Objective Zero: Improving the water quality mission objectives of the Watershed Protection Department

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Introduction

The mission of the City of Austin Watershed Protection Department (WPD) is "to protect the lives, property, and environment of our community by reducing the impact of flooding, erosion and water pollution." The WPD goal with respect to water quality is "to protect and improve Austin's waterways and aquifers for citizen use and the support of aquatic life." The current objectives of WPD relative to the water quality mission are (City of Austin 2015):

Table 1. WPD (City of Austin 2015) water quality mission objectives.

WQ1	In local creeks, achieve or exceed Good (≥ 62.6) Environmental Integrity Index scores
WQ2	In Urban creeks, restore baseflow quantity and quality to the maximum extent possible
WQ3	In Nonurban creeks, preserve the existing baseflow quantity and quality to the maximum extent possible
WQ4	In all creeks, reduce the existing and future pollutant loads to the maximum extent possible
WQ5	In the Edward's Aquifer, maintain or enhance the existing rate of recharge to the maximum extent possible
WQ6	Maintain or enhance high quality environmental features (e.g., springs, seeps, wetlands, swimming holes, threatened or endangered species habitat) to the maximum extent possible

Doran (Doran 1981) describes the importance of establishing clear organizational objectives, and outlines the S.M.A.R.T. framework for objectives that ideally are: Specific, Measurable, Achievable, Relevant, Time-Specific. Existing WPD water quality objectives (Table 1) are less than ideal in multiple aspects.

Specific

Existing objectives are generally lacking quantitative specificity, as 5 of 6 objectives contain the ambiguous "maximum extent possible" language. However, existing objectives do appropriately identify the variable spatial context of Austin's watersheds, recognizing differential objectives for urban and non-urban creeks. Existing objectives do generally address both water quality and water quantity concerns, and note that high-value environmental resources (e.g., the Edwards Aquifer, wetlands, endangered species habitat) may be deserving of special protection. Consideration of all aspects of stream function, from hydrology to water chemistry and biology, are critical to restoration success (Fischenich 2006, Harman et al. 2012).

Measurable
Existing objectives are measurable, but existing WPD water quality monitoring programs may not directly align with the objectives such that progress towards goal attainment can be easily assessed. For example, while discharge quantity is noted, and has been demonstrated to relate to aquatic community health in Austin (King et al. 2016), not all watersheds of interest in Austin have stream discharge gauges. While pollutant load reduction is noted, not all watersheds of interest are monitored for both storm and non-storm water quality or stream discharge although some load reduction activities (e.g., volume of spilled contaminants recovered) are tracked separately. Aquifer recharge rate preservation is noted as a WPD objective, but groundwater recharge quantification other than direct recharge (Hauwert and Sharp 2014), as measured by stream discharge gauges bracketing the recharge zone, needs additional examination (Hauwert 2009, Hauwert and Sharp 2014, Slade 2017). Monitoring of high quality environmental features beyond the Barton Springs Complex does not occur on a consistent citywide basis other than on a localized scale during the site development permit application review process.

Achievable
Achievability of the existing objectives is unknown and questionable. Clear restoration targets are not established for degraded urban creeks or developing non-urban creeks, other than maintaining an Environmental Integrity Index (EII) score of "Good" or better which may or may not be reflective of minimally-acceptable specific levels of ecological function so that Austin creeks maintain all designated and desired uses. The "maximum extent possible" language utilized in 5 of 6 objective statements does not establish quantifiable targets for success.

Restoration of degraded urban systems to a pre-disturbance (non-urban) condition, as is implicit in the score calculation methodology of the Environmental Integrity Index (City of Austin 2002) in which urban streams are compared to non-urban streams, may be not be achievable or cost-effective (Booth 2005, Bernhardt and Palmer 2007, Burns et al. 2012) ultimately limiting success. End points for urban environmental restoration should be based on current site potential and "the greatest possible degree of self-regulation" rather than on an original condition (Kowarik 2005), and degraded systems may need customized restoration methods as traditional restoration efforts may be insufficient to counter existing constraints (Suding et al. 2004).

The erosion control and flood hazard mitigation missions of WPD, for which problems directly threaten existing infrastructure, yield success targets that are easily quantifiable even if they are expensive to implement. In contrast, success for the water quality mission of WPD is at present more abstract and harder to define as it is not known what would be required to achieve "Good" or better EII scores. The disparity in quantification of ultimate potential success between missions may complicate resource allocation within WPD among missions, especially as community goals evolve over time.

Relevant

Existing objectives may not be relevant to all current City of Austin stakeholders. In November 2012, Austin voters approved transition of the Austin City Council from all at-large council members to geographic single-member district representation, marking a significant milestone in local government decision-making and potentially reducing the influence of geographically-specific environmental advocacy groups on a citywide basis. District boundaries could have been drawn consistent with watershed boundaries (Porras and Herrington 2013), but were not and have impacted how WPD describes watershed management activities (e.g., austintexas.gov/department/watershed-protection-council-district-profiles). Austin continues to experience substantial population growth and change in demographic composition including becoming less Anglo, having fewer children in the urban core, less African-American, more Hispanic, more Asian, and with a growing divide become more affluent and less affluent residents (Robinson 2016).

Recently, Austin City Council established 6 areas for prioritization in budgetary decision making for Fiscal Year 2018 reflecting some of these changes: affordability, mobility, safety, health, culture, and trust in government. While "health" may include factors relating to environmental quality, it is unclear how these priorities directly relate to WPD water quality objectives, or what explicit sociocultural values are reflected in the existing objectives. Existing objectives, or at least the manner in which they are expressed, may no longer be relevant to current citizen stakeholders. New attention on alternative multi-benefit approaches like integrated water resource management (Agarwal et al. 2000) may be needed for holistic stormwater management to remain a high priority in municipal operations.

Recognition of the sociocultural context for urban stream management enhances success (Yocom 2014), and successful urban stream restoration projects must meet stakeholder needs (Palmer et al. 2005). The European Union REFORM Project ("REFORM: REstoring rivers FOR effective catchment Management" 2015) noted that a common reason for failure of stream restoration projects was "failure to get adequate support from public and private organizations." Without sociologically-relevant objectives, justification of WPD water quality protection activities to the public may be increasingly difficult as competition for municipal resources increases with increasing population and demand. Objectives must also be ecologically relevant to result in meaningful ultimate outcomes for stream functionality, as pollutant load focused stormwater management strategies may have limitations especially when they do not adequately address ecologically relevant elements of the hydrograph (Burns et al. 2012). Although restoration to a pre-disturbance condition may not be possible in urban environments, successful projects to restore varying levels of ecologic function in urban streams have occurred (Riley 2016) and frameworks for establishing objectives based on stream function exist (Fischenich 2006, Harman et al. 2012).

Time-specific

While existing objectives contain some implicit temporal specificity in recognizing a difference between current and future conditions, there is no explicit target date established for objective attainment. Capital solution costs for the water quality mission on a citywide basis are estimated to be $347,816,463 (see Table 10.4-1 in City of Austin 2015). Current capital improvement project allocations to the water quality mission are approximately $2,000,000 annually. At current funding levels, by simple division it could take approximately 174 years to complete the WPD master plan for implementation of capital water quality improvement projects. While 174 years at current funding levels may be temporally-specific in some context, it is certainly not relevant in the sociological context of human life spans and, with an unknown potential for hysteresis (Beisner et al. 2003) over such a long period of time in a degraded condition, may not be ecologically relevant within 174 years. The potential length of time for completion of the master plan suggests that a more systematic and systemic approach to managing stormwater on a watershed scale is necessary for more cost-effective restoration in a timely manner.

Objective Definition Challenges not Unique to WPD

The lack of S.M.A.R.T. objectives (Doran 1981) for urban stream management programs is not localized to WPD. In a meta-analysis of more than 37,000 restoration projects on a semi-nationwide basis using the National River Restoration Science Synthesis database, Bernhardt et al. (Bernhardt et al. 2007) concluded that 20% of projects had no stated goals and only 10% had any form or monitoring or assessment to identify if the intervention was ultimately successful. A follow-up analysis (Bernhardt et al. 2007) with 317 confidential telephone interviews of restoration project managers found again that less than half of all projects set measurable objectives, although ironically more than two-thirds of all interviewees felt that their projects had been completely successful raising questions about the appropriate degree of intuition involved in evaluating intervention effectiveness.

The lack of S.M.A.R.T. objectives (Doran 1981) for urban stream management is not localized to the United States. A meta-analysis of European stream restoration projects under the REFORM initiative (Friberg et al. 2016) concluded that while more positives than negatives had resulted from river restoration projects, key reasons for the modest success rate can be attributed to the lack of attention to watershed scale considerations and a lack of clear objective setting and planning. Booth and Bledsoe (Booth and Bledsoe 2009) specifically note "[w]hen faced with the diverse and complex responses of streams in urbanizing watersheds, stormwater and floodplain managers often find themselves in a costly yet ineffective cycle of treating the many symptoms of stream degradation with makeshift solutions that are based on neither geomorphology nor strategic planning for the streams within their watershed context."

Origin of Objective Zero

Recognizing the problem of a lack of specificity in existing water quality objectives, managers within WPD revisited the objectives of the water quality mission. WPD managers were challenged to convert existing objectives into S.M.A.R.T. objectives (Doran 1981) for the water quality mission in a short time due to a need for more intensive data analysis, literature review, and involvement of WPD expert staff. Interim objectives were developed (Table 2) to describe existing programs in an organized manner. While these objectives are a more accurate description for organizing existing WPD water quality protection programs, they continue to have the same overall shortcomings of the existing water quality objectives in the WPD master plan.

Table 2. Interim objectives of the water quality mission of WPD.

1	Monitor, assess, investigate and compile data on Austin surface water and groundwater resources
2	Reduce pollution loads to receiving waters to the maximum extent practicable
3	Maintain and increase baseflow to Austin waterways to the maximum extent practicable
4	Protect and restore the functional integrity of riparian buffers on all Austin creeks and lakes
5	Preserve and enhance high-quality and critical environmental features

WPD managers identified the need for an "Objective Zero" to bridge the knowledge gap. The objective of Objective Zero was to "Develop quantitative time-specific water quality objectives and align programs to meet objectives." Objective Zero contained two fundamental parts:

- Analyze water quality and hydrologic data to create watershed and receiving water models; synthesize models with regulatory and state of science best management practices to create desired future conditions for Austin waterways.
- Conduct an evaluation of existing WPD water quality monitoring, data management, assessment (e.g., modeling) capabilities, and effectiveness of water quality best management practices to identify and recommend the most effective method to achieve the water quality mission and objectives.

Thus, Objective Zero is the process by which S.M.A.R.T. objectives (Doran 1981) for the water quality mission would be established, gaps between current and desired conditions would be evaluated, and a suite of best management practices recommended to close the gaps and achieve success.

Objective Zero Problem Statement

Existing WPD objective statements are not quantitative or time-specific, and may not be ecologically-relevant. Without improved objectives, clearly measuring success of the water quality mission of WPD over time may be difficult; justification of water quality protection activities to the public and policy makers may become increasingly difficult; resource allocation between missions within WPD may be increasingly difficult; and the efficient implementation of cost-effective watershed management activities may be impaired.

More specifically:

- The existing objectives of the water quality mission of WPD are not expressed using S.M.A.R.T. (Doran 1981) principles. Five of 6 of the existing objectives of the water quality mission (Table 1) are not quantitative and include the caveat to the "maximum extent possible". Zero of 6 water quality objectives are time-specific.
- There are no explicit critical degradation limit thresholds for urbanizing watersheds, and restoration targets for urban watersheds that approximate limited development conditions (as implied by the EII "Good" or better score) may not be feasible in intensely urban watersheds. Thus, there is no quantitative water quality target for restoration of urban

watersheds, or similar targets for the prevention of unacceptable degradation of streams in developing watersheds.

- Existing objectives (or at least the manner in which they are expressed) may not be relevant to current stakeholders, and may not be consistent with integrated water resource management (Agarwal et al. 2000) principles.
- Existing objectives may not be ecologically relevant due to an insufficient focus on the fundamental stressor driving degradation, hydrologic regime alteration (Fischenich 2006, Harman et al. 2012) from anthropogenic disturbance (Walsh et al. 2005).
- Without relevant objectives, justification of WPD water quality protection activities may be increasingly difficult for stakeholders, or internally within the department in regards to resource allocation between missions.
- Quantitative tools to simulate suites of water quality best management practices (BMP) on a citywide (watershed) scale for cost-effectiveness optimization and for quantitative long-range planning do not exist, impeding effective long-range planning.
- WPD monitoring initiatives and best management practice selection/implementation to achieve water quality goals are not consistently connected under a long-range plan, limiting the effectiveness of WPD to achieve specific water quality conditions on a citywide scale.

Objective Zero Project Purpose

Objective Zero seeks to establish ecologically-relevant objectives for the water quality mission of WPD that are time-specific, quantitative, feasible and relevant to Austin stakeholders. Critical levels of keystone ecological stressors will be identified to establish watershed specific quantitative objectives. This would create ecologically-relevant objectives for each watershed that could replace the current "maximum extent possible" language in existing objective statements. Objective Zero tools will generate a suite of stormwater best management practice solutions to enable data-based resource allocation decisions for the WPD water quality mission to achieve those objectives given a specific amount of money or time (Figure 1). WPD will thus be enabled to determine the time necessary to feasibly achieve those ecologically-relevant objectives for a given amount of funding, or funding necessary to feasibly achieve those ecologically-relevant objectives in a given amount of time. Based on either funding or implementation time decisions by WPD, time-specificity can be added to the ecologically-relevant objectives to create S.M.A.R.T. (Doran 1981) WPD water quality mission objectives.

Objective Zero also seeks to institutionalize the process of directly linking all aspects of monitoring, best management practice implementation, and long-range planning in WPD water quality protection activities. While these practices exist currently in various forms, they may not always be well coordinated or occur in an organized fashion at the departmental mission scale.

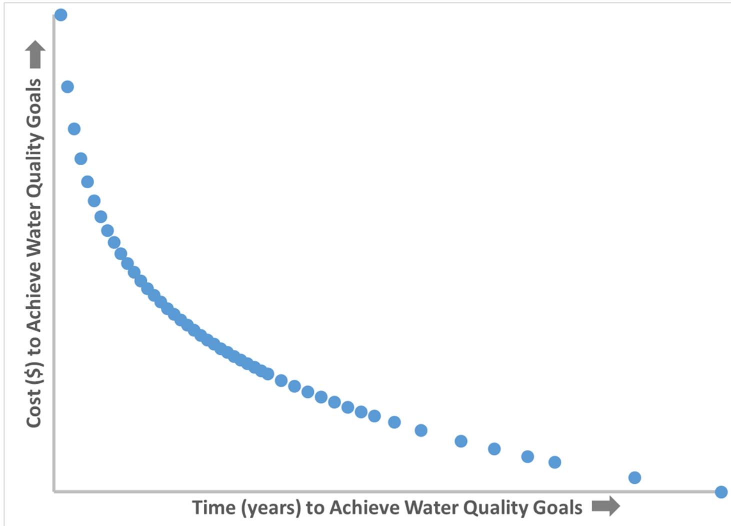

Figure 1. Hypothetical Objective Zero output of best management practice solution suites that all achieve stated objectives for given amounts of implementation time and money.

Objective Zero Project Pathways

The implementation of Objective Zero can be broken into four classes or pathways for projects to proceed in parallel towards the overall project purpose (Figure 2):

1. Develop quantitative, feasible, ecologically-relevant water quality objectives that are relevant to WPD internal and external stakeholders. This requires:
    a. identifying critical ecological functions to be performed by Austin streams;
    b. developing an understanding of primary stressors and the pathways by which stressors link to responses in Austin streams affecting those selected critical ecological functions;
    c. quantifying target levels of ecological function to be achieved or maintained to establish ecologically relevant objectives;
    d. identifying the stressor or response factors that can be affected by WPD water quality best management practices to determine feasibility; and,
    e. validating objective statements with stakeholders to ensure social relevance.

2. Quantify the performance and costs of structural and non-structural best management practices on a city-wide scale. This requires:
    a. establishing links between best management practice functions to quantitative effects on selected critical stream functions (see 1e);
    b. identifying existing information on best management practice life cycle performance relative to selected critical stream function effects, including probability and risk of failure, to quantify benefits or otherwise identify knowledge gaps;
    c. accurately estimating best management practice full life cycle installation, maintenance costs, and replacement costs;
    d. establishing suites of compatible best management practice strategies that could be implemented on a citywide basis to affect critical stream functions at a watershed level; and,

e. developing studies to acquire needed information when it does not exist to address knowledge gaps.

3. Develop modeling tools capable of evaluating the performance of best management practices on a watershed scale to achieve the quantitative water quality objectives. This requires developing:
   a. parsimonious models with minimized input parameters that can be efficiently extended to application in multiple watershed types (e.g., different ecoregions, different levels of development) at a citywide scale;
   b. models for which varying climatic data may be input in order to account for varying levels of current and future climate change;
   c. models that can evaluate numerous different suites of best management practices with high efficiency to enable large-scale replication;
   d. multiple modeling tools that can be deployed in parallel in order to utilize a weight-of-evidence approach in identifying optimal suites of best management practices and better quantify uncertainty for model predictions;
   e. models that can simulate the effects of best management practices on selected critical stream functions; and,
   f. models that can predict responses of selected critical stream functions based on alterations of the underlying stressors.

4. Develop an optimization tool to understand the performance of different best management practice suites capable of achieving the selected water quality objectives given varying amounts of implementation time and funding (Figure 1).

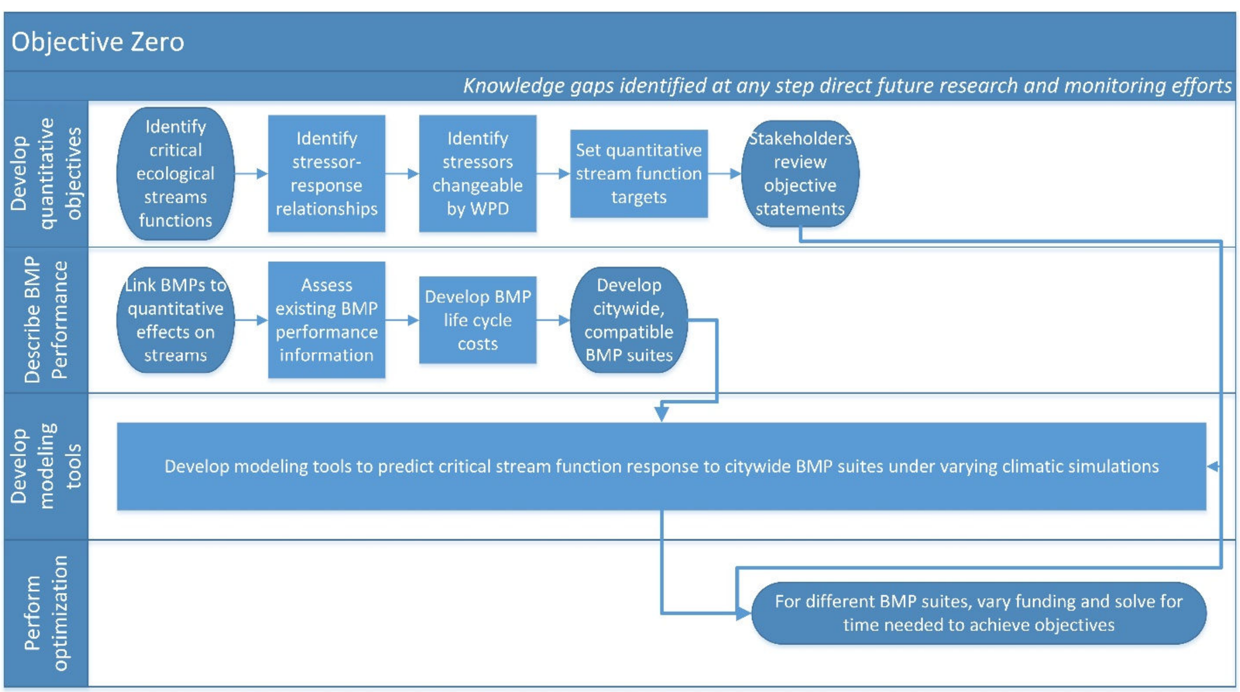

Figure 2. Objective Zero project pathways visualization.

Objective Zero First Steps
Objective Zero is an ambitious and complex effort requiring substantial dedication of resources from staff across the WPD water quality protection mission in order to be successful. To implement Objective Zero in a pragmatic way that minimizes adverse impacts on existing WPD water quality protection efforts, Objective Zero must be implemented with a phased approach that is adaptively adjusted over time as staff skills are developed, existing efforts are adjusted to be complementary with Objective Zero, knowledge gaps are resolved, and unforeseen opportunities arise.

The first steps of Objective Zero to be accomplished in Fiscal Year 2018 relate to the first three project pathways:

1. Quantitative, ecologically-relevant water quality objectives
    a. Utilizing the already in-progress complete audit of the WPD Environmental Integrity Index (City of Austin 2002), identify critical ecological functions, describe stressor-response relationships for critical functions, create function targets, and begin to validate relevance to internal and external stakeholders.
    b. Mine existing stormwater runoff quality and quantity data (stormwater monitoring is not explicitly part of the Environmental Integrity Index) to document the full range of hydrologic conditions of Austin watersheds.

2. Best management practice performance
    a. Review all existing WPD studies and databases on stormwater structural control measure performance, and direct monitoring when knowledge gaps are uncovered that cannot be addressed by literature or the International Best Management Practice Database.
    b. Complete a literature review of non-structural best management practices (in particular public education and outreach) to develop quantitative estimates of non-structural best management practice performance.
    c. Attempt to quantify the effectiveness of the Save Our Springs Water Quality Ordinance (Austin Land Development Code Chapter 25-8 Article 13) and the Texas Commission on Environmental Quality Edwards Aquifer Protection Program rules (Title 30 Texas Administrative Code Chapter 213).
    d. Identify or develop parsimonious models to predict stormwater structural control measure performance relative to selected critical stream function stressors and/or responses.

3. Develop hydrologic modeling tools
    a. Assuming that hydrology is a primary stressor in stream systems consistent with the stream functions pyramid (Harman et al. 2012), develop functional linear models for predicting hydrological and biological response to varying hydrologic conditions. Statistical models may be used to predict hydrologic conditions, and then estimate relationships between hydrological and ecological conditions (Patrick and Yuan 2017). While WPD has developed models relating biological response to varying hydrologic conditions using calculated hydrologic metrics (Richter 2011), the metrics can be misleading and a general loss of data can be assumed by computing the

hydrologic metrics. Using functional data analysis, models can be developed relating biological response directly to a hydrograph and not the computation of hydrologic metrics (Stewart-Koster et al. 2014, Masselot et al. 2016).

b. Conduct a functional analysis of variance to determine the variation in hydrology between watersheds in Austin as well as a functional classification analysis to group watersheds by similar hydrology so that a minimum number of watershed models can be developed but results can be extended to a citywide scale.

c. Develop a parsimonious model of a watershed for predicting hydrology capable of incorporating best management practices (including riparian management and subsurface water movement). Parsimonious models can also aid in identifying gaps in our knowledge of the hydrologic system and optimizing for a suite of best management practices on a reach level as a first order approximation.

d. Compare output of SWAT with alternative, established simulation models to identify a stable of models that can be utilized to develop a weight-of-evidence approach moving forward.

Objective Zero Implementation Time

Objective Zero must begin slowly. As existing projects are completed such that more staff resources can be devoted to the effort, as data gathering efforts are aligned with Objective Zero needs, and as critical path knowledge gaps are resolved, the pace of Objective Zero implementation should increase over time. It is vital to explicitly recognize that a critical secondary outcome of Objective Zero is to further institutionalize the process of directly aligning the planning and prioritization of data gathering exercises with the implementation of best management practices in a long-range planning effort that clearly charts a course of achieving defined water quality outcomes for given amounts of time or funding. This maximizes the probability that resource allocation decisions within WPD are made on an objective basis, and that the activities of WPD are likely to provide meaningful water quality protection services to WPD stakeholders.

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