# SCIENTIFIC SOUNDNESS AND SOCIO-ECONOMIC REALITIES IN RECLAMATION FOR HABITAT[1]

by

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Abstract

Reclamation projects must balance data requirements for scientifically-sound design with uncertainty and socio-economic constraints. Whether designing for physical stability, cultural benefits or ecological enhancements, the reclamation project can work with or fight natural processes (physical, chemical, biological). Projects which anticipate and design to fit natural processes have greater chances of success with lower short and long-term cost, and with achievement of a greater range of social objectives. However, the cost of anticipating natural processes (succession, geomorphic patterns, etc.) increases the budget allocation at the design stage in order to save on construction and maintenance. In southern Ontario, once design teams recognize that designing for an "ideal" natural condition is not feasible, they too often revert to conventional, single-objective approaches which compromise design integrity and social benefits. Case studies are reviewed with analysis of alternative approaches that seek to balance ranges of achievable objectives with cost allocation and scientific soundness.

## Introduction

With increasing interest in achieving environmental benefits from reclamation of surface mined lands, comes the paradox of balancing fiscal responsibility against scientific soundness and desired outcomes. The less economic effort expended improving the design, the more assumptions and risks that are accepted in the final product on the ground. On the other hand, unnecessary expenditures, or efforts toward the wrong goals, can lead to unwanted outcomes as well.

In our own ways, industry, researchers, and reclamationists are acutely aware of this paradox as we strive not only to stabilize a site and meet regulations, but also to achieve environmental gains (and satisfy the public and government agencies).

The objective of this paper is to present an alternative means of optimizing cost:benefit ratios in reclamation projects. Shortfalls in past and current paradigms are discussed, as a basis for the presentation of an alternative new paradigm.

## The Old Way

Reclamation of surface-mined lands was most often carried out either to achieve a desired land use or to meet regulatory requirements. Sometimes, these objectives were combined to achieve specific rural, residential, open space or agricultural municipal zoning designations.

This outdated paradigm often persists and is characterized by narrowly focused impact mitigation without regard for ecosystem context or holistic rehabilitation targets (Fraser et al. 1994).

## The Current Paradigm

The current paradigm, brought on partially by societal values, effectively adds to the list of objectives contained in the old paradigm. Not only must reclamation projects achieve physical stability and produce a regulated land use outcome, but now they must also look attractive and contribute to an ecosystem.

[1] Paper presented at the 1997 National Meeting of the American Society for Surface Mining and Reclamation, Austin, Texas, May 10-15, 1997.

[2] Beak International Inc., 14 Abacus Road, Brampton, Ontario

Proceedings America Society of Mining and Reclamation, 1997 pp 317-328

DOI: 10.21000/JASMR97010317



https://doi.org/10.21000/JASMR98010317

In general, the surface mining industry has a heightened awareness of environmental enhancement in reclamation. This comes in part with a desire to:

- remove constraints imposed by ambiguous regulations;
- satisfy residents and resource users;
- improve public relations and corporate image;
- improve the landscapes we produce;
- achieve economic accountability; and
- achieve low maintenance.

These are assumed to be the "true objectives" of the industry in striving for ecosystem-based reclamation. In the presentation of an alternative new paradigm below, an argument is made for the need to design for ecosystem objectives in order to achieve all of the socio-economic objectives of community and industry combined.

## Fundamental Reasons That We Don't Achieve Our True Objectives

### Reluctance

Industry is often reluctant to design for ecological gain as part of reclamation due to perceptions of:

- "going too far" beyond what is necessary for agency or public acceptance;
- unnecessary cost;
- increased complexity in obtaining agency approvals for innovative designs;
- "too much study and not enough product in the ground"; and
- lack of connection between ecosystem design and other reclamation objectives.

Alternatively, attempts at ecosystem based reclamation may not produce the expected outcome due to incomplete design or a lack of performance measurements. This may be especially true when considering ecological gain relative to reclamation dollars spent.

### Definition And Measurement Of Objectives

A common problem in reclamation and resource management in general, is understanding when an objective has been achieved. Questions relating to "how much is enough" are justifiable from the perspectives of scientific soundness, cost:benefit ratios and goal achievement. Tree plantings are an excellent example:

- how many will meet agency requirements for environmental enhancement?
- how many will meet public calls for "something more natural"?

These questions are difficult to answer without scientific soundness in data requirements, objectives, design criteria and monitoring protocols. This has potential to exacerbate the challenge of integrating social values with reclamation as well as the cost effectiveness of the project (Prager 1997).

Questions relating to the definition and justification for objectives are also valid within the surface mining industry. Objectives may be defined inadequately or narrowly, resulting in unnecessary or misplaced reclamation effort (Doran and McIntosh 1995). Land use constraints or expropriation may be required by resource management agencies or municipalities to protect "natural features", or to create buffers or wildlife corridors (Grand River Conservation Authority 1993; Riley and Mohr 1994). However, the scientific rationale behind management decisions and land designations has been challenged (Simberloff 1992).

White (1991) discussed a need to state objectives in management programs. It is conceivable that workers have a sound knowledge of the ecosystem context within which the reclamation project is being conducted, but it is not clearly stated for stakeholders and other project proponents.

An overlooked facet of objective setting is the definition of specific monitoring measurements to assess performance. For example, Atkinson et al. (1996) determined that measurable evidence of wetland development may take between three and ten years. Monitoring programs may not account for this time lag.

### Multiple Objective Projects

The objectives of society, industry and agencies are often considered in isolation, rather than collectively. For instance, regulated land use may determine the pattern of grading upon site closure, while mechanical, structural or vegetative means are used to stabilize erosive areas, and trees are planted along perimeter berms to satisfy aesthetic concerns. Objectives such as fiscal responsibility (cost:benefit for reclamation effort relative to goals achieved), environmental enhancement and landscape improvement may be ignored.

"Swimming Upstream"

Treating the symptoms at hand and setting immediate goals without exploring underlying causes is analogous to fighting natural processes rather than anticipating and working with them. Some reclamation projects are installed deliberately to resist a natural tendency. An obvious example of the latter lies in our attempts to control erosional processes, such as migrating streams or slopes seeking an angle of repose. Examples of the former are found in recent applications of vegetation establishment, and in runoff management. For instance, six different seed mixtures were tested on a reclamation site in southern Ontario between 1991 and 1992 (Browning 1993). The general objectives of the seeding project were to determine which seed mixes would stabilize sites, promote diverse native plant communities and initiate succession. After one year, wild colonizers occupied 48% (range 8-92%) of the six plots, consisting primarily of sweet clover, black medic and tufted vetch. Diversity was relatively low. Admittedly, there was no replication, and valid questions can be asked about whether the colonizers would invade regardless of the presence of seed plots, and whether they are desirable or controllable. The same question has been asked of numerous other reclamation projects such as succession management and wetland construction (Thompson et al. 1996; Atkinson et al. 1996).

In order to manage runoff, or create habitat in stream corridors, many channel designs attempt to use relatively soft materials (e.g. bioengineering instead of gabion or armourstone). Meander patterns are added along with habitat structures for popular fish species. However, these attempts may not anticipate the natural tendencies of the system (needed balance in parameters such as gradient, cross section, velocity, shear stress, sinuosity particle size, and the most sustainable bioregional faunal communities). Therefore, the results often depart from expectation with significant expense (Trimble and Planck 1994). There is a growing body of literature documenting failures, short life spans, intensive maintenance and overlooked objectives resulting from river and slope management projects (Brooke and Marker 1988; Imhof et al. 1991).

Means Versus The End

Many projects are carried out to achieve goals such as:

- plant species diversity;
- geomorphologic stability/erosion control;
- forest succession;
- a particular rare species;
- water quality targets; or
- a certain "Best Management Practice" (BMP).

When viewed critically, these are all "means" to some other "end" (objective) and most are undefined or unmeasurable. "If we don't know where we are going, almost any road will get us there" (White 1991). For the project goals above the following is possible:

- diversity is a means to achieve ecological integrity, aesthetics or recreation objectives;
- stability is a means to liability prevention, habitat objectives or aesthetics;
- succession is a process through which to achieve vegetative cover or ecological integrity;
- a particular rare species may be an objective unto itself for heritage, or a means to a greater ecological endpoint;
- water quality targets may be established to achieve better water quality, liability prevention, or fisheries objectives; and
- BMPs are means to achieve various combinations of objectives.

In many cases the focus of reclamation becomes a means or technique. The underlying reasons for the project are more likely to comprise true objectives, parts of which are achieved by the techniques employed. The danger is that parts of objectives such as ecological integrity or geomorphologic stability may result in failure or low cost:benefit ratios.

The Parts Versus the Whole

Many reclamation projects deal with immediate problems such as contaminant management or slope stability, treating them as the most critical contributions to environmental enhancement on a site. Habitat enhancement measures are treated separately. While this approach may be worthwhile in some cases, there is a risk of having reclamation activities that contribute to different long term ecosystems or detract from a potential level of ecosystem sustainability. "Designing parts of a self-sustaining ecosystem does not a self-sustaining ecosystem make."

Constructed wetlands for the purpose of treating contaminants are a case in point (Ganse and Herron 1995). Both the treatment of a contaminant and the construction of a wetland should be viewed as contributing to a broader ecosystem objective in order to determine how much treatment is sufficient and which alternative methods to utilize.

Andrews and Kinsman (1990) and White (1996) suggest that the term "diversity" is an incomplete concept as an objective, relative to ecological integrity, of which diversity is a part. Andrews and Kinsman (1990) concluded that:

"*Creating a mishmash of habitat types and hoping that it will chance to fit the requirements of...unspecified wildlife all too often means expenditure for no good result, the habitats created being in the wrong place, having the wrong structure, plant composition or extent to meet the needs of all but the commonest and least demanding of wildlife.*"

## Design Versus Implementation Of Reclamation Projects

Many reclamation projects, while perhaps not ignoring ecological objectives, tend to underestimate the effort levels and analyses necessary to set and achieve them. Budget allocation may focus on the design effort needed to take action toward an immediate objective (or symptom), as described above. A new paradigm might offer cost savings and improved cost:benefit ratios if sufficient effort is dedicated to exploring causes of problems, and establishing larger scale objectives, even when unquantifiable.

## An Alternative Paradigm

A new paradigm considers the ecosystem as one of the main objectives for a reclamation project, even if it is not a major impetus for the project. One of the most critical goals in reclamation should be sustainability. Bradshaw (1984) suggested that the goal should be to design a system which is self-sustaining to minimize maintenance or repair must be a functional part of a complete ecosystem.

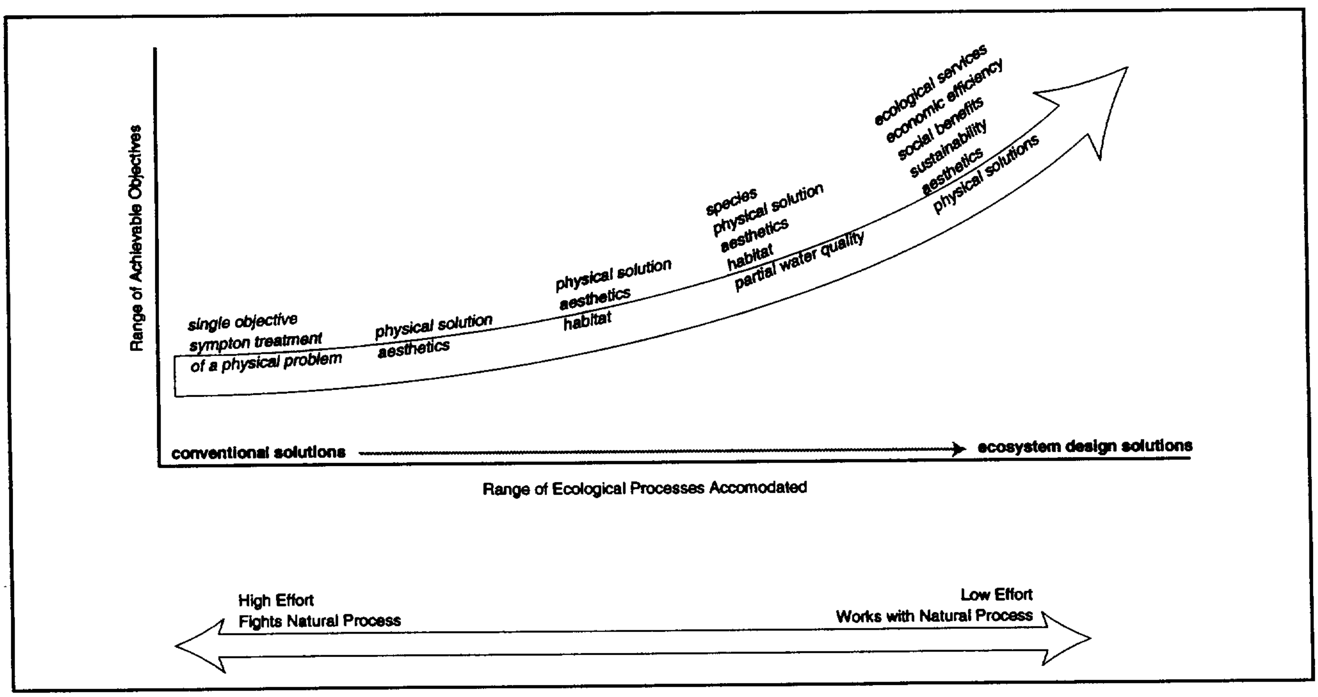


Figure 1: Schematic Representation of the range of feasible objectives to be achieved with increasing number of complete ecosystem processes included in the design of a given reclamation project

The premise of the new paradigm is that success rates and cost:benefit ratios are improved by reclamation designed for the ecosystem, regardless of whether the impetus for the reclamation project is ecosystem enhancement or some other objective. Box (1996) suggested that the best results are achieved by defining "outputs" of the design process, including habitats, vegetation types, biological processes and intervening processes. The natural processes influencing reclamation success on a site operate at a broad ecosystem level (Tueller 1990). Therefore, reclamation design should begin at the ecosystem level.

Regardless of the features installed on a site, it will function as part of a bioregional system, and it will be influenced by ecological processes of that system. A complete ecosystem is comprised of structural habitats, physical elements, biological material, energy and nutrient flows, temporal dynamics, cause-effect relationships, feed-back mechanisms and key structuring processes (Planck et al. 1995). Regier (1993) identified up to 38 characteristics of an ecosystem with integrity. Noss (1995) identified more than 50 indicators or measures of ecosystem organization or integrity.

| | | | | | |
|---|---|---|---|---|---|
| Alternatives to achieve socio-economic goals (public/landowner) | 1 | ② | 3 | 4 | ⑤ |
| Alternative to achieve engineering objectives and constraints | | 2 | 3 | | 5 |
| Alternatives to achieve ecological objectives | | 2 | | | 5 |

*Figure 2: Of the number of methods available to meet reclamation objectives, selection may be based on which alternative(s) meet ecological objectives (see detailed explanation in text).*

Our design efforts must recognize collective, synergistic ecosystem implications, even if our capability to establish the finite levels of organizations and specific parameters is limited. In order to support a given species (e.g. humans at a specific standard of living), the system must maintain a minimum level of organization. This concept has been put forth many times in the literature dealing with the ecological services our society requires from the environment (Ecological Society of America, 1996; Costanza, 1996; IUCN 1980; Rees and Wackernagel 1992). Kelso and Wooley (1996) discuss the need to include ecosystem level objectives even when unquantifiable:

*"Fry (1947 p. 59) suggested that although our present understanding may be flawed, it needs to be expressed 'for there is a great deal more value in having things corrected than there is in never stating them; the road to truth lies much through argument'."*

Ecosystem Objective Must Appear Higher In The Heirarchy Than Other Objectives

A given reclamation project may have a number of objectives, some of which conflict. One of the challenges is discerning the most important, all-encompassing objectives, within which the others fit. The second challenge is to evaluate potential reclamation actions for their potential ecological outcomes, as well as their ability to meet the greatest range of objectives (Figure 1). If objectives are not prioritized correctly, or if some are omitted, the chosen action may not bring the greatest benefits or achieve the expected outcome.

While it is possible to design for an ecosystem that can support other land use objectives, it is not necessarily possible to do the opposite. Figure 2 illustrates an example in which up to five alternative methods are feasible for achieving an immediate reclamation objective, such as contaminant management or slope stability. Of those alternatives, three have potential to meet objectives for natural heritage, aesthetics, recreation, etc. One or two of those alternatives achieve the objective of the site's role in a self-sustaining ecosystem in addition to the other objectives. Within the heirarchy of possible design objectives, the role of the complete ecosystem should be targeted because it facilitates achievement of all other objectives (Trimble and Planck 1994; White 1991).

Traditionally, habitat and ecological objectives were secondary or sideline design elements added after more important issues were considered. The new paradigm recognizes the ecosystem as the central focus, containing other structural, social (safety, recreation, etc.), and economic components. A complete system provides all of these components in an optimal, sustainable, and economically sound fashion.

The Ability To Achieve More Immediate Objectives

The heirarchical approach to objective setting does not compromise our desire to achieve other specific objectives. Various design disciplines, agency programs, community agendas, etc. may suggest that the ecosystem objectives are of less importance than physical stability of the site, aesthetics, land use, etc. However, as long as the specific objectives are identified in the heirarchy, and checked in the final design (and preferably the monitoring plan), the reclamation process will achieve that objective. In fact, ecosystem objectives are useful tools because they provide a basis on which to decide among reclamation options.

The most important benefit of the new paradigm may be that broad ecological objectives provide a context and basis for selecting alternative means to achieve specific objectives (White 1991).

Definition Of Ecosystem Objectives

The objectives of a reclamation project must be defined clearly enough that managers and the public can determine if they have been attained (Karr 1981).

Owing to the fact that human manipulations of the environment often control the large scale ecological processes that the landscape can support, there should be options available in setting an objective for the future (Regier 1993). Attributes of a system that meet the needs of a community can be combined with ecological analysis in order to derive a vision of the complete system, and allow tests of its viability (Costanza 1996; Ecological Society of America 1995; Noss 1995; Imhof et al. 1996).

The ecosystem objective may take on different forms but should include the key elements of a complete, self-sustaining ecosystem. The following is a partial list modified from Regier (1993):

- viable populations of organisms which adapt to environmental change;
- organized groupings of organisms that modify their physical and biological surroundings through effects on other biota and abiotic features within thresholds of "self-organizing capabilities";
- the biota supports larger or longer lived life forms which are sensitive to narrow ranges of life supporting disturbances;
- the biota cumulate and integrate the effects of the system's phenomena and partially regulate its features and functions;
- complex and integrated trophic structures that incorporate external energy and abiotic material into organic material that can be transferred and stored in different forms;
- specific transfers and interactions across scales of organization in a spatio-temporal domain or landscape with persistent structures and cyclical processes;
- has the ability to adjust into different organizational states, with different sets of dominant organisms in each; and
- interrelates dynamically with adjacent systems at a number of scales or levels of organization with specific boundary characteristics that affect system organization.

The foregoing is intended solely to illustrate the complexity of the ecosystem that a site belongs to and the need to consider choices and components in reclamation design. Ignorance toward any set of components has implications for the system at large.

White (1991) described a continuum of objectives, thereby replacing confusing terminology related to aims, goals, etc. The continuum consists of broad objectives that can be defined but not quantified, as well as specific objectives oriented toward short-term results and actions. He argued that the only justifiable short term actions are the ones that are geared toward a long term objective. Even though not quantifiable, these broad objectives must be defined enough to establish measurable short term objectives.

The most difficult objective to set is the less tangible, long-range ecosystem objective. Comprehension of terms such as integrity, health, stability, climax, production level, etc. add to the difficulty, because they require measurable definitions. In traditional paradigms, this complex stage in reclamation planning has been skipped or de-emphasized. However, it is critical to setting the overall direction to reclamation design.

The new paradigm requires an adjustment in traditional budget allocation to reclamation projects. Direct experience suggests that the design costs are higher, including a component to study natural processes and establish objectives, but that overall costs (including implementation and maintenance) are lower. For example, the City of Cambridge, Ontario budgeted approximately \$225,000 (Cdn.) for an erosion control project along a reach of Groff Mill Creek in 1992. After public concerns were expressed, the project objectives were expanded to include aesthetics, habitat, balanced erosion and sediment transport, and water quality along with bank stabilization. System-based objectives, built into a "Natural Channels" design process resulted in approximately 30% reductions in overall spending on the project, even though the up-front studies were slightly more complex. Post construction monitoring suggests that the project is performing well physically, biologically and aesthetically.

Considerations In Setting Ecosystem Objectives

The danger in objective setting is unwittingly setting overly narrow and short term objectives. The simplest solution is to ask why an objective was set, and then to seek underlying reasons which are the true objectives (White 1991). For instance, the ecologist might challenge the basis for using the term "diversity" and conclude that either aesthetics or biological productivity was the true objective.

Alternatively, the inclusion of unachievable objectives should be avoided as well. For instance, land use designations for natural area buffers or habitat specific to a rare species may not be realistic if the ecological functions of concern have already been compromised by larger scale land use decisions (i.e. the ecosystem will not support a viable population of the species for which reclamation is targeted).

Anticipating or predicting the natural tendencies and processes of an ecosystem is a critical activity in setting objectives, especially when incorporating economic considerations. For example, projects that do not consider successional processes (e.g. local species invasion) or geomorphologic processes, may end up fighting these natural tendencies of the regional ecosystem. This would result in a different outcome than expected, higher maintenance costs, or a change in the range of objectives achieved (Figure 2).

The long range ecosystem objective should be envisioned at a watershed or larger geographic scale, with consideration for the scale at which biophysical processes have the greatest effect on the site.

Planck et al. (1995) suggested that four logical steps are required: 1) assess underlying physical/chemical processes that have the greatest effect on ecological functions; 2) determine which of these processes can be modified; 3) determine the ecological implications of various manipulations; and 4) determine the probability of achieving the expected outcome.

A revegetation project in Australia presents one example of ecosystem analysis with site specific implications for reclamation (Ludwig and Tongway 1996). The authors' site specific design was based on large scale determinations of the composition, controlling processes and habitat distribution in a semi-arid grassland. This led to detailed design criteria including dimensions and juxtaposition of structures as well as soil and vegetation development.

Analysis of ecological outcomes and probability of achieving objectives are critical to socio-economic accountability and scientific soundness in reclamation projects. Added expense in studies to set objectives should be weighed against the amount of confidence gained in the selected reclamation alternative. On a project specific scale this will optimize cost:benefit ratios and minimize risk of failure or liability.

On a larger scale, the field of ecological economics is emerging to account for the benefits derived by society for provision of "ecological resources" in the long term (Rees and Wackernagel 1992; Williams 1997). At the same time, there is a need to identify the ecological service provided for the greater public good by the existence of mining operations in the first place.

An in-depth view of the methods (and implications) of defining ecological integrity and the criteria for management was compiled by Davis and Simon (1995). Tueller (1990) discussed the landscape level considerations in reclamation success. Imhof et al. (1996) present an approach to determine key ecosystem processes and components based on heirarchical scales of influence and central biological communities that are supported by them. They start with regional climate, geology, etc. and tabulate the cause-effect relationships that "trickle down" to site-specific biophysical processes, as well as the local processes that operate independently. This is another tool for use by ecologists in determining the most realistic ecosystem functions and components in the future, and the site specific contributions to be made by a reclamation project.

Other approaches involve setting target levels of human life support criteria at an ecosystem level (e.g. oxygen/carbon dioxide balance, food production levels, soil production and maintenance, etc.) for use in establishing site specific design targets.

## Summary

The most important considerations are that:

- reclamation projects must incorporate comprehensive objectives for a complete, self-sustaining ecosystem which supports other land use objectives;
- analytical tools are available to ecologists to derive these objectives and provide input to the design of reclamation projects;
- ecosystem objectives are valuable even when quantification is limited; and
- ecological models are intrinsic to economic accountability.

The new paradigm establishes true objectives, expands the range of achievable objectives, and reduces uncertainty, cost:benefit ratios and total costs.

Measurable ecosystem objectives provide a basis for analyzing each reclamation scenario during the design, providing a framework for developing specific objectives and a basis for monitoring to determine success. Care should be taken not to confuse "means" with "ends". When an underlying reason for a reclamation objective can be identified (e.g. diversity for the reason that it promotes ecological integrity), that underlying reason may constitute a higher level objective which modifies the array of possible reclamation actions.

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