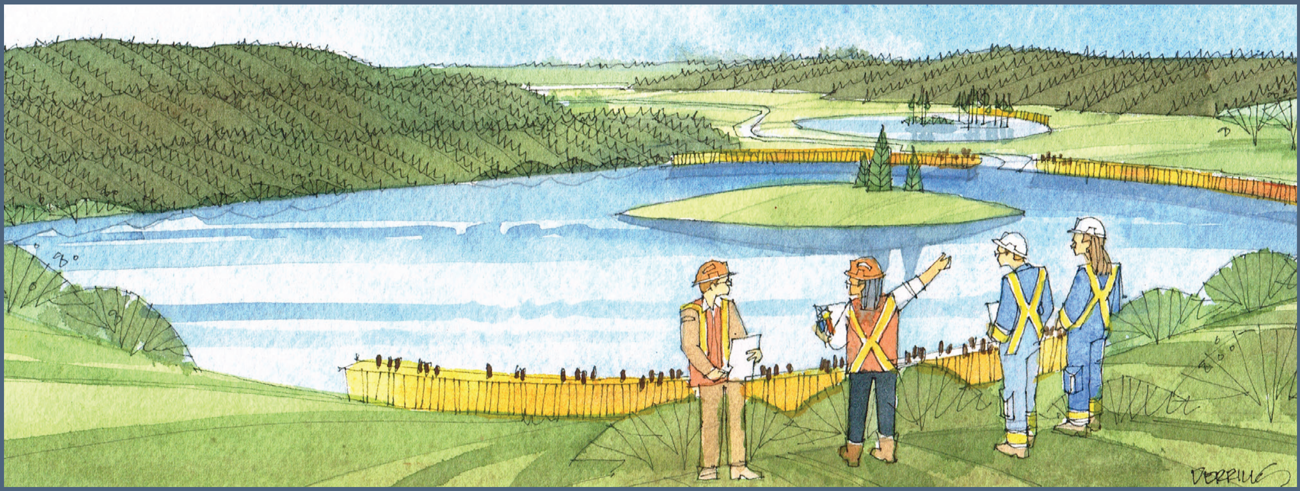

DEVELOPING A DESIGN BASIS MEMORANDUM FOR LANDFORM DESIGN

LANDFORM DESIGN INSTITUTE

NOVEMBER 2024

The Landform Design Institute at a glance

The Landform Design Institute (LDI) is an independent, not-for-profit organization collaborating with the international mining community, regulators, and Indigenous and local communities. It was created in 2019 to develop and support a global community of landform design practitioners.

Landform design is an emerging, integrated, multidisciplinary process to successfully reconstruct mine land. It allows industry, regulators, and communities to work together to manage costs and risks, minimize liability, and produce progressively reclaimed landscapes with confidence and pride. Done well, landform design leads to a positive mining legacy — it is a pillar of sustainable mining.

The LDI has a five-member Board of Directors and 11 technical advisors with experience in all aspects of landform design and mine reclamation around the world. They represent a range of disciplines and roles and responsibilities.

The Institute's vision is that all mining occurs with the land in mind. Mining with the land in mind means creating a vision for the reclaimed land, one shared by the mine, Indigenous Peoples, and stakeholders. It means working together to earn one another's trust.

The vision is achieved through the mission, which is to make landform design routine in the mining industry worldwide by 2030 by developing clear how-to guidance, providing education and training, and supporting the global community of practitioners. The Institute is building a community of practitioners, attracting individual and student members as well as corporate members and sponsors.

Over the past five years, the LDI has undertaken numerous educational initiatives aimed at broadening practitioners' knowledge of landform design. Highlights include the "Lunch and Learn" series for corporate members, the "Getting Closure" podcast, the *Landform Design Quarterly*, two in-person short courses, university lectures, and hot-topic video vignettes. This document represents a major pillar in the assemblage of measures that set the basis for the emerging global discipline of landform design.

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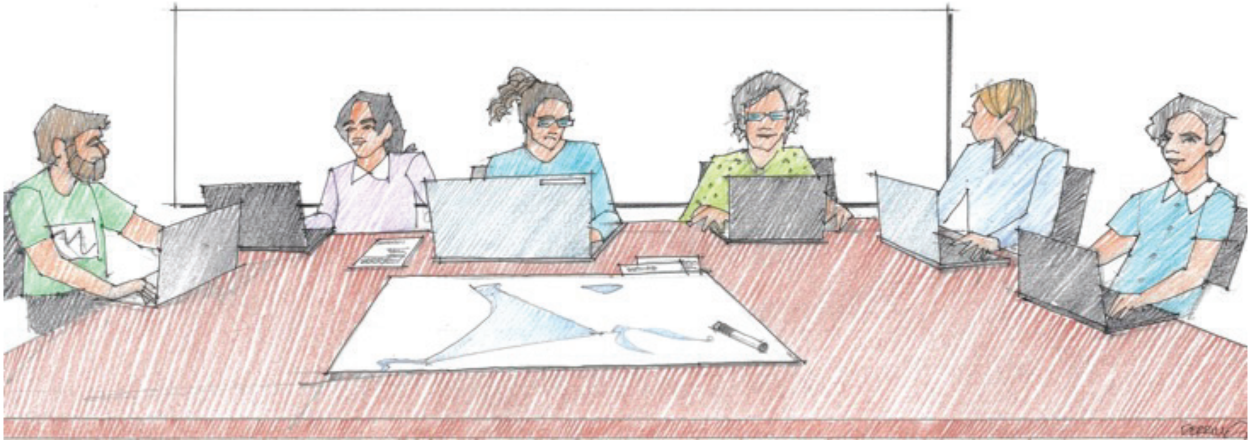
LANDFORM DESIGN INSTITUTE

DEVELOPING A DESIGN BASIS MEMORANDUM FOR LANDFORM DESIGN

TR-02

November 2024



Land acknowledgment

The head office of the Landform Design Institute lies in shared, traditional, ancestral, and unceded territories of the scəwaθən (Tsawwassen), xʷməθkʷəyəm (Musqueam), and other Coast Salish Peoples.

Acknowledgments

The concept of landform design was conceived by Dr Norbert Morgenstern, Professor Emeritus at the University of Alberta. This new discipline has been developed and field-tested over the past 25 years by landform design teams comprised of mine staff, Indigenous Peoples, local communities, regulators, consultants, contractors, and academics, all working together and drawing on their training, their experience, and on published information from around the world.

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Suggested citation: LDI. 2024. Developing a Design Basis Memorandum for Landform Design. Report TR-02. Landform Design Institute. Delta, BC, Canada. 84 pp.

Request for feedback

To provide feedback on this DBM guide, please go to *landformdesign.com/DBM*. We will use this feedback in our courses, for the next update of this Guide, and for other products the LDI produces for the community of landform design practitioners.

LDI members have access to copies of selected references and to resources that include Microsoft Word templates. These are accessible under the "Tools" menu item of the members' section of the LDI website.

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FOREWORD

This document provides guidance on how to develop a design basis memorandum (DBM) for landform design. The DBM is intended to be used for the design and assessment of individual mining landforms and for closure planning. The Landform Design Institute (LDI) has produced this guidance partly in fulfillment of its mission and in response to numerous requests from landform design practitioners for precise direction on this critical component of landform design. DBMs have several inter-related aims, among them the involvement of local communities and Indigenous Peoples, the acceleration of mine approvals, supporting mine operations, and improving mine closure outcomes. This guide is the work of a dedicated team of writers and editors, as well as an illustrator, and has benefitted from extensive review.

A DBM is a document that sets out the vision for the reclaimed landform or mine site, and includes the goals, objectives, and design criteria needed to support that vision. This extends from mine closure plans (the mine site / landscape scale) to individual landforms and sometimes to the design of specific landform elements (such as a wetland or a lookout tower) on a mining landform. The level of detail in the DBM, and its format, depends on which of these scales it is intended to address. Although this guide focuses on explaining how to develop a standalone document for an individual landform, it is equally applicable to a mine closure plan, wherein the DBM section may form a chapter in the closure planning document.

> "A ***landform*** is a distinctive topographic feature created by natural or artificial processes. Together, landforms make up the surface of the earth. A ***mining landform*** is constructed through mining activities. Examples include a waste rock storage facility, tailings storage facilities, mined-out pits / pit lakes, and site-wide drainage systems. Together, mining landforms make up a mining landscape (often delineated by the mine site's property boundaries)."
>
> — *Mining with the end in mind: Landform design for sustainable mining*
> Position Paper 2021-01
> Landform Design Institute (2021)

For many years, DBMs have been used in other disciplines, such as commercial and industrial projects, to capture the design inputs, principles, and rationale relevant to the given project, as well as the required design and performance outputs. DBMs are becoming more common among mine reclamation practitioners. The literature review undertaken for this guidance document revealed that most DBMs have a similar general format that includes: a major section on pertinent background information (including site conditions, climate and geography, regulatory requirements, corporate commitments, constraints and schedules, and a declaration of long-term monitoring and maintenance requirements); a vision for the reclaimed landscape; and a large section or table of nested goals, objectives, and design criteria in support of the objectives, all written with an eye to achieving the vision.

Members of the Institute have developed and tested the landform design DBM on numerous projects over various scales over the past 30 years. It is a fundamental part of the landform design process. A typical DBM for a landform design is succinct — 10 to 20 pages long — and is developed over several weeks. It becomes the guiding document for subsequent designs and is updated over time with new learnings and performance data as expectations and preferences for the reclaimed landscapes evolve.

This document also provides guidance on governance for the process, including collaboration with Indigenous Peoples and local communities. It describes the composition of the landform design team. It provides practical advice, along with examples of landform design visions, typical goals, the level of detail needed to document the design inputs and background information, and direction on how to assemble a Master Table of goals, objectives, and criteria (Section 4.7 and Table H-2). It provides a complete example of a DBM for a simple, hypothetical mining landform, along with references to the few available DBMs that relate to mine reclamation.

Notably, a mining landform is considered a landform from the day mining construction starts (or even beforehand during planning). This definition / framework encourages the use of natural landform knowledge (such as geomorphology, soil science, landscape ecology) to be adapted to mining landforms during design, construction, reclamation, and aftercare. The potential for confusion arises from the suggestion found in several mining publications that a tailings storage facility should be converted into a landform only after it is closed, or can only be considered a landform when some level of long-term stability is assured and might cease to be a landform if at some future point in time it risks failing, as in the manner of a vulnerable dam. This guide uses LDI terminology, which specifies that a mining landform is a true landform from the outset.

1 INTRODUCTION AND BACKGROUND

Landform design is the interdisciplinary process used to build mining landforms, landscapes, and regions, and to meet agreed-upon land-use goals and performance objectives. It was first developed in the 1990s to address the concern that, despite the best efforts of mine reclamation practitioners, mining companies, and regulators, almost no one was achieving signoff on even well-reclaimed land (McKenna 2002). One of several reasons for this lack of signoff is poor alignment among the mining company, the regulator, and the local community regarding expectations for the design, construction, and performance of reclaimed lands and the reclaimed mine site overall.

In response, the landform design process has been developed and tested at dozens of mines over the past 30 years (LDI 2021). In 2019, the Landform Design Institute (LDI) was formed to provide practitioners with the how-to tools and resources to practice landform design. The Institute is focused on helping mines and practitioners close the gap between what is being promised and what is being delivered for reclaimed mine sites. One of the 12 principles of landform design (Appendix A) is to create a design basis memorandum (DBM) for each landform design.

A DBM, also often referred to as a design basis report, or simply a design basis, is a concise document, prepared under the leadership of the landform design team, for every landform design. It contains background information about the site, a precise listing of all the design inputs, the vision for the reclaimed landform or mine site, and a nested list of the design and landscape performance goals, objectives, and design criteria needed to support the vision. It is used to gain broad acceptance for future designs and assessments of the landform or landscape by the landform design team, mine management, Indigenous and local communities, and the regulator. It is a living document, one that co-evolves over the years and decades of design and mining / mine reclamation activities. Ideally a DBM would be developed for each mine closure plan and for each mining landform before disturbance begins. However, it is likely that most practitioners will be developing DBMs for existing mining landforms, each of which will be at a different stage of the mining life cycle.

DBMs are commonly used in other industries but have been under-utilized in landform design and closure planning. Various forms of DBMs have been applied at a few mine closure and reclamation projects since the 1980s. For some mining companies, producing a DBM for landform design is now becoming routine, and some have produced internal standards for its development. For others, it is a novel approach to landform design.

Few DBMs are publicly available, and as a result numerous practitioners have requested that the Institute provide detailed guidance on how to craft one and provide successful examples. This document is the first edition of DBM guidance for use by landform design practitioners, regulators, and local communities. It includes a sample table of contents and a worked example. Our website, landformdesign.com provides additional publicly available examples.

When most mines worldwide begin actively using DBMs for their landform designs in the coming years, then the Institute's mission — making landform design routine in the mining industry — will have been largely accomplished.

1.1 Evolution of this guidance document

In November 2022, the LDI formed a writing team of landform design practitioners to produce this guidance document. The team, consisting of professional engineers and geologists working in Canada and the US, reviewed the available literature on the landform design basis published in Canada as well as abroad, particularly in Australia and the US. They met virtually over six months to discuss the literature review, create a report outline, assign chapters, write the text, provide an example of a DBM Master Table (Section 4.7 and Table H-2), and review each stage of the draft.

Subsequently, LDI Chair Gord McKenna worked with editor David Wylynko of West Hawk Associates to refine the document, undertake some rearrangement of how material was presented, and add examples of landform design projects (published and unpublished) completed over the past 30 years (Appendix B). Though the document is applicable worldwide, much of the context has a Canadian focus, reflecting the experiences of several of the writers and in consideration of Canada's unique Indigenous communities. For example, the worked example of a DBM for landform design (Appendix G) profiles a hypothetical coal mine in the foothills of the Rocky Mountains in Alberta, Canada. Users are encouraged to adapt this guidance to their own circumstances and provide feedback the Institute can reference in future versions.

The draft document was reviewed by members of the LDI Board, the LDI's technical advisors, and representatives of the LDI corporate membership. The resulting document provides landform design practitioners with the background and tools required to produce a DBM suitable for landform-scale and mine site / landscape–scale designs. The document is also intended to give regulators and local communities the ability to contribute directly or indirectly to DBMs. Specific guidance on how Indigenous communities and mining companies can work together on a DBM and related activities is included. Hopefully, both regulators and Indigenous communities will incorporate the DBM approach to landform design into their policies and procedures.

In the fall of 2024, the Institute will begin providing online and in-person training to support this guide. Visit *landformdesign.com* for announcements. LDI members will receive email invitations to this training. The Institute welcomes feedback from these courses and from members of the Institute on improvements for future editions. The Institute will post examples on the LDI website and in other LDI products of actual DBMs for landform designs from mines at liberty to share such documents.

1.2 The DBM format

In preparation for assembling this document, the authors reviewed several publicly available and unpublished corporate DBMs in detail. The results of this literature review are presented in Appendix B and the major learnings summarized below.[1] This synthesis is intended to help authors establish the format of their DBM and to emphasize that the approach provided here has been used by others. See Section 4 for the LDI recommended approach.

Most DBMs are 10 to 100 pages in length, depending on the level of detail, with the key material requiring about 20 pages. Some documents are crafted as a memo, some as a letter, some as a formal report. Most are written by professionals within the company, often working with discipline consultants. Typically, a single individual leads the design team, drives the process, and does most of the writing, often in a group setting. The format and content of DBMs vary widely. Most are developed independently to fit the specific project and the team. However, many DBMs share a common general outline:

- Introduction
- Background
- Vision
- Goals, objectives, and criteria
- Signoff
- References
- Appendices

Each DBM has three main sections. First, the background section provides a compilation of all relevant input required for the design. Second, the vision for the reclaimed landscape is clearly communicated. Third, the DBM sets out what the design will achieve. This consists of specifying the goals, objectives, and criteria, which may be listed as bullet points or, for more detailed documents, presented in a nested table. For more conceptual designs, the specific design criteria are often left unspecified (which can greatly accelerate the DBM process for these early designs). For DBMs at the landform scale (for example, a mine rock stockpile, a tailings facility, or a mined-out pit), the existing closure plan DBM (or design basis chapter) is adapted. It often provides 70% to 80% of the information needed and care is taken to ensure that the DBMs for different landforms within the same mine site / landscape remain in alignment. As adapted from the COSIA *Deep Deposit Design Guide* (2022), the essential elements of a design basis memorandum include:

- key requirements and commitments
- supporting information and constraints
- a record of the design goals, objectives, and criteria
- key design decisions for the project (targeted land use and time frames)
- guidance (or a reference point) for implications of changes to the design
- the current "state of practice" and "state of knowledge"
- guidance to support corporate decision-making and stakeholder engagement
- support for attaining land-use goals and signoff that the work has met the design intent and is meeting the stated goals, objectives, and criteria.

1.3 Define DBM success[2]

A successfully established DBM results in a comprehensive, complete design and a governance team established for the life of a landform. The document includes a list of key references, corporate and regulatory requirements, and commitments to stakeholders. The DBM will feature a clearly defined set of end land uses, vision, goals, design objectives, and design criteria. These are all agreed upon by the mine, relevant government agencies, regulators, and Indigenous and local communities. A brief, living document, signed by all affected parties, will guide the design and operational decisions for the coming decades, leading to the achievement of the vision and the goals. The document acknowledges what constitutes acceptable costs and acceptable levels of residual risk.

2 REASONS TO DEVELOP A DBM

Numerous reasons exist why the landform design team should develop and maintain a DBM. Seven of the reasons are described in this section.

2.1 Bring alignment and clarity to mine reclamation

Mines typically employ hundreds of people and spend tens to hundreds of millions of dollars over decades on reclamation. A well-crafted DBM is an integral part of the landform design process and is intended to ensure alignment over those decades among company management, the design team, mine operations, reclamation operations, Indigenous and local communities, and the regulator. It helps manage expectations and maximize the probability of successful reclamation.

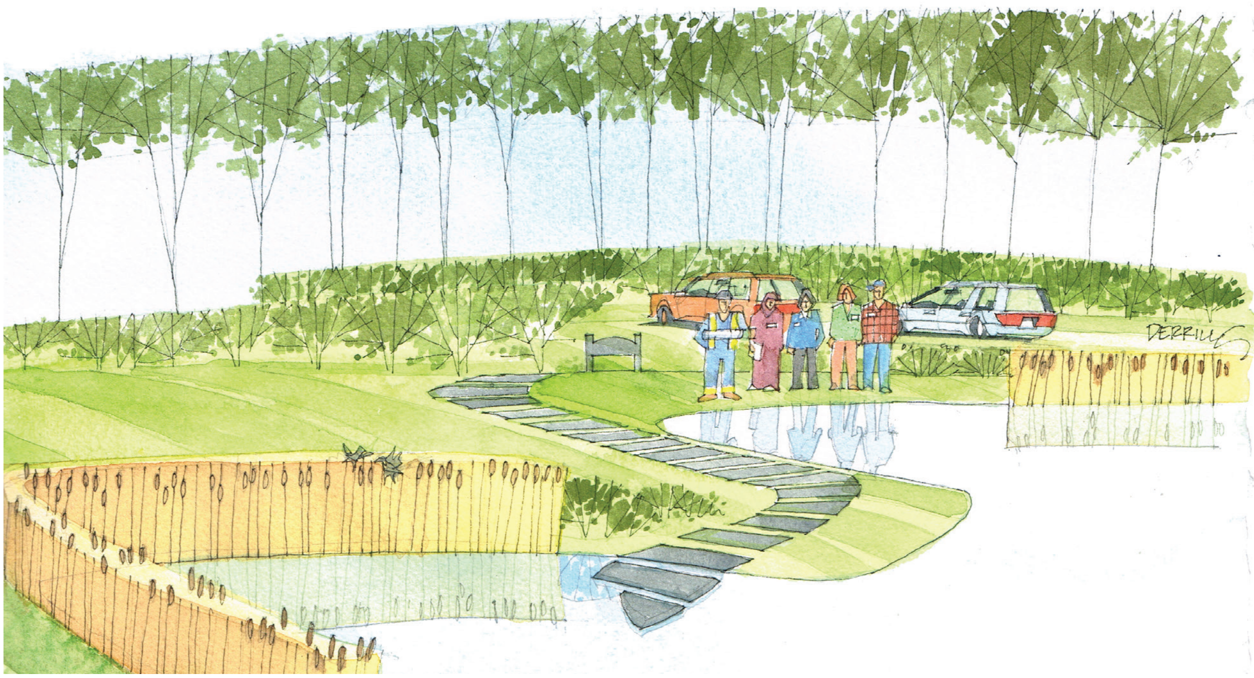
A DBM is also a useful basis for engineering risk assessments and can clarify the residual risks of the closure landscapes and landforms. It helps avoid costly rework, poor landscape performance or increased risks, and becomes the basis of the monitoring and maintenance program, which is also an integral part of landform design.

2.2 Involve local communities and Indigenous Peoples

Numerous ways exist to involve communities of interest in the landform design process, varying primarily in terms of the time commitment involved and degree of interdependence between the company and the community. At the higher levels of community involvement, a trusting partnership between the company and the community must be built and maintained, requiring that a company act with a dedicated level of patience and cooperation. In deciding how to involve the community in the design of an individual landform, a company needs to determine how the landform fits into the overall closure plan and whether it warrants deviating from the community engagement approach taken for closure planning. For example, in the case of a small mine-rock stockpile, if the closure landscape has been designed in collaboration with the community, and if it aligns with the closure design, the landform design for the stockpile may not require significant community involvement.

Mining companies often state that they are building the reclaimed landscape for future land users. In Canada, it is increasingly understood that the Indigenous communities that have traditionally and historically called much of this territory their home will constitute those future land users. In fact, for successful reclamation to occur, mines need to be building a reclaimed landscape in cooperation with Indigenous communities, recognizing their political, economic, and social structures, and with an appreciation for their cultures, spiritual traditions, histories and philosophies, and the rights they possess to their lands, territories, and resources. This recognition is clarified in The United Nations Declaration on the Rights of Indigenous Peoples, a Resolution adopted by the UN General Assembly in 2007.

In Canada, the 2015 report of the Truth and Reconciliation Commission called on the federal government to adopt the UN declaration — which it did in 2021 — as a reconciliation framework, and to apply its principles, norms, and standards to corporate policies and core operational activities involving Indigenous Peoples and their lands and resources. Cooperative ventures between the mining industry and Indigenous communities are evolving rapidly and becoming commonplace in mainstream discussions on mine closure, which in the Canadian context constitutes an element of reconciliation. This degree of active collaboration is a significant departure from past practices, which were viewed more as exercises in colonization than a respectful dialogue and partnership.



The DBM is an important vehicle for collaboration, but it is only one part of a much larger relationship. For mines preparing a DBM, the current state of practice is to develop the first draft internally based on the design team's understanding of the needs of Indigenous and local communities, then to work with them to refine the DBM. Some mines are taking a more collaborative approach and developing the DBM together with Indigenous and local communities.

2.3 Accelerate mining approvals

As a DBM can provide evidence that a mine is practising sound environmental and social governance, it may be a useful tool in accelerating mine approvals. According to the Mining Association of Canada, a broad consensus exists that the timeline for planning and approval for new projects must be shortened from the current 10–15 years without losing the requirement for sound planning, environmental protection, and Indigenous collaboration. These are concerns a DBM can help alleviate. Motivating influences in this urgency include the transition to a low-carbon economy, changing technology, and geopolitical tension.[3] The DBM provides clarity on what is being promised, and in a format suitable for detailed review.

The aim of the DBM process aligns with a major priority of Canada's federal government, which includes improving the efficiency of impact assessment and permitting for major mining projects, clarifying timelines, and improving engagement and partnerships. The contents of the DBM may also help quicken approvals in the US. According to the National Mining Association, protracted delays are a serious problem for the industry and by extension the entire economy. These permits require the involvement of other stakeholders, including Indigenous groups, non-governmental organizations, and the public at large. The combined impact of open-ended delays can make mining projects financially unviable.[4]

Historically, mines have overpromised and under-delivered on mine reclamation, which adds to concerns about new mines or mine expansions. Globally, permitting has become a major obstacle to the advancement of many resource projects, with consequences for employment, government revenues, benefits for Indigenous Peoples, and the value supply chain. Groups may try to delay permitting, some with the goal of halting the project all together. Given that the major keys to achieving permitting goals include balancing technologies, investment, the environment, stakeholders, and governance, a DBM can play a significant role in expediting a mining project.

For approved mines and those transitioning through the approvals process, the use of DBMs can help alleviate stakeholder concerns. In many cases, a well-written DBM could assuage governments and stakeholders wary of the environmental and social impacts by bringing clarity to what is being promised and a clear basis for evaluating future decisions, designs, and landscape performance.

2.4 Incorporate the GISTM requirement

Throughout the global mining sector, tailings management has become relevant to all aspects of an operation, including landform design and closure. A DBM needs to address guidance from the recently produced Global Industry Standard on Tailings Management (GTR 2020), which many mines have committed to honouring. The Standard has numerous requirements for the design, construction, operation, and monitoring of tailings facilities. While most GISTM conformance work focuses on the operational phase of tailings landforms, the Standard is also relevant to landform design. In particular, Principle 4 calls on mines to develop plans and design criteria for the tailings facility to minimize risks for all phases of its lifecycle, including closure and post-closure.[5]

For the purposes of this guidance document, it is also worth taking note of Requirement 4.8, which states: "The EOR [engineer of record] shall prepare a Design Basis Report (DBR) that details the design assumptions and criteria, including operating constraints, and that provides the basis for the design of all phases of the tailings facility lifecycle.... The EOR shall update the DBR every time there is a material change in the design assumptions, design criteria, design or the knowledge base and confirm internal consistency among these elements."[6]

McKenna and Van Zyl (2020) provide guidance on how to use landform design for tailings facilities to meet GISTM requirements. Notably, tailings facilities are but one aspect of the broader focus of this guidance document, which is intended for all mining landforms and mine sites and is directed at achieving acceptable post-reclamation performance and encouraging design and operational practices that bring about satisfactory landscape performance.

2.5 Support mine operations

Mine plans evolve on a continual basis for many reasons. Mines often use a "management of change" process as part of their decision making. Having the goals and objectives spelled out in a DBM helps avoid operational changes that can undermine desired closure outcomes by providing a sound basis to evaluate changes. The DBM is a major tool to help mines consider all time periods in the lifecycle of each mining landform. In some cases, changing a mine plan will require a change in the landform design DBM.

Unavoidable tension tends to arise between progressive reclamation and the ongoing operational requirements of the mine. Most mine plans place a high value on "optionality" — keeping options open for inevitable changes. A DBM recognizes that a commitment to progressive reclamation must be balanced with some degree of disturbance of reclaimed areas. Certain areas, such as laydown areas, powerlines and pipeline corridors, access and haul roads, electrical substations, water retention ponds, soil stockpiles, and snow dumps, will remain unreclaimed for some period. It is also common practice to maintain access roads and paths for monitoring of reclaimed areas, reclamation tours, and community access. Such operational needs are itemized in the DBM.

2.6 Clarify responsibility

Many members of the landform design team will have individual professional responsibility for their work, in the same way that dam designers are professionally responsible for the design, construction, and performance of tailings dams. Others will be responsible to their organizations and their communities. Clarity in what is being promised is central to managing expectations and liability.

Formally declaring the applicable regulatory requirements in the DBM is a significant step in clarifying responsibility. The authors (ideally working with the regulator) list the regulatory requirements for the landform design and the DBM Master Table shows how these priorities will be addressed. The design lead is responsible for all the items in the DBM, but not for any items excluded from the DBM. They will, however, recognize that the DBM will be updated as regulations change. Clarifying the design intent at each point in time is key to managing liability of the company and that of members of the design team.

The cost of poor landscape performance for a large mine is similar to that of the cost of a tailings dam failure.[7] Corporate reclamation liability for mine sites is typically tens to hundreds millions of dollars, and should the company cease to exist, these costs revert to the state and the local communities. The DBM allows for better management of this liability.

Clarifying what is being promised by developing a DBM acceptable to all not only helps minimize professional and corporate liability but also helps Indigenous and local communities and the regulator manage society's liability for the mine sites. The use of a DBM is an important method of avoiding the trap of overpromising and underdelivering.

2.7 Provide a basis for signoff

Few mines ever achieve signoff for their reclaimed land — even lands performing well and meeting expectations — mostly due to differences between the regulator's expectations and those of the mine's owners, and partly due to concern about assuming residual risks.[8] The DBM Master Table provides an excellent basis for design of the monitoring program, ongoing risk assessment, and for ultimate signoff of the reclaimed landform, helping ensure that it was built according to the design and is performing as intended. This is the same process used for dam design and construction.

3 PREPARING TO WRITE THE DBM

As practitioners contemplate the DBM, some key steps should be completed, as outlined below. Typically, the lead designer or the manager of the design team will champion this early work.

3.1 Set up the governance team and process

Organizers of landform design teams find it beneficial to first set up specific governance for their projects, including for the development of the DBM.

3.1.1 Corporate guidance

On the corporate scale, it is useful to set up a small steering committee, typically with members of middle management, including Operations, Planning, Regulatory and Public Affairs, and Environment / Reclamation. Representatives from other site teams may also be asked to join.

The steering committee provides overall governance to the DBM process, sets expectations and timelines, and communicates information between the landform design team and senior management. It is common for such steering committees to meet a few times during the DBM development, and to continue meeting monthly (or quarterly or as needed) as the subsequent landform design progresses. These meetings provide an opportunity to invite members of steering committees to various workshops, especially those related to vision development.

3.1.2 Indigenous and local community guidance

Collaboration with Indigenous Peoples and local communities is central to landform design and critical to DBM development. Different mines and their surrounding communities use varied approaches to collaboration in landform design. The LDI recommends full participation of community members in DBM development (and all aspects of planning, design, construction, reclamation, monitoring, and maintenance, as well as the decision-making processes that go with each step). However, few mines and their communities achieve this level of collaboration. More commonly, the different groups work in parallel but with frequent communication. Discussions typically involve the vision, land use, and goals, with the landform design team working up a draft DBM, followed by review and revision.

Many Indigenous communities oversee activities on their lands. Some have explicit visions for the outcomes of industrial development such as mining, with a focus on the processes that influence the land. In contrast to a DBM vision, which is concerned more with the reclamation product than how to achieve it, an Indigenous vision prioritizes process. Following is a Canadian example based on extensive research in the burgeoning field of co-reclamation.

Project and/or mine closure vision	Collective vision for mine reclamation and closure of the Fort McKay Traditional Territory (traditional shields)
"Reclaiming the land is a form of reconciliation, and Fort McKay First Nation must define those targets. Part of reconciliation is to recognize the land in its original state, who are the original peoples of the land, the Impacts which have been done, and to acknowledge loss. We will achieve this through long-term commitment with proper ceremony, First Nation (Cree and Dene) languages and knowledge, and the best of reclamation science to foster mutual respect, understanding, and bringing back respect of the land."	

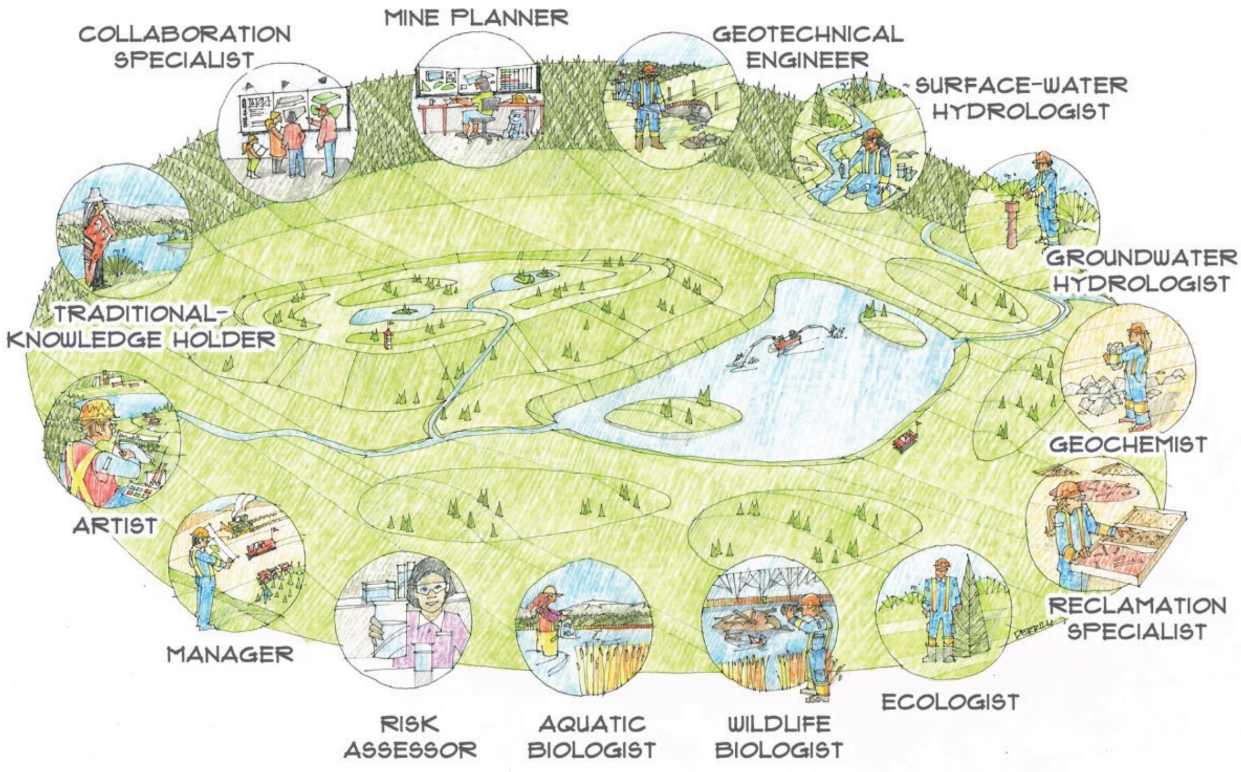
From Daly (2023), used with permission.[9]

3.2 Assemble the team

Establishing the landform design team is a core starting point to eventually producing and implementing the DBM. This process is overseen by a lead designer who is accountable for overall design and implementation, promotes dialogue across the disciplines, and helps to avoid the undesired trap of "designing by committee." They need to lead the design activities and guide the interdisciplinary team and assign responsibility for specific aspects to a variety of specialists. Sometimes they will be responsible for stamping the design, although more often the design will be stamped by a variety of specialists, each taking responsibility for well-defined areas based on their professional expertise.

Some members of the team will be staff, others will be consultants. Including at least one member of the local community (as just one of many aspects of collaboration) is ideal. The participation of an Operations representative will help keep the team grounded.

While the entire DBM team is involved at all stages, including the post-reclamation (aftercare) period, the level of effort expected of each specialist varies over time. In the early stages, the mine planner, geotechnical engineer, and surface water and groundwater hydrologists are the busiest. When it comes time for reclamation activities, the soils, vegetation, and wildlife specialists assume more responsibility (specifically for sites being reclaimed to wildlife habitat).



Working in such a team is generally rewarding, but it can take several years for specialists to learn to work together, with considerable cross-training required. In fact, far more effort is needed in landform design than traditional reclamation, while the level of design effort and site investigation are similar (and additional) to those needed for dam or mine-rock stockpile design. Appendix C sets out the roles and responsibilities of the members of the landform design team. Many of these positions are professionally regulated.

3.3 Identify the audience

Readers of the DBM will represent a variety of disciplines. Some may be external to the company creating the DBM and unfamiliar with mining or the region. They could be from abroad. While the authors are not obligated to explain all the details to non-experts, the document provides an opportunity to offer clarity to those unfamiliar with the site and background information that might be obvious to other members of the design team. This information might include a brief description of the mine and mine operations, the country, the province / territory / state, the general geographic setting, and the broad intent of the landform design and reclamation activities. Accordingly, it can be useful to consider the following readers: technical members of the landform design team and others from mine engineering and mine management (the main audiences for this DBM), Indigenous Peoples, the local community, regulators, and technical and management people in the company's head office (which may be in a different country).

3.4 Set expectations

Mining will always disturb the landscape, and the result will be an altered — though not necessarily inferior — environment. The DBM needs to account for expectations surrounding the notions of equivalency of land use versus exact restoration. Opportunities will arise to create ecosystems and habitats that may not align with the region historically but that can thrive nonetheless. An example is a project that deforests an area that was once cool and moist, but which mining transformed into a slope-aspect-elevation-substrate that is warmer and dry. While this implies fewer trees than found there previously, the carrying capacity for ruminants may be greater thanks to the addition of grassland.

As many as half of all mine sites may be reclaimed to land uses that do not focus on ecology or wildlife habitat. Landform design is still required when the post-closure land use might be something very different, like an industrial or business area, a sports area, a park or other forms of recreational use. Setting expectations for these "redeveloped" sites can be simpler than for ecological uses. The DBM is used to set expectations for these sites as well (ex., clarity in the quality of groundwater and remaining soils and the potential for excessive settlement).

The DBM has a significant role to play in emphasizing what can be reasonably achieved. Once the goals and objectives for the post-reclamation land are determined, the DBM then constitutes less of an aspirational tool and more of a binding contract, with changes requiring approval of all stakeholders. Expectations cannot exceed the time, budget, or technology allocated. The base case should be the outcomes that can be executed with current technology and fall within the cost environment, with wording allowing for improvement if possible. Overpromising or changing plans that negate anticipated reclamation activities can undermine the trust of a public constituency who might have been told "this will be the world's best post-mining site and won't ever be disturbed again" or "no water treatment will be required." Bold statements such as "walk-away solutions" or "maintenance-free" may be good public relations, but they are often overly idealistic. Design teams are best to approach their work with modesty while aiming for excellent outcomes.

Even as the DBM sets expectations for future landscape performance, practitioners might also find it useful to set expectations for the DBM itself. For example, it may not be practical or even desirable to write a complete DBM on the first attempt. Mines often find that working quickly to create a first draft of a DBM over the course of a couple weeks can pay great dividends; the draft document becomes immediately useful to a broad audience and can be tested and improved over time.

3.5 Decide upon the scale

Landform design operates at five distinct scales. The landform is the fundamental scale: it is a distinctive topographic feature created by natural or artificial processes. Landforms make up the surface of the earth. A mining landform is constructed through mining activities. Examples include mine-rock storage facilities, tailings storage facilities, mined-out pits / pit lakes, and site-wide drainage systems.[10] Together, mining landforms constitute a mining landscape (often delineated by the mine site's property boundaries).

Most mining landscapes comprise up to two dozen contiguous mining landforms, which also serve as the basic units of planning and design. Each square metre of the mining landscape belongs to precisely one mining landform. Most mine sites / mining landscapes are also part of a mining (or ecological or socioeconomic) region. Many practitioners have learned to think about their sites as a collection of mining landforms. This approach taps into centuries of geomorphological and ecological literature on the processes by which natural landforms evolve and integrating and applying this knowledge to the design of mining landforms. These landforms are logical management units for the design, operation, decommissioning, reclamation, and aftercare of mines.

Table 3-1. Landform design scales

Design scale	Representative dimension, m	Description and examples
Regional	100,000	A grouping of mines in a valley or region Regional plan, cumulative effects assessment
Lease / landscape	10,000	A single mine lease / property. More generally: everywhere you can see from a particular point on the land (the Renaissance definition) Life of mine plan, mine closure plan, landscape ecology
Landform	1,000	A single mine facility: mine rock stockpile, mined out pit, ore stock-pile, tailings facility Mine rock stockpile design, dam design, landform design
Landform elements	10 to 100	Specifically designed physical subcomponent of a mining landform Wetland, hummock, berm, rock pile, lookout tower
Microtopography	1	Small additions, often for wildlife, field fit Roughening, mounts and pits, individual boulders

Adapted from LDI 2021

By thoughtfully delineating boundaries, responsibilities are assigned to ensure no areas of the mining landscape are orphaned. Experts debate where to draw these boundaries for individual mining landforms. For example, consider a toe ditch (toe creek) at the base of two mine-rock storage facilities: does it belong to the first or the second facility, or is it part of its own landform unit in the surface water drainage system? The answer is that it doesn't matter. What matters is that the design team deliberately and carefully chooses logical boundaries and then manages each landform and the mining landscape overall.

Two smaller scales are also considered: landform elements (such as ridges, wetlands, access roads, mounds, lookout towers) and several kinds of microsites (an ecological term for features such as shade under a boulder, roughened topography, and piles of woody debris). These scales are nested within one another and are important for the integration of closure design. They affect the flow of water, wildlife, people, trucks, and materials throughout the mine site and ultimately the reclaimed landscape.

3.6 Choose the level of design detail

The LDI provides a description of four levels of detail useful in landform design (LDI 2021). These levels roughly align with typical mine planning levels. Table 3-2 provides guidance on how these different levels affect the writing of the DBM. In all cases, the DBM has the same outline, but different levels of detail.

Table 3-2. Levels of landform design relevant to a DBM

Level of design	Description	DBM guidance
Conceptual design	The initial design of either an entire mine site or an individual facility within the site. Often first drawn on a whiteboard (then drafted later), it establishes the shape of the containment, types of materials, general stratigraphy and slope of the deposit, key elevations, initial volumes, the overall approach to the design of reclamation cover systems and revegetation, and other post-mining land use considerations (e.g., provision of wildlife habitat). Closure plans (for the whole mine site) often rely on this level of design for individual landforms.	Designs sometimes simply rely on criteria set in the mine closure plan DBM. Background information sometimes assumed to be the same as the closure plan. Often the design criteria column is unpopulated.
Preliminary design	Typically produced for an individual landform. The design includes the selection of technologies (sometimes called concept selection), materials prescriptions, and preliminary topography and elevations, and advances the conceptual-level approaches to reclamation cover systems and revegetation. It includes a reclamation materials balance and revegetation polygons. It supports development of the mine and tailings plan and the closure plan. It is typically required for environmental impact assessments and / or permitting, and for big-picture business decisions (identification of large projects, potential risks, and costs).	The DBM from the closure plan is enhanced to include additional detail pertinent to the individual landform. All background information is declared. Some design criteria specified as needed.

Level of design	Description	DBM guidance
Planning-level design	Sometimes referred to as a feasibility design, it applies to landform scales and typically includes data review, modelling and analysis, development of landform-scale surfaces and elevations, materials, volumes, and outlet parameters. It includes a detailed reclamation materials balance, revegetation polygons, and associated treatments. It provides information to be incorporated into various business plans (material balance, budgets, infrastructure, regulations, and risk assessments). It takes place three to five years before construction of each stage.	Full DBM is employed and includes all design criteria. DBM is checked in detail for completeness in all regards.
Detailed design	Involves the full landform scale, including modelling, engineering design of all surfaces for deposition and construction, schedules, material properties and volumes, and cost estimates. It includes detailed revegetation design and other considerations for return of post-mining land uses. It elaborates on each aspect of the project, with a complete description of the design through modelling, reporting, and drawings. Detailed designs are typically stamped by the responsible professionals and guide field construction activities. They are typically done about 6 to 12 months in advance of construction of design surfaces.	The DBM from the closure plan is enhanced to include additional detail pertinent to the individual landform.

Adapted from Table B-5 of LDI (2021)

3.7 Plan to keep the DBM current[11]

The DBM is written as a snapshot in time, and it is updated over the decades-long process of planning, design, construction, reclamation, and aftercare for the mining landform or landscape. As the DBM evolves, so will the landform design, and vice versa. The historical DBMs will continue to act as valuable references.

In updating the DBM, the landform design team (and the governance team) keep watch not only over the performance of the landform, but also changes in regulations, practices, management strategies, technologies, and the expectations of Indigenous and local communities. They work closely with all involved to ensure the updates are supported. See Appendix B for a list of examples of eventualities that may warrant an update.

Over time, making major changes to the design of the landform becomes less feasible and the justification for the major changes comes under increased scrutiny. An understandable hesitancy arises to change mining materials that have already been put in place, or to disturb areas already considered reclaimed. Nonetheless, some changes to the DBM will be expected, particularly given that this process is co-managed by the mine, Indigenous Peoples and other local communities, and the regulator. A well-written DBM provides clarity for all parties around the table on what has been previously agreed upon, how the landform is performing against the goals and objectives, and at what point updates or change of course are required.

4 DBM GUIDANCE BY SECTION

This section provides advice on how to write the DBM, organized by sections similar to the example table of contents below. Appendix G provides a hypothetical example of a DBM that also follows the organization of the example table of contents, with the exception that the subsections are provided as a table. Authors are encouraged to modify the outline and contents to meet the needs of the landform design team and the DBM readers.

EXAMPLE DBM TABLE OF CONTENTS

Executive Summary

1. Introduction

1.1 Purpose of the DBM
1.2 How the DBM was produced

2. Background

2.1 Project description, existing site conditions
2.2 Geographic setting
2.3 Climate setting
2.4 Ecological setting
2.5 Location, survey grid, and datum
2.6 Mine plans and supporting documents
2.7 Regulatory requirements
2.8 Corporate commitments
2.9 Other corporate requirements
2.10 Post-reclamation care, maintenance, and design life
2.11 Constraints
2.12 Schedule and key milestones
2.13 Quality control and quality assurance
2.14 Materials and material properties

3. Vision

4. Master Table of goals, objectives, and design criteria

5. Highlighted risks, opportunities, and data gaps

6. Implementation

7. References

8. Appendices

4.1 Title page

The title page provides:

- the formal name of the landform (or landscape) including the operational name and the closure name (if different)[12]
- the name of the mine
- the location of the mine (including the country)
- the names of the report authors
- the dates.

Some authors add a cover photo or illustration of the landform or the team.

4.2 Table of contents

The table of contents allows the reader to quickly see the structure of the document and easily find specific elements. Some authors choose to omit the table of contents, and others choose to show just the major headings.

4.3 Executive summary

An executive summary provides a concise overview of the document. It is usually kept to a single page and includes:

- the intention of the document
- how it was put together (and by whom)
- an abbreviated vision / land use
- an abbreviated list of key goals
- highlights from any major findings from the work, particularly if there are items that will require additional management input or intervention
- if available, an artist's rendition of the vision.

4.4 Introduction

The introduction presents the document by indicating who this DBM is being prepared for (i.e., the name of the mine, the landform name,[13] and the general location). It describes when the landform construction will begin (or for an existing facility when it began), the next major milestone, when it will close, and when the mine site is scheduled to close. The introduction describes in general terms what needs to be done to fully reclaim the site. It indicates the major issues related to closure, reclamation, and aftercare. It describes its returning land use. Next it describes the team that put together the DBM, how the DBM was created, how it is intended to be used, and when it will be updated. It indicates how local communities were involved in creating the DBM.

4.5 Background

This section details all the major inputs into the DBM (and the design more generally). The purpose is to make clear the scope of the work, the key documents and files that are being used, the major constraints, and the probable schedule for landform construction and reclamation. It provides information that is critical to understanding the rest of the document, and it specifies what information the design team will use to create the landform design.

Successful background sections are concise, as short as two pages and generally not longer than eight. Being specific provides strict guidance to the design team and allows reviewers to both understand and question these inputs. Given that the landform design (and the DBM) will be updated over the decades of landform construction and reclamation, clarity on exactly which mine plan and which regulatory requirements are being used at this time is key. Much of this section is supported by reference documents. Electronic versions of each reference document are kept in the DBM project files and accessible to all members of the design team. When referencing these documents, authors are encouraged to include version numbers and publication dates.

4.5.1 Project description, existing site conditions

This section provides a general description of the operational landform and its current status. It includes:

- [ ] a description of the landform in some detail and how it supports the mine operation (why it was created)
- [ ] a description of the existing site conditions — any active deposition of tailings or mine rock, general access, or nearby infrastructure — and any important geotechnical, geo-environmental, or mine planning issues that affect the landform design
- [ ] a map / engineering drawing that clearly delineates: the boundary of the project area (everything inside this boundary will be designed and constructed to meet the requirements of this DBM); any climate boundaries (in particular for mountainous sites); any areas that are already reclaimed and not to be redisturbed; adjacent landforms that may affect or be affected by the design; and any element (e.g., another landform, stream, facility, or road) mentioned in the DBM.

4.5.2 Geographic setting

Descriptions of the geography provide an overview of the setting of the landform, including:

- ☐ regional or local physiographic features (valleys, ridges, and plateaus)
- ☐ a simple account of the bedrock geology, the surficial geology, and why these are important
- ☐ listing of geographic features such as towns or villages, creeks or rivers, and other sensitive features and how these could affect the designs
- ☐ a description of the general surface water and groundwater conditions and any unusual constraints these impose
- ☐ a description of geohazards (such as existing or potential landslides, alluvial fans, boulder rollout areas)
- ☐ a general description of the seismic setting and details of the seismic conditions, including a list of the magnitude and peak ground acceleration of maximum credible earthquake, even if this is not a design criteria
- ☐ the natural / background geochemistry of the area
- ☐ local and regional infrastructure
- ☐ existing land use and land tenure
- ☐ sensitive cultural features near the landform.

4.5.3 Climate setting

The local climate is one of the major drivers in landform design. This section provides background information and related supporting reference documents / databases. Some of these details relate directly to design, while others supply useful information regarding construction and seasonality, not just for designers, but contractors as well. Some mines in mountainous areas will have different climate regimes at different elevations. In this case, designers partition the landscape into different zones depending on the design and construction requirements. This section will describe the following:

- ☐ zonation of different climate zones in the project area
- ☐ Köppen–Geiger climate classification (current, predicted future)
- ☐ typical air temperatures
- ☐ average annual precipitation (mm/year) and patterns
- ☐ average annual potential evapotranspiration (mm/year) and patterns

- typical runoff depths (mm/year)
- the 24-hour probable maximum precipitation event (mm)
- the probable maximum flood at key points on the landform (if known)
- typical windspeed and direction (potentially incorporating a wind-rose diagram).

Climate change is a key element of design; methods to design for climate change are rapidly maturing. The above list should consider the existing and post-closure values. It is important to recognize that climate change predictions are currently only made to a point 100 years in the future, whereas the design life of mining landforms is usually much longer. This is an inherent limitation and should be declared in the DBM.

This section also indicates how climate affects field operations and what constraints it imposes, and includes:

- references for the climate record / climate database
- a description of how climate change will be incorporated into the design process
- references for the climate change scenarios being considered.

4.5.4 Ecological setting

This section references the ecoregion and such items as:

- major ecosystems
- habitats
- species-at-risk (or rare species)
- sensitive or highly valued areas
- land uses that these ecosystems support.

4.5.5 Location, survey grid, and datum

This section indicates:

- the approximate latitude and longitude and elevation (generally or a range of elevations) of the landform (mostly for quick and easy reference)
- the survey grid / coordinate system and datum that will be used for design (referencing which correction algorithm will be used if the current grid is different than the historical one).

4.5.6 Mine plans and supporting documents

Landform design and closure plans are based on specific versions of mine plans. Mine planners often carry multiple versions of plans, and the plans often evolve rapidly. It is therefore critical to specify which mine plan forms the basis for the landform design. Regarding the mine plans, this section provides:

- ☐ the specific mine plan that will be used as the basis for the DBM and a general description of the plan
- ☐ the specific computer design files (typically in AutoCAD or mine-planning software, often in the form of digital elevation models / surfaces)
- ☐ a description or map of areas that are undisturbed, under construction, at final elevation, or already reclaimed. These zones may be included on the DBM map, but are more commonly represented by polygons in computer design files.

Regarding the supporting documents, this section provides a list of related documents that will be used for design:[14]

- ☐ industry guidelines and good / best practices
- ☐ regulatory guidelines and advice
- ☐ internal documents such as geotechnical and mine planning designs
- ☐ internal standards
- ☐ internal design guides
- ☐ operations, maintenance, and surveillance manuals (OMS)
- ☐ standard operating procedures (SOPs)
- ☐ historical design or performance assessments
- ☐ site investigation and monitoring reports.

Most mines also carry a corporate risk register, which can provide useful information for the DBM.[15]

4.5.7 Regulatory requirements

This section includes a list of the regulatory requirements that apply to the landform and the DBM. Typical regulatory documents include:

- ☐ policy papers
- ☐ acts

- legislation
- regulations
- mine permits (typically the most useful information for the DBM).

As in the case of mine plans, these regulatory instruments change over time. The DBM therefore clearly states which documents (and which version of those documents) are being accessed at the time of the design. In some cases, the design will refer to historical documents, as some areas of the landform and its design will be regulated by these documents as opposed to the most recent standards. Most readers of the DBM will not be familiar with the regulatory framework. Authors are encouraged to consider including key passages with which readers should familiarize themselves. If needed, additional excerpts can be included in an appendix.[16]

4.5.8 Corporate commitments

Most mines have a formal list of corporate commitments (made to the regulators, local communities, or individuals). This list may be confidential. Key commitments from the list are referenced in the DBM. The DBM will only acknowledge the commitments on this sublist (that is, designers will not be responsible to address commitments not shown in the DBM).

4.5.9 Other corporate requirements

A list is produced of the applicable corporate requirements. These documents may be generated at the corporate or site level. They may include corporate standards, guidelines, or specific management decisions or directives. Some mines develop a landform design or closure planning strategy document to guide decision-making. It can be referenced here.

4.5.10 Post-reclamation care, maintenance, and design life

A description is provided of the expected level of post-reclamation care and maintenance. This is fundamental to design, and as such, a care and maintenance plan will be developed as part of the design. For this section, a high-level overview of the strategy for care and maintenance is provided. This section also makes reference to the mining landform design life (internationally, many are using 1,000 years) and sets out the design life of any artificial elements (such as concrete structures, liners, bridges, culverts, or monitoring instruments).

4.5.11 Constraints

In this section, the team describes the constraints on the landform design, including items such as maximum constructed elevations, other critical elevations, and sensitive habitat to avoid. Some mines describe these in the text of the DBM, while others use a constraint map. It is important to indicate, at least at a high level, the reason for the constraints, in the event they are questioned later. Many mines flag key elevations in this section (e.g., dyke crest elevations, pond elevations, outlet invert elevations, and receiving water body elevations). Some mines use the constraint map or this section to describe land tenure, critical habitat, and linear (and other) infrastructure. Future expansion of the landform, or any other plans that may constrain the design, are also listed. Figure G-1 provides an example of a simple constraint map.

4.5.12 Schedule and key milestones

The DBM includes a feasible, high-level schedule with milestones that align with those of the mine and business plan. This section includes milestones for:

- permitting
- operations and progressive reclamation
- closure
- reclamation
- post-reclamation care and maintenance (aftercare).

Seasonal constraints affecting the design, construction, or reclamation are also highlighted.

4.5.13 Quality control and quality assurance

In this section, the team indicates in general terms the type of quality control and quality assurance that will be employed during construction and reclamation. It spells out how the company will ensure that the design is being followed, and that the landform is performing as intended. It may be useful to list the roles and responsibilities of various groups in this regard.

4.5.14 Materials and material properties

At a minimum, a list of all key materials (natural stratigraphic units, mining materials, and reclamation materials) is provided. Investing in such a list or table is useful for both a common understanding of materials across all disciplines, and also for consistency in design reports and drawings. Some mines create a stratigraphic table of all natural and artificial materials the reclaimed landscape will comprise. These will include bedrock units, surficial geology units, building materials for roads and dykes, and mine materials (mine rock, tailings, other wastes, landfill, and process water). Each unit is named and described geotechnically and geo-environmentally in detail. It is useful to take care in assigning logical and consistent names to each material, and even to ensure proper capitalization. Table G-2 provides a simple example.

Some mines describe the geotechnical / hydrogeological design values for these units, such as friction angle, cohesion, undrained strength, saturated hydraulic conductivity, dry density, grainsize, specific gravity, pore-water pressure response to loading, and compressibility.[17] Some planners will also detail the geochemistry and water quality. Others will describe the properties related to soil cover, such as moisture-holding capacity and nutrient regime. Such details can be provided in a table or included in an appendix. The design properties of the various units are likely to change with time as more learnings and testing become available. Typically, the design parameters will be common to more than one mining landform, although different designers may choose different design values for different landforms on the same mine site.

4.6 Vision

The landform design vision is the big-picture idea of what is to be achieved, usually relating to post-mining land uses. It is typically distilled down to a few sentences. An artist's impression of the closure landscape goes a long way to supporting the team's vision, particularly if done as a group effort. For individual landform designs, much or all of the vision may already be available in the closure plan for the landscape or mine-site-scale plan. One method of developing a landform design vision is to use the following simple recipe:

- [ ] Describe what the reclaimed landform will look like to the land users.
- [ ] Describe ways that the reclaimed landform can be used.
- [ ] Describe who will be involved in designing, constructing, reclaiming, and caring for and maintaining the reclaimed landform.
- [ ] Describe the timeline for when these things will occur.

On the following page is an example of a vision statement. Appendix E provides additional hypothetical examples of visions.

Our vision is to create a clear path forward to take the operating tailings facility into a stable landform that can support native species similar to the surrounding area in the coming decade. It will be a hill with a broad plateau with a parkland patchwork of trees and open grassy / shrubby areas. The design process will be a collaborative effort with geotechnical engineers, as well as experts in biodiversity, and will result in an executable design that is ready for the end of mine life. The land will be a safe and traversable area for the local residents who want the mine site turned into a nature conservatory that they can hike through with their families. The local municipality has agreed to eventually be responsible for monitoring and maintenance of this park.

4.7 Master Table of goals, objectives, and design criteria

The design team creates a Master Table with "design and performance goals, objectives, and criteria that support the agreed-upon vision."[18] Typically, meeting the goals (in design and in the field) would be both necessary and sufficient to achieve the vision and successfully complete reclamation, and form the basis of eventual signoff by the mining company, the regulator, and Indigenous and local communities. As such, this table is akin to a contract between all involved parties and will evolve over time. Goals, objectives, and design criteria are chosen that are necessary and important, as well as fully achievable with current technology, and which together constitute a reasonably concise list.[19] Commonly, the Master Table will be represented in a landscape-orientation 17" × 11" format or in A3 paper size.

Table 4-1. Organization of Master Table of goals, objectives, and criteria

Goal	Objective	Design and performance criteria
Goal 1	Objective 1	Criterion 1
		Criterion 2
		Criterion 3
	Objective 2	Criterion 1
		Criterion 2
Goal 2	Objective 1	Criterion 1
		Criterion 2
	Objective 2	Criterion 1
		Criterion 2
		Criterion 3
Goal 3…		

The Master Table is developed for the closure plan (the landscape / mine-site scale plan). This table can be enhanced and customized for use for an individual landform design by the design team. The Master Table becomes a central feature of the design and risk assessment. Each goal and objective are evaluated for risk, and the lead designer takes formal professional responsibility for meeting the design criteria and objectives. For conceptual level designs, the column of design criteria is often only partially completed or in some cases omitted. Table H-2 is an example of a Master Table with appropriate levels of details and language.

4.7.1 Goals

Each goal is an overarching design or performance requirement in support of the vision. These goals are achievable, practical, environmentally sound, and sufficient to ensure reasonable landscape performance. The stated goals of the mine, regulator, and Indigenous and local communities tend to overlap. The goals are intentionally broad but supported by specific objectives. The goals and objectives often evolve together as the team works through the details. It is useful to group the goals by discipline, as in this example:

- mine operations
- construction / reclamation
- regulatory requirements and corporate commitments
- geotechnical and geomorphology
- surface water and surface water quality
- geochemistry, groundwater, and groundwater quality
- cover systems
- land use and human / ecological risk
- soils, vegetation, and ecology
- wildlife
- visual aesthetics
- long-term care and maintenance
- social acceptance
- site access.

Such groupings provide a checklist for crafting goals. In most cases, there are one to three goals for each category, and usually not all categories are used. Each goal is usually written as a succinct phrase that starts with an action verb (e.g., create, design, minimize, maintain, support, limit). Examples include:

- maintain a geotechnically stable landform
- minimize timeframe for long-term monitoring and maintenance
- limit contaminant loading to groundwater
- create wildlife habitat.

Appendix F provides a longer list of example goals.

4.7.2 Objectives

An objective is a specific design or performance requirement in support of the goal. This may be the most critical column of the Master Table as it provides the greatest contribution to design and assessment. Objectives are also the most accountable element of a DBM. It is advisable to use SMART (specific, measurable, achievable, relevant, and time-bound) objectives.[20] Examples include:

- avoid reclaiming areas that can interfere with mining operations and infrastructure
- provide opportunities for progressive reclamation as areas become available
- conserve reclamation material
- design haul roads to the corporate standard to give large haul trucks access to reclamation materials
- design landform slopes that have an adequate factor of safety that does not decrease over time
- allow no liquefiable tailings that present a risk of catastrophic flowslides
- avoid long-term reliance on artificial materials
- incorporate long-term integrity into the surface water network and design flood flows without significant erosion
- protect aquifer water quantity
- provide a suitable topography, moisture conditions, and rooting conditions to support the planned vegetation and targeted ecosystems
- maintain connectivity for wildlife in the reclaimed landscape
- design watercourses to accommodate the design height of a beaver dam
- protect pit lake shorelines from wave erosion during the design storm
- ensure all tailings areas have sufficient bearing capacity to allow trafficking by trucks and dozers for efficient reclamation material placement.

4.7.3 Design and performance criteria

Design and performance criteria are required to fulfill aspects of the design objective. A criterion must be capable of unambiguous evaluation (i.e., be a test or standard by which achievement of a closure objective can be judged). This is more or less the Greek etymology for the word criterion: “a test or standard by which a thing can be judged.”

The design criteria are under the control of the design team and are typically specified by specialists in the relevant discipline. The performance criteria are often the product of regulations, established by practice, or based on agreements with Indigenous Peoples and local communities. Not all criteria are specified at the early stages of design, but all are required at the detailed design stage. There are often between one and six design criteria for each objective. Teams may choose to include considerable detail in the criteria, such as the software to be used for the calculations. A suite of criteria can ensure that each objective is SMART.

Examples of design criteria:

- ☐ related to a pit lake design objective
  - the pit lake shall have a littoral zone (water depth ≤ 3 m) with an area of 20% to 35% of the total lake area
  - the shoreline complexity shall have a range of 1.3 to 4.0
  - the lake shall have a hydraulic residence time of at least 10 years
- ☐ related to objectives involving operational requirements for reclamation equipment
  - haul roads designed to accommodate two-way traffic for 40 tonne articulated trucks
  - benches designed to allow one-way traffic for 40 tonne articulated trucks
  - tailings surfaces designed to be trafficable to 40 tonne trucks and Cat D3 dozers
- ☐ related to objective for covers and revegetation
  - average cover depth of 1.0 m
  - available water holding capacity ≥ 200 mm
  - black spruce (*Picea mariana*) seedling density of 2000 stems per hectare
- ☐ related to wetland design
  - maximum height of containment berm ≤ 2 m
  - static water depth ≤ 0.5 m
  - hydraulic residence time ≤ 2 years
  - total dissolved solids of pond water ≤ 2000 mg/L.

4.8 Highlighted risks, opportunities, and data gaps

This section lists the key risks, opportunities, and data gaps that were either discovered as part of the DBM process or have been previously documented in related assessments. In a simple risk assessment, the design team quickly goes through every objective in the Master Table and flags the ones that have risks, opportunities, or data gaps that they would like to emphasize for the DBM reader. Appendix H provides a simple, proven system. The purpose of this section is not to conduct a full risk assessment, but to screen those objectives that are not routine and will require management attention.

4.9 Implementation

This section provides a view of how the DBM will be used, who will steward the document, and when it will likely be next updated. Commonly the landform design DBM is used by the landform design team to guide design and construction of each landform. It is also used to guide risk assessments and periodic design and performance reviews. The DBM is commonly stewarded by the lead designer and the landform design team and updated when there is a significant change in a mine or closure plan, in response to new technical or corporate guidance, or as the landform design and construction evolves and new learnings emerge. The DBM is reviewed annually, and experience has shown that it is reasonable to expect that the DBM will be updated at least every five years.

4.10 References

A bibliography is supplied for all references used in the DBM. Care is taken to record the exact titles, version numbers, and dates of each source as they are likely to evolve over time. This section may also include links to computer files and databases. Electronic copies of all references should be available to all design team members through corporate servers.

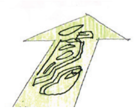
4.11 Appendices

The number of appendices is generally kept to a minimum. But some teams include appendices with excerpts or even entire reports or regulations for ready reference.

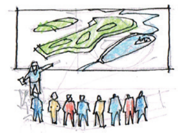
APPENDIX A: 12 PRINCIPLES OF LANDFORM DESIGN

1. Mine with the Land in mind. Create a vision for the reclaimed land, one shared by the mine, Indigenous Peoples, and stakeholders. Work together to earn one another's trust.

2. Establish governance. Assemble an interdisciplinary team with a lead designer who promotes dialogue across disciplines. Design with flair.

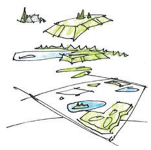


3. Co-develop a design basis memorandum that sets a clear vision, then develop the goals and objectives to achieve that vision. Design, construct, and maintain the land as it evolves and adapts to the ever-changing climate.

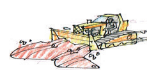


4. Work collaboratively and embrace co-reclamation. Build the reclaimed landscape with the local communities, not for them.

5. Design for spatial and temporal scales simultaneously.



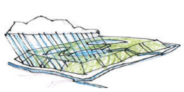
6. Adopt demonstrated technologies and multiple lines of defense. Design for construction, operations, and closure. Incorporate source control of contaminants; avoid producing soft tailings.



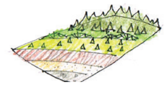
7. Use a risk-based approach; employ the observational method and adaptive management. Design for the most likely case, then monitor closely and employ contingencies that allow the landform to perform as intended.

8. Know your materials — their properties, quantities, and locations. Conserve soils and biota. Value biodiversity.

9. Follow every drop of water through the landscape. Water is key to life and a great agent of disruption. Understand the water balance for each landform across the mine lifecycle.



10. Favour progressive reclamation, learn by doing, and minimize post-closure tasks. Help local communities re-establish connections to the reclaimed land by providing progressive access to it.



11. Acknowledge that the land will revert to the local communities and support their duty of stewardship. Plan for the sustainable closure and reclamation of every square metre. Anticipate the residual risks that will require financial assurance.

12. Share experiences. Learn from failure and celebrate success.

APPENDIX B: LITERATURE REVIEW

In preparing the DBM, the authors reviewed numerous published and unpublished DBM documents in detail, gathering the most pertinent ideas and formats, to allow for a thorough distillation. Below is a list of informative, publicly available documents related to landform design (see References for the full citation):

- Ansah-Sam et al. (2016) – an overview of use of a DBM for landform design at an operating mine
- CEMA (2005) Landscape design checklist – a concise checklist of design objectives (in an oil sands mine reclamation framework)
- COSIA (2022) Deep Deposit Design Guide – a chapter on creating a DBM
- DOE (1991) – a classic reference from the Uranium Mill Tailings Program with a very specific set of criteria for design (also discusses design life)
- Fortuna Silver Mines (2019) – clearly written design standards for tailings, heap leach, and mine rock storage facilities
- Kinder Morgan (2007) – a DBM for a pipeline loop project for a heavy civil application that is quite detailed. It includes design philosophies and numerous site details and moves much further into design than landform DBMs
- LDI (2021) – a position paper that sets out the use of a DBM within the framework of landform design
- Norwest (2015) – a DBM used for tailings disposal technology assessment. Its Table 4.1 provides a tight design basis to guide assessments.

The following are the major takeaways from this review.

General findings

The use of the term "Design Basis Memorandum," or simply DBM, is fairly common. But many variations on the title exist, including a design basis report, design basis, basis of design, and design standards. The Institute chose DBM as this is probably the oldest and most recognized term. Strong opinions exist related to the naming of these documents, but it is the contents that matter. Sometimes a DBM is a standalone document, and sometimes condensed versions are included as an early chapter in a design report. Some are aimed at facilitating the selection of technology. Many are aimed at site-wide closure plans and landform designs for individual mining landforms. Many tailings and dam designs have specific DBMs that may include a closure component. Although the format of every document varies, all have a section related to design objectives and criteria. All the reviewed documents indicated that ample opportunity presents itself for innovation and for tailoring of the DBM to the specific site and corporate conditions.

A DBM can be from 10 to 100 pages in length, depending on the level of detail. Some DBMs have considerable detail on how to craft the design (e.g., which analysis methods and which assumptions to use). Some have many appendices with copies of key documents (e.g., regulatory publications and codes). Some have appendices with raw climate and other site-history data. A few delve into the design philosophy. Most have a useful map depicting site conditions. A few have an upfront executive summary. Most documents have extensive reference lists, and some will indicate whether the design team has an up-to-date library of all the reference material in its original format (often stored online).

One mining company created a template that allows its design teams to "fill in the blanks" to produce a landform design DBM. This approach streamlines production, allows for easy comparisons of different mine sites and different landforms, and helps ensure that all the bases are covered. Such DBMs are crafted to provide for flexibility, allowing practitioners to deviate from the template for items unique to different sites and avoid being locked into a form.

Many documents indicate that the DBM will need to be updated over time. As adapted from COSIA (2022), a DBM update may be required due to changes to:

- ☐ expectations of Indigenous and local communities
- ☐ regulatory requirements
- ☐ international practice
- ☐ proposed land uses
- ☐ mine ownership
- ☐ dyke containment design
- ☐ methods of analyses
- ☐ the mine plan (often aimed at major cost savings or an expansion of ore reserves)
- ☐ the engineer of record, reclamation designer of record, or the qualified person responsible for design and construction
- ☐ available technology (often a change in tailings technology)
- ☐ accumulated field experience (positive or negative) at the site and elsewhere
- ☐ landscape performance no longer meeting the goals and objectives and unchangeable within the current design.

Introduction

Most documents have a few paragraphs of introduction that include:

- ☐ Purpose of the DBM. COSIA (2022) lists the main functions of a DBM, which include:
    - Identify key requirements and commitments
    - Identify supporting information and constraints
    - Provide a record of the design goals, objectives, and criteria
    - Document key design decisions for the project (targeted land use, time frames)
    - Provide guidance (or a reference point) for implications of changes to the design
    - Document current "state of practice" and "state of knowledge."
- ☐ How the DBM was compiled
- ☐ An explanation of consultation / collaboration with local communities, mostly related to land use
- ☐ A section that refers to other supporting documents, such as business plans, closure plans, strategy documents, execution strategies, dam designs, and risk assessments. Some copy out the most important elements from these documents into the report text
- ☐ A drawing that clearly indicates the project boundaries (the area to which the DBM applies). This is a critical element of the document
- ☐ A definition of specific timeframes — landform construction, closure, decommissioning, reclamation, and post-reclamation monitoring period.

Background

These documents usually have a background section that includes most of the following subsections (or as line items in a table):

- ☐ Purpose of the facility / landform
- ☐ Existing site conditions / description (many have more detailed descriptions of the components and sometimes a schematic)
- ☐ Which mine / tailings / closure plans are being stewarded. It may include the names and properties of material streams and their volumes; often the names of specific surfaces (digital elevation models) are provided
- ☐ Topography, projection, datum, and coordinate systems
- ☐ Drafting files and 3D model files (pit and dyke design and as-built reports), bedrock geology, surficial geology, dyke and mine rock stockpile solid models (with material types),

infrastructure as-builts, existing substrate map, closure plan maps (final surface substrate map), roads and infrastructure map (as-built and planned), reclamation material map (as-built and planned), revegetation map (as-built and planned), surface water features map (as-built and planned), and soil stockpile map and designs (as-built and planned)

- ☐ A comment on the general climate for the site, and some details on air temperature, precipitation, evapotranspiration, runoff, probable maximum precipitation and probable maximum flood, windspeed and direction, and climate change
- ☐ Geologic setting, including foundation conditions (bedrock geology, surficial geology), geochemistry, regional geohazards, site seismicity, creeks and rivers
- ☐ Relevant regulations, codes and standards, corporate guidelines, industry guidelines, design guides, corporate and social commitments; some documents provide considerable detail from these documents, and some include them as appendices, while most just name the documents and provide a reference
- ☐ Specifications on a landform design life (often 1,000 years)
- ☐ Expected levels of post-reclamation maintenance
- ☐ A comment indicating the designs will be cost-effective and fit for purpose
- ☐ Discussion on the need to allow for future expansion
- ☐ A list and description of closure materials and borrow sources; some provide the actual design values (strengths, densities, permeability, pore-water pressure response to loading, etc.) of the various materials, often in a table; such a design table is extremely valuable but is also considerable work
- ☐ Design constraints, either on a map, or in writing; often the elevations of key items are specified (e.g., dyke crest elevations, outlet invert elevations, receiving water body elevations, plant site elevations); other design constraints such as land tenure, critical habitat, linear infrastructure
- ☐ Explanation of quality control, quality assurance, and maintenance; some refer to an Operation, Maintenance, and Surveillance (OMS) manual (see Crossley et al. 2011); some indicate generally what kind of instrumentation will be required; some refer specifically to the closure water balance
- ☐ A high-level schedule and any seasonal constraints on construction or operation.

Vision

Unfortunately, few have a clearly stated vision, and many do not detail the proposed returning land uses. Those with a vision generally describe what the site will look like when completed, how this will be accomplished, and the benefits provided to the company and future users.

Goals, objectives, and criteria

Goals and objectives are often lumped together under objectives; each is supported by design criteria. Some documents have a long paragraph for each goal / objective that provides further description and lists out the criteria; other documents use a nested table. For example:

- Goals and objectives are often gathered under subject headings such as:
    - Ongoing mine operations
    - Construction / reclamation
    - Regulatory requirements and corporate commitments
    - Geotechnical and geomorphology
    - Geochemical performance
    - Surface water and surface water quality
    - Groundwater and groundwater quality
    - Cover systems
    - Land use and ecology
    - Visual aesthetics
    - Long-term care and maintenance
    - Social acceptance
    - Site access.
- Some include criteria for which kinds of equipment will be used (e.g., haul truck size), which can be important to the design (e.g., road widths)
- Most have considerable hydrologic criteria including the design storm events, the inflow design flood (IDF) and the environmental design flood (EDF); some have water storage requirements and / or water quality requirements; some provide the hydraulic conductivity specifications for barrier layers, and design parameters for underdrains and leak detection systems; some have filter criteria; and some have settlement / consolidation criteria
- Many have target geotechnical factors of safety listed
- Many have specific water-quality targets listed
- For sites involving mine rock stockpiles, the type of rock that can be accepted into each zone of the stockpile may be described

- ☐ For sites involving ongoing tailings deposition, the specification for the end of pipe tailings is provided (especially slurry density), and the assumed dry density of the beaches and their assumed deposition slope angles is indicated.

Signoff

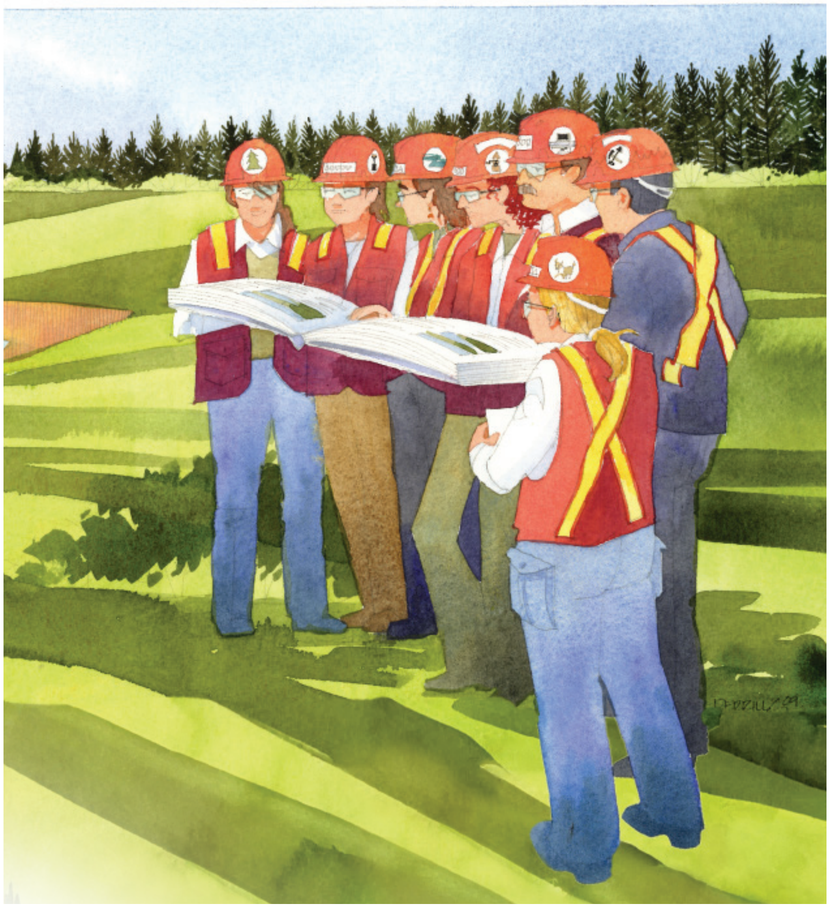
Some DBMs have a signature page for formal signoff of the DBM, typically by different corporate departments.

References

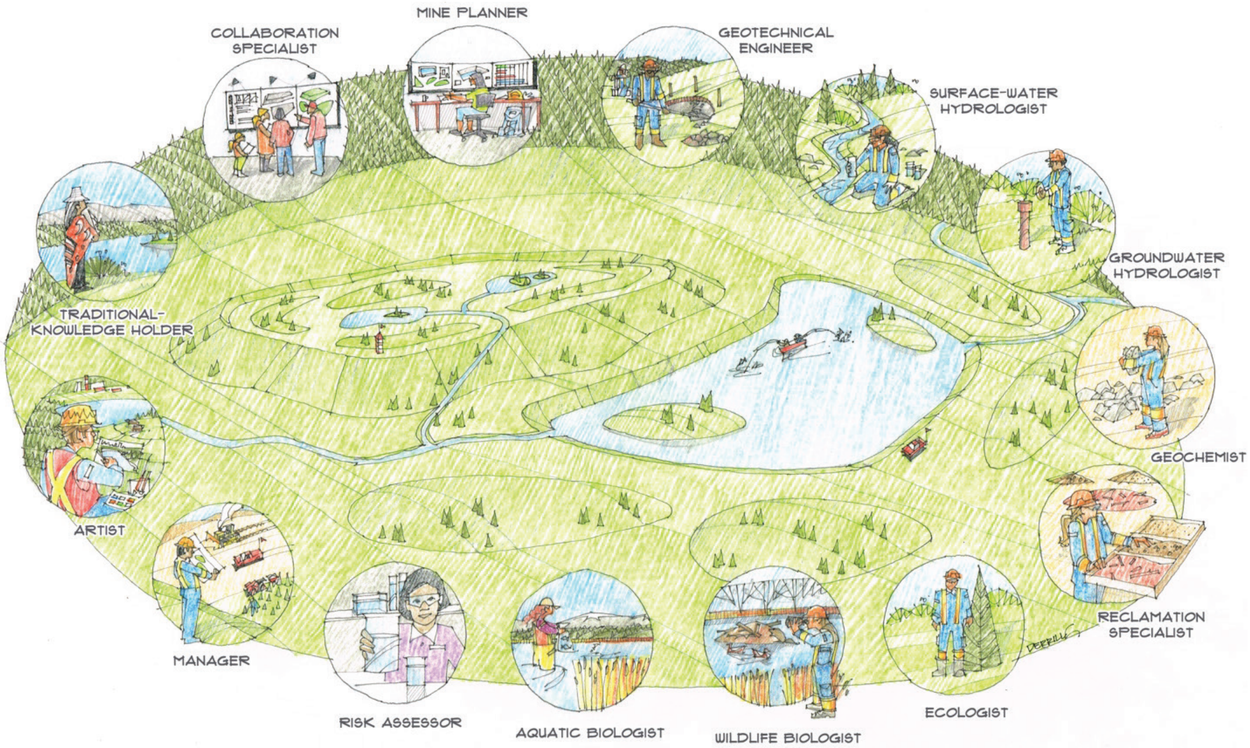
All documents have a reference list; some refer to an onsite library.

Appendices

Most document have several appendices, with key regulations included; sometimes entire codes or standards are reproduced.



APPENDIX C: ROLES AND RESPONSIBILITIES OF THE LANDFORM DESIGN TEAM



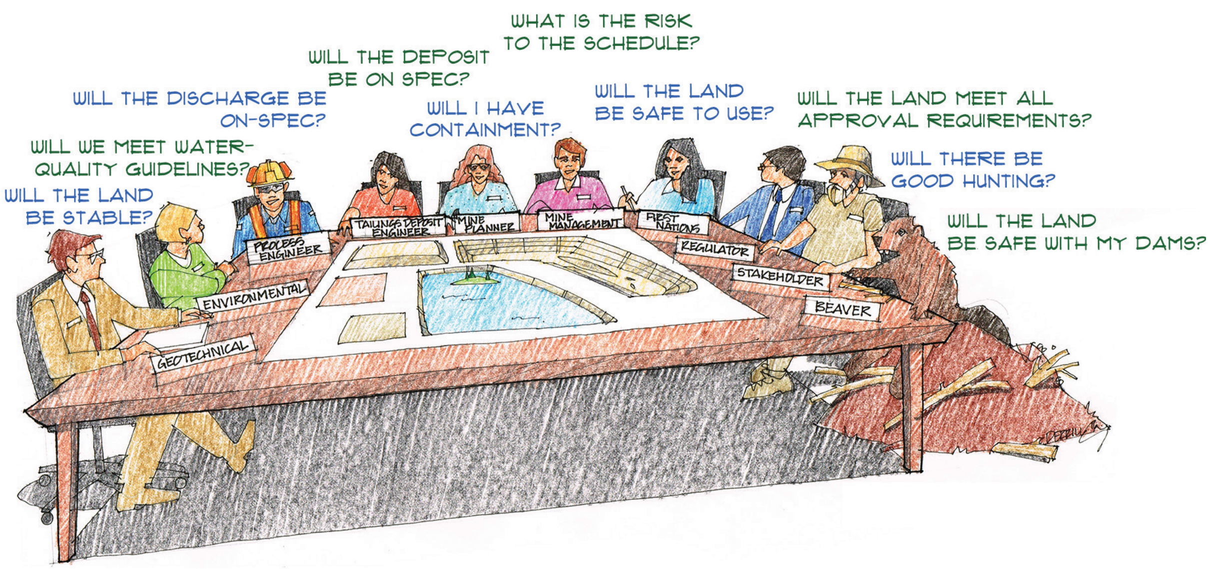
- The **lead designer** often (but not always) comes from a geotechnical, geology, or mining discipline. They will have the role of "reclamation designer of record" (Straker and McKenna 2022). They will have practical design experience and experience leading an interdisciplinary team and usually a related professional designation. The lead designer provides technical leadership and takes overall professional responsibility for the design. In some cases, they will also manage the team, although this role is commonly filled by a project manager. This lead designer may also be the geotechnical engineer of record for the landform, or they may work in parallel to the engineer of record, who is part of the design team.
- **Traditional-knowledge holders** are often both specialists and generalists familiar with the ecology and use of the lands around the mines. They may be on the mine staff or representatives of the local community. Some are trained in western science or engineering. Some will be Elders in the local Indigenous community. Most will be stewards and users of the land.

- **Collaboration specialists** focus on working with groups external to the mine — the regulator and local communities at larger mines often have their own group. At larger mines, this is the government and regulatory affairs department, but they are often only weakly linked with the design team. They typically have the best understanding of the regulations (and how they are employed) and reporting requirements. They are often intermediaries between the mine and these other groups. They come from a variety of backgrounds (some will be social scientists) and all will require training and experience in consultation. Some will have a connection to the mine's legal representatives. It is increasingly apparent that social scientists are needed who understand how different communities work together.
- **Mine planners** are focused on optimizing mine waste management, putting together the initial designs of landforms, and developing sequences, schedules, and budgets. They are often mining engineers but may also be technologists or operational staff. They focus on gathering constraints and optimizing costs for bulk material placement. Some are specialists in tailings planning or reclamation planning.
- **Geotechnical engineers** focus on the physical stability of mining landforms, specifically slope stability, trafficability, and settlement. Often, they will be the engineer of record for a tailings dam or mine rock stockpile. Many also have geological training and some are cover-system design specialists. Much of their work is guided by sophisticated but relatively straightforward slope stability and settlement models.
- **Surface-water hydrologists** are often civil engineers or engineering geologists by training. They focus on getting every drop of water safely off the landform and off the site through overland flow or channels constructed on and around each landform. Some are climate specialists, and some focus on water quality. They often work closely with the mine planner and geotechnical engineer to design the topography. They typically take charge in design of the site-wide drainage network. They often work with surface water models to calculate runoff and to design channels.
- **Groundwater hydrologists** are typically geologists / hydrogeologists with specialized training in seepage and groundwater. Many are also geochemists by training. They tend to focus on controlling groundwater contamination, but are also closely involved in understanding water balances, water quality, and the location of the groundwater tables in mining landforms. Many are working to link surface water and groundwater models, as this is an important area for landform design.

- **Geochemists** are chemists or more commonly geologists who focus on chemical changes in mine waste, understanding how to control and manage the production of contaminants. They often have a groundwater background, and many specialize in handling acid rock drainage. They work closely with the surface water hydrologist for water quality modelling and are often a link to water treatment specialists.
- **Reclamation specialists** come from a variety of disciplines, often the biological sciences or environmental management. Many are soil scientists. Their forte is the practical know-how required to organize and conduct reclamation activities, from sourcing seedlings to setting out equipment contracts to conducting field operations and weed management to reporting back to the company and regulator. Many reclamation specialists fill other technical roles on the team depending on their background and training. They are the key integrators of the various disciplines from all the sciences as well as integrators between designers and field operations.
- **Ecologists** focus on the "living skin" of the landform — on the surficial materials and vegetation that occupy its surface. They have backgrounds in soil science and vegetation ecology, and work on the ecological, land use, and surface-water aspects of landform design. They often play a key role in sites where creation of ecosystems and wildlife habitat are part of the land use requirements.
- **Wildlife biologists** are involved if land uses include wildlife habitat, and they usually focus on terrestrial animals and their needs.
- **Aquatic biologists** are concerned with wetlands and streams and may become involved in pit lakes. Ecologists, wildlife biologists, and aquatic biologists help design and evaluate the reclaimed landscape as it relates to plant and wildlife performance.
- **Risk assessors** are a new addition to the core team. Engineering risk assessment is often led by a geotechnical engineer, ecological risk assessment by a biologist or toxicologist, and human health risk assessments by a specialized member of the medical community. Most practitioners are only familiar with one of these three areas, and as such, the notion of "risk assessment" means different things to different people. The identification of "residual risk" as a central hurdle to successful reclamation, and the understanding that acceptable risk is also a social and cultural issue, shows the need to develop a much more holistic use of risk assessment.
- **Managers** are key to the team; they often act as supervisors for the staff and provide governance and supervision of the team. They focus on process, budgets, and communications.

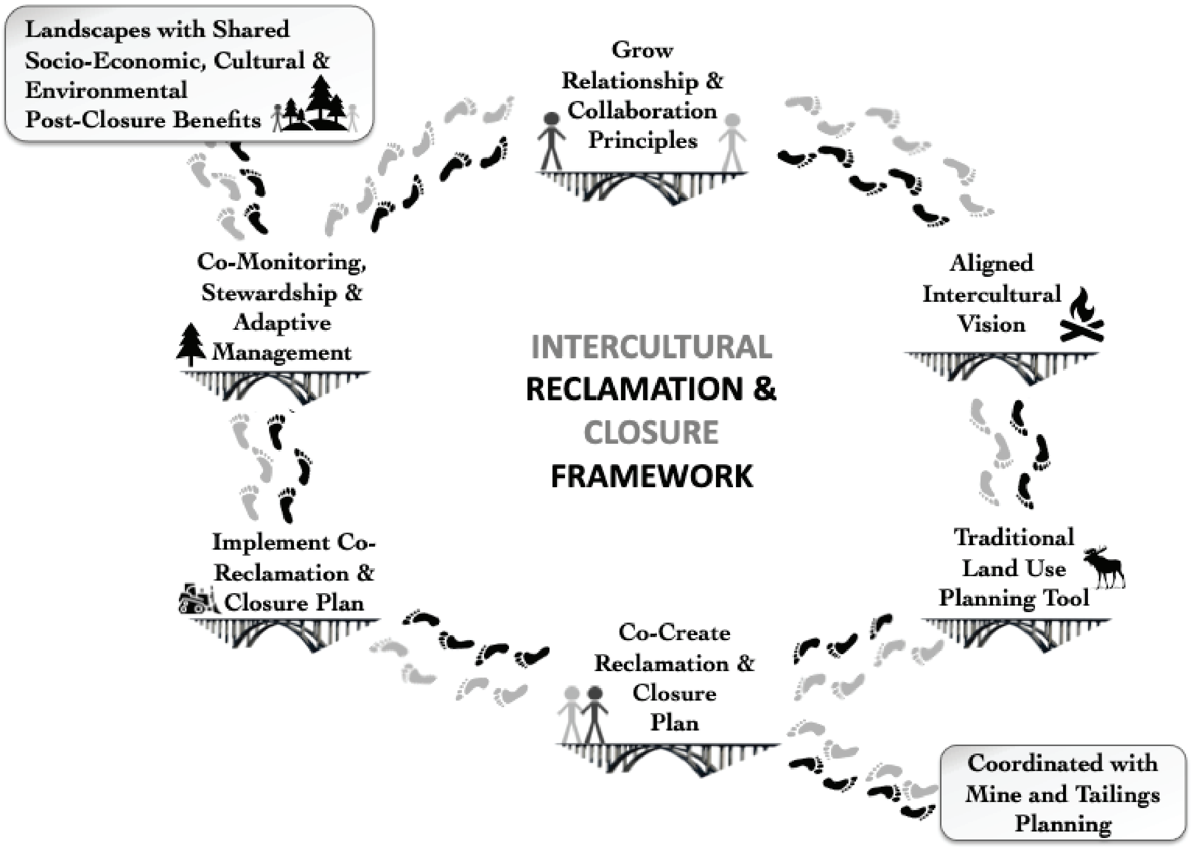
- **Artists and illustrators** help forge a common vision for the reclaimed landscape. They facilitate communication of details in construction, show how mining changes the land over time, communicate what the final reclaimed landscape will look like, and foster communication among team members and all those involved. They use a variety of tools to produce drawings, paintings, 3D models, digital images, flyovers, and virtual reality.

The LDI provides courses in design and how to work in such teams, and is assembling tools and guides to aid practitioners, regulators, and local communities. It is also working on assembling a library of available information. Some of the available guidance is global, but much is highly specific to the climate and geography, and the collection of such libraries will be one of the first and ongoing tasks of the design team.



EACH MEMBER OF A DESIGN TEAM BRINGS DIFFERENT OBJECTIVES

APPENDIX D: TWO-ROADS RECLAMATION AND RECONCILIATION FRAMEWORK



In Canada, in the oil sands region of northern Alberta, Indigenous groups (First Nations) and academic co-researchers have created intercultural planning tools to prioritize Indigenous voices and leadership in the country's energy transition. Under the new Intercultural Reclamation & Closure Framework, lands reclaimed using this process are proposed to have shared socio-economic, cultural, and environmental post-closure benefits (see figure on Intercultural and Reclamation Closure Framework). For the Fort McKay First Nation, the re-establishment of vegetation, forests, peatlands, and traditional uses of land disturbed by energy projects are of the utmost importance. The six bridges of the framework that supports these actions are:

1. **Growth of relationships and establishment of reclamation collaboration principles:** This foundation should precede energy project approval and continue throughout project operations and closure (e.g., by using an intercultural code of conduct to support dialogue and mutual learning).

2. **An aligned intercultural closure vision:** A shared idea about the future reclaimed landscape that acts as a guiding light for mine closure and reclamation planning and design decisions.

3. **Design of a traditional land use planning tool:** A Fort McKay-created geospatial planning tool communicates where and how to incorporate key traditional land use features into reclamation and closure plans from their unique worldview.

4. **The making of a co-reclamation and closure plan:** This plan is made with (not for) Fort McKay First Nation with support from the shared Intercultural Closure Vision, Traditional Land Use Planning Tool, and the best of reclamation science.

5. **Implementation of a co-reclamation and closure plan:** The degraded landscape is co-reclaimed (i.e., land recontoured and the soils, plants, wildlife habitat, and Fort McKay access re-established) using the Co-Reclamation and Closure Plan.

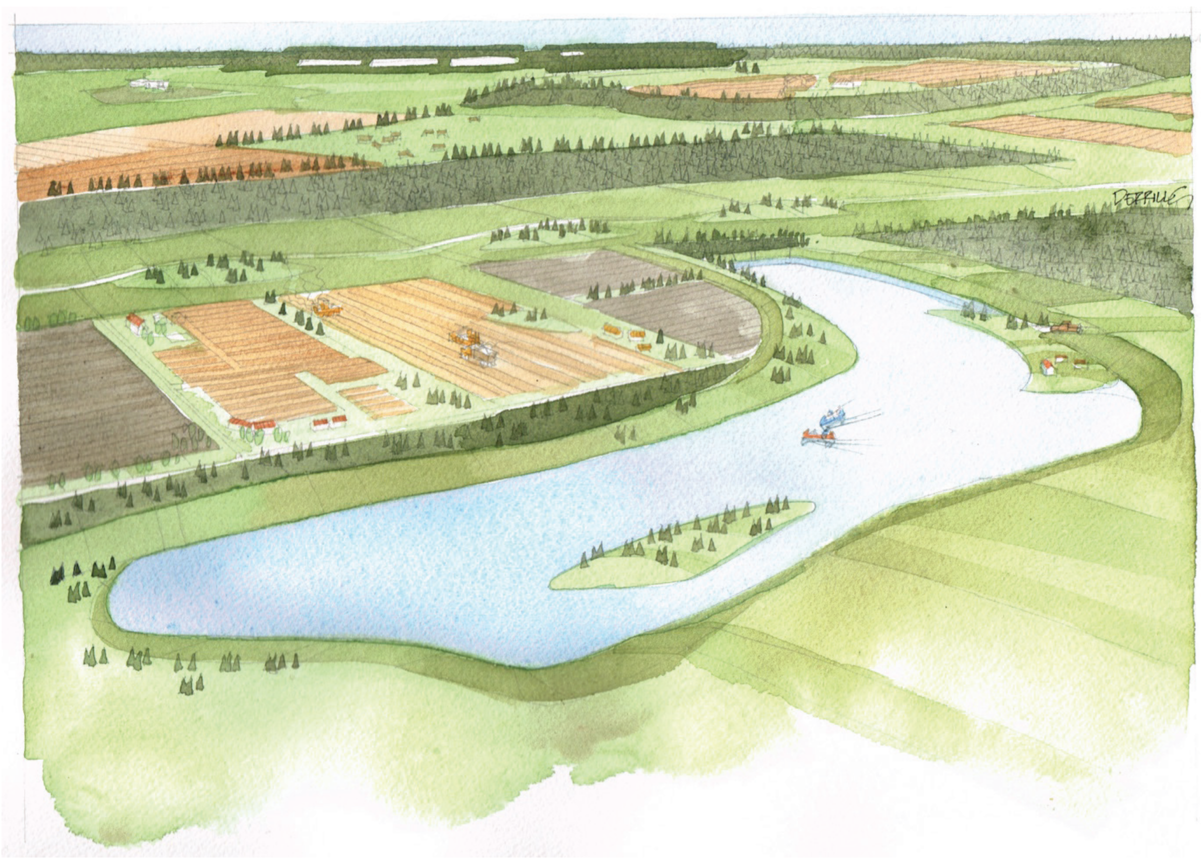
6. **Co-monitoring and maintenance:** Monitoring data are gathered from reclaimed parcels of land using a Two-Roads Approach to determine whether a reclaimed landform has achieved the aligned closure vision. Maintenance and / or adaptive management is applied when the landform is not meeting the target (Davies Post).

Condensed from "A Two-Roads Approach to Co-Reclamation: Centring Indigenous Voices and Leadership in Canada's Energy Transition." Canadian Climate Institute. June 22, 2022. A Two-Roads Approach to Co-Reclamation (*climateinstitute.ca*).

APPENDIX E: VISION STATEMENTS FOR LANDFORM DESIGN

Five generic examples of visions for mining landforms and landscapes follow.

Landform Design Vision Example 1



Our vision is to transform the operating mine into a safe and productive landscape that blends in with the surrounding agricultural community. The design will be guided by surrounding landforms, in collaboration with local farmers, in a progressive reclamation fashion, to return the area to farmland with some forest and wetland patches over the next 10 years. The final product will need to be safe for livestock, crops, and farmers in order to transition the land stewardship over to agricultural producers who depend on the land.

Landform Design Vision Example 2

The vision is to return the disturbed lands to a state similar to what existed before the disturbance. This will mean achieving a self-sustaining boreal forest with adequate biodiversity to support the local caribou herd. There will be close collaboration with local Indigenous communities, who will provide feedback on the experience aspect of the final design. The landform will be designed iteratively by a team including the Indigenous stewards, geotechnical and mining engineers, biodiversity experts and a water quality team. The local Indigenous group anticipates that the land will be returned to a natural state, in a manner that aligns with their values.

Landform Design Vision Example 3

The vision for this work is, at the end of mine life, to close the mine with stable landforms, and capitalize or repurpose the existing infrastructure to support the local community long term. The team will work with the mine planners and geotechnical engineers to create functional landforms, and community engagement will be initiated to make use of the access roads and power lines to create the ski and golf resort. The local residents have made it clear that they want to maintain a livelihood and a place for their children to grow up in, with enough economic drive to maintain the school and hospital.

Landform Design Vision Example 4

The team's vision is to convert the long-term liability of the mine site into an economic driver of sustainable energy. The site will be safe and stable, will utilize the gravitational potential of created topography, and will use the disturbed ground for new infrastructure. A solar farm will cover much of the reclaimed area. Because the mine is already at the end of its working life, and as this area is quite isolated, there is no local community to consult. The key collaborators will be engineers and regulators. The remote location and existing connection to the grid is the perfect opportunity to generate renewable energy without creating new disturbance.

Landform Design Vision Example 5

The vision is to create a clear path forward to take the operating tailings facility into a stable landform that can support native species similar to the surrounding area in the coming decade. It will be a hill with a broad plateau with a parkland patchwork of trees and open grassy or shrubby areas. The design process will be a collaborative effort with geotechnical engineers, as well as experts in biodiversity, and will result in an executable design that is ready for the end of mine life. The land will be safe and traversable for local residents who want the mine site turned into a nature conservatory that they can hike through with their families. The local municipality has agreed to eventually be responsible for monitoring and maintenance of this park.

APPENDIX F: GOALS FOR LANDFORM DESIGN

Below is a collection of sample landform design goals copied or adapted from the literature[21] and the professional experience of the writing team. Many are aimed at the closure landscape as a whole. Some of these goals may be better adapted as objectives for certain DBMs.

- [ ] Mine operations
  - Accommodate the mining materials mass balance
  - Allow progressive reclamation as areas of the landform become available
  - Design infrastructure with consideration of future decommissioning
  - Design operational wind and water erosion control measures
  - Design to allow logical decommissioning and reclamation
  - Integrate long-term infrastructure with reclamation plans
  - Meet all corporate requirements
  - Minimize wind erosion / dusting during reclamation
  - Plan construction techniques to enhance trafficability for reclamation
  - Provide reclamation demonstration / show site for public relations
  - Provide safe working conditions for personnel and equipment
  - Select mining, tailings, and reclamation technologies
  - Support ongoing mining operations
- [ ] Construction / reclamation
  - Create a safe and stable landform
  - Design for progressive reclamation and provide processive access
  - Design to avoid combustion of mine waste
  - Design landform to be simple to regrade
- [ ] Regulatory requirements and corporate commitments
  - Integrate landforms within the lease-scale closure landscape, including natural areas and adjacent landforms
  - Meet all applicable regulatory requirements
  - Meet all corporate commitments
  - Meet all permit requirements
- [ ] Geotechnical and geomorphology
  - Design landscapes to be acceptably stable under a variety of natural hazards and extreme events including fire, floods, drought, extreme precipitation, blight and disease, wind, earthquakes, or animal effects

- Design long-term properties and topography to accommodate settlement and control any undesirable ponding
- Design the surface water drainage system to accommodate settlement, including long-term settlements
- Design landforms to be geotechnically stable and remain stable under a natural disturbance regime
- Design to allow only acceptable consequences of potential flowslides
- Design to protect downstream areas from effects of catastrophic release of mobile materials
- Design to protect slopes from instability
- Design trafficability and bearing capacity to be compatible with end land use
- Eliminate catastrophic risk to humans and the environment
- Manage non-catastrophic risks to humans and the environment
- Meet dam safety criteria for all stages: bulk tailings infilling, capping, reclamation, and post-closure
- Provide a geotechnically stable landform (which includes the drainage basin, drainage outlet, and dyke slopes)
- Provide tailings infilling that allows reliable capping to form a surface that can be accessed using typical mine reclamation equipment

☐ Surface water and surface water quality

- Avoid pond / lake evapoconcentration that leads to unproductive water bodies
- Design for climate change
- Design the landform so that off-lease water quality and quantity support downstream landforms and land uses
- Design surface water drainage systems to provide acceptable performance for downstream aquatic ecosystems
- Design watercourses and waterbodies to have capacity to accommodate all ranges of hydrologic processes at acceptable rates of erosion
- Integrate landform, landscape, and regional drainage systems
- Integrate operational and closure water balances to reduce inventory of mine-affected water at closure
- Integrate tailings deposits into the closure landscapes that have functional drainage systems with acceptable water quality in shallow soil and runoff
- Manage surface water through design of topography, water courses, and wetlands such that water is safely conveyed off-landform

- Manage unacceptable erosion that affects closure landform performance through a surface water network
- Meet downstream water quality regulations
- Meet downstream water quantity agreements
- Protect downstream aquatic ecosystems

☐ Geochemistry, groundwater, and groundwater quality

- Avoid impacts on downgradient drinking water wells
- Limit production of acid rock drainage
- Meet regional groundwater criteria
- Protect groundwater from impacts that affect offsite and / or on-site end land use
- Restore aquifer water quality
- Retore water levels to regional aquifers

☐ Cover systems

- Design reclaimed landforms on tailings deposits to have soil and soil process development consistent with local forest soils
- Isolate all mining materials with covers
- Limit net percolation into mine rock stockpile
- Maximize runoff to downstream wetlands
- Provide a suitable growth media for forest vegetation

☐ Land use and human / ecological risk

- Avoid sterilizing byproducts or materials that might be re-mined
- Create an instrumented watershed for reclamation research
- Design landscapes to be acceptably stable under target end land uses
- Design to meet goals for land uses including access
- Design with human and wildlife health and safety as the highest priority
- Protect humans and wildlife from exposure to chemical hazards
- Manage human health risks
- Meet instream flow needs for fish
- Preserve historical artifacts
- Protect fish habitat
- Ensure a mix of agreed-upon land uses is achieved and maintained
- Provide vegetation and topography for hunting and productive traplines
- Provide access including a boat launch to the pit lake for fishing
- Re-establish fish habitat lost through historical mining

- [ ] Soils, vegetation, and ecology
    - Conserve reclamation soils
    - Create a vegetation plan that meets intended land uses for landform
    - Design and construct landform morphology and substrate to support replaced soil quality and to protect soils from loss and degradation
    - Design ecological communities on reclaimed tailings to have functional and structural aspects consistent with the regional forest
    - Design reclamation material layers to achieve target soil capability
    - Design a vegetation plan to aid landform stability (erosion, water table, moisture)
    - Meet available soil water holding capacity targets for optimal vegetation growth
    - Meet end land use goals and re-establish self-sustaining landscapes and ecosystems
    - Meet vegetation percent cover requirements
    - Meet vegetation stocking densities
    - Mimic vegetation performance of the nearby reference area
- [ ] Wildlife
    - Incorporate wildlife habitat and movement into design of landform and landscape scales
    - Provide spatial attributes appropriate for wildlife and aquatic habitat goals
    - Re-establish pre-disturbance habitat for wildlife
- [ ] Visual aesthetics
    - Aim for a natural appearance
    - Design topography to resemble natural landforms in the region
- [ ] Long-term care and maintenance
    - Design for only limited or finite monitoring and maintenance
    - Design to minimize long-term water treatment volumes and longevity
    - Develop a monitoring and maintenance program for all life-cycle phases
    - Minimize long-term liability
    - Minimize post-closure monitoring costs and monitoring time period
    - Repurpose mine buildings to support land use
    - Repurpose mine roads to support access / land use
    - Return reclaimed land to a willing third-party custodian
- [ ] Social acceptance
    - Achieve signoff by regulators and Indigenous and local communities
    - Create long-term employment opportunities
    - Design to meet acceptable levels of post-reclamation residual risk

- Involve Indigenous and local communities in design, construction, and reclamation
- Avoid human habitation on the land

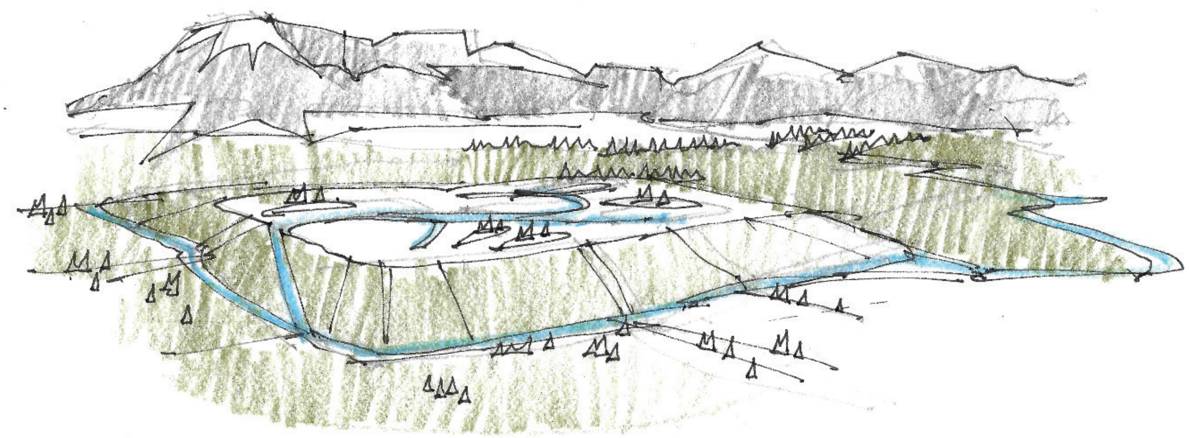
- [ ] Site access
  - Avoid fences
  - Limit vehicular access to reclaimed lands
  - Link access on site to regional foot trails
  - Provide accelerated / progressive access to the reclaimed land
  - Provide access that supports planned land uses

Two useful books that describe the breadth of post-mining land uses are:

- [ ] Pearman G. 2009. *101 things to do with a hole in the ground*. Eden Project. Post Mining Alliance. Cornwall. 69 pp.
- [ ] Whitbread-Abrutat P and Lowe R. 2024. *102 Things to do with a hole in the ground*. Eden Project. Cornwall UK. 264 pp.

APPENDIX G: WORKED EXAMPLE OF DBM FOR A LANDFORM DESIGN

Design Basis Memorandum for the East Forty Mine Rock Stockpile Landform Design



ABC Coal Mine

Cardston, Alberta, Canada

February 29, 2024

A worked example based on a hypothetical mining landform that has been simplified for clarity and brevity. This information is not intended for use in the preparation of an actual DBM.

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EXECUTIVE SUMMARY

The East 40 Mine Rock Stockpile at the ABC Coal Mine in southern Alberta, Canada is a mining landform covering 99 ha that is nearing a final height of 40 m. The outer slopes have been progressively reclaimed. Mine rock placement will end at the end of mine life (2026), resloping of as-yet-unreclaimed areas is scheduled for 2026, and reclamation (placement of cover soil and revegetation) on these areas is scheduled for 2027.

The purpose of the landform design DBM is to guide the detailed design of the slopes, plateau, central swale and downslope swale and ensure continued alignment on the design basis with the mine management, the design team, the landowner/rancher and area First Nations. The DBM was assembled by the design team with the assistance of mine management, the rancher, and Elders of the local First Nation, and has been shared with the provincial regulator.

The vision for the reclaimed landform was developed with the rancher and First Nations Elders and remains unchanged since its inception. The landform will be reclaimed as a prominent hill perched near the top of a natural Rocky Mountain foothill. It is roughly rectangular in shape with a large central plateau. It will be covered and reclaimed as an equal mix of open pasture and forest suitable for ranching and wildlife habitat similar to that of surrounding lands.

The key goals are to make a low-maintenance landform that is accessible, is useful for ranching as well as traditional Indigenous practices including hunting and trapping, and provides some wildlife habitat. The goals are modest and crafted to be achievable. The final placement and reclamation work are expected to be straightforward and will be based on this updated DBM. The remaining uncertainty is the long-term performance of the treed areas given the hard, nearly subalpine conditions that are characterized by a strong water deficit.

INTRODUCTION

This design basis memorandum has been prepared for the ABC Coal Mine's East Forty Mine Rock Stockpile (MRS, the stockpile) in the Rocky Mountain foothills of southwestern Alberta, Canada. Initial placement of mine rock began in 2010 and will be completed in 2025, which is also the end of ore production. Most of the slopes of this 99 ha MRS have been progressively reclaimed. The active haul ramp and plateau are scheduled to be resloped in 2026 and covered and revegetated in 2027. See Figure G-1 for project boundaries.

Reclamation work will involve establishing the surface water drainage system for the plateau, placement of a reclamation cover system, and revegetation to parkland vegetation (pasture grasses and mixed wood stands) suitable for ranching. The haul ramp will be turned into a vegetated waterway to drain the plateau and will also provide an access road to aid ranchers. The mine rock has benign geochemistry. Sufficient reclamation material is available in a nearby reclamation stockpile. This is a small and simple mining landform and reclamation performance to date has been acceptable. The major challenge for reclamation is the establishment of trees in this highly browsed, windy site. Groundwater chemistry has remained benign but will continue to be monitored. The local ranchers have accepted full responsibility for road and channel maintenance, after a period of monitoring and maintenance by the mine.

PURPOSE OF THE DBM

The purpose of this DBM is to guide the design and construction of the final resloping and reclamation of the East Forty MRS and to maintain alignment between the design team, mine management, the regulator, ranchers, First Nations, and the local community.

HOW THE DBM WAS PRODUCED

The mine landform design team was formed in 2000, before mining began. It created a closure plan that follows modern landform design principles. Building on this landscape scale plan, a conceptual landform design (including a DBM) for the stockpile was developed in 2009, followed by a detailed design in 2010. This DBM represents an update to the existing design, with a focus on the plateau and drainage channel. Much of the original DBM has been preserved.

The team worked together in Q3 of 2023 to develop this updated DBM. It will be used for the final updated detailed landform design for the landform and ought not to require future updates. The design team has worked closely with the rancher and a group of Elders from the local community, mainly through quarterly field tours undertaken since 2009. The design team also includes one youth and one Elder from this group, who co-designed the landform and this DBM. Unlike the previous DBM, which had the background information arranged in sections, this one presents the information in a table for ease of use.

BACKGROUND

Figure G-1 is a constraint map and shows the MRS in planview. Table G-1 provides the background information.

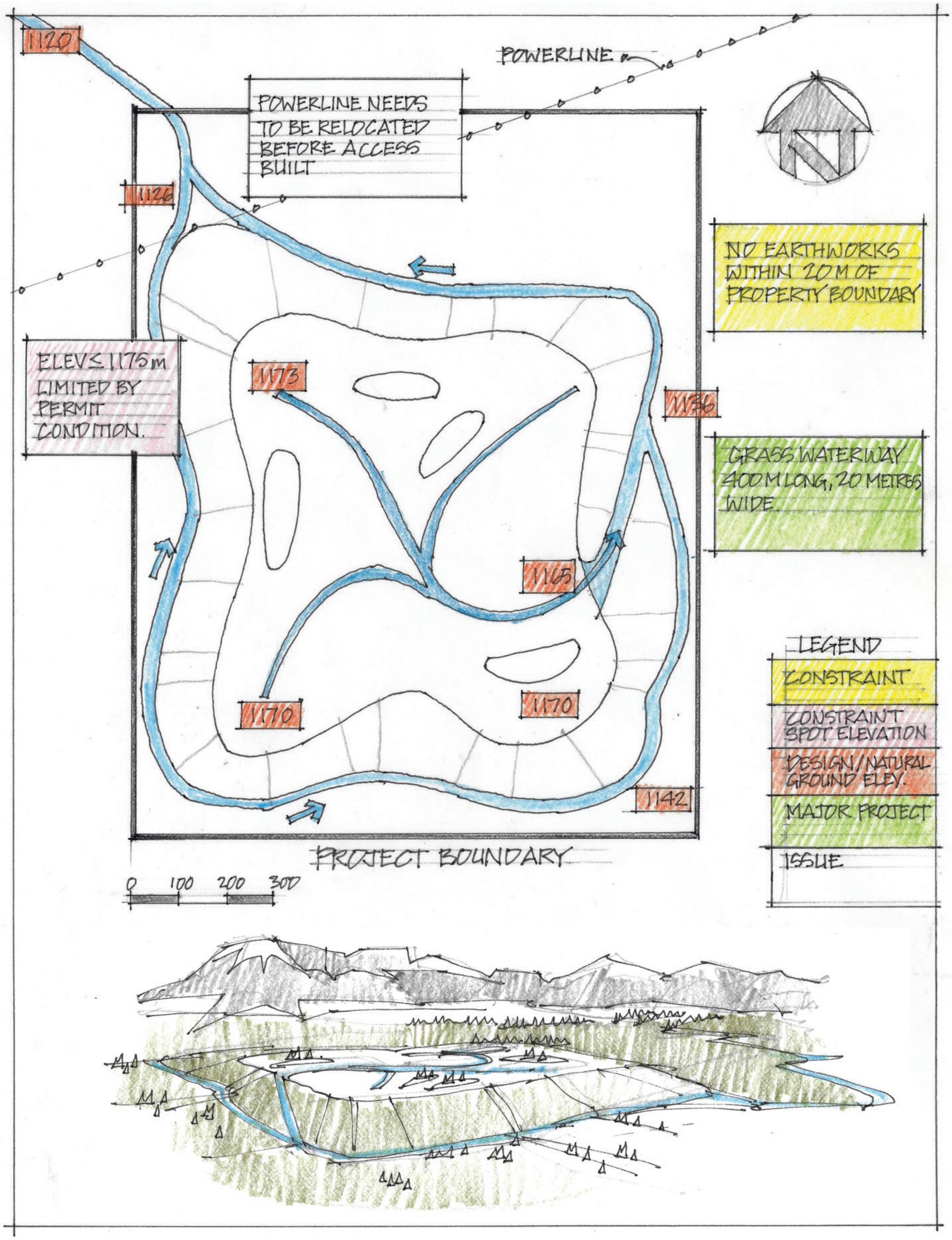


Figure G-1. Planview drawing / constraint map

Table G-1. ABC Coal Mine North 40 MRS background information

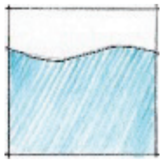
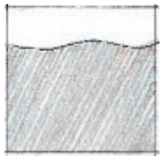
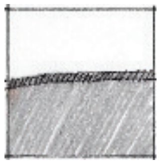
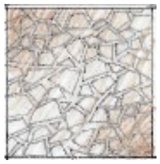
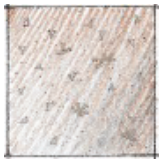
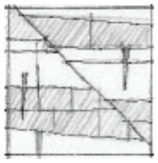
Item	Element	Details
Project description, existing site condition	Project description	The East 40 MRS is a ridge-shaped landform 30 m high covering 90 ha on a gently sloping plain. This stockpile is being constructed in 5 m high lifts placed with 100 tonne trucks and spread with D10 dozers. The mine rock is angular cobbly gravel with some sands and is comprised of blasted sandstone overburden removed to expose the coal seam in the nearby Pit Number 2. It has good geotechnical and geochemical properties and is free draining. The foundation comprises gravelly glacial till that is also free draining with a water table that is 10 to 20 m below the ground surface.
	Existing site conditions	Coal mining will continue until 2026 with mine rock being placed in the final lifts of East 40 MRS. The bottom benches have been resloped, covered, and revegetated. The toe creek that surrounds the landform was constructed and reclaimed as final drainage and drains at about 1% to the southwest. There are no geotechnical, surface water, or geochemical issues and the landform is being built to design. There has been some difficulty in establishing the patches of forest due to the dry winds and browse pressures. These are being resolved with use of thicker covers (with increased moisture holding capacity) and fencing the treed areas until the trees are tall enough to withstand browsing.
Regulatory	Federal requirements	There are no specific federal requirements related to the ABC landform design (the mine is regulated provincially).
	Provincial requirements	All related provincial requirements for the landform design are provided or referenced within the mine permit (see below).
	Permits	The mine is regulated under Alberta EPEA permit 204-01 and most recently updated 2022-01-04.
	Indigenous government	The local First Nations community is located in southern Alberta. There is an agreement between the First Nation and the mine.
Geographic setting	Physiography	The MRS stockpile is set in the Rocky Mountain foothills just east of Waterton National Park, 12 km south of Mountain View, and just north of the Montana border. A First Nations Reserve is located southwest of the mine. The site is underlain by a thick mantle of Pleistocene glacial till (unsorted sands and silts with cobbles and boulders) which overlies Upper Cretaceous sandstones, siltstones, and shales of the Scollard Formation. The economic coal seams are within this unit. The region is extensively farmed and ranched and has good access by paved highways and good gravel roads. The site is fairly flat, gently sloping to the southwest at about 1%, and has 5 m of high rolling hills. The site elevations vary from 1120 to 1150 m. Surface water drains to a collection pond, then to a sedimentation pond to the southwest, and is then discharged into the adjacent river. The groundwater table is located about 10 to 20 m below ground level, and also drains toward the river. There are a few potable wells in the region used for livestock. The area has relatively low seismicity with a 1:2475 return period earthquake with a peak ground acceleration of 0.10 m/s^2. There is extensive wildlife in the region including bear, cougar, mountain sheep, deer, elk, and moose.

Item	Element	Details
Climate	Climate station	The nearest government climate stations are in Waterton Park (1955-current). A weather station at the mine has been operating since 2000.
	Köppen–Geiger climate zone	DFb (warm-summer humid continental).
	Precipitation, temperature, and winds	Average annual precipitation is 910 mm/yr (half as snow) with annual potential evaporation of 590 mm/yr. The 24 hour PMP is 513 mm. Average daily low and high temperatures in January are about −10°C to −0°C in January; +9°C to 24°C in July. A strong breeze is common from the west, with periods of storms and maximum gusts of over 100 km/h. These winds redistribute snow and have drying effects on vegetation. These average values are not used for design and are provided for reference only. The site has a major annual water deficit. Winter winds redistribute snow from the plateau to the downwind east facing slope, causing small snow drifts. The weather does not generally affect mine or reclamation operations. Covers are typically placed and seeded in late fall. Trees and shrub seedlings are typically planted in late spring.
Ecological setting	Ecoregion / Natural region	A ridge in the Montane Natural Subregion. Prior to mine development, ecosystems consisted of mixed conifer and poplar forests and dry grasslands on exposed slopes.
	Typical vegetation	Vegetation includes lodgepole pine (*Pinus contorta*) and Douglas-fir (*Pseudotsuga menziesii*) in the overstory, with common understory shrubs being bearberry (*Arctostaphylos uva-ursi*) and juniper (*Juniperus communis*). Bluebunch wheatgrass (*Pseudoroegneria spicata*) is the prominent grassland species. Much of the immediate area outside the minesite has been logged and is being used for ranching.
	Threatened species / species at risk	None indicated by governments on or immediately adjacent to the mine site.
Location	Location	Lat/long: 49° 01’ N; 113° 36’ W.
	Coordinate system	UTM Zone 12U
	Datum	Canadian Geodetic Vertical Datum of 2013 (CGVD2013).

Item	Element	Details
Mine plans and supporting documents	Mine closure plan and geotechnical design	Mine plan: Version 2.3 dated 2018-08-01 Closure plan: Version 2 dated 2018-08-01
	Digital elevation model surfaces	Fully settled reclaimed surface: ABC_MODEL_Settled 2018.dng Top of mine rock design: ABC_DESIGN_TOPO 2018.dng Top of reclaimed surface design: ABC_DESIGN_RECL.2018.dng Top of reclaimed surface: ABC_ABRS_2022.dng Top of as-built mine rock: ABC_ABMR_2022.dng Lowest mined surface: ABC_LMS_2018.dng Original ground surface: ABC_OG_2018.dng Top of bedrock surface: ABC_BEDROCK_2023.dng
	Other supporting documents	ABC Mine Rock Stockpile Design Guide 2001 ABC MRS OMS Manual 2001 MRS geotechnical design. Version 1.1 dated 2018-08-01 ABC Coversoil placement SOP 2008 ABC Revegetation placement SOP 2008 Foothills Groundwater Use Survey 2OO9 Design of fencing for wildlife 2020 Regional land use plan 2001 ABC Environmental Impact Assessment 1999 ABC Corporate Risk Register 2022 Snow Fence Design Guide 2001
Corporate requirements		Post-reclamation residual risks must be low (or below) using the ABC engineering risk assessment tool 2020.
Corporate commitments		Agreement between ABC and Foothills Fish and Game Club (2022) (includes need to design fences to allow wildlife passage). Agreement between ABC and Rancher (2001) (includes provision to expedite access to the land and to provide an all-weather light vehicle road around the perimeter and to the plateau).
Constraints		There are few constraints highlighted for this landform. No disturbance outside the permit boundary is permitted. The permitted elevation of the MRS crest is restricted to 1175.0 m elev. (permit condition). The access road shall be maintained at all times.

Item	Element	Details
Key milestones		Present – ongoing mine rock placement and progressive resloping and reclamation. October 2025 – end of mine production and mine rock placement. February 2026 – final landform design complete and approved by provincial regulator and the local Indigenous First Nation. March to September 2026 – resloping, contouring, cover material placement (restricted to months without snow). April 2027 – revegetation. Present to 2037 – annual inspection and maintenance. 2037 – Target signoff date by the mine, the rancher, provincial and government regulators, and area First Nations. 2037+ Decadal inspection and maintenance.
Quality control and quality assurance		Regrading and reclamation material placement will be surveyed daily. The reclamation material borrow stockpile has been previously confirmed for suitability and quantity. The EOR will inspect and approve the final constructed mine rock surface. The RDOR will inspect and approve the reclamation material quality and placement, inspect and approve the revegetation activity, and take over all responsibility for the design and construction. Quality assurance will be provided by XYZ Engineering and Environment on an annual basis or more frequently if needed.
Materials and material properties		See stratigraphic column (Table G-2).

Table G-2. ABC Coal Mine stratigraphic column

Type	Unit name	Illustration	Description	Comment
Waters	Non-contact water		Runoff water that has not been in contact with mining materials	
	Contact water		Surface water or groundwater that has been in contact with mining materials	Defined as any water falling within the mine disturbance boundary
Reclamation materials	Road crushed gravel		Well-graded, sandy gravel, 3 inch minus angular, moist, tan coloured	From the ABC quarry, 9 km to the east of the site
	Cover / growth medium		Loose (uncompacted) glacial till fill	May require ripping to keep low density in rooting zone
	Filter cloth		Non-woven geotextile	Assumed to have a 40-year design life
Mine material	Mine rock		Blasted bedrock composed of angular sandstone and siltstone cobbles with gravel and sand, moist, loose, tan coloured, friable.	Benign geochemistry, minor salt flushing
Surficial units	Pleistocene glacial till		Sandy silty gravel, light brown to medium grey, loose to compact, free-draining, dry to moist, some organics.	
Bedrock units	Tertiary fractured bedrock		The upper 10 m of bedrock is highly fractured and forms a local aquifer.	
	Tertiary intact bedrock		Cretaceous sandstones, siltstones, and shales of the Scollard formation.	The economic coal seams are within this unit.

VISION

The vision remains the same since the start of mining and was developed with the rancher / landowner and Elders from the local First Nation.

The reclaimed landform will be a prominent hill with moderately steep slopes and an undulating plateau, reclaimed to an equal mix of open pasture with large patches of mixed-wood forest. Like nearby areas in the region, it will be suitable for ranching and wildlife habitat. A large central swale will carry surface water runoff down a vegetated channel and down the haul ramp and out to the river. The landform will be designed by a team of specialists in collaboration with the rancher and the Elders and constructed and progressively reclaimed over about 30 years. The mine will maintain the site until 10 years after reclamation when custody will revert back to the rancher.

MASTER TABLE OF GOALS, OBJECTIVES, AND DESIGN CRITERIA

See Table H-2 for the Master Table of goals and objectives.

HIGHLIGHTED RISKS, OPPORTUNITIES, AND DATA GAPS

As indicated in the FMA category column of Table H-2, all but two of the objectives can be reliably met using normal design and construction methods and proven technology (through progressive reclamation) at the mine site.

A highlighted risk for the project is delays or inability to achieving signoff for the reclamation performance by the rancher, the local First Nations community and the regulator. Immediate engagement on this topic is needed.

Insufficient information and site experience exist to determine whether the risk of winter desiccation that limits growth and survival of tree species planted on the landform plateau will be problematic. At other higher-altitude mine sites in the region, dry winds immediately above the snow negatively impact the vegetation. Mitigation measures (mounding and use of snow fences) being trialed to improve performance of the revegetation show early signs of success. It is unclear whether this desiccation will be an issue at the East Forty Mile stockpile plateau. Contingency measures are available and tentatively budgeted if monitoring indicates they are needed.

IMPLEMENTATION

This updated DBM will be used to prepare the detailed landform design over the next 18 months. It is likely the last version. It will be used for a risk assessment and to compare the performance against the goals in guiding monitoring and maintenance.

SIGNOFF / VERSION HISTORY

Table G-3. Signoff / Version History

Version	Date	Details of charge	Author	Reviewer
A	2008-10-01	Initial DBM, for permitting support	Ashley Orionto	Abe Sandruston
B	2016-05-01	Revised closure plan	Billy Terminati	Abe Sandruston
C	2024-01-01	Detailed landform design for closure	Charlie Hackinsaw	Cheryl Cardston

REFERENCES

Global Tailings Review. 2020. Global industry standard on tailings management (GISTM). International Council on Mining & Metals, UN Environment Programme, and Principles for Responsible Investment.

International Council on Mining and Metals (ICMM). 2021. Conformance protocols: Global industry standard on tailings management.

LDI. 2021. Mining with the end in mind: Landform design for sustainable mining. Position Paper 2021-01. Landform Design Institute. Delta, BC, Canada. 78 pp.

Williams B.K., Szaro R.C., & Shapiro C.D. 2009. Adaptive Management: The US Department of the Interior Technical Guide. Adaptive Management Working Group. Washington.

Copies of all documents are available on the landform design server.

APPENDICES

There are no appendices in this version.

APPENDIX H: USING THE MASTER TABLE FOR ASSESSMENT

The Master Table of goals, objectives, and design criteria can be used as a high-level tool to assess any landform design (or closure plan) against the goals and objectives. The team works together to review the table row by row and indicate how the design meets the design intent.

One useful tool is the screening-level classification system provided by FERC (2017) and known as a failure mode analysis (FMA). Two columns are added to the goals / objectives / criteria table, one for the classification and one for supporting comments. Each row is classified using the following scheme.

Table H-1. A suggested classification system for DBM goals and objectives

FMA category	Description	Comment
1 Highlighted	Objective may include a fatal flaw to the design. Non-routine work needs to confirm the design has adequately addressed the objective or indicate that the design needs to be reworked.	Objectives classified as Category 1 are commonly flagged to the steering committee and mine management. The number of objectives classified as Category 1 would ideally drop to zero when the detailed design is completed.
2 Noted	Noted and judged to be of lesser risk and can be adequately addressed through the typical design process. Generally, Category 2 objectives require important but routine design work.	
3 Need more information	More information or analysis is required to be reclassified as Category 1, 2 or 4.	A common example is where, early in design, there is little water quality information / predictions for seepage water quality.
4 Not applicable	The objective is not relevant and does not need to be considered for the specific landform.	This classification commonly occurs where a more generic site wide DBM is being used for a specific landform that lacks an element (such as a spillway or a wetland).

Definitions and method adapted from FERC (2017)

If multiple designs or landforms are being classified, a table showing each design / landform plotted against each of the goals with colour-coded assessment scores can constitute a useful one-page summary of the work.

Comments behind each score capture the team's reasoning and insights and the present level of knowledge. The Master Table can also be used for a gap analysis to list and prioritize the next steps in design.

Table H-2. Example Master Table of DBM goals, objectives, and criteria

No.	Closure goal	No.	Objective	Criteria or comments	FMA category	FMA comment
Mine operations						
1.0	Support ongoing operations	1.1	Avoid reclaiming areas that impact ongoing mining operations	The slopes will be reclaimed as they are available, but the haul ramp, the active slopes, and the plateau will remain unreclaimed until closure.	2	
		1.2	Provide opportunities for progressive reclamation as areas become available	Reclaim the slopes in the year following construction using material from the reclamation material stockpile.	2	
Construction and reclamation						
2.0	Design landforms to make reclamation	2.1	Construct topography to make reclamation efficient	Minimum haul ramp width 10 m (two-way traffic, 100 tonne trucks). Maximum haul ramp slope 8% (maximum efficient haul ramp angle). Bench heights 5 m (to minimize regrade volumes). The central haul ramp is designed with conversion to a vegetated waterway at closure. Hummock slopes < 10%. Hummock sizes = approx. 10 dump truck loads with 100 tonne trucks. Hummocks on the plateau will have broad enough slopes to allow placement with the mine fleet and reclamation using the reclamation fleet.	2	
		2.2	Conserve reclamation material	Distinguish between flow capacity of the channel and the capacity of the channel armouring to resist erosion. Erosion modelling is used to evaluate how susceptible the cover media are to erosion to inform robust cover design. Design criteria will need to be developed at future design stages to account for the impact of climate change. Climate assumptions incorporate anticipated precipitation trends over the closure timeframe.	2	

No.	Closure goal	No.	Objective	Criteria or comments	FMA category	FMA comment
Regulatory requirements and corporate commitments						
3.0	Meet applicable regulatory requirements and corporate commitments	3.1	Remain in compliance with all applicable regulations and regulatory requirements through the life cycle of the facility	All applicable regulations should already be met. If not, efforts to meet the regulations continue.	2	
		3.2	Maintain access road for use of the rancher	Road shall always be available during and after construction.	2	
		3.3	Avoid constructing perimeter fence	Construct no perimeter fence, just signage to restrict inadvertent human access. *Any fence may impede wildlife movement.*	2	
Geotechnical and geomorphology						
4.0	Design	4.1	Maintain factor of safety for slope stability	Static limit equilibrium factor of safety against slope instability ≥ 1.5; pseudostatic seismic stability ≥ 1.2.	2	
Surface water and groundwater						
5.0	Design slopes to be erosionally stable	5.1	Avoid excessive gullying on slopes	Tip benches outward at ≥ 2% to avoid ponding water. Use a 2 m high watershed berm around perimeter of crest. Grade plateau ≥ 1% toward a central swale.	2	
	Carry water from plateau to base of mine rock stockpile and out to river	5.2	Provide a channel with enough capacity to manage the design storm	Direct all runoff water from the plateau and central channel to the downslope channel. Channel capacity to carry the 1:500 return period precipitation including consideration of rain on snow event.	2	
	Ensure groundwater quality is maintained	5.3	Install wells and monitor water quality within mine rock, beneath mine rock, and downgradient of the stockpile	*Note: All wells already installed and show no elevated levels of any constituents as of January 2024.*	2	

No.	Closure goal	No.	Objective	Criteria or comments	FMA category	FMA comment
Land use and access						
6.0	Reclaim to pasture land and wildlife forest	6.1	Revegetate with native species using a landscape ecology approach	Reclaim open areas with native grasses. Reclaim forest areas with 1000 stems per hectare white spruce and 1000 stems per hectare balsam poplar. Vary patch size for forests between 1 and 4 hectares. Provide a 100 m wide forested wildlife corridor on each slope from the toe to the plateau. Connect with existing off-site forested areas.	3	Survival and growth of trees on the plateau may require additional measures to avoid winter desicc-ation.
	Provide post-reclamation access to the plateau and to all areas of the toe perimeter	6.2	Construct a light vehicle road around the perimeter and beside the downslope channel to provide land use access and maintenance access	One-way light vehicle road, 4 m wide, use 0.5 m of mine rock capped with 0.3 m of road crush.	2	
Cover system						
7.0	Provide a cover to limit erosion and act as a vegetation growth media	7.1	Provide erosion protection for slopes	Cover cobble + gravel content ≥ 50%. Repair any gully that exposes mine rock.	2	
		7,.2	Provide sufficient water-holding capacity for tree growth / productivity	Cover depth = 500 mm. Sand + silt content ≥ 35%.	2	
Long-term care and maintenance						
8.0	Minimize need for long-term care and maintenance	8.1	Design and construct grass waterway for central swale on plateau and downslope swale	Follow guidance in grass waterway design guide.	2	

No.	Closure goal	No.	Objective	Criteria or comments	FMA category	FMA comment
Social acceptance						
9.0	Maintain social acceptance of reclaimed landform	9.1	Collaborate with landowner / rancher and local Indigenous government for all aspects of landform design, construction, monitoring, and maintenance	Active participation.	2	
		9.2	Work toward signoff by provincial regulator, landowner / rancher and local Indigenous government	Achieve progressive signoff (DBM, landform design, end of construction, end of reclamation, 10- year performance).	1	Signoff on reclaimed mine land is often difficult to obtain. Acceptance of this DBM should help.

ENDNOTES

1. Readers interested in more information regarding landform design and closure planning can consult the following key references:
    - APEC. 2018. Mine closure checklist for governments. Asia-Pacific Economic Cooperation. APEC Mining Task Force. Singapore. Feb 2018. 104 pp.
    - Government of Western Australia. 2015. Guidelines for preparing mine closure plans. Department of Mines and Petroleum. May 2015. 100 pp.
    - IBRAM. 2014. Guide for mine closure planning. Instituto Brasileiro de Mineracao. Brasilia: Brazilian Mining Association. 225 pp.
    - Global Tailings Review. 2020. The Global Industry Standard on Tailings Management. Internet accessed May 1, 2022. https://globaltailingsreview.org/wp-content/uploads/2020/08/global-industry-standard-on-tailings-management.pdf.
    - ICMM. 2019. Integrated mine closure: good practice guide, 2nd edition. International Council on Mining & Metals. London. May 2021. 132 pp.
    - LDI. 2021. Mining with the end in mind: Landform design for sustainable mining. Position Paper 2021-01. March 2021. Landform Design Institute. Delta, BC, Canada. 78 pp.
    - McKenna, G. 2002. Landscape engineering and sustainable mine reclamation. PhD Thesis. Department of Civil and Environmental Engineering. University of Alberta. Edmonton. 660 pp.
2. This section adapted from COSIA (2022) Deep Deposit Design Guide. Internet Accessed September 10, 2024. https://nma.org/wp-content/uploads/2021/05/infographic_SNL_minerals-permitting_5.7_updated.pdf
3. Mining Association of Canada. 2022. Project Permitting in Canada and the Mining Industry. Internet accessed September 10, 2022. https://mining.ca/resources/reports/project-permitting-in-canada-and-the-mining-industry/
4. SNL Metals & Mining. 2015. Delays in the U.S. Mine Permitting Process Impair and Discourage Mining at Home.
5. Global Tailings Review. 2020. The Global Industry Standard on Tailings Management. Internet accessed May 1, 2022. https://globaltailingsreview.org/wp-content/uploads/2020/08/global-industry-standard-on-tailings-management.pdf.
6. Global Tailings Review. 2020. The Global Industry Standard on Tailings Management. Internet accessed May 1, 2022. https://globaltailingsreview.org/wp-content/uploads/2020/08/global-industry-standard-on-tailings-management.pdf.
7. Straker, J and McKenna, G. 2022. The case for a reclamation designer of record. BC Mine Reclamation Symposium. 15 pp.
8. LDI. (2021)
9. Daly C. 2023. Exploring co-reclamation: gesturing towards intercultural collaboration and the renewal of Indigenous cultural landscapes after oil sands extraction in the Fort McKay First Nation Traditional Territory, Treaty 8, Alberta, Canada. PhD Thesis, University of Calgary. Calgary, Alberta, Canada. 209 pp.
10. LDI (2021) provides a list of 21 mining landform types.
11. This section is adapted from the COSIA (2022) Deep Deposit Design Guide.

12. Some mines use an operational name for their mining landform (such as the South Tailings Storage Facility, the West Mine Rock Stockpile, etc) then rename the landform after reclamation is complete (for example Sandhill Fen, Moose Mountain, South Bison Hill). Inclusion of both names in the DBM is key. (Other mines use landform-like names to remind those designing, constructing, and reclaiming these mining landform of the vision and bypass the need for a name change.) Indigenous and local communities should be involved in naming landforms.
13. DBMs may be created for the landscape / mine site / closure plan scale, or for one of the individual mining landforms (such as a mine rock stockpile, a tailings facility, a mined-out pit, etc.), or for a specific major element of a landform (such as an engineered wetland or a spillway). To avoid wordiness, this document refers to all of these as simply landforms but the advice applies equally to landscapes and elements.
14. The reader and the design team will expect the design to follow the requirements set out in any documents listed here; only include documents that will be followed by the design team. If there are documents that the reader might expect to be used and are not being followed, this fact is discussed at this point in the DBM.
15. A risk register is a document or database that mines use to identify, describe, and classify significant risks to the operation of the company and is used to manage these risks at a corporate level.
16. It is good practice to include the full electronic copies of all the relevant regulatory, industry, corporate, and social documents on a common shared drive so that these are easily accessible to all landform design team members. The most recent copies should be made easy to find; in some cases, it will be important to archive historical documents that may be applicable to the DBM.
17. Such tables are routine in tailings dam and mine rock stockpile geotechnical design DBMs.
18. This structure and definitions are adapted from the LDI (2021) Position Paper.
19. A problem common to most mines worldwide is that they neglect to set out their goals and objectives or describe them vaguely, tend to be too optimistic, and are rarely fully achieved. Different groups have different expectations of what is being promised and what is being delivered. The DBM, and in particular this Master Table, is meant to correct this fundamental issue. It is imperative that participants avoid overcommitting or using imprecise language in this table.
20. Doran GT. 1981. There's a S.M.A.R.T. way to write management's goals and objectives. Management Review. Volume 70 (11). pp. 35–36.
21. References include:
    - Cumulative Environmental Management Association (CEMA). 2005. Landscape Design Checklist, Revised RSDS Government Regulator Version. May 2005. CEMA-RWG Landscape Design Sub-group. 8 pp.
    - McKenna GT. 2002. Landscape engineering and sustainable mine reclamation. PhD Thesis. Department of Civil and Environmental Engineering. University of Alberta. Edmonton. 660 pp.
    - Alberta Government. 2015. Owner Athabasca Region: tailings management framework for the mineable Athabasca oil sands. Government of Alberta, Edmonton, Canada. Report dated March 2015. 58 pp.
    - COSIA. 2022. Deep Deposit Design Guide for Oil Sands Tailings. Canada's Oil Sands Innovation Alliance – Deep Deposit Working Group. Calgary. July 2022. 260 pp.
    - OSTDC. 2014. De-Licensing of oil sands tailings dams. Technical guidance document. Oil Sands Tailings Dam Committee. Edmonton. 46 pp.

REFERENCES

Ansah-Sam M, Hachey L, McKenna G, & Mooder B. 2016. The DBM approach for setting engineering design criteria for an oil sands mine closure plan. International Oil Sands Tailings Conference. Lake Louise. University of Alberta Geotechnical Group, Edmonton. 11 pp.

CEMA. 2005. Landscape Design Checklist, Revised RSDS Government Regulator Version. Cumulative Environmental Management Association CEMA-RWG Landscape Design Subgroup. May 2005. CEMA. Fort McMurray. 8 pp.

COSIA. 2022. Deep Deposit Design Guide for Oil Sands Tailings. Canada's Oil Sands Innovation Alliance – Deep Deposit Working Group. Calgary. July 2022. 260 pp.

Crossley, C, Russell, B, van Zyl, D, and McKenna, G. 2011. Developing an operation, maintenance, and surveillance manual for the post-closure management of tailings facilities. Mine Closure 2011 Lake Louise. Australian Centre for Geomechanics. Perth. 10 pp.

Daly, C. 2023. Exploring co-reclamation: gesturing towards intercultural collaboration and the renewal of Indigenous cultural landscapes after oil sands extraction in the Fort McKay First Nation Traditional Territory, Treaty 8, Alberta, Canada. PhD Thesis, Graduate program in Environmental Design, University of Calgary. Calgary, Alberta, Canada. 209 pp.

Davies Post, A. 2024. Indigenous Guardian programs as a model for evaluating traditional land use in post-reclaimed sites. MSc thesis in Environmental Studies in Social and Ecological Sustainability. Waterloo, Ontario, Canada. 118 pp.

DOE. 1991. Lakeview, Oregon Final Completion Report. Volume 1. Remedial Actions Contractor for the Uranium Mill Tailings Actions Project. Department of Energy, Albuquerque Operations Office. MK-Ferguson Company. 47 pp.

FERC. 2017. Chapter 14: Dam safety performance monitoring program. Engineering Guidelines for the Evaluation of Hydropower Projects. Federal Energy Regulatory Commission. Washington, DC, USA. 188 pp.

Fortuna. 2019. Design standards for tailings and filtered storage facilities, heap leach facilities and mine rock storage facilities. Report dated August 26, 2019. Fortuna Silver Mines Inc. Vancouver. 258 pp.

Global Tailings Review. 2020. Global industry standard on tailings management (GISTM). Global Tailings Review. International Council on Mining & Metals, UN Environment Programme, and Principles for Responsible Investment. August 2020.

Kinder Morgan. 2007. Anchor Loop Project Design Basis Memorandum. Owners report dated 2007-06-12. Kinder Morgan Canada Inc. Calgary. 100 pp.

LDI. 2021. Mining with the end in mind: Landform design for sustainable mining. Position Paper 2021-01. March 2021. Landform Design Institute. Delta, BC, Canada. 78 pp.

McKenna, G.T., 2002. “Landscape engineering and sustainable mine reclamation,” PhD Thesis, Department of Civil and Environmental Engineering, University of Alberta, Edmonton, 660 pp.

Straker, J and McKenna, G. 2022. The case for a reclamation designer of record. BC Mine Reclamation Symposium. 15 pp.

McKenna, G and Van Zyl, D. 2020. Closure & reclamation. Chapter VIII Management of Tailings: Past Present & Future. Towards Zero Harm: A Compendium of Papers Prepared for the Global Tailings Review. London: Global Tailings Review.

Norwest. 2015. Ajax Project. Tailings disposal best available technology assessment. Consultant’s report prepared for KGHM. Norwest Corporation & M3 Engineering & Technology Corp. 57 pp.

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