologies, Inc. creates real-time, water quality monitoring equipment to aid professionals involved in water treatment, water analysis, and environmental analysis. We apply solid-state optical techniques requiring no chemicals, reagents, operators or routine maintenance, and apply these techniques in a framework of continuous, integrated quality assurance processes. This strategy results in equipment that runs unattended 24/7 while producing thousands of tests per day on flowing water; from raw wastewater to finished drinking water (rivers, lakes and marine environments).

Online Monitoring – The Promise

Treatment plants, much like rivers, are influenced by natural and societal patterns that, when monitored continuously, lead to identifiably regular and predictable daily, weekly and seasonal cycles. These cycles generate the pulse of our water systems, and through real time online methods we now have an even greater ability to monitor these, the vital statistics of our water processes. Process efficiencies, overall treatment quality and the regulatory approach can be enhanced by knowing these patterns and recognizing when unpredicted deviations occur. Online monitoring allows operators to focus on the question of what drives these patterns (and anomalies) in their processes.

Because online, continuous measurements run automatically, water quality managers need not devote resources to manual sample collection and processing. Rather, these resources can be focused more directly on protecting human health and the integrity of watersheds and aquatic ecosystems by facilitating greater process control while enabling more timely and effective enforcement of environmental laws and by ensuring compliance with wastewater treatment regulations.

Keys:

- **Direct measurements, no sample alteration** (adulteration and/or preservation): No surrogates (bacteria, chemical processes, etc), no filtration, no handling.
- **Observe compounds in their natural matrix** (in time and location)**:** Measure immediately, and at the point of interest.
- **High definition data available online:** Millions of readings combined with integrated quality management processes build statistical strength to better characterize complex matrices. Enable control systems efficiency and oversight with real time data.

The three keys listed above lead to an **increased commitment to water efficiency** achieved by deploying water professionals to high value activities such as process oversight; prevent, detect and respond.

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A continuous, accessible process enables more timely and effective enforcement of environmental laws to ensure compliance with regulations on drinking water purity and wastewater effluent discharge.

An optical approach: 'HMA' and the LiquID

Hybrid Multispectral Analysis (HMA) is an optical approach to online monitoring which uses a combination of *in situ* fluorescence, absorption and scattering measurements in a single flow-cell to characterize chemical bonding and molecular structure continuously over time.

Hybrid Multispectral Analysis (HMA) is the hybridization of three optical approaches

- Light Absorption
- Light Scattering
- Light-induced Fluorescence

These three types of optical measurements are applied at multiple wavelengths from the deep UV through the Visual portions of the light spectrum. Finally, data from these three types of optical measurements are automatically analyzed and interpreted.

The HMA approach benefits from the speed and reliability of decades old spectrophotometric technology combined with rapid modern computational and communication technology to measure, analyze and report matrix characterizations. Thousands of readings are taken in each cycle to produce a reported parameter value approximately every two minutes.

The ZAPS Technologies' LiquID is an industrialized and fully automated machine developed around the HMA approach. The machine itself brings additional technology into the process such as digital valves that allow for automated cleanings and internal calibrations to be performed without human intervention and at an appropriate frequency for the rate at which data is being generated (i.e. higher sampling frequency – higher calibration frequency).

Three of the Benefits:

- **Continuous Data Record:** Readings every 2 minutes with embedded, automated calibration validation.
- **Efficiency:** Allow permit-holders to focus on their business while increasing awareness of the regulatory impact of their processes.
- **Direct measurement:** Characterize complex water matrices at the molecular level.

As you will see throughout this paper, our Quality Management processes match our scientific approach through its continuous and real-time nature.

Regulatory clarity: Benefits of real time quality management

Benefits of online, continuous monitoring in general and the HMA method in particular are significant and have the potential to beneficially impact the management of our water resources. When these approaches are combined with continuous quality assurance and control processes, they result in many benefits including:

- **Direct, Rapid and Reproducible:** Increases the accuracy and reliability of water quality monitoring because it directly measures the chemical bonding and particulates in the sample stream- instead of inferring their presence by indirect/surrogate, time-consuming, error-prone and labor-intensive means.

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- **Continuous Data Record:** By running continuously, automatically, and on-line, it allows water quality managers to focus their efforts more directly on protecting human health and the integrity of watersheds and aquatic ecosystems- instead of on manual sample collection and processing.
- **Enhancement of Regulatory Reporting:** Improved quality and depth of reports generated in less time. Drawing from large digital datasets, available on demand, reports can be automatically generated and sent electronically. It enables more timely and effective enforcement of environmental laws and ensuring compliance with regulations on drinking water purity and wastewater effluent discharge.

Real-time data combined with real-time quality assurance and control results in data which can be relied upon immediately for use in process control and – ultimately – to provide regulatory clarity by tying the processes in the water matrix directly to the real-time parameter data. This creates a closed feedback loop between real-time data and the process itself.

Real-time QA/QC

Quality assurance (QA) and quality control (QC) are decades-old concepts. Generations of experts have studied methods for applying QA/QC to various processes. At ZAPS Technologies, our approach involves applying these time-tested practices to our monitoring instrumentation. As we outline our approach, we have defined these two terms by the following aspects:

Quality Assurance	Quality Control
Control of Process	Control of Product
Proactive	Reactive
Prevent errors from entering dataset	Identify potential errors in the dataset

In this sense, Quality Assurance – proactive control of the process – becomes our focus and responsibility as an instrumentation manufacturer. Further, as a proactive aspect, the controls that we apply to prevent bad data from being generated reduce the QC burden on the customer which minimizes the amount of time between the generation of data and the point at which that data can be used for process control. This is a critical step for realizing the full potential of real-time data acquisition.

Our approach to generating quality data was developed while keeping in mind the needs of the end user. As documented by Wang, Storey and Firth in their paper, "A framework for analysis of data quality research"[4], the most important aspects of data for information consumers are:

- quality
- completeness
- consistency and
- accuracy.

These dimensions are highly important in ensuring that the end user is presented with data that can be relied-upon for decision-making activities.

The remainder of this paper describes ZAPS Technologies' view that an aggressive and continuous QA/QC approach provides the necessary structure required for maximizing data continuity and minimizing post processing; key variables for delivering real-time water monitoring data that meets the needs of the information consumer.

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An Introduction to ZAPS Real-Time QA

Throughout this document we use UVA measurements to demonstrate the impact of our continuous QA processes. Although the HMA approach on the LiquID station is able to monitor many parameters, UVA is a straight forward optical parameter ideal for direct comparison between the HMA QA/QC approach and the laboratory method described in EPA 415.3. Use of this parameter focuses on the application of our QA/QC processes rather than on differences between the measurement methods themselves. For all other LiquID HMA measurements (e.g. BOD, Free Chlorine, *E. coli*, etc), the same QA process described in this document is applied behind the scenes to ensure that a rigorous quality framework backs all of the LiquID parameters. Information on other parameters can be found online at www.zapstechnologies.com.

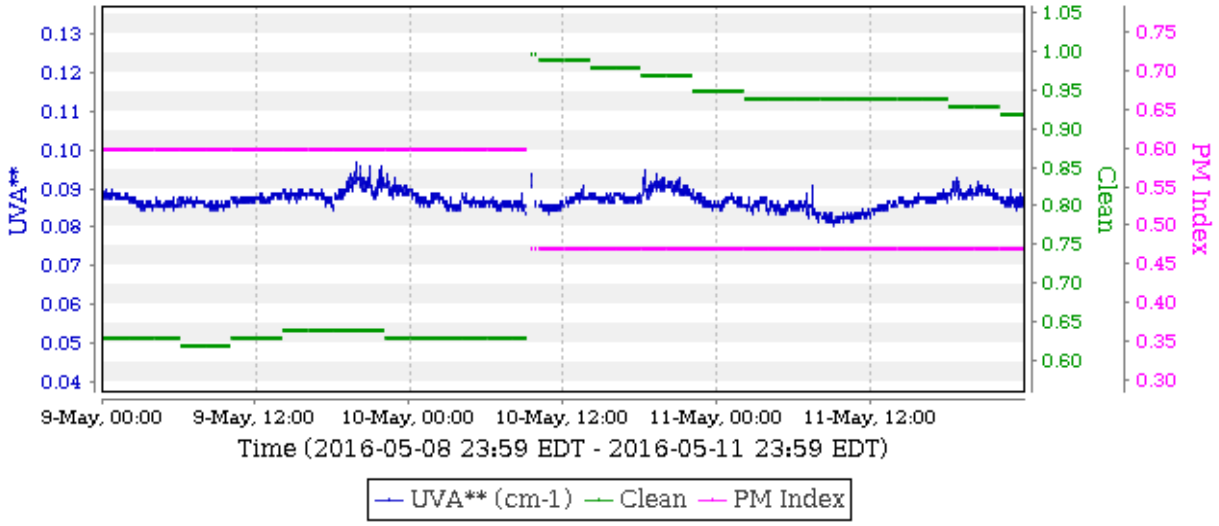

Figure 1: 3-day LiquID station WUI screenshot - UVA, Clean, PM Index in North American Reservoir

The graph above is a screenshot from the Monitor tab of ZAPS Technologies' Web User Interface (WUI). It shows data spanning 3-days in a source water environment. This graph displays the UVA parameter output along with two of our contextual QA parameters, Clean and 'PM Index'.

Clean and 'PM Index' are both customer-viewable parameters designed to visually present the active QA processes operating in the background to produce a reliable parameter output. They are both reflections of the impact of internal and external variables on the total photon budget available for making measurements, but they differ in the timeframe and source of decay that they reflect.

'Clean' is a measurement of short-term fouling that is driving loss of light. Depending on the environment the instrument is operating in it is evaluated roughly every one to four hours and commonly reflects the impact of variables such as biofouling or other sample-derived plating of the optical surfaces. Under normal conditions, the system uses a series of automated cleans to minimize or slow the occurrence of the fouling and a series of automated stabilization to adjust for any fouling that remains. Because simple human intervention or maintenance is capable of removing the effects of fouling, these short-term processes can be reversed as frequently as deemed necessary for any application or water matrix of interest. As shown in the graph, this parameter is reset during the 15-20 minute manual clean process during which the operator removes the fouling from the system's two optical surfaces. For a more detailed description of our bio-fouling management the reader is directed to the Biofouling management section of the paper 'Online Optical Monitoring : Hybrid Multispectral Analysis of BOD & cBOD' - LINK.

By contrast, the 'PM Index' is a measurement of long term decay such as aging of the instrument's flash lamp. The rate of this long term decay is reasonably predictable, happens over months-years and can only be effectively evaluated in the

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absence of short-term impacts. As such, you will notice that it is only re-calculated immediately following a manual clean, when short-term decay is verified to be at a minimum. Because the data feeding 'PM_Index' is generated and evaluated only following manual cleaning it provides a means to evaluate both the successfulness (or quality) of the maintenance performed while also tracking the rate of the long term degradation occurring within the system. As demonstrated in Figure 2, this decay is also reversible through more involved but far less frequent preventative maintenance activities which include flash bulb replacement.

Zooming out from this 3-day view to a 2-year record this quality assurance scaffolding can be seen alongside the data as generated during this period. During these two years, 11 manual cleanings were performed on the instrument and – as shown in the large increase in the pink 'PM Index' parameter in August of 2015, a single scheduled preventative maintenance service. Meanwhile, during this period of time the LiquID station generated over 470,000 UVA readings. The only traditional QA activities during this period were the completely automated calibration verifications performed by the LiquID station.

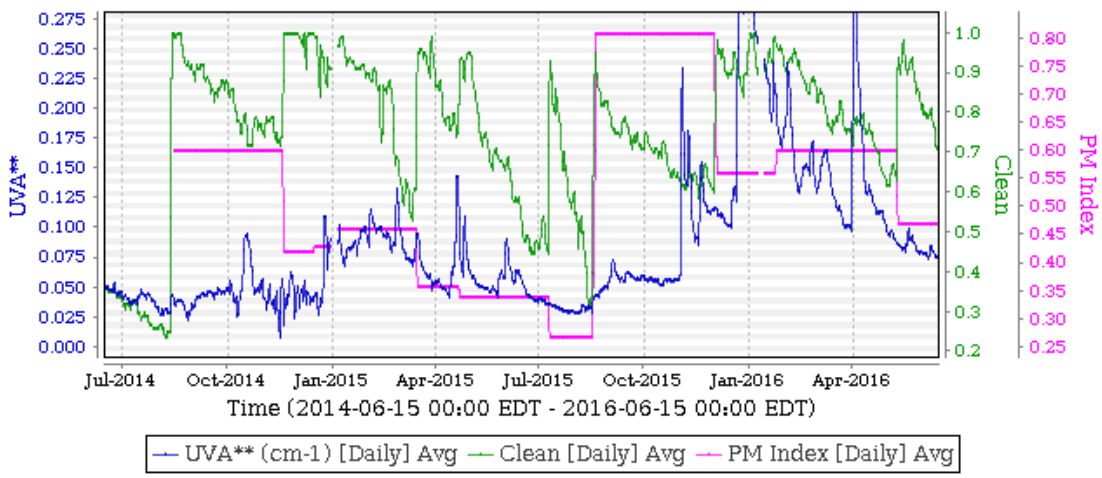

Figure 2: 2-year LiquID station WUI screenshot - UVA, Clean, PM Index in North American Reservoir

In the following graph, the Clean and 'PM Index' parameters have been removed and the 2-year UVA record has been supplemented by 441 grab sample results as entered into the LiquID station WUI grab sample tracking functionality by customer lab personnel. The LiquID station UVA data has been plotted as a daily average and consists of 472,527 real time UVA measurements. The resulting graph, with R^2 of 0.91, is a testament to the strength of this type of automated QA process in favorable contrast to the traditional lab QA method which relies upon manual QC steps to be performed during each lab reading.

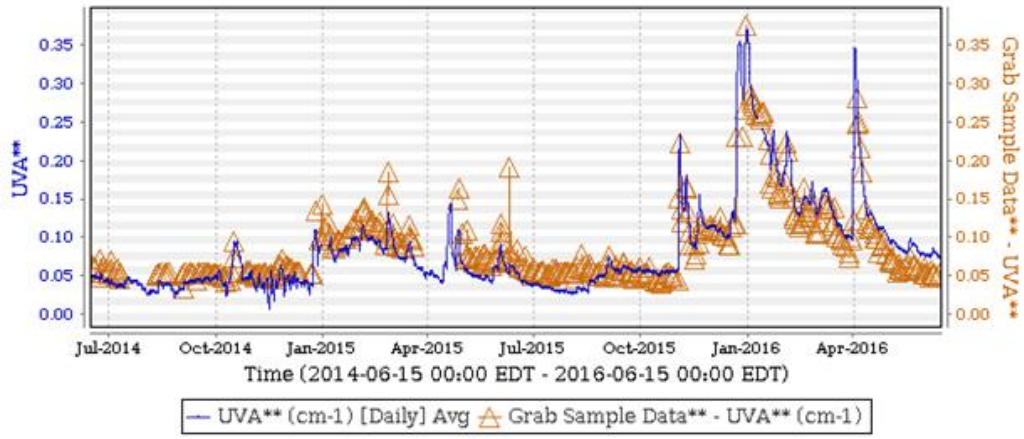

Figure 3: 2-year LiquID station WUI screenshot. Comparison of LiquID station daily average UVA data and Lab UVA data.

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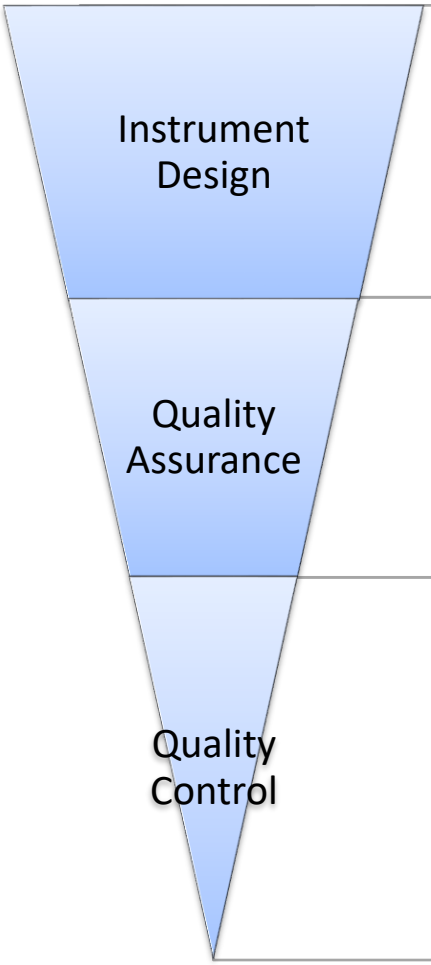
ZAPS Quality Management Chain

ZAPS Technologies' quality management chain forms a quality assurance scaffolding that supports every LiquID station HMA reading. Our quality processes are ongoing, integrated readings which are used to evaluate station performance, identify external issues impacting data continuity or evaluate the quality of maintenance being performed.

All Variability

This active management process for handling variability extends from our instrument design process through the minute-by-minute generation of real-time water quality data.



Eliminate: Designed for Real-time measurements, in the design aspect of our instrumentation we attempt to eliminate as many potential sources of variability as possible. This includes variation such as those driven through the use of techniques including – but not exclusive to – reagents, biological seeds, gravimetric processing, combustion, filtration and dilution. These sources of variation are eliminated during the design process and are therefore do not impact the potential future data generated by the LiquID station.

Mitigate: However, not all sources of variation can be eliminated, and in our Quality Assurance automated processes we attempt to further mitigate remaining sources. For example, biofouling cannot be entirely eliminated through design and is a potential source of variation present in the LiquID station. However, automated cleaning and calibration processes are capable of mitigating and tracking the impact of biofouling on our measurements enabling further management of the accumulation of this variation.

Monitor: The variation mitigated and monitored through our active QA processes is visually represented by the customer-viewable parameters Clean and 'PM Index', but these visual representations only represent a few percent of the measurements used by the software to fully track both short-term and long-term degradation in the system. The complete suite of measurements extends our QA approach across the UV/VIS spectrum providing a robust characterization of the remaining sources of variability. In their totality, these form the foundation on top of which degradation is quantified, managed and monitored to provide a real-time quality context for every data point generated by the LiquID station.

Real-time Data

Report: Finally, at the end of the Quality Management Chain, both real-time data and the automated QA processes are reported in a manner that they can be easily interpreted and used to support managerial evaluations or regulatory audits. An aggressive real-time QA/QC approach ensures output from the LiquID station is reported with a high degree of certainty and provides a contextual means that facilitates its immediate use.

QA – Station Status Analysis – Wastewater

The previous sections in this document have focused on the QA parameters most closely associated with maintaining data quality as viewed on the 'Monitor' tab of the web user interface (WUI). These data are an important component of the overall approach and provide a good measure for people who interface with the data regularly or who are dedicated to maintaining the instrumentation. However, this view alone does not adequately describe or summarize the ongoing,

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integrated nature of the QA readings or how they can be used to further evaluate station performance, identify external issues impacting data continuity or evaluate the quality of maintenance being performed. Using the QA data generated for these purposes requires a different view which is described in the next section and is presented to the customer via the "QA/QC" tab of the WUI .

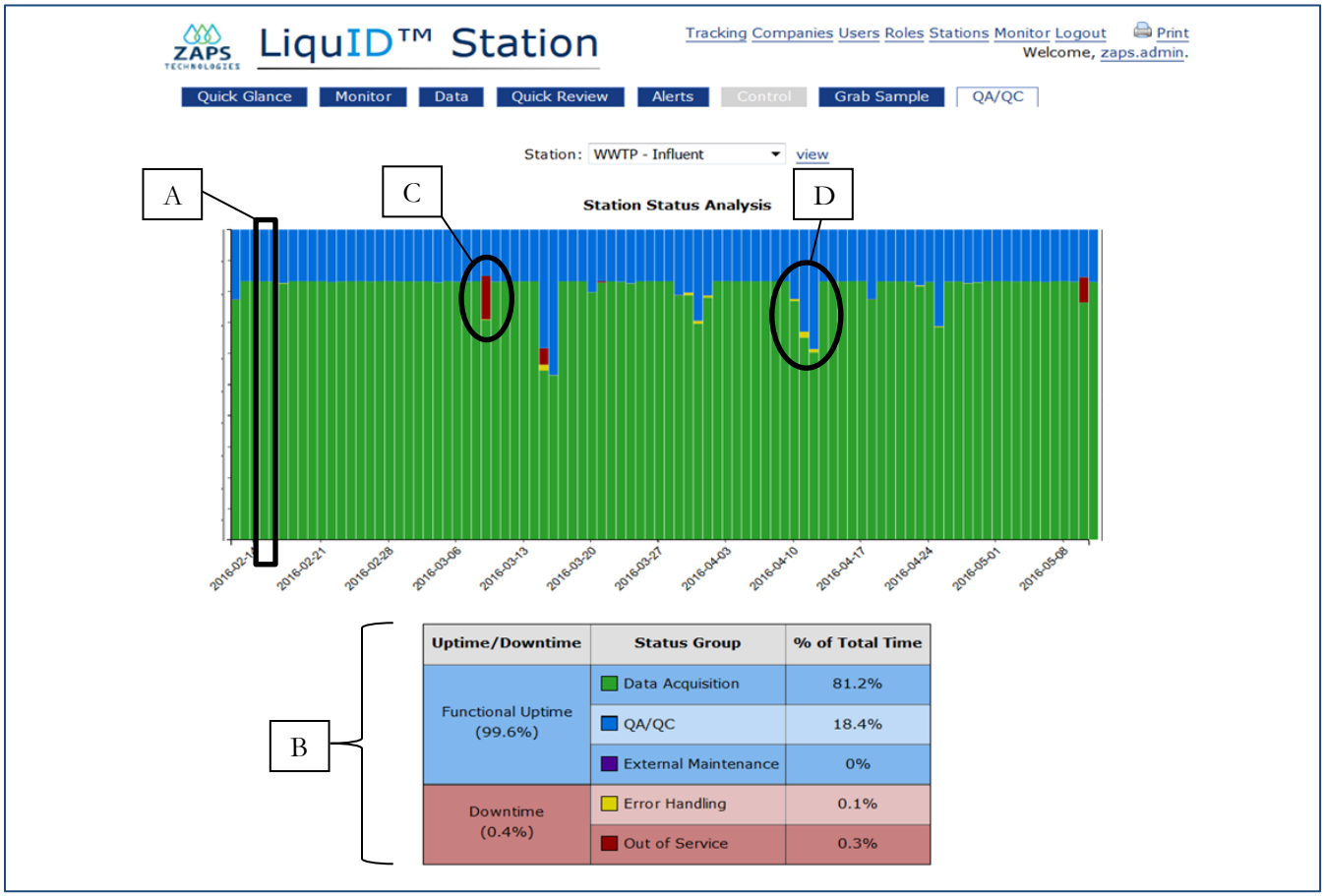

Figure 4: Screenshot from LiquID station QA/QC tab showing a stacked bar chart of 3 months of operating data from an instrument at the Influent of a wastewater treatment plant with a summary table of this data below the graph.

A) Each stack in this graph represents a single day of data from the LiquID station.
B) This data is automatically categorized and color-coded by operating status groups according to the table below the graph. This summary table includes the aggregate time in each status group rounded to the nearest 10th of a percent.
    a. Functional Uptime includes:
        i. **Data Acquisition**: Data taken while the instrument is taking parameter readings from the sample matrix.
        ii. **QA/QC**: Instrument time allocated to QA/QC activities such as automated calibrations, automated cleaning or other events that relate to expected operation of the instrument.
        iii. **External Maintenance**: Time associated with scheduled maintenance such as manual cleaning events which are initiated by the customer and are related to routine events.
    b. Station downtime includes:
        i. **Error Handling**: Automated error codes which reflect issues related to the operating specifications of the instrument such as a compromised sampling system that is not delivering sufficient sample to the LiquID station.

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ii. **Out of Service**: Downtime during which the instrument is not operating in its normal capacity such as during a power outage.

C) This event, in which a period of system downtime (red) corresponds with a proportional reduction in both QA/QC events as well as data generation, is indicative of a power outage at this instrument. The LiquID station resumes operation after this type of an outage although, naturally, no data is generated during this period.

D) This shows a period in which the operating conditions of the LiquID station were not met (in this case, a failing or clogging pump). When the system detects an error (yellow) a series of actions are triggered including alert generation via text or email and results in an increase in QA/QC events and a suspension of data generation to avoid potentially-compromised data. The LiquID station automatically responds by dynamically increasing QA activities to monitor sample supply, perform automated flushing activities in an attempt to dislodge any potential plug and continuously monitor the operating conditions of the instrument. Once operating conditions are acceptable to produce reliable data, the LiquID station automatically resumes normal operation.

The type of automated, dynamic response shown in item D represents smart, continuous QA processes which – through their application – reduce the QC burden on the end user by automatically suspending data generation when the generation of that data would be compromised by identified issues. It is better to produce no data, and send alerts to the end user than produce suspect data that must then be subsequently identified, evaluated and weeded out after the fact, delaying the use of the real-time data and introducing suspicion into the data chain of custody.

To facilitate comparison with the actual data generated from the instrument, we have overlaid the finished parameter data from the UVA, Clean and PM Index channels on top of the Station Status Analysis chart. This view shows the continuous performance of the LiquID station even during periods of dynamically-increased QA/QC, ensuring that reliable, robust data is produced even during challenging operational conditions such as when a pump may be failing or during a transient sample supply plug.

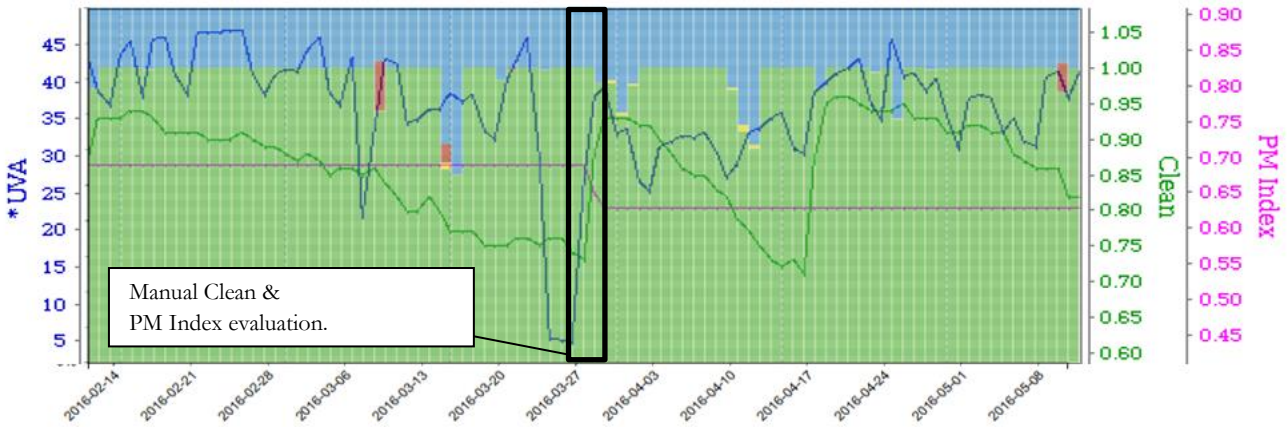

Figure 5: 3 months of operating data from an instrument at the Influent of a wastewater treatment plant. This hybrid chart includes the previous graph from LiquID station QA/QC tab with an overlay of the parameter data generated from that same period of time.

As shown in this overlay, a significant event (just prior to the black box) occurred and recovered back to baseline prior to the manual clean indicated through the recovery of the Clean parameter as well as the re-evaluation of the PM Index. The manual clean did not further affect the UVA parameter readings, demonstrating stability of readings even after periods of significant change to the sample matrix.

Although month-by-month or longer views such as the one presented above provide a practical demonstration of the longer-term stability provided by continuous, automated QA processes, it should be recognized that plotting them as stacked bar charts does not show the integrated nature of these activities during the course of a day. The following graph

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is a status chart similar to the 3-month view, but for a 3-day interval. In this shorter view, the statuses are not stacked for each day, but are instead displayed in a minute-by-minute fashion based on the operational status of the LiquID station at each point in time.

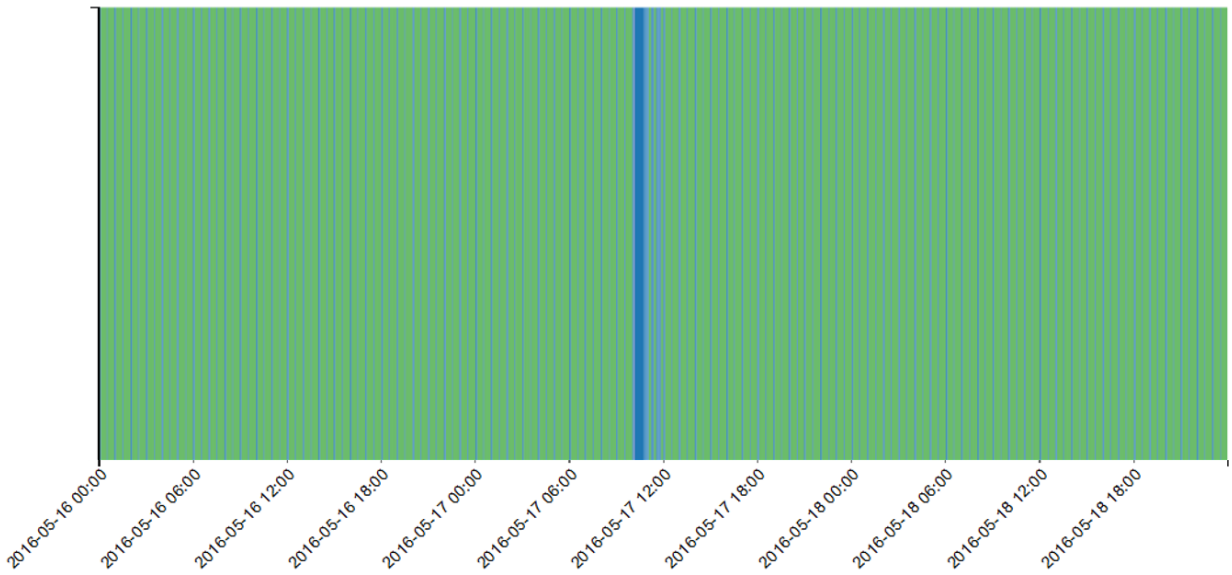

Figure 6: Screenshot from LiquID station QA/QC tab showing a chart of 3 days of operating data from an instrument at the Influent of a wastewater treatment plant.

In this view, the scaffolding provided by the interspersed QA activities (blue) becomes evident in the regular, repeating pin-stripe style of alternating shorter-duration (narrow stripes) QA and longer-duration (wider bands) of ongoing parameter measurements (green).

Once again overlaying the synchronous parameter data (UVA, Clean and PM Index) shows how the parameter data and contextual QA parameters are supported by a strong background of real-time QA. The red box in the following chart highlights a period of increased QA that corresponds to the additional automated QA performed by the LiquID station in response to a manual clean performed by the end user. Even during this period of high variability, the QA processes ensure that the instrument produces data that accurately reflects the ongoing process before and after the manual clean. Note that the vigorous high UVA measurements occurring daily between 6 AM and early afternoon are emblematic of leachate intrusions at this wastewater treatment facility, and are an accurate reflection of this sample stream.

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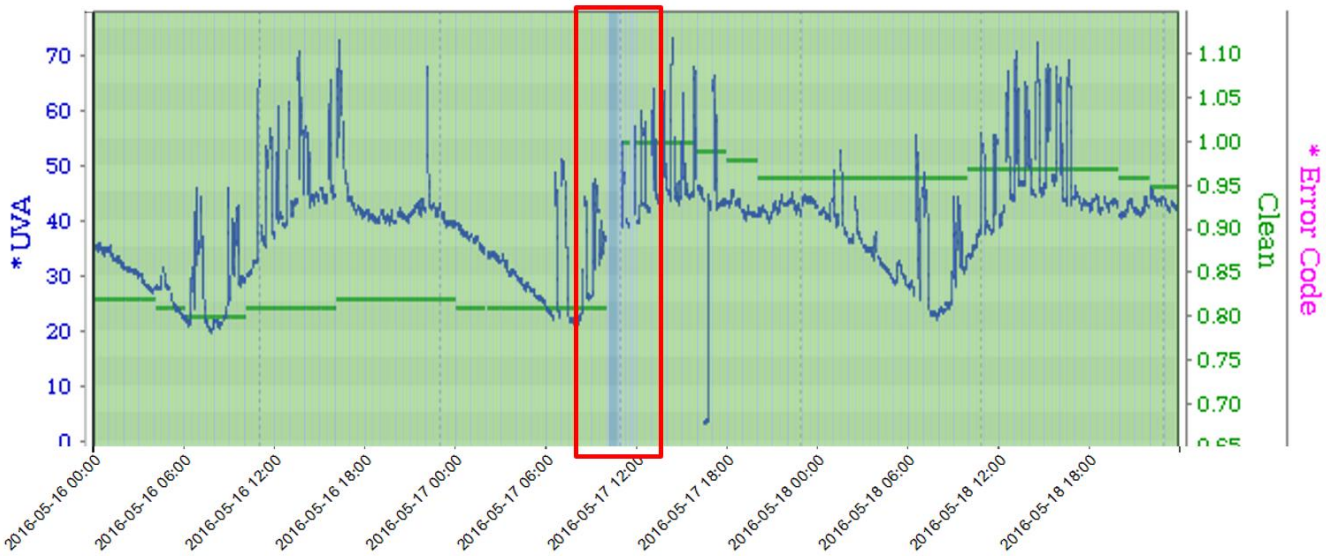

Figure 7: 3 days of operating data from an instrument at the Influent of a wastewater treatment plant. This hybrid chart includes the previous graph from LiquID station QA/QC tab with an overlay of the parameter data generated from that same period of time.

Finally, zooming in further to an 8-hour window from the same influent wastewater instrument provides an example of the ability of real time QA to autonomously respond to unforeseen events. In the screenshot below the regularly-repeating pattern of parameter readings and QA background activities is interrupted by an issue with the supply of sample to the instrumentation (in this case, a failing or clogging pump) beginning shortly before 3AM as evident by the arrival of the thin yellow stripes signifying an error condition. In response to the error condition, the frequency and duration of QA activities automatically increases as the instrument attempts to resolve the error through automated activities. In this instance the instrument is able to resolve the issue of lost flow shortly after 5 AM as demonstrated by the return to the regular alternating pattern of the QA activity (blue stripes) and data acquisition (Green bands). The automated and dynamic QA approach allows the instrument to continuously monitor the situation and continue operating without requiring any manual intervention and helping to preserve data continuity throughout the early morning hours.

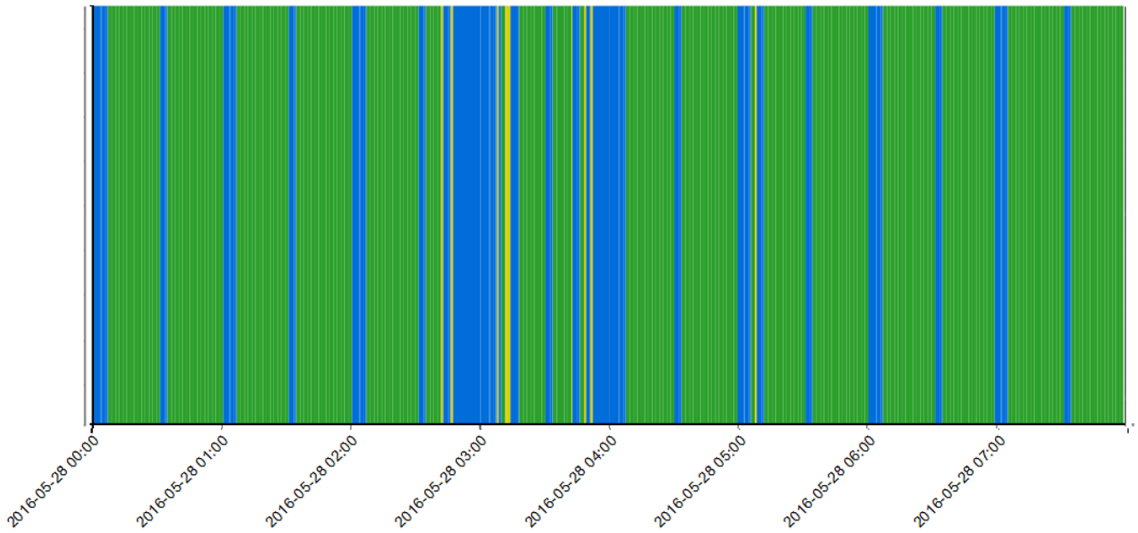

Figure 8: Screenshot from the LiquID station QA/QC tab showing a chart of 8 hours of operating data from an instrument at the Influent of a wastewater treatment plant.

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By once again overlaying the parameter data on this diagram (see below) it is possible to demonstrate additional benefits of an automated and dynamic QA approach. Focusing on the region highlighted by the red box it becomes apparent that wherever green bands are observed parameter data is output and wherever yellow stripes are observed error codes are generated (pink dots near the bottom of the image). As the instrument detects problematic operating conditions error codes are generated and the instrument responds by sending out alerts via text message or email (user configurable – pink dots).The error also triggers a series of automated responses in an attempt to clear the issue while suspending data generation during periods where conditions are outside of the operating specifications of the LiquID station.

Meanwhile, the instrument continues to monitor and respond to the evolving conditions, producing data as possible, but – through active QA processes – protecting the finished data by preventing erroneous data from entering the dataset as demonstrated by the smooth downward trend in UVA values across this entire 8-hour period. In this case, the issue was able to be resolved without any user intervention while the integrity of the data was preserved and the end user received a fully-documented QA record of the issue when they reported to work the following morning. As shown below, the instrument continued to produce stable, reliable, documented data through this entire period. By preventing compromised data from entering the dataset, alerting the end user to issues as they occur and working to resolve these same issues the LiquID station's real-time QA reduces the QC burden on the end user while simultaneously maximizing data continuity.

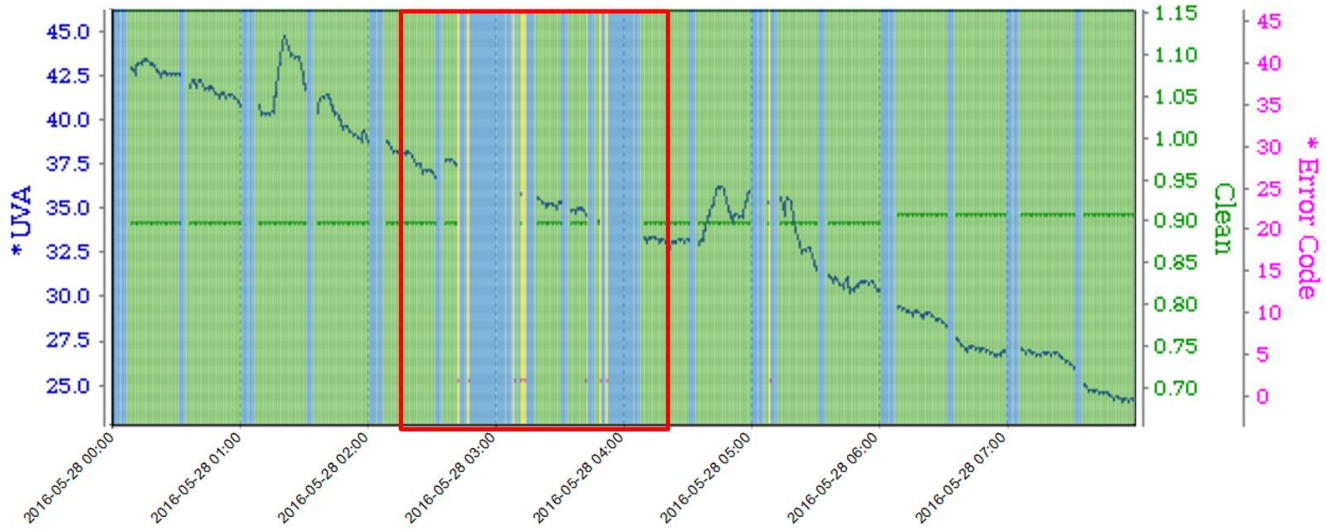

Figure 9: 8 hours of operating data from an instrument at the Influent of a wastewater treatment plant. This hybrid chart includes the previous graph from the LiquID station QA/QC tab with an overlay of the parameter data (UVA, Clean, Error Code) generated from that same period of time.

As previously stated, these examples were taken from a LiquID station operating at the influent to a wastewater treatment facility and represent a physically challenging and messy environment in which to operate. The challenging nature of this environment leads to relatively faster fouling rates, the mitigation of which requires more frequent cleaning and calibration leading to the relatively high percentage of time spent performing QA/QC activities (~18%). However, as demonstrated in the next section of this publication, automated QA/QC does not have to be 'one size fits all' and can be optimized for the environment in which the instrument is operating.

QA – Station Status Analysis – Source Water

Wastewater influent is a highly complex matrix for water analysis and requires a strict QA framework in order to ensure that stable, reliable data is produced. In contrast, although stable and reliable data is of no less importance, in source water monitoring, the QA framework can be less frequently applied without compromising the integrity of the data. In both cases, real-time QA monitoring of integral system specifications (available light, sample supply pressure, integrity of

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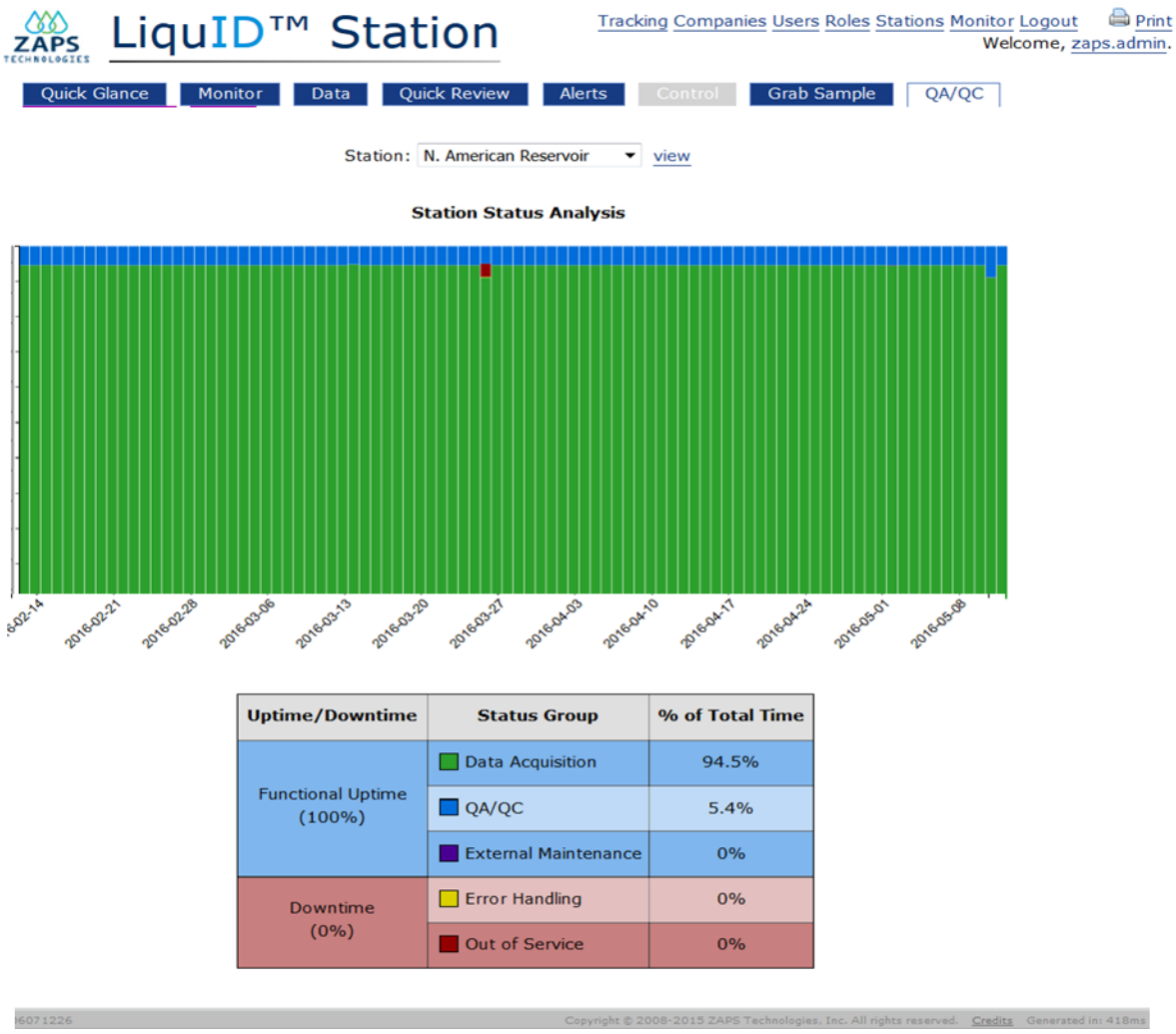
primary instrument components, etc. are continuously monitored) while the frequency of calibration checks and cleaning processes can be applied in a variable manner. The variable nature of these activities are demonstrated in this next section by focusing on similar WUI displays from an instrument operating at the intake to a drinking water plant sourced from an approximate 40-foot depth in a large reservoir.



Uptime/Downtime	Status Group	% of Total Time
Functional Uptime (100%)	Data Acquisition	94.5%
	QA/QC	5.4%
	External Maintenance	0%
Downtime (0%)	Error Handling	0%
	Out of Service	0%

Figure 10: Screenshot from LiquID station QA/QC tab showing a stacked bar chart of 3 months of operating data from an instrument at the intake to a drinking water plant with a summary table of this data below the graph.

In a similar manner to the previously-discussed Station Status overview, the foremost activities in this 3-month WUI screenshot are represented by the dominant Data Acquisition activity (94.5% of the time) and supplemented by the QA/QC activities (5.4%), providing a >99.9% functional uptime during this three-month period. None of the remaining categories, External Maintenance, Error Handling and Out of Service represent 0.1% of the time for this period (the minimum resolution for inclusion in the summary chart). As should be expected, the less challenging and less messy nature of this environment leads to fewer error states, but also requires less frequent automated cleaning and calibration as demonstrated by the significantly lower percentage of time spend performing QA/QC activities (5.4% vs. 18.4%).

When the parameter data and contextual QA/QC parameters are overlaid onto this Station Status Analysis, we can see that the system performed continuously throughout this three-month period aside from a single short power outage (near the half-way point). Additionally, at the end of this three-month period a single manual optics clean was performed,

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indicated by the Clean parameter, the update of the PM Index and the characteristic slight increase in background QA activities during that day (see black-boxed focus area in following chart).

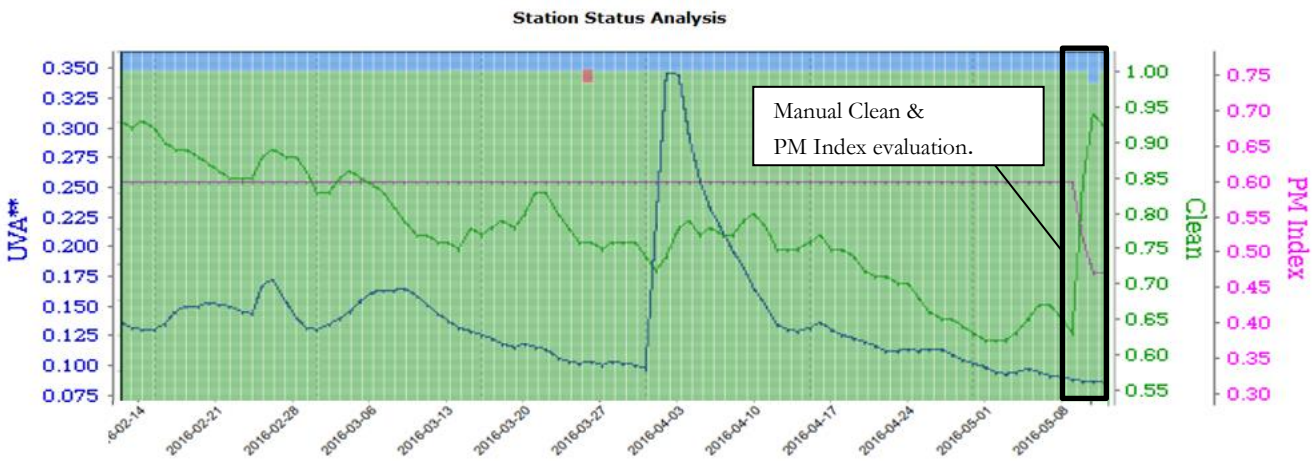

Figure 11: 3 months of operating data from an instrument at the intake of a water treatment plant. This hybrid chart includes the previous graph from LiquID station QA/QC tab with an overlay of the parameter data generated from that same period of time.

Zooming into a three-day view, the data is once again presented in a minute-by-minute format. The integrated QA activities can be seen as a similar, but less-dense pin striping when contrasted to the wastewater instrument.

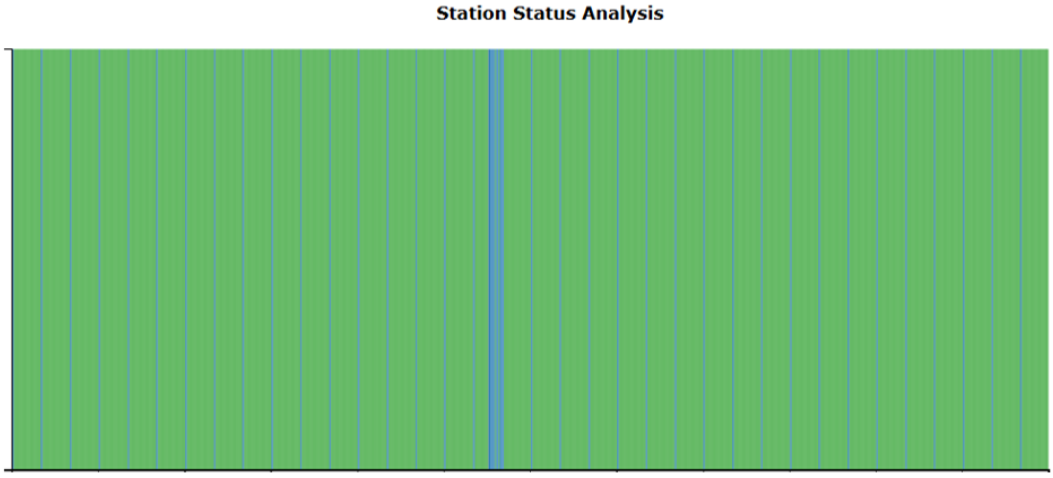

Figure 12: Screenshot from LiquID station QA/QC tab showing a chart of 3 days of operating data from an instrument at the intake to a water treatment plant.

Once the UVA parameter and contextual QA data is overlaid to the chart, the initial UVA example is revealed with the added context of the increased QA/QC activity surrounding the manual clean.

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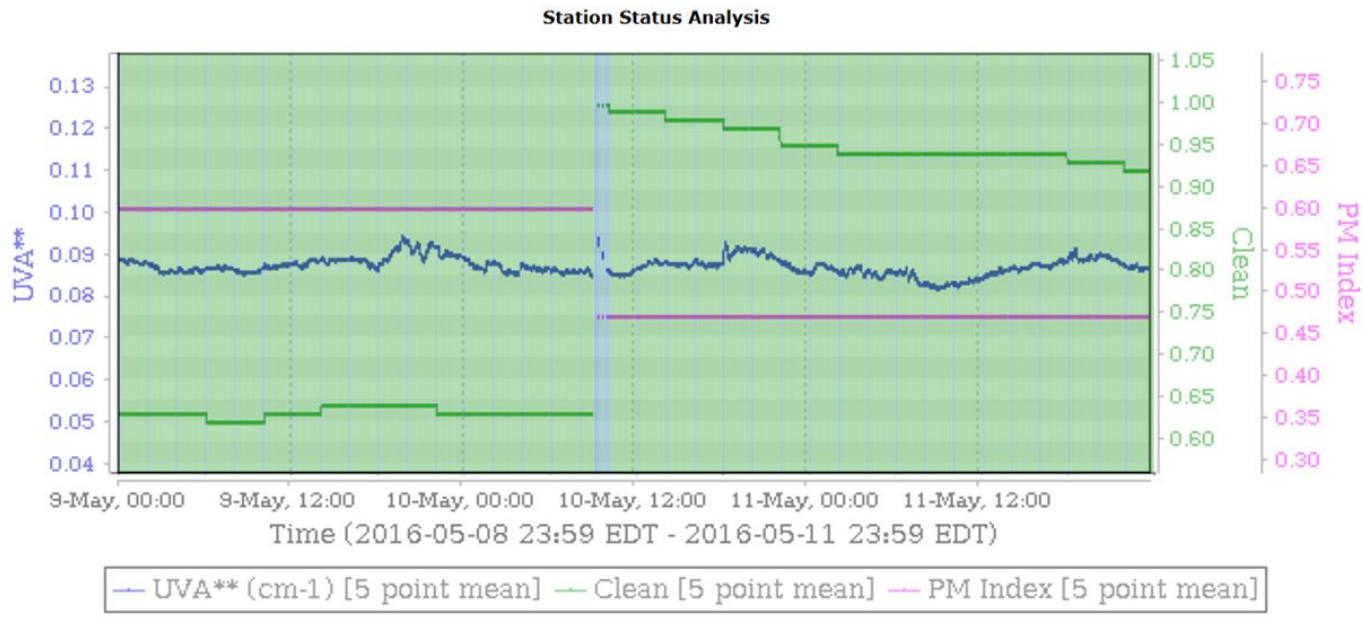

Figure 13: 3 months of operating data from an instrument at the intake of a water treatment plant. This hybrid chart includes the previous graph from LiquID station QA/QC tab with an overlay of the parameter data generated from that same period of time.

These integrated, continuous QA activities enhance the ability of the LiquID station to report stable, real-time data that compares favorably to lab-based measurements supported by traditional QA processes, as seen below.

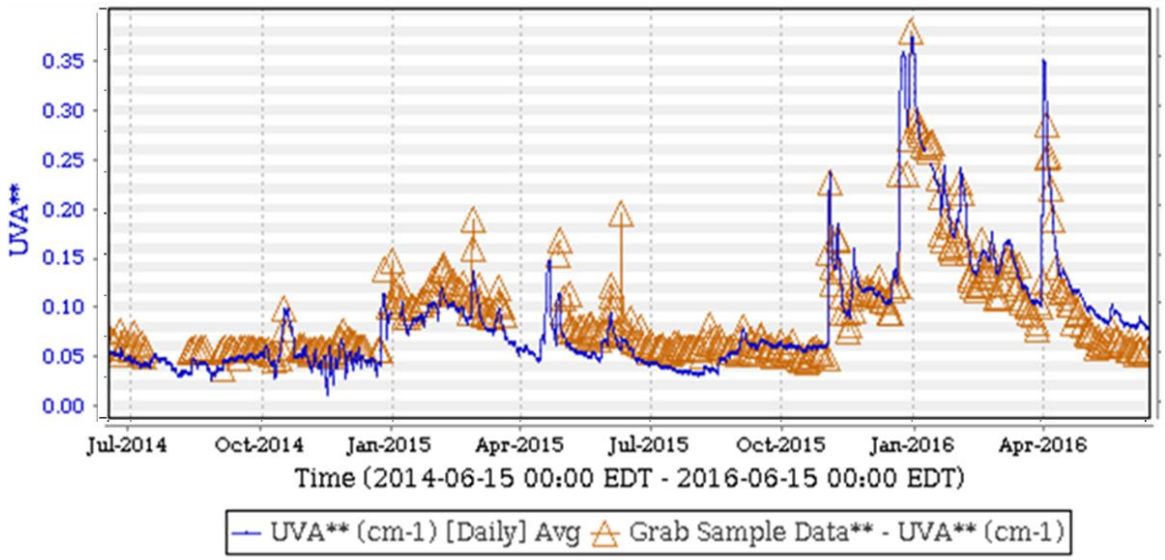

Figure 14: 2-year LiquID station WUI screenshot. Comparison of LiquID station daily average UVA data and Lab UVA data.

When the Station Status Analysis is overlaid on top of the two-year record it once again demonstrates that the constant vigilance of real-time QA produces reliable data over extended periods of time. Additionally, during the annual plant maintenance (see downtime in early January each year), the LiquID station and lab data agree both before and after this period especially in the most recent year during a period when the reservoir was trending from high UVA values brought on by large winter storms down towards more typical baseline winter values.

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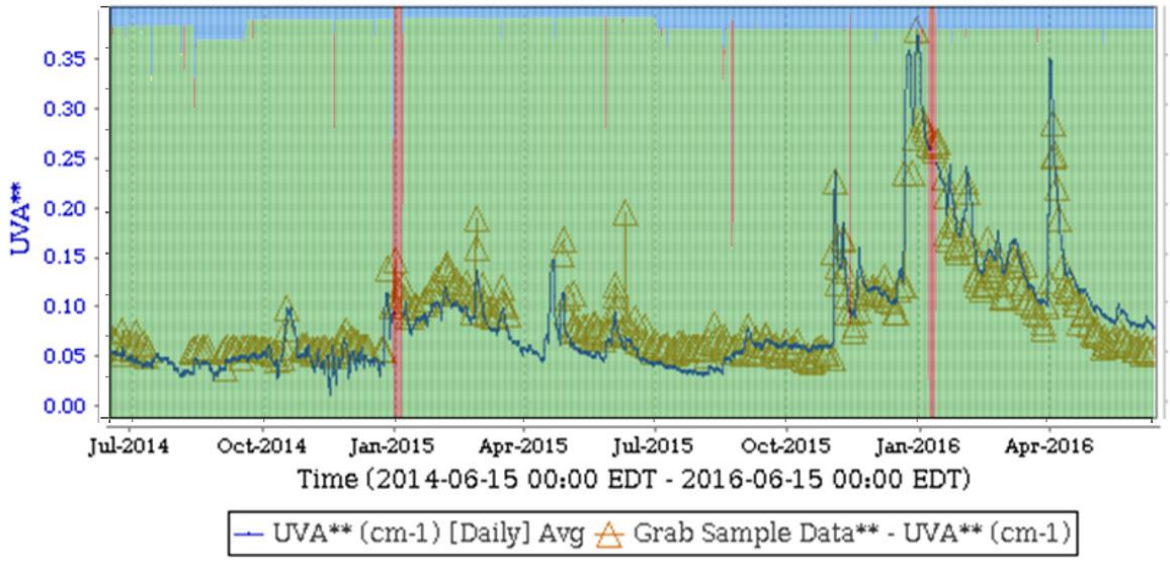

Figure 15: 2-year LiquID station WUI screenshot. Comparison of LiquID station daily average UVA data and Lab UVA data. Overlay of percentage of each day spent in Data Acquisition (green), QA/QC (blue) and Out of Service (red).

Relative to traditional laboratory-based approaches, online continuous data instruments produce vastly larger data sets which require similarly more frequent QA checks to maintain data quality, reliability and continuity over a broad range of operating conditions. Meeting the quality assurance needs of these types of instruments requires an automated and integrated approach that allows data consumers to spend more of their time using the data being produced and less of their time evaluating its suitability for use. Real-time data demands real-time quality assurance in order to meet the needs of all information consumers from operators to modelers to regulators.

Quality Control

As an instrumentation manufacturer, our primary locus of control is Quality Assurance as we have the most direct control over the data produced by our instrumentation as well as the process used to do so. The greatest benefit that we provide in terms of facilitating essential Quality Control activities is to prevent poor data from entering the dataset thereby simplifying, accelerating and streamlining the Quality Control timeline.

No matter how vigilant the QA process, QC is a necessary process and the following charts demonstrate how we can facilitate QC review, primarily by flagging statistically-suspect data and providing continuous QA context that can be used in root-cause analysis.

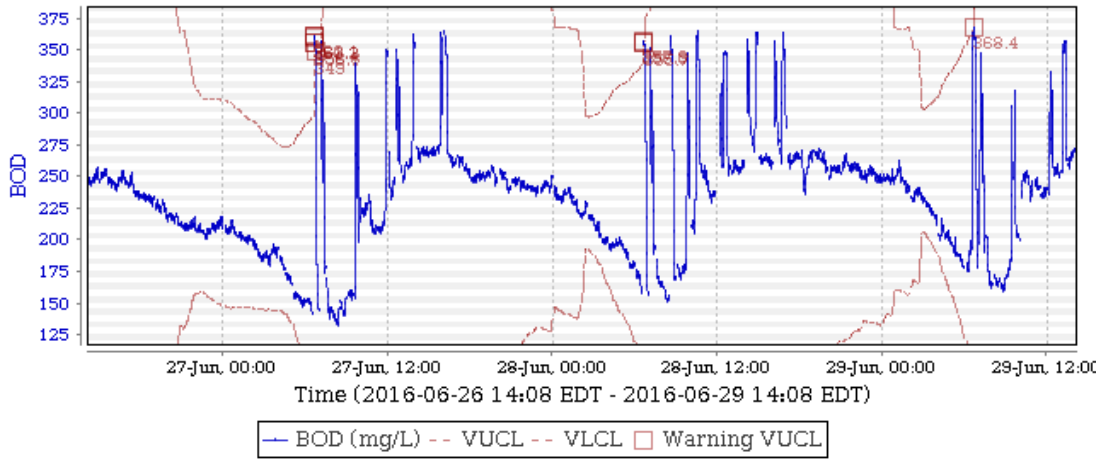

Figure 16: 3-days of wastewater influent BOD data with 3-sigma data quality bands used to flag data that exceeds these control limit boundaries.

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In this first screenshot from the Quick Review tab of the LiquID station WUI, three-days of wastewater influent data shows a repeating pattern of highly variable data beginning in the early hours of each weekday. While these data are justifiably flagged using a 3-sigma rolling limit, these are normal aspects of the plant's operation, reflecting leachate being pumped to the facility. This is an example of a statistical QC flag that, with plant context, is an accurate reflection of the process.

In a second example, from three-days of source water data, the graph below shows a transient fluctuation of UVA (highlighted in the red box). The contextual QA parameter Sample Pressure shows a hiccup in the sample delivery, most likely a minor pumping issue. In this case, the instrument data accurately reflects the sample being delivered to the LiquID station, but does not indicate an issue with the overall process being monitored.

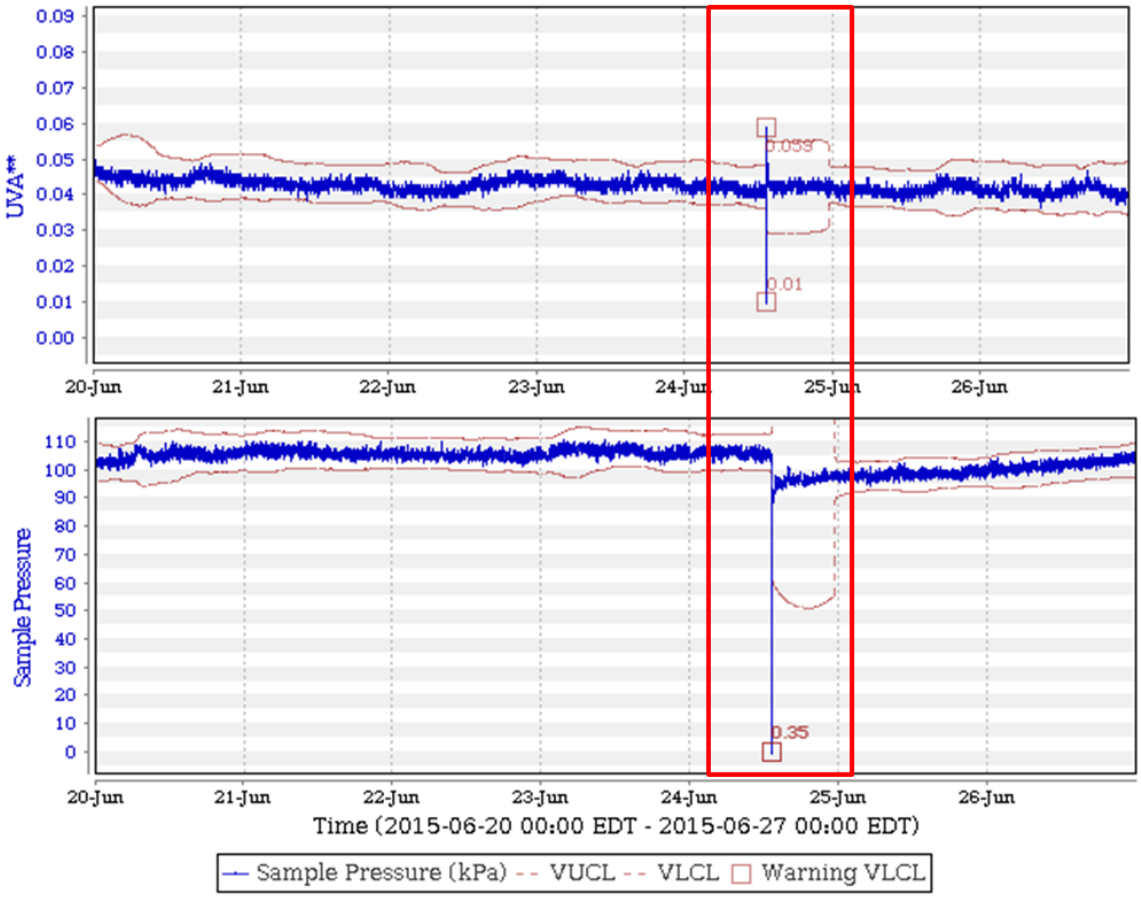

Figure 17: 1-week of UVA data at a source water monitoring location shown concurrent UVA and Sample Pressure data.

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Advanced HMA Parameters

While this process has been documented here using UVA as an example, this quality management approach is applied behind the scenes to every parameter generated on a LiquID station and demonstrates successful implementation across the UV/VIS spectrum and three optical measurement techniques. As a complement to the HMA measurement approach, this integrated QA/QC stabilizes, underpins and affirms every data point even on significantly more complex HMA parameters.

Whether Nitrate+Nitrite at a reservoir:

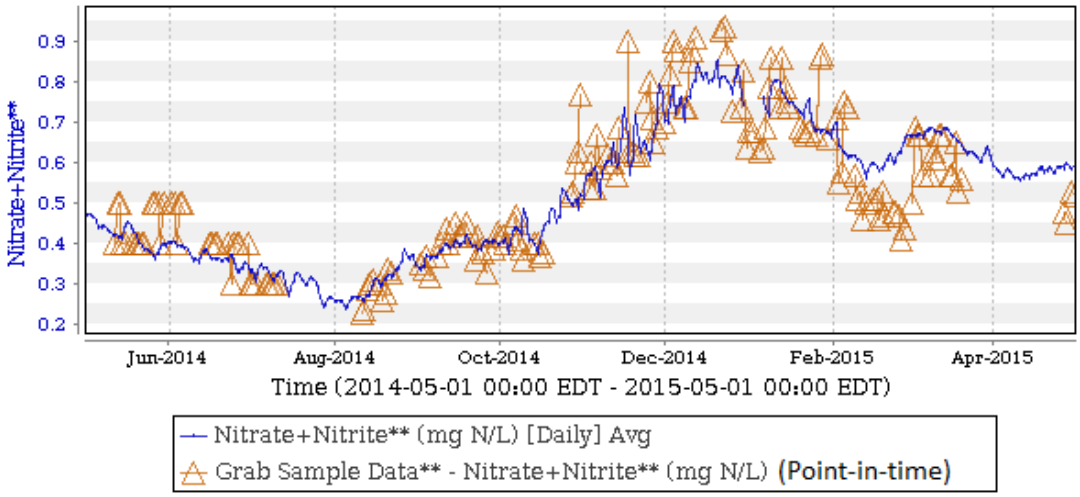

Figure 18: One-year of Nitrate+Nitrite data from the LiquID station (blue) and Lab grab samples (gold) at a North American reservoir.

Or cBOD at the influent to a wastewater treatment plant:

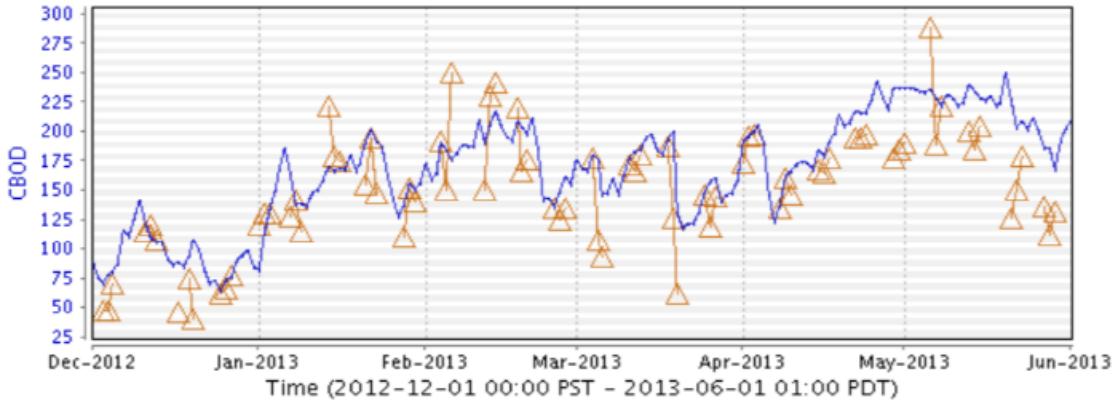

Figure 19: Six-months of cBOD data from the LiquID station (blue) and flow-weighted lab composite data (gold).

For real time data to meet its' full potential protecting communities or improving process control the data needs to be observed, trusted and acted on as closely to the time it is generated as possible. An integrated, continuous QA/QC approach is a necessary component for ready-to-use, real-time data generation.

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Conclusions

As acknowledged in QA/QC and environmental disciplines, "Quantity is nothing without quality"[2] JL Campbell, et al. 2013). The QA/QC scaffolding described in this document has been developed specifically for the HMA approach as implemented by a LiquID Station in support of real time data generation. The ultimate goal of all analytical QA/QC processes is to provide consistent, reliable results however, unlike more traditional batch analytical methods that often involve steps spanning days (e.g. sampling, transportation, processing, analyzing, reporting) real time data generation eliminates steps and compresses the time span to minutes. In this sense the most significant difference between more traditional analytical methods and real time monitoring is the timescale encompassing the approach. The automated, rapid and continuous nature of the HMA approach involves fundamentally different steps than other traditional analytical approaches and as such requires a different more continuous and automated approach to QA/QC. The HMA approach depends on the continuous monitoring of internal and external variables in order to prevent compromised data from entering the dataset, provide alerts to the end user if issues arise while simultaneously working to resolve these same issues. The LiquID station's integrated and continuous QA reduces the QC burden on the end user while simultaneously maximizing data continuity and delivering finalized data output in a ready-to-use state.

As a manufacturer of real-time water quality monitoring instrumentation, the framework that ZAPS Technologies' applies to ensure the quality of our data is of paramount importance. In mission-critical applications, ensuring that every data point is underwritten by a firm scaffolding of Quality Assurance controls providing confidence that the data presented to the end user can be relied upon to deliver the accuracy, completeness, consistency and timeliness[4] demanded by information consumers. This framework also allows the data to be used – over extended periods of time – for applications such as networking, process control, visualization and data mining. In these and many other applications, the value of the data is proportional to the length of time between the data generation and when that data can be ultimately relied upon to be used. **Real-time data demands real-time QA/QC processes.**

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The references included on this page are intended as a representative sampling of some of the foundational concepts mentioned and built upon in this document. It should not, however, be taken in any means as an exhaustive listing.

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