RESEARCH ARTICLE

A Conceptual Planning Framework to Improve Integration of Reclamation with Site Remediation

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ABSTRACT

Ecological restoration and reclamation has become a large industry in the United States. However, the industry lacks generalizable planning processes to identify and mitigate the wide-ranging factors capable of driving unsatisfactory outcomes, especially on remediation sites. In this paper, we outline the potential challenges arising from planning shortcomings and propose a structured planning and evaluation process aimed at increasing the probability of achieving acceptable reclamation outcomes. Our proposed four-step planning process 1) establishes criteria to evaluate competing design concepts, 2) defines restoration success across five critical dimensions, 3) balances operational constraints and optimizes across ecological gradients, and 4) applies pre-determined evaluation criteria to select a final reclamation concept. We suggest that an ecologist should be brought into planning reclamation for remediation projects from the onset when the range of potential reclamation strategies is the broadest and potential to plan successful outcomes is the highest. Finally, we propose potential next steps to operationalize concepts presented herein.

Keywords: ecological design, ecological gradients, operation and maintenance, planning, project management

Restoration Recap

- Successful reclamation following site remediation hinges on adequate planning. We outline a four-step planning process designed to improve reclamation outcomes that 1) establishes evaluation criteria for competing designs, 2) defines success, 3) balances constraints and optimizes across ecological gradients, and 4) applies pre-determined evaluation criteria to select the ultimate reclamation concept.
- Ecologists are rarely part of initial reclamation planning; however, simultaneous consideration of engineering and reclamation aspects of the overall project is important. The reclaimed areas act as the interface between the engineered components of the system and the natural environment.
- Upfront assessment of potentially limiting factors and development of mitigation plans within a structured framework is the best way to increase the likelihood of a successful reclamation project.

In recent decades, restoration and reclamation of disturbed ecosystems in the United States has grown into a multibillion dollar per year industry (BenDor et al. 2015a, BenDor et al. 2015b, Kimball et al. 2015). Despite this rapid growth and significant total expenditure, the industry lacks generalizable planning processes aimed at identifying and mitigating the wide-ranging factors capable of driving unsatisfactory outcomes. Our premise is that some non-trivial fraction of projects fails from poor planning. This planning gap could be especially pronounced on contaminated sites where remedial actions take precedence and are currently not well integrated with restoration/reclamation of ecosystem functionality post-remediation (Hull et al. 2015, Kapustka et al. 2015, Rohr et al. 2015, Wagner et al. 2015, Efroymson et al. 2004).

The terms "reclamation" and "restoration" are quite broad, encompassing activities ranging from geotechnical ground stabilization to management of soil dynamic properties. In practice, however, a large fraction of this work is aimed at resetting ecosystem function through re-vegetation, which is the primary focus of this paper. In general, we favor the term "reclamation" over "restoration"

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because the objectives associated with remediation projects are largely forward-looking as opposed to aimed at achieving an historic ecosystem state (Wagner et al. 2015). For example, deep rooting, woody vegetation is typically excluded from reclamation of landfill sites situated within historically forested landscapes (Handel et al. 1997). Hereafter, we use the term "reclamation" except when "restoration" is more aligned with the meaning of a work being cited.

Even when the scope is narrowed to focus only on revegetation, it is common for ecological restoration and reclamation projects to proceed without clearly defined measures of success (Kimball et al. 2015, Wagner et al. 2015). Shortcomings during the planning stage are problematic because reclamation occurs against the backdrop of environmental variability (e.g., weather patterns, species invasions) and shifting cultural desires and norms, which pose risks to long-term project success (Rieger et al. 2014). Thus, development and consistent application of generalizable planning processes could significantly increase the probability of achieving reclamation objectives within the context of remediation projects. In this paper, we propose a structured four-step planning process aimed at: 1) establishing evaluation criteria by which competing designs will be compared; 2) clearly defining success across relevant dimensions; 3) balancing constraints while optimizing across ecological gradients; and 4) applying the pre-defined evaluation criteria to select among resulting design concepts.

Background

The field of restoration ecology has existed for several decades (e.g., Luken 1990, Zedler and Callaway 1999). Journals, textbooks, and university degree programs speak to the advancements in knowledge and maturing of the field. On-the-ground application of restoration and reclamation concepts draws on wide-ranging scientific disciplines, including hydrology, soil science, plant biology, and ecological design. Consequently, the field entails much complexity. Practitioners know that various factors can limit project success either independently or through interactions with other factors, but much of the industry is still dominated by trial and error and specific regional guidance documents (USACE 2010, Pyke et al. 2015). In contrast, civil engineering, which is critical to the completion of remediation and follow-on reclamation projects, tends to fall more cleanly into systematic planning processes. Previous authors have noted this imbalance and proposed potential corrections as briefly reviewed below.

Rieger et al. (2014) presented a comprehensive view of restoration project management from a biological perspective, which focused on planning a project, managing risks, and setting goals. They underscored the need for interdisciplinary perspectives in project design and implementation. To define how restoration was planned and executed, Murcia and Aaronson (2014) presented a classification of restoration approaches that ranged from basic trial and error to complex, hypothesis-driven experimental designs. Failing et al. (2013) performed a case study to demonstrate an effective "values-based" approach to implementing adaptive management. These authors encouraged principles of decision analysis to evaluate trade-offs, and asserted that long-term experimental programs require adaptive management that is responsive to shifts in values, information, and the political climate. Hull et al. (2015) evaluated opportunities and challenges of early integration of restoration practices into planning for impaired and contaminated environments. These authors argued that the practice of early integration of restoration has not been more widely embraced due to divergent stakeholder objectives, timing incongruence, conflicting stewardship criteria, locational obstacles, and limited guidance. They asserted that integrating restoration into the assessment and management of contaminated sites may not be appropriate at all sites, but practitioners should promote integration that allows for early restoration planning on contaminated lands wherever possible. While these disparate ideas have appeared in the literature, in our view, they have not yet been woven into a consistent, general framework that is suitable for use by practitioners and referenced by remediation engineers and project managers.

Entry Points for Reclamation Planning

Remediation projects initiated in the 1980s and 1990s began before planning for ecological reclamation found its way into regulations and site considerations. Today, ecological and reclamation issues are generally known and understood to be part of a remedial program, but for various regulatory, stakeholder, organizational, or financial reasons, addressing these issues is frequently delayed until the later stages of the remedial project timeline. Furthermore, site cleanups range from small, relatively simple, urban projects to vast tracts of land that include multiple ecosystems. Realistically, some remediation sites have minimal revegetation requirements and require de minimis reclamation planning (e.g., former service stations in urban settings). However, for large and complex sites, it becomes especially important to define desired ecological outcomes as early as possible. Our basic argument is that ecological reclamation planning should be implemented from the outset, particularly in situations where the final land-use is understood and hinges in any way on ecological function.

Planning and design constraints for reclamation increase as projects progress and construction shapes the site (Figure 1). As the site takes form, the range of options for reclamation design decreases, thereby narrowing the scope of available alternatives. This effect can be amplified when engineering aspects are designed independent of explicit consideration of reclamation. Simultaneous planning of engineering and reclamation aspects of the overall project is important because the reclaimed surface serves as the interface between the engineered components of the system and the dynamic natural environment. Ecological practitioners in the remediation field see these dynamics play out and there is a growing awareness of the need to couple ecological and remedial planning (Hull et al. 2015, Wagner et al. 2015). Thus, the challenge, addressed below, is to develop a generalizable planning framework that can be used at any stage of a site cleanup.

A Structured Planning Process

In this paper, we propose a generalizable process for planning reclamation aspects of site remediation across the breadth of hazard waste sites that require cleanup. The overarching goal for the process is to ensure that reclamation projects are successful by increasing the options for reclamation design, while reducing the probability of failed reclamation. This process (Figure 2) includes four steps, which are detailed in subsequent sections. The process can be used irrespective of the cleanup stage at which the reclamation efforts commence. Our objectives in developing this process are to: 1) formalize the manner in which evaluation criteria are used; 2) standardize dimensions along which success measures are defined and applied; and 3) place equal emphasis on engineering and ecological considerations such that they can be optimized simultaneously.

Define Criteria for Evaluating Reclamation Concepts

The point of entry within the general phases of site cleanup will influence the scope of reclamation planning work and will affect specific evaluation criteria used to compare competing reclamation concepts (ITRC 2006). However, several general elements are likely to be common across projects and are potentially widely useful evaluation criteria. Within this process, criteria are defined a priori, and refined as project evaluation proceeds.

Criteria for Evaluating Concepts

Within the context of remediation of contaminated sites, risk management is an ever-present concern (Kapustka et al. 2015). In fact, the reclamation component of these projects is often explicitly tied to risk management. For instance, vegetation is frequently used to ensure erosion control on landfill caps and is therefore part of the total containment system. When presented with a range of plant community options in reclamation concepts, there is likely to be variability in the degree to which plant structure and function can aid in managing potential risk associated with the remedy. For example, some plant communities can reduce risk of contaminant migration via ground cover and evapotranspiration, but can also present risks associated

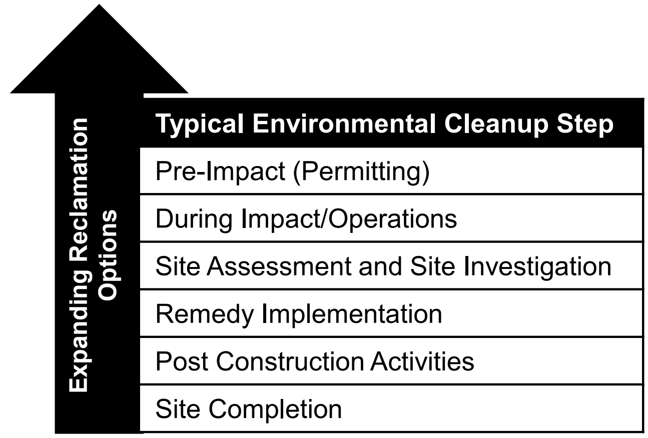

Figure 1. Typical phases of environmental cleanup planning, ranging from pre-impact and operations through assessment, planning, and completion.

with operation and maintenance (O&M) activities, facilitation of human encroachment, or management stakeholder perceptions. The degree to which various reclamation concepts can influence total risk is therefore likely a useful evaluation criterion.

Projects are executed on finite budgets making cost a constant consideration. Within the context of remediation projects, site cleanup takes precedent. The reclamation component can be modestly funded from the outset, even occasionally experiencing downward pressure if other project components experience cost overruns. These funding challenges can lead to poor planning and implementation. As a remediation project moves through the general stages (Figure 1), the probability of reduced budgets typically increases. Robbins and Daniels (2012) provide an overview of economic valuation techniques to guide the planning, prioritization, and evaluation of restoration projects, and discuss frameworks that aid in evaluating tradeoffs associated with various management alternatives. Their take-home message is that ecologists should consider the economics of a project in the early phases of planning and design. While we agree with this message, in practice, ecologists are often brought into projects too late to affect the overall financial aspects of reclamation activities. However, researchers who have evaluated project cost generally conclude that large differences exist in the cost-effectiveness of reclamation approaches (e.g., Kimball et al. 2015), implying that knowledge and rigorous planning can, to an extent, offset budgetary challenges. Specifically, a few key considerations appear to influence the cost-effectiveness of restoration and reclamation: 1) understanding of underlying environmental variation (Boyd and Davies 2012, Kimball et al. 2015); 2) well-defined a priori success metrics; and 3) the selection of a realistically obtainable reference community that fits the restoration goal (Kimball et al. 2015).

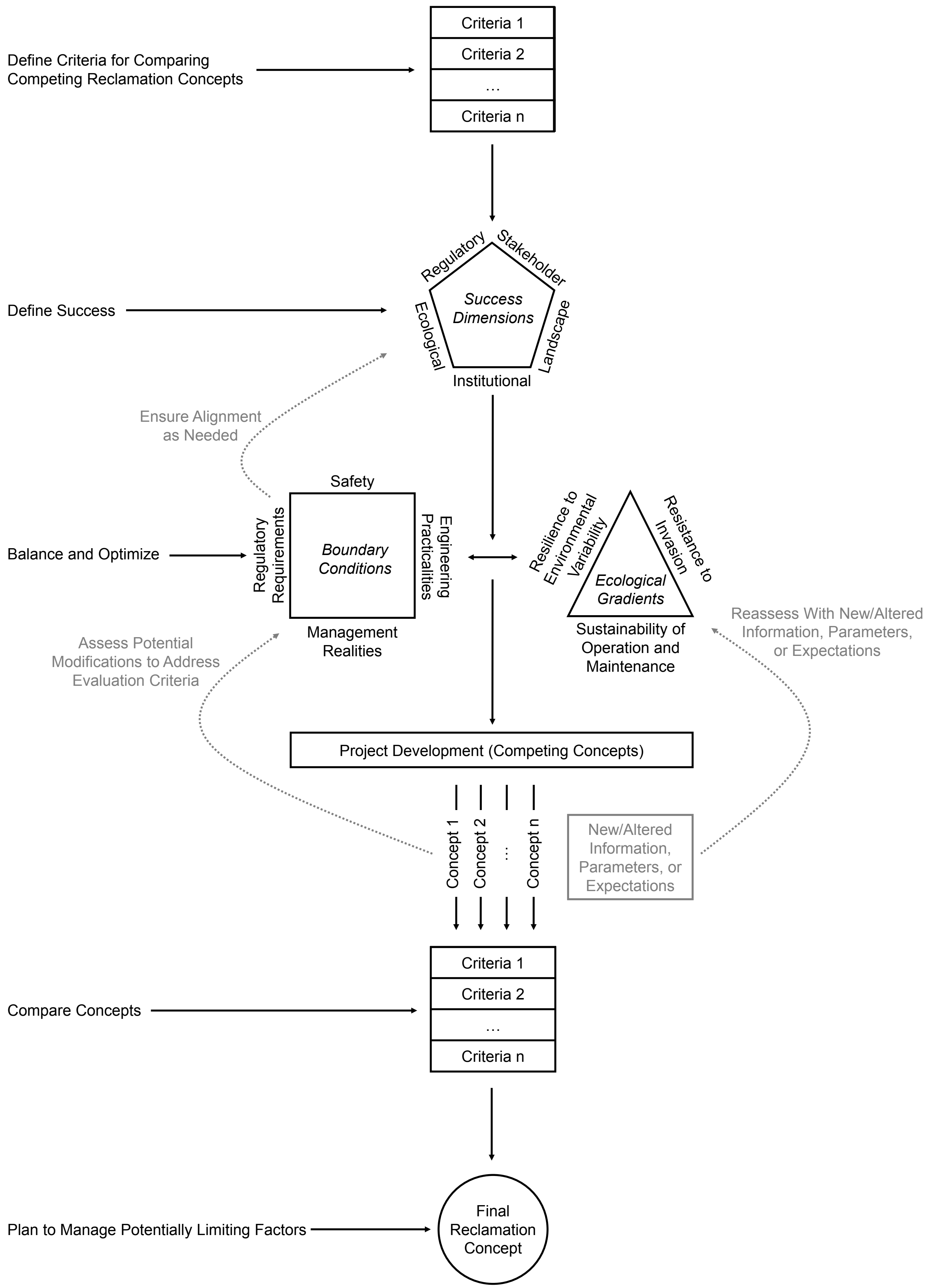

Figure 2. Reclamation planning workflow schematic.

Many forms of reclamation are ultimately aimed at leveraging ecological succession and therefore play out over long time lines (Luken 1990). Years may be required for targeted plant communities to become fully established. Projects that are following an appropriate ecological trajectory could be deemed unsuccessful if pronounced temporal mismatches occur between the timeline on which a project is evaluated and the actual time required for the desired successional stage to be achieved. Data collection and analysis should be tailored to ensure that measurements and interpretations are appropriate to the developmental stage and the ultimate goals.

Reclamation of remediation sites occurs within a regulatory context. Regulatory guidelines are intended to provide clarity for effective environmental management and drive progress towards a goal. However, in some instances, regulatory requirements are not consistent with long-term ecological success. For example, regulatory frameworks with a narrow focus on immediate prevention of erosion and sedimentation typically stipulate rapid establishment of some threshold plant cover. These regulations can lead to seeding with fast-growing agronomic grasses, which may lead to arrested succession and reduce the flows of ecosystem services relative to a slower-establishing native plant community.

Owners of sites that undergo remediation must plan for their long-term use and eventual disposition. Early assessment could highlight synergies (or conflicts) among remediation, reclamation, and real estate goals. Potential disposition options may include industrial or commercial real estate redevelopment, conservation divestment, or a long-term hold for ongoing management purposes. Disposition planning efforts tend to occur late in the development of the remediation and reclamation project. In some cases, sites could be promoted as ecological habitats, open space, or valuable natural amenities. In other cases, reclamation projects could be considered barriers to disposition. Therefore, long-term goals for site disposition will influence reclamation planning and design.

The overarching purpose of remediation is always site cleanup. However, the goals and objectives can be more nuanced for the reclamation component, ranging from a strict focus on regulatory compliance at one extreme to achieving synergy with broad corporate sustainability goals at the other extreme. Thus, this gradient can become a factor for selection among competing reclamation designs.

Define Success

We would argue that the industry does not as yet have a unified definition of success. Herein, we build upon concepts in the literature and practitioner experience to propose five dimensions critical to a holistic definition of success (Figure 2): 1) regulatory; 2) institutional; 3) stakeholder; 4) ecological; and 5) landscape. Our concept is that, for a given project, success should be defined such that specific metrics are stated for each dimension.

Hobbs and Norton (1996) provided a framework to refine the practice of ecological restoration by including the characteristics of success. Higgs (1997) introduced the need to look beyond ecology and include historical, social, cultural, political, aesthetic, and moral aspects into the definition of success. Other authors have identified numerous issues that affect the definition of success including goals of restoration (Asbjornsen et al. 2005, Thorpe and Stanley 2011), climate change (Choi 2004, Fule 2008, Seabrook et al. 2011), and socioeconomic conditions (Hull and Gobster 2000, Burke and Mitchell 2007, Hobbs 2009, Le et al. 2012). Despite this work, Zedler (2007) argued that vague use of the term "success" has depressed advancement of the science of restoration ecology and Kimball et al. (2015) stated that most reclamation projects are initiated without clearly defined measures of success. Our goal is to provide a framework to make defining success more structured, useful, and universally applied.

Dimensions of Success

Of the success dimensions, regulatory success is the most prescriptive. In principle, technical criteria for regulatory success are defined within the rules and regulations governing the work at hand. On occasion, regulations are written flexibly or criteria are negotiated. However, once a regulatory agreement is in place, translating that agreement into measurable success criteria should be tractable. Furthermore, monitoring of field-based performance measures and reporting to the regulator is typically required.

Overarching strategies and goals of the organization that owns the project will likely drive specific measures of institutional success. For example, a project team could explicitly define success criteria such that reclamation on a site-specific remediation project support corporate goals or reporting metrics (e.g., biodiversity goals). Institutional priorities are typically defined by senior management and can vary through time, which can lead to reevaluation of these success criteria.

A technically sound reclamation could be perceived as a failure if it is inconsistent with the desires or expectations of key stakeholders or if results are not effectively communicated to the public/stakeholders. Therefore, stakeholder engagement is critical to understanding perspectives that may be built into success criteria. Krueger et al. (2017) highlighted the potential value in establishing an expert panel to promote feedback among stakeholders and help prioritize project objectives to improve reclamation outcomes. Active engagement of stakeholders can also reduce the potential for conflict among competing groups (Collier 2011). Surveys could provide a means to capture metrics around stakeholder perceptions of reclamation progress.

Ecological success may be measured by habitat area and flows of ecosystem services. Ecological success can also include reintroduction or establishment of species assemblages and habitats (Wortley et al. 2013). Often, ecological success in a reclamation context is rooted in setting the stage for locally and environmentally appropriate long-term plant community succession (Luken 1990).

Landscape success refers to the functional interactions among reclaimed ecosystems within the landscape (Aronson and Le Floc'h 1996). Achieving landscape success allows reclamation projects to contribute to larger, regional restoration goals (e.g., New York and New Jersey Harbor Estuary Program Comprehensive Restoration Plan [USACE 2016]; the Sustainable Raritan River Collaborative [Rutgers 2009]; and the Chesapeake Plan [USACE 2014]), species-focused goals (Sage Grouse Initiative across western rangelands), or state-wide management goals (e.g., Louisiana's Comprehensive Master Plan for a Sustainable Coast [Coastal Protection and Restoration Authority 2012]).

Balance and Optimize

In reclamation of remediation sites, there are two broad categories of variables requiring balance and optimization: 1) project management/engineering aspects that lead to boundary conditions and 2) the broad range of ecological gradients. Historically, the former received more attention than the latter, especially during early planning and remedy selection (Figure 1). However, incomplete understanding of ecological interactions at remediation project sites can lead to unsatisfactory outcomes and costly reworks. Thus, simultaneous consideration of engineering boundary conditions and ecological gradients in project planning is needed (Figure 2).

Boundary Conditions

We define a boundary condition as a threshold or standard that cannot be crossed within a given project. Reclamation, within the context of site remediation, is constrained by four basic aspects with associated boundary conditions (Figure 2), described individually in subsequent sections. Any one aspect can be driven toward an ideal, but doing so can potentially lead to trade-offs with respect to the other three aspects. Therefore, balancing and optimization is required.

Safety considerations are the highest priority of any project. Safe work practices must include minimization of hazardous conditions for employees, contractors, and the public. Safe practices are site- and project-specific and are built around the complexity of project construction and equipment, site conditions (e.g., slope, materials, potential for flooding, etc.), project emissions (e.g., contaminant releases), and the potential for site access by the public (e.g., security issues).

There is overlap between regulatory and safety considerations. For instance, noise abatement regulations are designed to reduce hearing loss in employees, limit noise pollution for the public, and permit natural foraging and breeding cycles among regional wildlife (Francis and Barber 2013). Thus, safety considerations also inherently involve nature. Potential impacts to natural resources trigger a suite of environmental protections designed to minimize construction-related impacts.

With respect to reclamation specifically, different revegetation strategies will include variability in O&M requirements. Because all field O&M activities entail some risk, safety considerations are applicable to selection among reclamation designs both in terms of installation and with respect to long-term O&M.

Regulatory compliance is a dominant project constraint in which the project adheres to environmental laws at all jurisdictional levels and permit provisions as stipulated by the issuing authority. Within the bounds of regulatory requirements, there are often multiple ways in which to meet the terms of a permit. For example, a permit for remediation and follow-on reclamation may stipulate tree planting, but the spatial patterning, planting methodology, and species distribution may be open to optimization.

Engineering and planning constraints present logistical challenges that limit the flexibility of a project based on specific site characteristics and project needs. They can be numerous, dynamic, and may override ecological priorities, particularly when ecological planning is not on the table from the beginning. Common constraints include: basic remedial engineering priorities (e.g., pumping groundwater, excavating soils); site civil engineering constraints such as the presence of existing underground facilities, hazards, or utilities; the presence of sensitive resources (e.g., jurisdictional wetlands) or locations (e.g., airports or airfields); natural factors such as topography, climate, or site access; and inadequate supply of materials (e.g., sediments, native vegetation). Other engineering constraints might follow from the goals of a project. For instance, the presence of contamination could require an area to be fenced off, groundwater pumped, liners constructed for surface water management, or entire areas might need to be isolated from a habitat enhancement project.

Planning constraints might include regulatory restrictions that prohibit public access, concerns over neighboring properties, or the need to achieve contradictory goals. When the engineer of record plans the project in the absence of ecological inputs, the range of potential outcomes for the ecological layer is likely to be restricted.

Every project has some form of project management. A project manager (PM) ensures projects are planned, permitted, and constructed appropriately and within budget while managing communications and information flow. The degree of autonomy given to PMs varies widely, which can lead to variability in the decision frameworks employed both across projects and for different components within a project. PMs managing remediation projects are rarely trained as ecologists. Their primary focal points are likely to be on components within their areas of expertise and potentially viewed as more central to the overall remedial design. This can lead to reliance on outside consultants, contractors, and literature. The quality of these resources will influence the quality of the resulting decisions.

Ecological Gradients

The purpose of reclamation is to create habitat and improve the flow of ecosystem services at a remediation site following or in parallel with completion of cleanup activities. Reclamation actions can range from relatively simple planting of native or semi-natural vegetation over a closed landfill to complete restoration toward a baseline condition.

Regardless of project complexity, a basic understanding of underlying ecological concepts is critical to reclamation success, which in turn influences the success of the entire remediation project. This task is complicated because reclamation areas serve as the interface between remedial solutions and the dynamic environment, which includes spatial variability in local edaphic factors, legacies of historical land use practices, regional disturbances, weather variability, and long-term climate (Grygiel et al. 2012, Haan et al. 2012).

With these factors in mind, the balancing and optimization tasks described above for engineering and project management have analogues with respect to ecological considerations of site reclamation, three of which are described below.

In the ecological literature, resilience is typically defined by a system's ability to recover and persist following a perturbation (e.g., Scheffer et al. 2015). A rich literature base describes attributes that influence ecological resilience (reviewed in Scheffer et al. 2015). Among the most commonly cited attributes are physical heterogeneity and biodiversity. Biodiversity leads to enhanced resilience by increasing functional redundancy, which in turn allows for population fluctuations and community dynamics while maintaining ecosystem-level function (Tilman and Downing 1994, Folke et al. 2004). Thus, redundancy provides a buffer for recovery following a disturbance (Naeem and Li 1997).

A continuum exists in the degree to which reclamation projects design for resilience. While adding species and functional redundancy in revegetation projects may add upfront costs, greater species diversity could lead to a more resilient solution less likely to require subsequent interventions and expenditures. The increased cost and effort associated with favoring diverse, native species (as opposed to non-native or semi-natural) and ecotypic vegetation can provide additional resilience and improve long-term success as these species are specifically adapted to local ecological conditions (Funk et al. 2008). Similarly, diversity in plant functional type could present challenges in initial establishment and early-stage O&M, but lead to greater resilience and more favorable successional trajectories.

Resistance to invasion broadly refers to the degree to which ecosystem attributes prevent the establishment of self-sustaining populations of invading, undesirable species. The potential for biological invasions to negatively influence ecosystems is well-documented, leading to regulations in some jurisdictions mandating invasive species control (De Lucia 2018). Thus, maximizing resistance to invasion is (or should be) a primary goal of all reclamation projects. Resistance to invasion can potentially be increased by considering the phenology of common exotics and disproportionately introducing functionally similar native species in plantings (Cleland et al. 2013), using transplants instead of spread seeds (Middleton et al. 2010), or by adjusting soil characteristics to enhance and promote native species. For example, modifying soil nitrogen availability through amendments that promote nitrogen immobilization through microbial fixation (Cleland et al. 2013) can improve native plant growth and survivorship. Similarly, reduced nitrogen loading in mine land reclamation has been shown to limit noxious weed establishment (Borden and Black 2011).

In many ways, the O&M regime for a reclamation project mimics the disturbance regime of natural ecosystems. For example, periodic mowing or controlled burns of prairie reclamation projects are (imperfect) substitutes for historic natural fires. More generally, O&M activities can include technical, managerial, financial, and social actions, often mandated to achieve regulatory compliance aimed at ensuring the long-term stability of the project. There is growing recognition of the need to approach projects in a comprehensive way that emphasizes post-construction activities, in addition to design and construction to ensure sustainability (Johnston and Zedler 2012, Robertson 2012). In essence, sustainability of the design declines as the technical O&M actions needed increase, particularly for actions that are energy intensive (e.g., mowing, fertilizer application).

Compare Concepts

Predefined evaluation criteria, as discussed above, should serve as the framework for comparing competing reclamation concepts (Figure 2). Simple scoring systems could be developed and applied, which could be flexible and allowed to vary from project to project or among organizations. However, maintaining discipline in terms of applying only the pre-defined criteria should serve to ensure that concepts are compared in a consistent manner. In cases where an important evaluation criterion is discovered later in the process, care should be taken to ensure that the absence of this criterion did not bias design and development processes, that the addition of this criterion is needed and has potential to materially change the decision, and that all reclamation concepts can be equally evaluated against the new criteria set.

While the overall objective of this paper is to present a structured planning process, all practitioners know that surprises (e.g., injects of new information) occur and new information is gained throughout the planning process. It is critical to acknowledge these injects, rethink assumptions, and recycle as needed. However, practitioners should look thoughtfully at the potential for the new information to alter previous decisions, only re-working if the new information has real potential to have affected decisions already made.

Our fundamental assertion is that adopting structured planning processes and explicit consideration of ecology in parallel with engineering can lead to fewer reclamation failures. In principle, the process is designed to guide users such that potential challenges are avoided in the selection of a final design. However, it is advisable to reconsider any potentially limiting factors at the end of the process and ensure they have been accounted for and, if not, seek mitigation strategies prior to project implementation.

Proper planning, training, communication, and development of an adaptive management program can ameliorate the many elements that derail potentially successful reclamation projects. Many of these elements are common sense or best professional practices, but are all too often minimized due to the constraints described earlier ranging from fiscal limitations to poor management decisions.

Conclusions and Potential Next Steps

In this paper, we have argued that bringing ecological reclamation planning into the earliest possible stages of remediation projects will increase the likelihood of successful outcomes. We have further proposed a generalizable process to achieve this goal across the breath of remediation sites encountered. Our suggested planning process seeks to define four key stages: 1) development of evaluation criteria for comparing reclamation designs; 2) development of well-defined success criteria; 3) balancing project constraints in concert with optimization along ecological gradients, and 4) applying pre-defined criteria to select and final reclamation concept. This process should allow practitioners to guide reclamation projects towards successful outcomes. The range of available opportunities and therefore the likelihood of success increases as reclamation planning is driven earlier into overall project planning.

We believe that the following actions are logical extensions of this work and could be useful next steps. First, entities engaged in site cleanup could potentially benefit from considering business cases for improved planning that more explicitly integrates reclamation and remediation. For example, from a holistic perceptive spending more time and money up front could reduce risk, decrease the timeline to achieve success, and potentially meet sustainability goals. Second, a retrospective examination of case studies, spanning projects that went well and those that did not, could be used to identify relationships among planning completeness and project outcomes. Third, translation of this conceptual paper into an actual planning tool could serve to operationalize these concepts. Finally, application of a developed planning tool to case-studies could serve to verify and validate effectiveness and highlight areas for improvement. Clearly the best way to verify and validate the approach presented herein is to "field test" it with actual ongoing projects. Because these projects are often long lived, it is reasonable to test the planning tool using a gradient of project types to compare outcomes of different scales.

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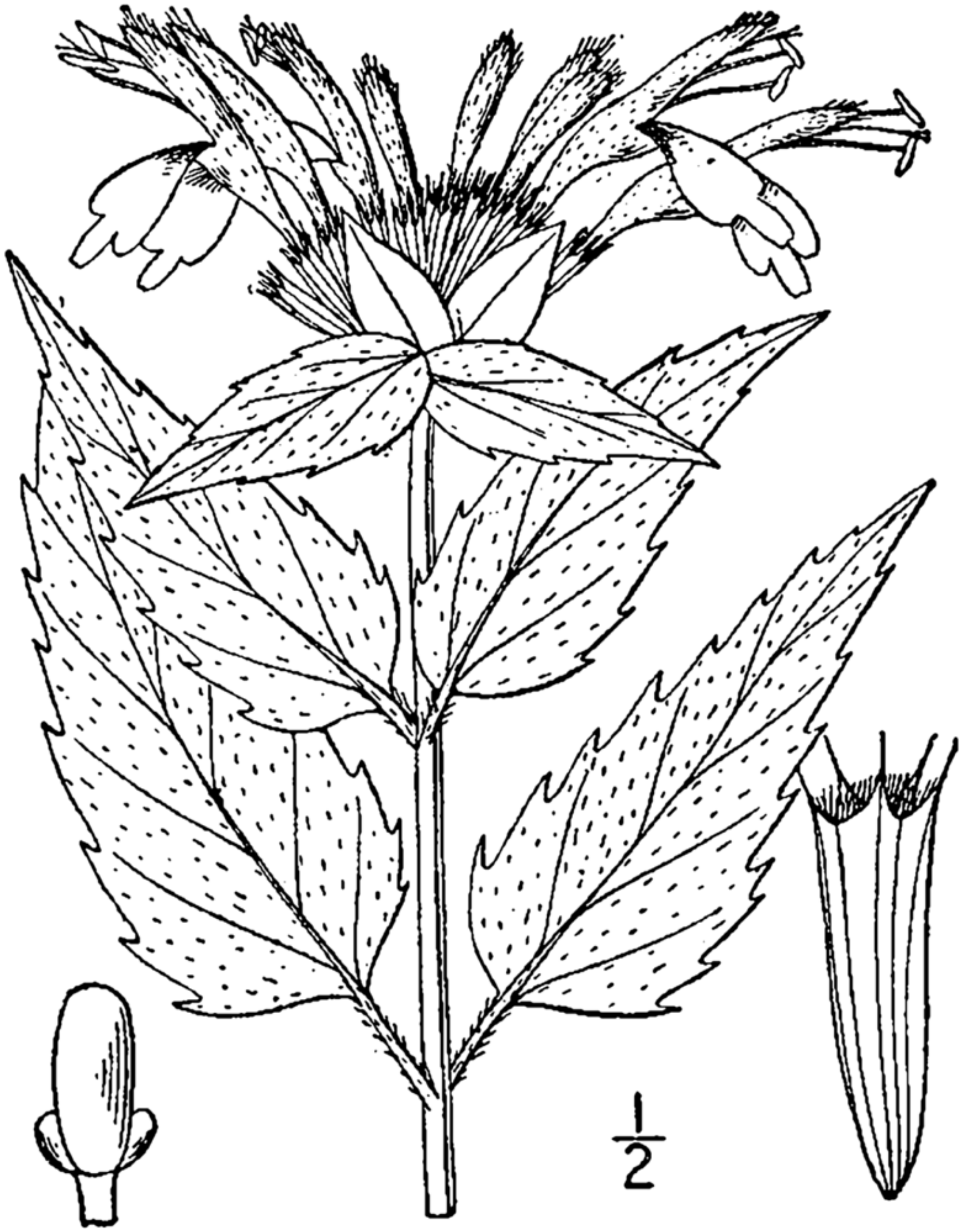

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