

## STORMWATER RECHARGED: INNOVATING WITH ELECTRICAL FLOCCULATION

Authors: Grace K. Kerr, Megan A. Sharpe<sup>1</sup>, Barry Fagan<sup>2</sup>, Michael A. Perez<sup>3</sup>

Grace Kerr, E.I., Graduate Research Assistant, Auburn University Dept. of Civil Engineering, 238 Harbert Engineering Center, Auburn, AL 36849, 724-970-0888, [gkk0012@auburn.edu](mailto:gkk0012@auburn.edu)

Megan A. Sharpe, Ph.D., E.I., CPESC-IT, Graduate Engineer, Fagan Consulting, LLC, 787 Glennbrooke Blvd., Prattville, AL 36066, (731) 676-7906, [megan@faganllc.com](mailto:megan@faganllc.com)

Barry Fagan, PE, PLS, ENV SP, CPMSM, CPESC, Owner/Vice President, Fagan Consulting, LLC, 787 Glennbrooke Blvd., Prattville, AL 36066, (334) 850-5721, [barry@faganllc.com](mailto:barry@faganllc.com)

Michael A. Perez, Ph.D., PE, CPESC, Associate Professor, Auburn University Dept. of Civil and Environmental Engineering, 238 Harbert Engineering Center, Auburn, AL 36849, (334) 844-6267, [mike.perez@auburn.edu](mailto:mike.perez@auburn.edu)

### PRESENTER BIO

Grace Kerr is a Ph.D. student in Auburn University's Department of Civil and Environmental Engineering, where she conducts research in the Stormwater Research Facility under the advisement of Dr. Michael A. Perez. She collaborates with Fagan Consulting, LLC, on applied stormwater research and serves as a technical liaison between Auburn University and Fagan Consulting on a U.S. Department of Transportation Small Business Innovation Research (SBIR) project. Her research focuses on the development and evaluation of a compact, portable electrical flocculation-based device for sediment and non-sediment pollutant removal in stormwater applications.

Dr. Megan Sharpe is a graduate engineer at Fagan Consulting. She recently earned her doctorate from Auburn University, specializing in construction stormwater management. She is the research and development lead for the collaborative U.S. Department of Transportation Small Business Innovation Research (SBIR) project between Fagan Consulting and Auburn University. She has served as the project's lead graduate student and now as a graduate engineer, supporting the development of a portable stormwater treatment device that uses electricity to remove contaminants from the water column.

Barry Fagan is an owner and vice president of Fagan Consulting LLC located in Prattville, Alabama. Fagan Consulting is an engineering consulting firm with a primary focus on stormwater management and water quality protection. Barry has over 30 years of stormwater management-related experience at project and programmatic levels, serving in roles of inspector, practitioner, project manager, trainer, manager, leader, and consulting expert. Barry has trained thousands of construction stormwater management professionals in practical application, inspection, contract administration, and environmental leadership. Barry and Fagan Consulting support infrastructure delivery at the intersection of built and natural environments.

Dr. Michael Perez is the Brasfield and Gorrie Associate Professor in the Department of Civil and Environmental Engineering at Auburn University. He oversees research at the Auburn University – Stormwater Research Facility, specializing in full-scale evaluation of construction and post-construction stormwater management practices. He currently serves as the chair of the standards and practices committee for the International Erosion and Sediment Control and as chair of the Transportation Research Board's AKD50 standing committee on Hydrology, Hydraulics and Stormwater. He is a licensed Professional Engineer in the State of Alabama and is a Certified Professional in Erosion and Sediment Control.

**KEYWORDS:** Electrical Flocculation, Turbidity Removal, Erosion and Sediment Controls, Stormwater, Runoff, Aluminum Release, Toxicity

## ABSTRACT

Construction stormwater runoff is a major contributor to sediment loading and turbidity impairments in receiving waters. Sediment basins are widely used best management practices but often provide limited removal of fine silts and clays, resulting in prolonged settling and dewatering periods. This study presents development and large-scale evaluation of a portable electrical flocculation-based treatment technology designed to improve sediment basin clarification through in situ generation of aluminum hydroxide flocs. Development of an electric floc generator was advanced to a floating batch-mode configuration (“SOLO”) model capable of in-basin treatment without reliance on downstream BMPs for floc capture.

Large-scale testing was conducted at the Auburn University Stormwater Research Facility using a lined sediment basin. For both baseline and treated conditions, stormwater was introduced and amended with locally sourced soils to simulate construction site runoff (initial turbidity 500 to 750 NTU). The sediment-laden water was conditioned to a controlled ionic state of approximately 300  $\mu\text{S}/\text{cm}$  to support evaluation of electrical flocculation performance. Passive turbidity reduction was monitored for 24 hours, followed by SOLO activation and controlled dewatering. SOLO operation substantially improved clarification compared to natural settling alone, reducing turbidity from an apparent settling-limited steady-state of approximately 250 NTU (40% reduction) to near 10 NTU (97% reduction). Dissolved aluminum concentrations remained low throughout testing (baseline 0.0002 to 0.0004 mg/L; maximum 0.0018 mg/L), with highest values observed during final dewatering. Widely accepted chronic aluminum toxicity benchmarks for *Ceriodaphnia dubia* indicate that adverse reproductive effects occur at aluminum concentrations well above those measured during SOLO operation. Overall, results demonstrate that treatment using the SOLO model electric floc generator can substantially enhance turbidity reduction in construction site runoff while maintaining low dissolved aluminum concentrations under tested conditions.

## 1.0 INTRODUCTION

Construction activities are a dominant source of sediment pollution due to disturbed soils, increased runoff, and erosion from exposed surfaces (U.S. EPA, 2016; U.S. EPA, 1998). Sediment is commonly the primary pollutant in construction stormwater runoff and is associated with elevated turbidity, transport of sediment-bound contaminants, and aquatic habitat impairment (Kerr & Ontario MNR, 1995). Sediment basins are frequently required under stormwater permits to detain runoff and promote settling; however, they primarily remove coarse particles, while fine suspended sediments (silts and clays) can remain in suspension for prolonged durations, resulting in delayed clarification and extended dewatering times (Kerr & Ontario MNR, 1995; Kazaz et al., 2021).

Basin dewatering is often managed using floating skimmers, which reduce withdrawal of settled solids; however, skimmers do not remove turbidity caused by fine particles remaining in the water column. Field evaluations indicate that the remaining suspended fraction is often dominated by very fine material that will not settle efficiently under practical basin retention periods. McLaughlin (2007) noted that “remaining suspended materials are very fine and will not settle by gravity alone under typical retention times,” highlighting an inherent limitation of relying solely on detention and gravity settling for turbidity reduction (McLaughlin, 2007).

Chemical flocculants can accelerate settling, but performance is sensitive to dosing control and site-specific water chemistry and may raise ecological concerns (Kazaz et al., 2021). Electrocoagulation (EC) provides an alternative treatment strategy by producing coagulant species in situ through controlled dissolution of sacrificial electrodes, destabilizing colloids and promoting aggregation without bulk chemical addition (Mollah et al., 2004). This study advances development of a portable electrical flocculation device (Floc Generator) and evaluates a floating batch-mode configuration (SOLO) designed to enhance sediment basin clarification while explicitly evaluating aluminum release risk and environmental safety.

## 2.0 LITERATURE REVIEW

Electrical flocculation destabilizes suspended particles and colloids through electrochemically generated coagulants. When direct current is applied to aluminum electrodes, anodic dissolution releases dissolved aluminum ( $\text{Al}^{3+}$ ), while cathodic reactions produce hydroxide ( $\text{OH}^-$ ) and hydrogen gas ( $\text{H}^+$ ). Hydrolysis and precipitation produce a neutrally charged metal hydroxide, aluminum hydroxide (e.g.,  $\text{Al}(\text{OH})_3$ ), that promotes sweep flocculation, adsorption, and aggregation of suspended contaminants (Mollah et al., 2004). Electrical flocculation performance is governed by water chemistry and reactor design, including pH, conductivity, current density, electrode configuration, electrode spacing, mixing intensity, and passivation (Hakizimana et al., 2017; Boinpally et al., 2023).

Coagulant production is commonly estimated using Faraday’s law, with practical performance evaluated through Faradaic efficiency (Hakizimana et al., 2017). Current density influences both coagulant generation and gas bubble formation and must be balanced to avoid excessive flotation that can interfere with settling-based solids capture (Boinpally et al., 2023). Electrode material affects pollutant removal mechanisms; aluminum and iron are common due to cost and effectiveness, and both have shown strong turbidity and solids reduction across diverse wastewaters (Khandegar & Saroha, 2013; Naje et al., 2016; Boinpally et al., 2023).

Hydrodynamics should be considered when designing an electrical flocculation system. Sufficient mixing disperses fresh hydroxide flocs and improves contact with contaminants, while excessive shear can fragment flocs and reduce settleability (Hakizimana et al., 2017). Electrode spacing impacts electrical resistance and energy demand; suboptimal spacing increases voltage requirements and can contribute to uneven current distribution and reduced efficiency (Hakizimana et al., 2017). Electrode passivation (oxide/hydroxide films) can reduce performance over time, increasing voltage demand and lowering coagulant production; polarity reversal and design refinements are commonly used to improve longevity (Hakizimana et al., 2017; Boinpally et al., 2023). For stormwater applications, conductivity is often relatively low compared to many wastewaters, which can increase voltage required to sustain target current densities and influence feasibility (Hakizimana et al., 2017). These considerations motivate device

designs that improve electrical reliability and mixing while maintaining predictable settling behavior and minimizing potential for residual dissolved aluminum and ecological impacts.

### 3.0 PAST EVALUATIONS

Previous evaluations of the 6-inch (15.24 cm) electric floc generator cartridge in flow-through operation demonstrated effective turbidity reduction and preliminary removal of select contaminants. However, flow-through configurations may require downstream BMPs to capture formed flocs, creating deployment constraints for construction sites. This work emphasizes development of a batch-mode floating configuration to treat water directly within the sediment basin, allowing flocs to settle onsite and reducing reliance on downstream controls.

### 4.0 ELECTRICAL CONNECTION REFINEMENT

Electrode design and development have been a central priority in optimizing the performance, reliability, and manufacturing feasibility of the floc generator. Multiple electrode connection concepts were evaluated, including an aluminum rod-and-bolt connection, side-mounted bus bars, and a handle-integrated bus bar system (Figure 1). All configurations consisted of 16 Aluminum electrode and had similar anodic surface areas. The initial rod-and-bolt configuration (Figure 1a) consisted of electrodes with alternating hole sizes that enabled alternating polarity; however, long-term operation caused electrode dissolution around the connection point, reducing contact integrity and producing inconsistent current distribution. A second design using side-mounted bus bars (Figure 1b) demonstrated strong electrical performance but was sensitive to plate alignment within the constrained 6-inch (15.24 cm) PVC cartridge housing; minor shifting during handling and deployment resulted in partial plate contact, inconsistent amperage, and non-uniform dissolution. To improve manufacturability and reduce instability, a handle-mounted bus bar design was developed (Figure 1c), in which embedded bus bars pressed against slotted electrode plates and additional base bus bars improved current distribution and enabled series cartridge connection; however, contact inconsistency persisted when plates shifted during assembly or operation. These limitations highlighted the need for a centralized electrical connection that eliminated pass-through connections and did not depend on plate alignment. The final prototype incorporates formed aluminum tabs bent toward a central node for electrical lead attachment (Figure 1d), eliminating redundant components, preventing misalignment, and providing uniform current distribution. This design improves durability, reduces manufacturing complexity, and stabilizes performance even as sacrificial dissolution occurs, and it has been integrated into the standard floc generator cartridge for repeated construction-site deployment.

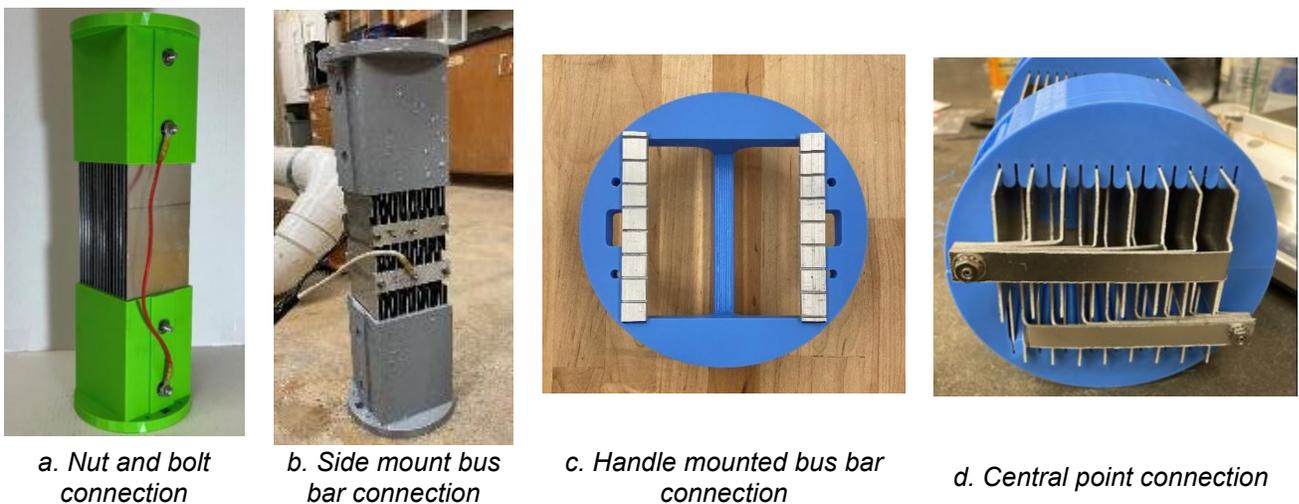


Figure 1. Electrical connection designs

## 5.0 SOLO ELECTRIC FLOC GENERATOR DEVELOPMENT

The SOLO model of the floc generator integrates the standard 6-inch (15.24 cm) electrical flocculation cartridge into a self-contained floating treatment system that actively recirculates basin water through the device using an internal thruster. The unit is tethered to a shore-based power supply via wiring routed from the basin bank. The SOLO model includes one 6-inch (15.24 cm) cartridge and a 3-inch (7.62 cm) diameter thruster to provide localized mixing and promote floc formation (Figure 2). Unlike passive flow-through models, the SOLO model operates as a batch-mode, in-basin treatment approach, allowing suspended solids and associated pollutants (e.g., nutrients and heavy metals) to aggregate and settle within the sediment basin. This configuration reduces dependence on downstream BMPs for floc capture and supports practical deployment on construction sites.

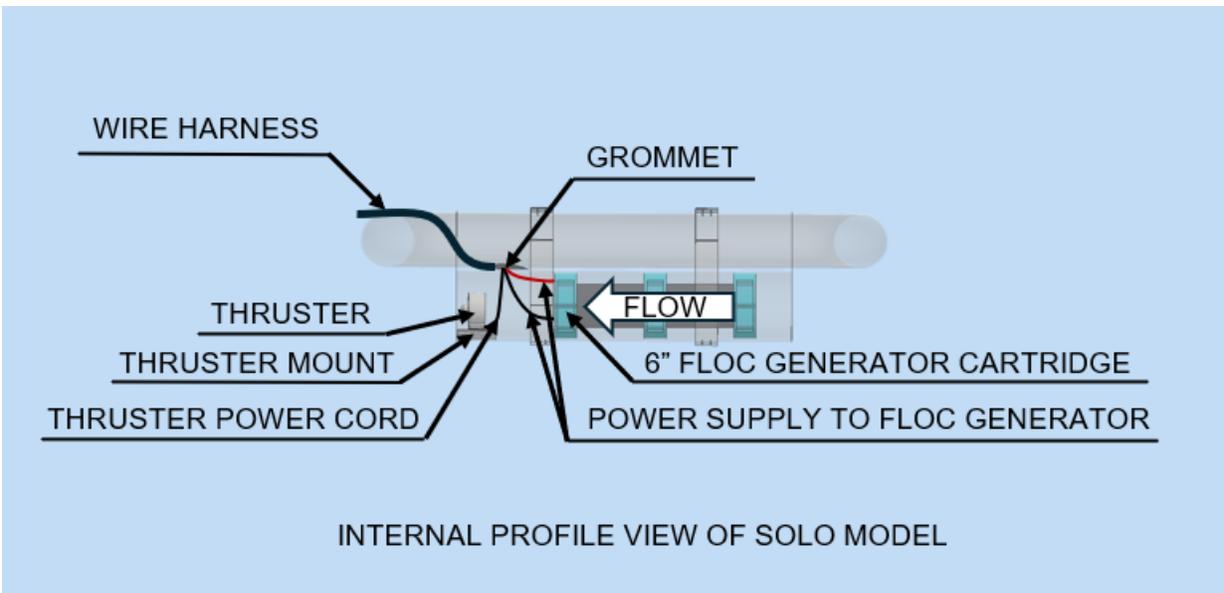


Figure 2. Rendering of SOLO Model

## 6.0 METHODOLOGY AND RESULTS

This section summarizes the experimental methods used to obtain results for SOLO large-scale testing, dissolved aluminum release testing, and toxicity testing.

### 6.1 SOLO Testing

#### 6.1.1 Sediment Basin Setup

Large-scale testing of the SOLO model was conducted in a sediment basin fully lined with plastic to prevent infiltration and cross-contamination. For both baseline and treated conditions, stormwater was introduced and amended with locally sourced soils to simulate construction site runoff at an initial turbidity of 500 to 750 NTU. Two soil-filled troughs were used as pre-conditioning basins to retain coarse particles while allowing finer sediments to overtop and enter the basin. Basin filling was completed in approximately two hours, followed by a 24-hour quiescent settling period. The total testing duration was 60 hours. The SOLO model was activated at hour 25 in the treated condition, and controlled dewatering began at hour 48 using a 4-inch (10.16 cm) Faircloth® floating skimmer. Basin discharge at the skimmer outlet was metered with a valve and verified using a V-notch weir. A dewatering duration of approximately 12 hours was targeted to evaluate rapid discharge of treated water. Rapid dewatering was selected to demonstrate that the device can clarify basin water sufficiently to support faster discharge rates than are typically achievable using conventional sediment basin settling alone. Figure 3a shows deployment of the SOLO model in the sediment basin. Figure 3b presents a plan view of the testing setup. The SOLO model was positioned in the center of the basin and tethered using rope to prevent movement during testing.



a. SOLO model deployed in sediment basin



b. Overview of SOLO model deployed in sediment basin

**Figure 3. Overview of Solo Flocc Generator's deployment in sediment basin**

### 6.1.2 Performance Enhancement

Rainwater typically exhibits low electrical conductivity due to minimal dissolved ionic content and was the primary water source available for basin testing (Hem et al. 1985). Surface waters sampled around Auburn, Alabama, showed a range of conductivities, with Parkerson Mill Creek exhibiting a high conductivity of approximately 300  $\mu\text{S}/\text{cm}$ . At this conductivity, the SOLO model operated at an amperage of approximately 16–18 A. Using an anodic surface area of 486  $\text{in}^2$  (0.3136  $\text{m}^2$ ), the corresponding current density was 4.7–5.3  $\text{A}/\text{ft}^2$  (51.0–57.4  $\text{A}/\text{m}^2$ ). To ensure reliable operation of the flocc generator during testing, the basin influent was conditioned to a target conductivity of approximately 300  $\mu\text{S}/\text{cm}$ . This ionic conditioning was applied solely to meet the operational requirements of the electrical flocculation process and was not intended to replicate ambient or site-specific water chemistry. While future development will incorporate a localized ionic support delivery mechanism within the SOLO configuration, basin-scale conditioning was used in this study to provide consistent ionic conditions for system evaluation.

### 6.1.3 Monitoring and Sampling

Following basin filling, the SOLO model was deployed at hour 0 of the 60-hour test but remained inactive. Basin water was held for 24 hours to evaluate natural sediment settling. At hour 25, the SOLO model was activated and operated continuously through hour 60 to treat the basin water. Controlled dewatering was initiated at hour 48 with a target duration of approximately 12 hours, while the SOLO model continued operating during the dewatering period. The basin was fully dewatered and the test was completed at hour 60.

## 6.2 Aluminum Release Concentration Testing

### 6.2.1 Objective

The objective of this testing, following SOLO performance evaluation, is to quantify dissolved aluminum release concentrations and compare these results with toxicity outcomes.

### 6.2.2 Sampling and Analysis

Sampling included both control and treated water from the SOLO basin test at the start, midpoint, and end of the evaluation period to monitor dissolved aluminum concentration. Water was held from 0 to 24 hr as a control, treated from 25 to 48 hr, and dewatered from 49 to 60 hr while the SOLO model continued operating. Dissolved aluminum concentrations were quantified using Inductively Coupled Plasma–Optical Emission Spectroscopy (ICP-OES). ICP-OES is an analytical technique used to measure dissolved metals in water by exciting atoms in a high-temperature plasma and detect the light they emit at element-specific wavelengths. The intensity of the emitted light is proportional to concentration, allowing accurate quantification of metals such as aluminum.

## 6.3 Toxicology Testing

### 6.3.1 Objective

Aluminum is one of the most predominant elements in soils, particularly in fine-grained materials (USGS, 2017). Elevated concentrations of dissolved aluminum in water can have adverse environmental effects, particularly on aquatic organisms, depending on water chemistry and exposure conditions. Widely accepted chronic aluminum toxicity benchmarks for the most sensitive group of freshwater aquatic invertebrates indicate that adverse reproductive effects typically occur at dissolved aluminum concentrations on the order of 0.1 to 1.0 mg/L, with commonly reported effect thresholds in the range of approximately 0.2 to 0.5 mg/L.

Specific toxicity testing was conducted using assumed worst case scenario concentrations to ensure that the device operates within environmental compliance and does not create conditions that negatively impact aquatic life. The results of the Aluminum Release Concentration testing were compared to the results of worst-case toxicology testing to verify that treatment with the SOLO model does not introduce unintended environmental consequences via aluminum release.

### 6.3.2 Experimental Overview

A one-gallon sample of treated effluent was provided to Environmental Resource Analysts (ERA) for a seven-day chronic definitive toxicity test using *Ceriodaphnia dubia* in accordance with EPA guideline EPA-821-R-02-013. Toxicity endpoints reported for the chronic test included the No Observed Effect Concentration (NOEC), Lowest Observed Effect Concentration (LOEC), and median effect concentrations (LC<sub>50</sub>/EC<sub>50</sub>). The NOEC is defined as the highest tested effluent concentration that produces no statistically significant adverse effect relative to the control, whereas the LOEC is the lowest tested concentration that produces a statistically significant adverse effect. The LC<sub>50</sub> (median lethal concentration) represents the concentration at which 50% mortality occurs during the exposure period, while the EC<sub>50</sub> (median effective concentration) represents the concentration that causes a 50% reduction in a non-lethal endpoint, such as reproduction (neonates per female), relative to the control. To eliminate chlorine interference, inlet water was filtered through two inline cartridges until total residual chlorine measured ≤ 0.1 mg/L, verified using a Hach DR3900 spectrophotometer. Toxicology testing was conducted under worst-case operating conditions (1.0 GPM, 31.2 V, and 24 A) to simulate maximum potential aluminum release. At ERA, a dilution series of the treated effluent was prepared (100%, 30%, 10%, 5%, and 0.5%); post-dilution aluminum concentrations were confirmed at Auburn University using

Hach DR3900 spectrophotometry. Table 2 summarizes the dilution splits and corresponding dissolved aluminum concentrations used for toxicity evaluation.

**Table 2. Dilution levels and concentrations**

<b>Dilution</b>	<b>AL Concentration(mg/L)</b>
100%	3.050
30%	0.880
10%	0.370
5%	0.232
0.5%	0.133

## 7.0 RESULTS

### 7.1 SOLO Testing

During operation, visible floc formation was observed along the basin sidewalls and at the water surface. Electrical flotation (attachment of generated flocs and debris to produced hydrogen gas bubbles) was minimal and is expected to be further reduced through additional mixing. Sediment deposition along the basin walls was thin and could be easily resuspended; however, resuspended flocs readily re-aggregated and settled, indicating stable floc formation behavior.

Visual comparisons between the control and treated conditions demonstrated substantial improvement in basin clarification. Figure 4 presents basin conditions after 24 hours of baseline settling (Figure 4a, hour 24) and after an additional 24 hours of SOLO treatment (Figure 4b, hour 48). Improved clarity was evident in the treated condition, including visibility of the PVC pipe conveying water from the basin to the weir, indicating effective treatment by the SOLO model. Upon initiation of dewatering, treated discharge appeared visually clear with measured turbidity of 20.8 NTU following 24 hours of natural settling and 24 hours of SOLO operation.



*a. Beginning of treated test*



*b. End of treated test*

**Figure 4. Comparison of the beginning of treated test and end**

Following sample collection, additional visual confirmation of clarification was observed in laboratory turbidity samples (Figure 5). Figure 5a shows the 24 hourly samples collected during SOLO operation (hours 25–48), illustrating a clear progression of turbidity reduction over time. Figure 5b highlights the contrast between the initial treatment sample (hour 25; 241 NTU) and the final sample after 24 hours of treatment (hour 48; 28.7 NTU), demonstrating substantial improvement in sample clarity.



*a. Showing the 24-hour treated samples with SOLO model activated (hour 25-48)*



*b. Comparing initial turbidity (hour 1) to final turbidity (hour 24)*

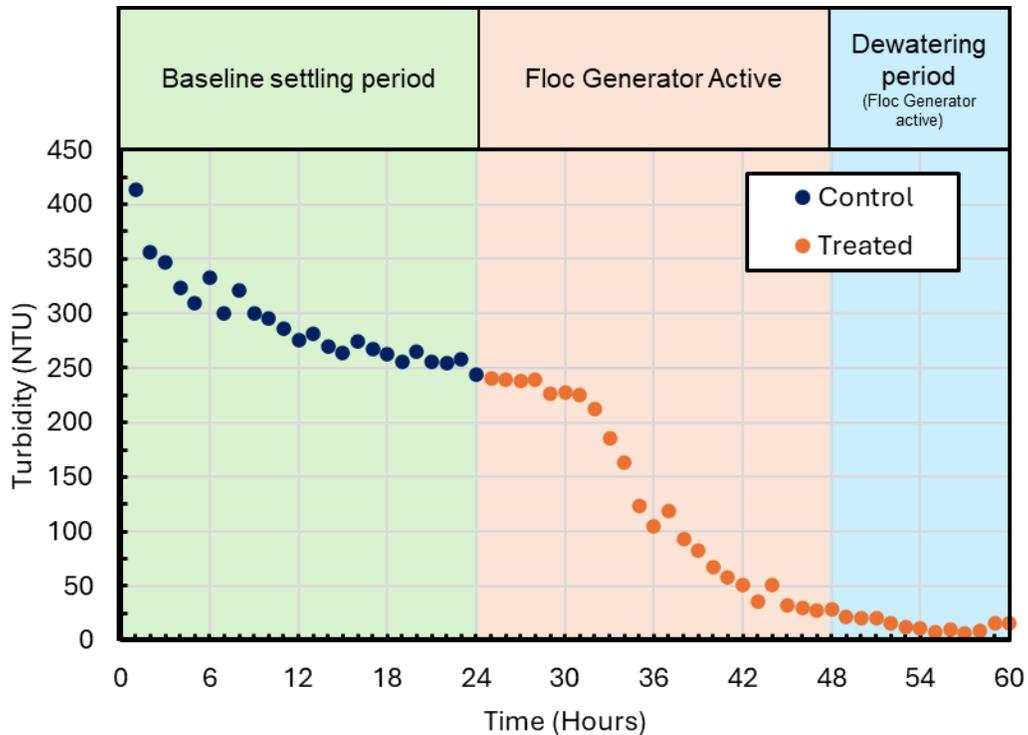
**Figure 5. Visual turbidity reduction for 24 hour treated testing with SOLO model.**

### **7.1.1 Turbidity Reduction in Basin**

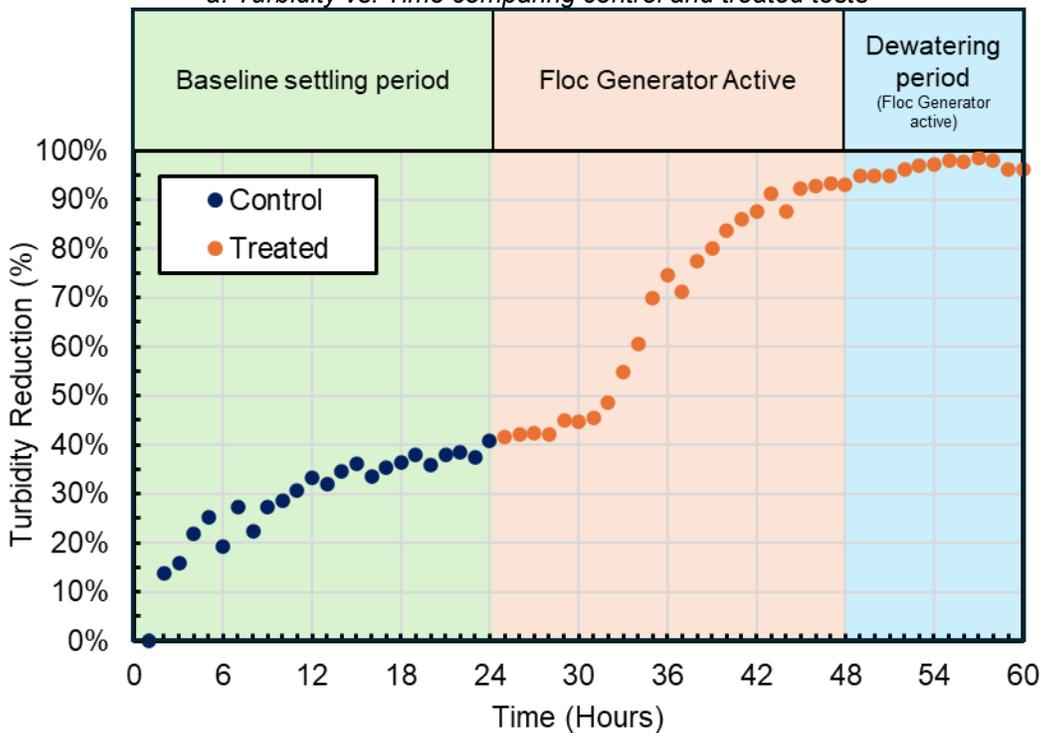
Turbidity trends for the baseline and treated conditions are shown in Figure 6a. The point at which the control and treated curves diverge (where the trends no longer align) corresponds to activation of the SOLO model. During the initial period (green), turbidity reduction reflects the baseline sediment settling, and the treated turbidity closely follows the control trend. This indicates an early treatment stage in which microbubble generation and initial floc formation begin without immediate measurable turbidity reduction. Following activation, a rapid decrease in turbidity occurs over approximately 10 hours (red), indicating accelerated clarification under EC treatment. In the final period (blue), turbidity reduction approaches a plateau, suggesting diminishing incremental removal as remaining suspended solids become limited.

Figure 6b presents turbidity reduction as a function of time and shows trends consistent with those observed in the turbidity versus time comparison. During the initial ~32 hours, turbidity reduction followed a pattern similar to natural sediment settling. Between approximately 32 and 45 hours, turbidity reduction increased substantially, corresponding to activation and sustained operation of the SOLO model. After this period, turbidity reduction plateaued over the subsequent ~15 hours, indicating diminishing additional removal as remaining suspended solids became limited.

Comparison of the control and treated conditions suggests that natural settling alone approaches a steady-state turbidity of approximately 250 NTU (40% reduction), whereas SOLO treatment continued to polish basin water to turbidity levels near 10 NTU (93% reduction). These results support a working hypothesis that basin settling alone reaches a stabilization threshold that can be exceeded through treatment with the SOLO model electric floc generator; however, additional large-scale testing is required to confirm repeatability under variable conditions.



a. Turbidity vs. Time comparing control and treated tests



b. Turbidity reduction vs. Time comparing control and treated tests

Figure 6. Comparison of turbidity vs time and turbidity reduction vs time

## 7.2 Toxicology

Widely accepted literature and results from the 7-day chronic toxicity test, shown in Table 3, indicate that elevated dissolved aluminum concentrations in electrical flocculation effluent can cause adverse effects to *Ceriodaphnia dubia*, particularly through reproductive impairment. The undiluted effluent (100% sample)

contained 3.05 mg/L dissolved Al and resulted in 60% survival and complete reproductive failure (0 neonates). Similarly, the 30% dilution, containing 0.88 mg/L Al, maintained 90% survival but also produced 0 neonates, demonstrating that reproduction was the most sensitive endpoint in this study. At lower aluminum concentrations, survival remained high and reproduction improved. Dilutions of 10% (0.37 mg/L Al) and 5% (0.232 mg/L Al) resulted in 100% survival, but reproduction was still suppressed (3.3 and 10.7 neonates, respectively) compared to the control (21.1 neonates). The lowest dilution tested (0.50%, 0.067 mg/L Al) exhibited 100% survival and reproduction comparable to the control (24.6 neonates). These results indicate that chronic toxicity was driven primarily by dissolved aluminum concentration, with full reproductive inhibition occurring at concentrations greater than 0.88 mg/L dissolved Al, while measurable sublethal effects on reproduction occurred at lower concentrations.

Table 3. ERA toxicity results

Dilution (%)	Al (mg/L)	Survival (%)	Average Neonates
Control	0	90%	21.1
0.50%	0.067	100%	24.6
5%	0.232	100%	10.7
10%	0.37	100%	3.3
30%	0.88	90%	0
100%	3.05	60%	0

### 7.3 Actual Aluminum Concentration Release

Dissolved aluminum results collected during the SOLO large-scale test are summarized in Table 4. Baseline dissolved aluminum concentrations measured during the control period (hours 0–24) were low (approximately 0.0002 to 0.0004 mg/L). Following activation of the SOLO model, dissolved aluminum increased during the treatment and dewatering phases (hours 25 to 60), with concentrations ranging from approximately 0.0004 to 0.0018 mg/L. The highest dissolved aluminum concentrations were observed at the end of the dewatering period (0.0016 mg/L at the weir and 0.0018 mg/L at the skimmer head), which is consistent with discharge occurring later in the drawdown when basin water is more influenced by resuspension and proximity to accumulated sediment. Overall, dissolved aluminum remained low throughout the test; however, elevated concentrations near the end of dewatering suggest that drawdown conditions and sediment disturbance may influence measured dissolved aluminum in the discharge.

Table 4. Dissolved Aluminum concentration by location and time of test

Location	Hour From Test Start	Concentration (mg/L)
Skimmer head (Control; Flocc Generator is not active)	1	0.0004
	12	0.0002
	24	0.0004
Skimmer head	25	0.0004
	36	0.0008
	48	0.0006
Weir	49	0.0007
	54	0.0008
	60	<b>0.0016</b>
Skimmer head	49	0.0007
	54	0.0010
	55	0.0010
	60	<b>0.0018</b>

Figure 5 provides a graphical summary of dissolved aluminum concentrations in the basin and during dewatering and illustrates an increasing trend as the dewatering period progressed. When comparing SOLO aluminum release results to the chronic toxicity testing performed by ERA Laboratories, measured dissolved aluminum concentrations during SOLO operation remained substantially below concentrations associated with adverse biological effects, including the threshold associated with complete reproductive inhibition ( $\geq 0.88$  mg/L dissolved Al). For additional context, the U.S. EPA Secondary Drinking Water Standard for aluminum is 0.05 to 0.2 mg/L; however, this standard is based on total aluminum, not

dissolved aluminum. Therefore, additional ICP-OES testing and comparison of dissolved versus total aluminum fractions are needed to directly relate SOLO field results to drinking-water guideline values.

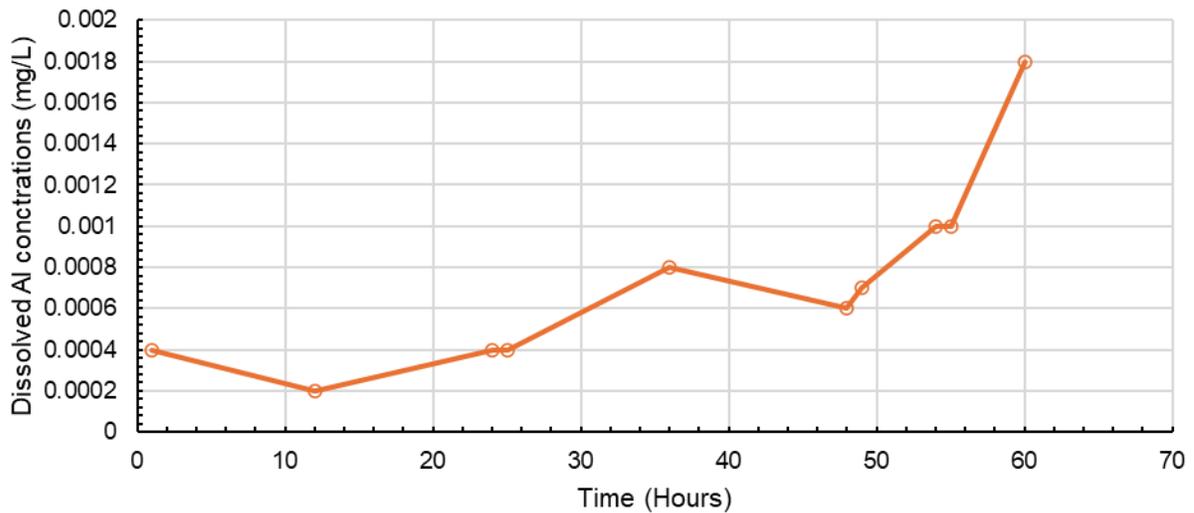


Figure 1. Time vs. Dissolved Al concentration within sediment basin and dewatering (adverse reproductive effects for invertebrates typically occur at 0.1–1.0 mg/L)

## 8.0 CONCLUSION

Large-scale sediment basin testing demonstrated that the SOLO model floc generator can substantially enhance sediment basin performance. Under representative construction runoff conditions (initial turbidity 500 to 750 NTU; conductivity 300  $\mu$ S/cm), SOLO treatment improved turbidity removal beyond the apparent natural settling limit, achieving polishing to near-complete clarity (~93% reduction) and producing visually clear discharge during controlled dewatering. These results support the feasibility of a floating, batch-mode electric floc generator approach for in-basin stormwater treatment.

Dissolved aluminum monitoring indicated minimal aluminum release during SOLO operation. Baseline dissolved aluminum concentrations during the control period were low (~0.0002–0.0004 mg/L) and increased slightly during treatment and dewatering (0.0004 to 0.0018 mg/L). The highest dissolved aluminum concentrations occurred near the end of the dewatering period, suggesting that drawdown conditions and sediment disturbance may influence measured dissolved aluminum in discharge waters. Importantly, observed dissolved aluminum concentrations during SOLO operation remained orders of magnitude below concentrations associated with chronic toxicity effects determined through independent ERA testing (complete reproductive inhibition at  $\geq 0.88$  mg/L dissolved Al).

Future testing will expand validation across additional water chemistry conditions (conductivity, temperature, and turbidity), evaluate dissolved versus total aluminum fractions, and support ongoing development of the electric floc generator and operational guidelines for safe field deployment.

## 9.0 REFERENCES

- Akyol, A. Treatment of Paint Manufacturing Wastewater by Electrocoagulation. *Desalination*, Vol. 285, 2012, pp. 91–99. <https://doi.org/10.1016/j.desal.2011.09.039>.
- Alimohammadi, M., M. Askari, M. H. Dehghani, A. Dalvand, R. Saeedi, K. Yetilmezsoy, B. Heibati, and G. McKay. Elimination of Natural Organic Matter by Electrocoagulation Using Bipolar and Monopolar Arrangements of Iron and Aluminum Electrodes. *International Journal of Environmental Science and Technology*, Vol. 14, No. 10, 2017, pp. 2125–2134. <https://doi.org/10.1007/s13762-017-1402-3>.
- Boinpally, S., A. Kolla, J. Kainthola, R. Kodali, and J. Vemuri. A State-of-the-Art Review of the Electrocoagulation Technology for Wastewater Treatment. *Water Cycle*, Vol. 4, 2023, pp. 26–36.
- Demirbas, E., and M. Kobya. Operating Cost and Treatment of Metalworking Fluid Wastewater by Chemical Coagulation and Electrocoagulation Processes. *Process Safety and Environmental Protection*, Vol. 105, 2017, pp. 79–90. <https://doi.org/10.1016/j.psep.2016.10.013>.
- Hakizimana, J. N., B. Gourich, M. Chafi, Y. Stiriba, C. Vial, P. Drogui, and J. Naja. Electrocoagulation Process in Water Treatment: A Review of Electrocoagulation Modeling Approaches. *Desalination*, Vol. 404, 2017, pp. 1–21.
- Hafez, O. M., M. A. Shoeib, M. A. El-Khateeb, H. I. Abdel-Shafy, and A. O. Youssef. Removal of Scale Forming Species from Cooling Tower Blowdown Water by Electrocoagulation Using Different Electrodes. *Chemical Engineering Research and Design*, Vol. 136, 2018, pp. 347–357. <https://doi.org/10.1016/j.cherd.2018.05.043>.
- Hem, J. D. *Study and Interpretation of the Chemical Characteristics of Natural Water* (3rd ed.). U.S. Geological Survey Water-Supply Paper 2254, 1985.
- Kazaz, B., M. A. Perez, and W. N. Donald. State-of-the-Practice Review on the Use of Flocculants for Construction Stormwater Management in the United States. *Transportation Research Record*, SAGE Publications Ltd, 2021, pp. 248–258.
- Kerr, S. J., and Ontario Ministry of Natural Resources. *Silt, Turbidity and Suspended Sediments in the Aquatic Environment: An Annotated and Literature Review*. Ontario Ministry of Natural Resources, 1995.
- Khandegar, V., and A. K. Saroha. Electrocoagulation for the Treatment of Textile Industry Effluent – A Review. *Journal of Environmental Management*, Vol. 128, 2013, pp. 949–963.
- Lantin, A., L. Larsen, A. Vyas, M. Barrett, M. Leisenring, K. Koryto, and L. Pechacek. *Approaches for Determining and Complying with TMDL Requirements Related to Roadway Stormwater Runoff*. Transportation Research Board, Washington, D.C., 2019.
- Liu, L., and M. A. Perez. Development and Evaluation of Lamella Settlers Combined with Electrocoagulation for Treating Suspended Sediment. *Journal of Irrigation and Drainage Engineering*, Vol. 148, No. 6, 2022. [https://doi.org/10.1061/\(asce\)ir.1943-4774.0001680](https://doi.org/10.1061/(asce)ir.1943-4774.0001680).
- McLaughlin, R. A. *Evaluating Sediment Capture Rates for Different Sediment Basin Designs*. North Carolina Department of Transportation Research Report (Project 2006–17), 2007.
- Naje, A. S., S. Chelliapan, Z. Zakaria, M. Ajeel, and P. A. Alaba. A Review of Electrocoagulation Technology for the Treatment of Textile Wastewater. *Reviews in Chemical Engineering*, 2016.
- Nandi, B. K., and S. Patel. Removal of Pararosaniline Hydrochloride Dye (Basic Red 9) from Aqueous Solution by Electrocoagulation: Experimental, Kinetics, and Modeling. *Journal of Dispersion Science and Technology*, Vol. 34, No. 12, 2013, pp. 1713–1724. <https://doi.org/10.1080/01932691.2013.767203>.
- United States Environmental Protection Agency. *Federal Register*. Reissuance of NPDES General Permits for Storm Water Discharges from Construction Activities; Notice. Washington, D.C., 1998.
- United States Environmental Protection Agency. *National Nonpoint Source Program – A Catalyst for Water Quality Improvements*. Washington, D.C., 2016.
- U.S. Geological Survey (USGS). Aluminum—Chapter in *Critical Mineral Resources of the United States: Economic and Environmental Geology and Prospects for Future Supply*. Scientific Investigations Report 2017–5118, 2017.