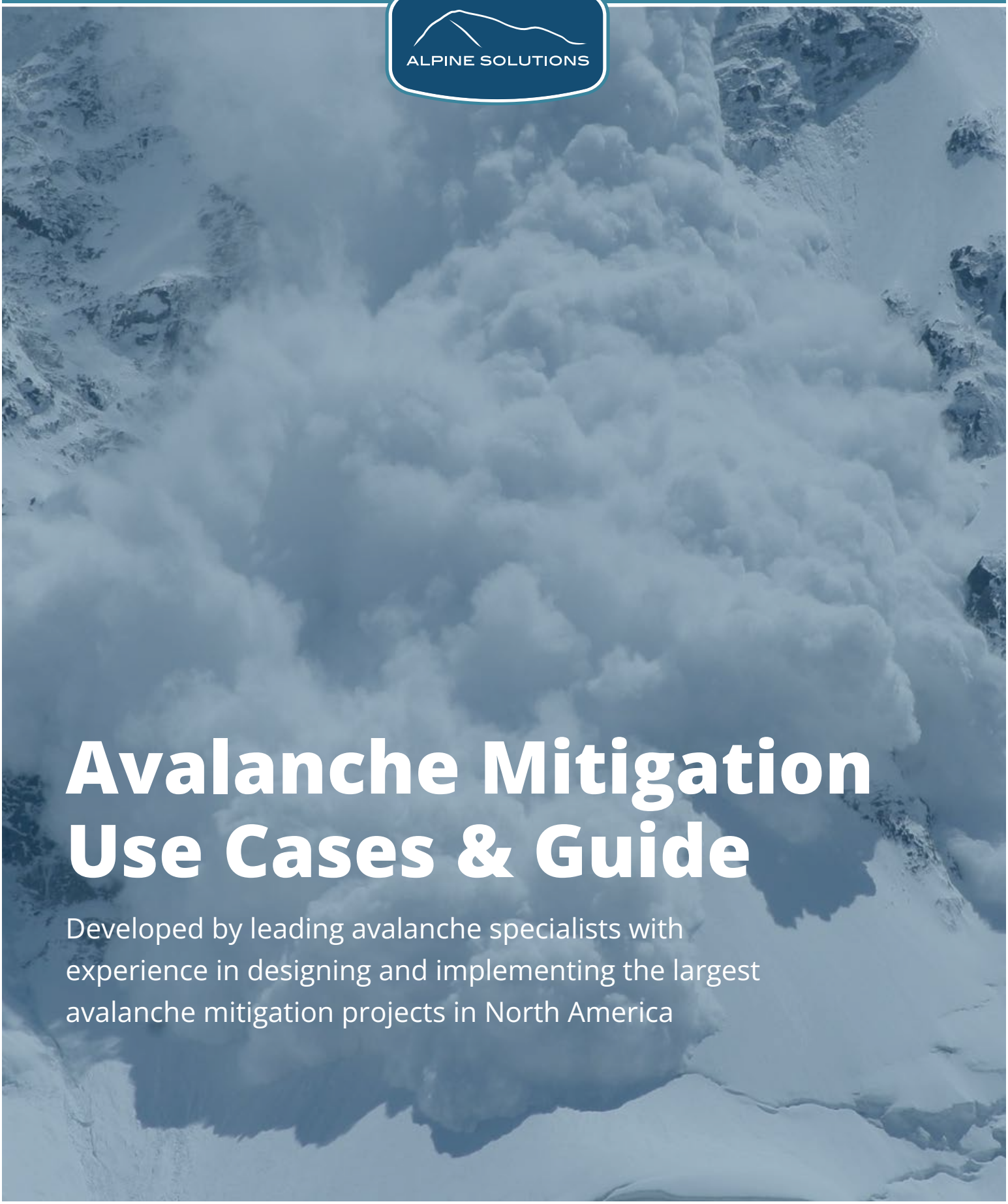
ALPINE SOLUTIONS



Avalanche Mitigation Use Cases & Guide

Developed by leading avalanche specialists with experience in designing and implementing the largest avalanche mitigation projects in North America

alpinesolutions.com | 604 892 9101

Table of Contents

Established in 2008

Since 2008, Alpine Solutions has been at the forefront of avalanche engineering and consulting. We've overseen the design and installation of nearly 50% of the Remote Avalanche Control Systems in Canada, as well as participated in avalanche mitigation design and risk management for some of the most challenging infrastructure projects, including the Kicking Horse Canyon, Trans-Canada Highway, Brucejack Mine, Coastal GasLink Pipeline, and more.

Our team brings decades of hands-on experience in avalanche risk management, with many serving as subject matter experts for industry standards and government advisory groups.

Alpine Solutions works with a wide variety of companies and agencies across many industry sectors, including highways, railways, mining, pipeline, hydroelectric, land development, forestry, and ski resorts. All of our projects are tailored to the specific needs of our clients. We regularly work with industry leading companies who are committed to ensuring a safe workplace for their personnel. Alpine Solutions has adopted safe workplace policies and procedures that meet or exceed regulatory requirements and best practices.

When Avalanche Hazards Impact Operations

Unlike other natural hazards, avalanches have the highest frequency which produces seasonal challenges to industries operating in mountainous regions. **Avalanches can damage infrastructure, endanger life and block access to worksites**. Operations must safeguard workers, protect critical infrastructure and minimizing economic losses from avalanche occurrences. Avalanche mitigation has become an essential aspect of operational risk management.

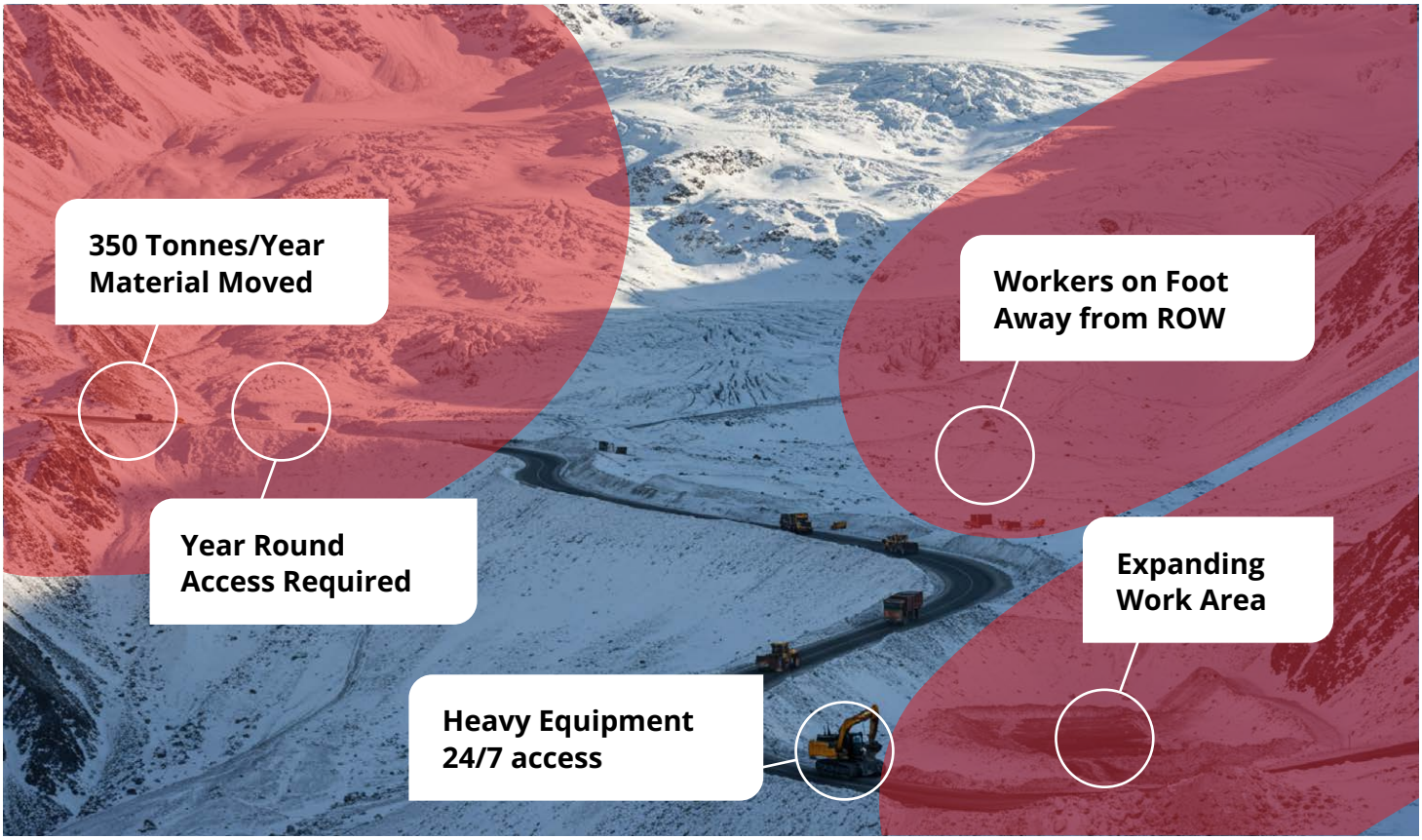
This eBook explores various avalanche mitigation strategies—showcasing mitigation designs which can address key concerns like asset protection, operational continuity, and regulatory compliance. **By investing in robust mitigation strategies, companies can not only protect their people and assets but also enhance their operational resilience**.

Avalanche Zone

Aligning Avalanche Mitigation with Project Needs

Each project is unique, with its own economic output to account for and a specific lifespan during which risks must be managed. To begin addressing an avalanche hazard and reviewing mitigation options, it is **essential to undergo an avalanche risk assessment which will define the elements at risk**. These may include people, property, vehicles, structures, environmental assets, economic activities, and services that could potentially be impacted.

The **spatial scale** refers to the geographical area covered by the project, both in its current state and future scope. The **temporal scale** relates to the duration during which the elements at risk will be exposed to the hazard. This is a technical way determining **what and for how long is your operation facing an avalanche risk**.



Avalanche Zone

Regulatory Compliance

It is important to recognize how avalanche hazard mitigation governed and how they would be evaluated in an incident or compliance review. Mitigation efforts will be compared against local regulations and best practices.

Worksafe BC

Section 4.1.1(2) of BC's OHS Regulations state that if a person working in a workplace may be exposed to a risk associated with an avalanche, the employer must undertake an avalanche risk assessment before any work is carried out at that workplace. If the assessment indicates that a person working at the workplace will be exposed to avalanche risk, the employer must then ensure that a written ASP is developed and implemented.

BC Mines Act

Section 3.3.6 of the BC Mines Act Health, Safety and Reclamation Code (Page 124), states that a written avalanche risk assessment must be conducted in accordance with the Technical Aspects of Snow Avalanche Risk Management (CAA, 2016).

If avalanche risk is found to exceed thresholds for worker safety provided in CAA (2016) then qualified professionals are required to develop an ASP (referred to as an avalanche safety program in the Code) that includes monitoring of weather, snow, and avalanche conditions, and implementation of closures, temporary evacuations or other measures.

Best Practice

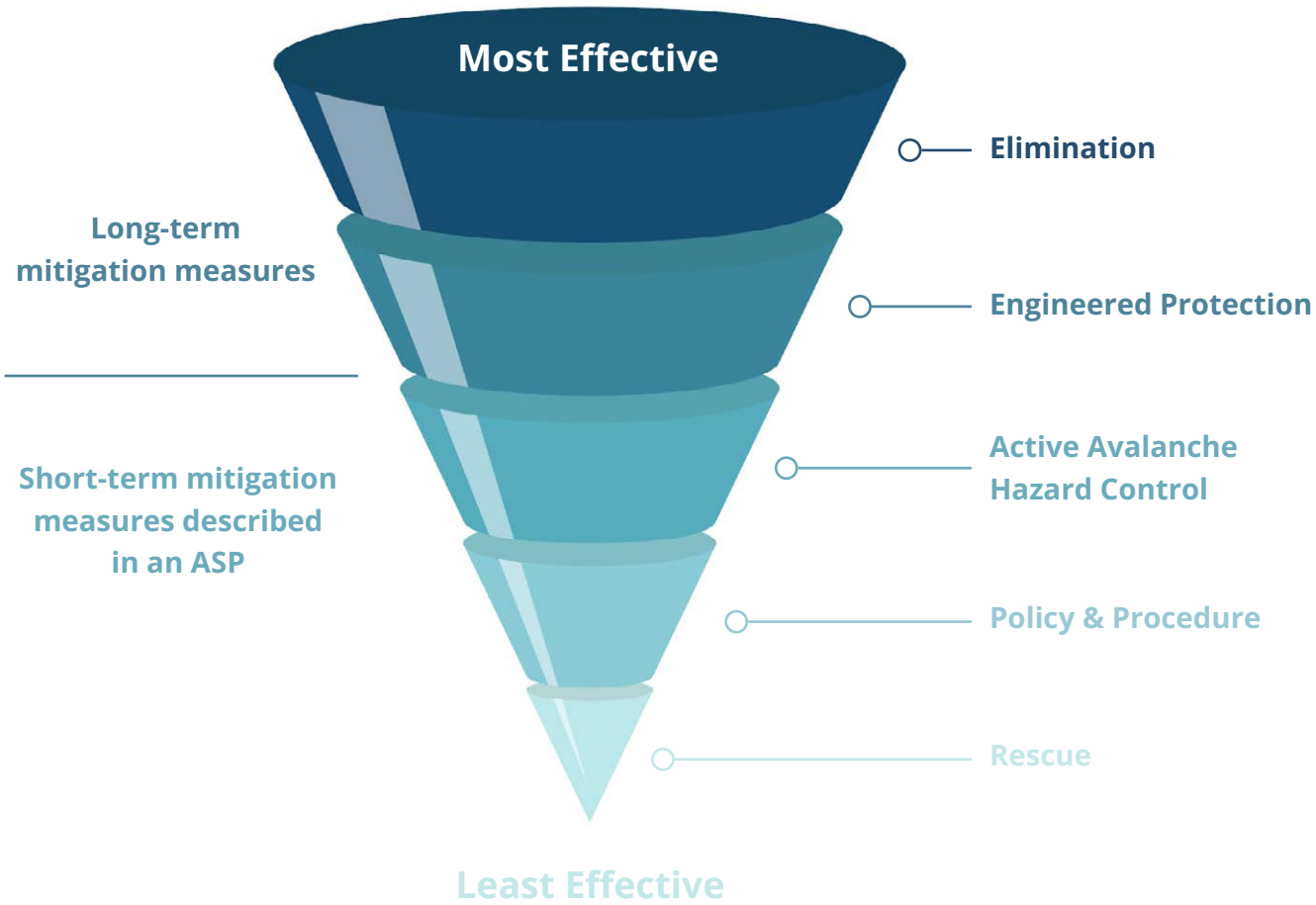
In the event of an incident, the operation will need to prove that mitigation measures in place align with the accepted industry practice and methods. Those developed by leading avalanche professionals and industry experts. By following these standards, projects not only demonstrate due diligence but also strengthen their defense in any potential litigation, showcasing a proactive commitment to worker and public safety.

What is Avalanche Mitigation?

Avalanche mitigation focuses on **reducing avalanche hazard** or minimizing the exposure and vulnerability of people, infrastructure, and operations at risk.

Avalanche mitigation involves implementing strategies that can **include single solutions or a combination of systems** working together to address the risk.

These measures may be **short-term**, such as temporary actions during high-risk periods, or **long-term** solutions like permanent structures or land use planning. The choice of approach depends on several factors, including the specific needs of the site, the resources available, and a **cost-benefit evaluation** to ensure the solution balances safety and efficiency.



Long-Term Avalanche Mitigation

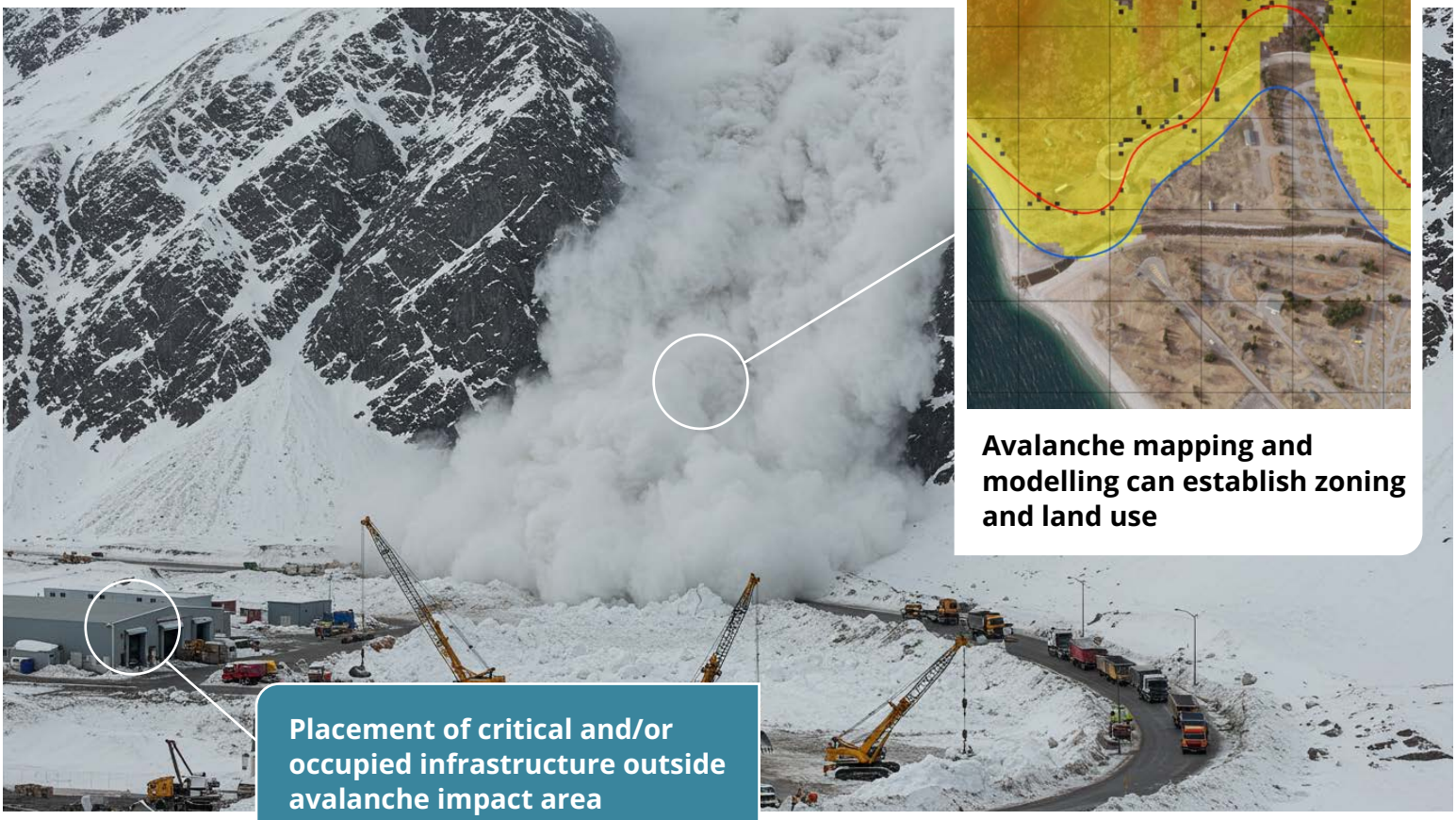
Long-term solutions are ideal for projects with longer lifetime that require minimal operational disruptions.

Long-term Location Planning measures focus on reducing risk by strategically locating elements at risk, such as through **zoning and location planning**. Long-term Engineered Protection is a key parts of mitigating risk for projects or infrastructure that are not flexible in relocation. These projects will require a thorough engineering analysis tailored to the specific goals and timeline of the operation.

Mitigation by Location Planning

Location planning is a critical strategy to eliminate or reduce avalanche risk. By using accurate avalanche hazard maps, **you can strategically position facilities in safer areas, potentially avoiding avalanche-prone paths** altogether. This proactive approach should be your first step in ensuring safety and operational efficiency.

Avalanche mapping and modelling can establish zoning and land use



Placement of critical and/or occupied infrastructure outside avalanche impact area

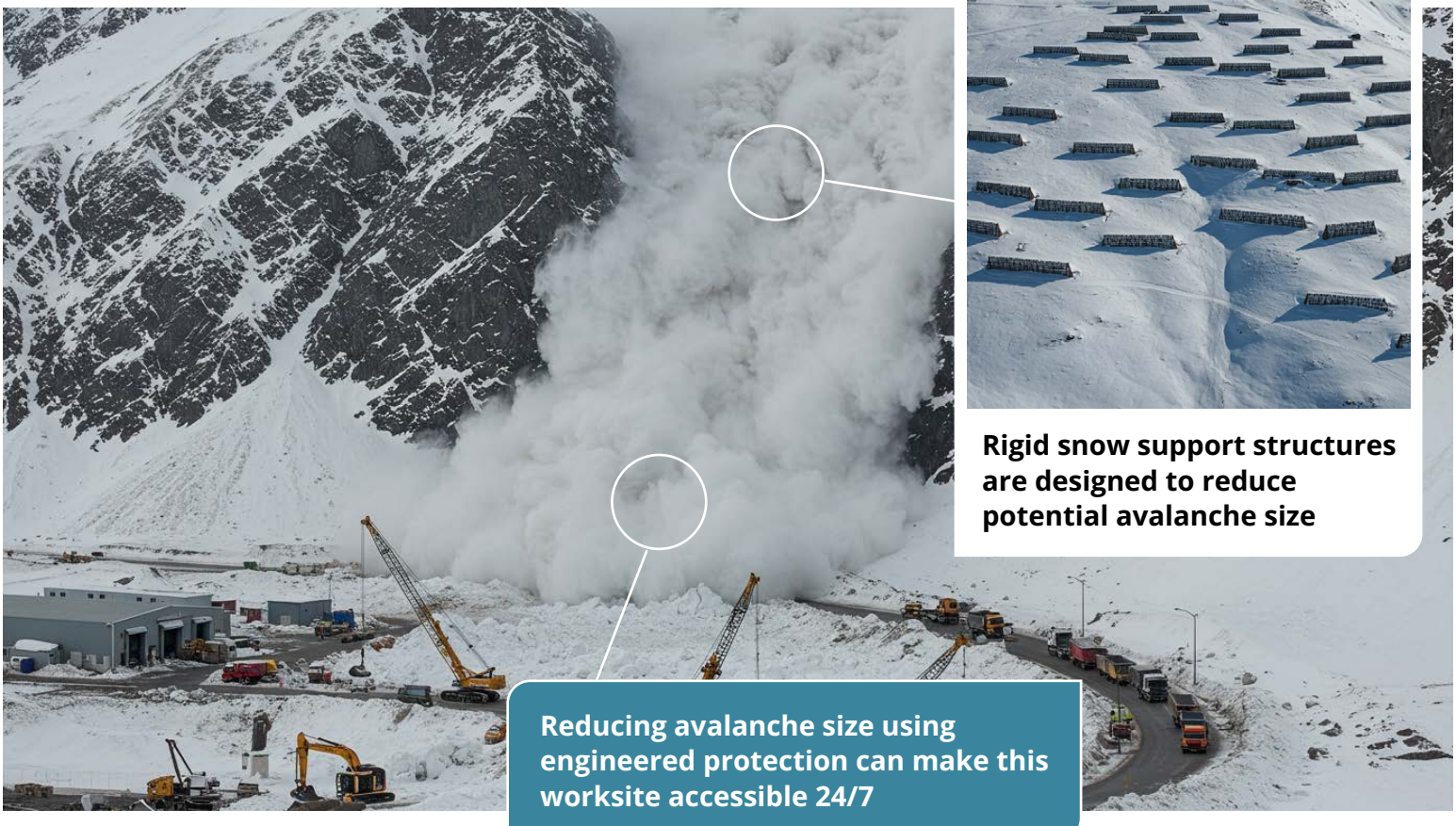
Mitigation Using Engineered Protection

If an avalanche hazard cannot be eliminated by location planning structural defenses, such as **concrete and steel structures or earthworks** can be designed to reduce avalanche hazards. These structures can **lower the frequency and/or magnitude of avalanches or act as reinforcements against impact forces**.

The benefits of reducing the avalanche hazard is weighed against constraints such as cost, legislation, regulations environmental etc. Once an optimized conceptual design is finalized, the project moves to detailed design and construction.

Avalanche engineers often collaborate with structural and geotechnical engineers to develop effective engineering protection. **The avalanche engineer defines the design criteria required for appropriate hazard reduction**. These criteria are then integrated with input from structural and geotechnical engineers, allowing the team to refine and optimize the design across all disciplines to ensure safety, functionality, and feasibility.

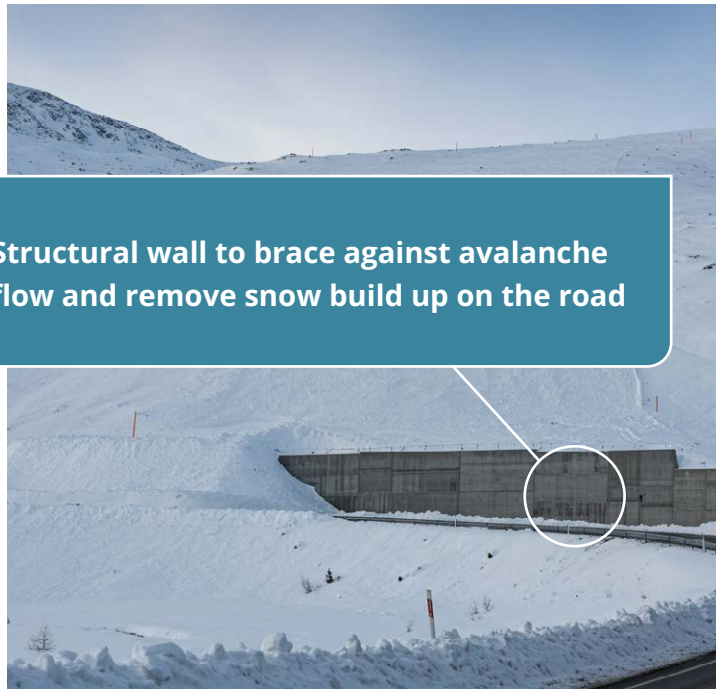
Rigid snow support structures are designed to reduce potential avalanche size

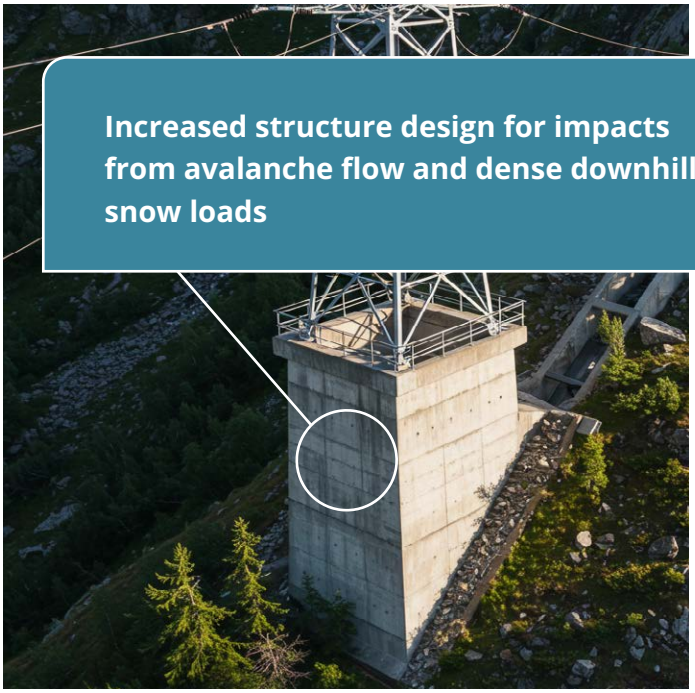


Reducing avalanche size using engineered protection can make this worksite accessible 24/7

Examples of Track and Runout Zone Defenses to Mitigate Avalanche Impacts

Examples of structural Defenses to Reduce Avalanche Impact





Short-Term Avalanche Mitigation

Short-term measures are designed to be scalable to reflect the level of onsite activity. These measures and applied either on a seasonal basis or within a timescale related to the fluctuation of snow and weather conditions.

PLANNING PHASE FIELD VISITS

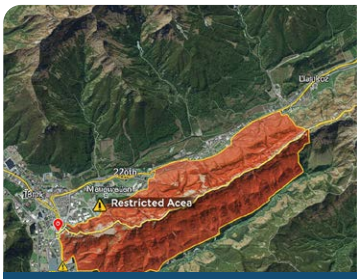
PROJECTS LASTING MONTHS

OPERATIONAL PROJECTS FOR A WINTER SEASON OR LONGER

Short-term avalanche mitigation measures are described in an Avalanche Safety Plan (ASP) and can include seasonal closures, restricted access, and avalanche hazard mitigation measures (e.g., explosives control) to reduce short-term hazard, and allow for increased access. Most short-term measures rely on operational avalanche hazard forecasting to be effective.

EXPLOSIVE CONTROL

CLOSURES



CONTROLLING ACCESS

REMOTE AVALANCHE CONTROL

SNOWPACK OBSERVATIONS

WEATHER STATIONS

RESCUE TRAINING

REMOTE FORECASTING

Depending on the time required to complete the project, various short-term mitigation strategies can be applied

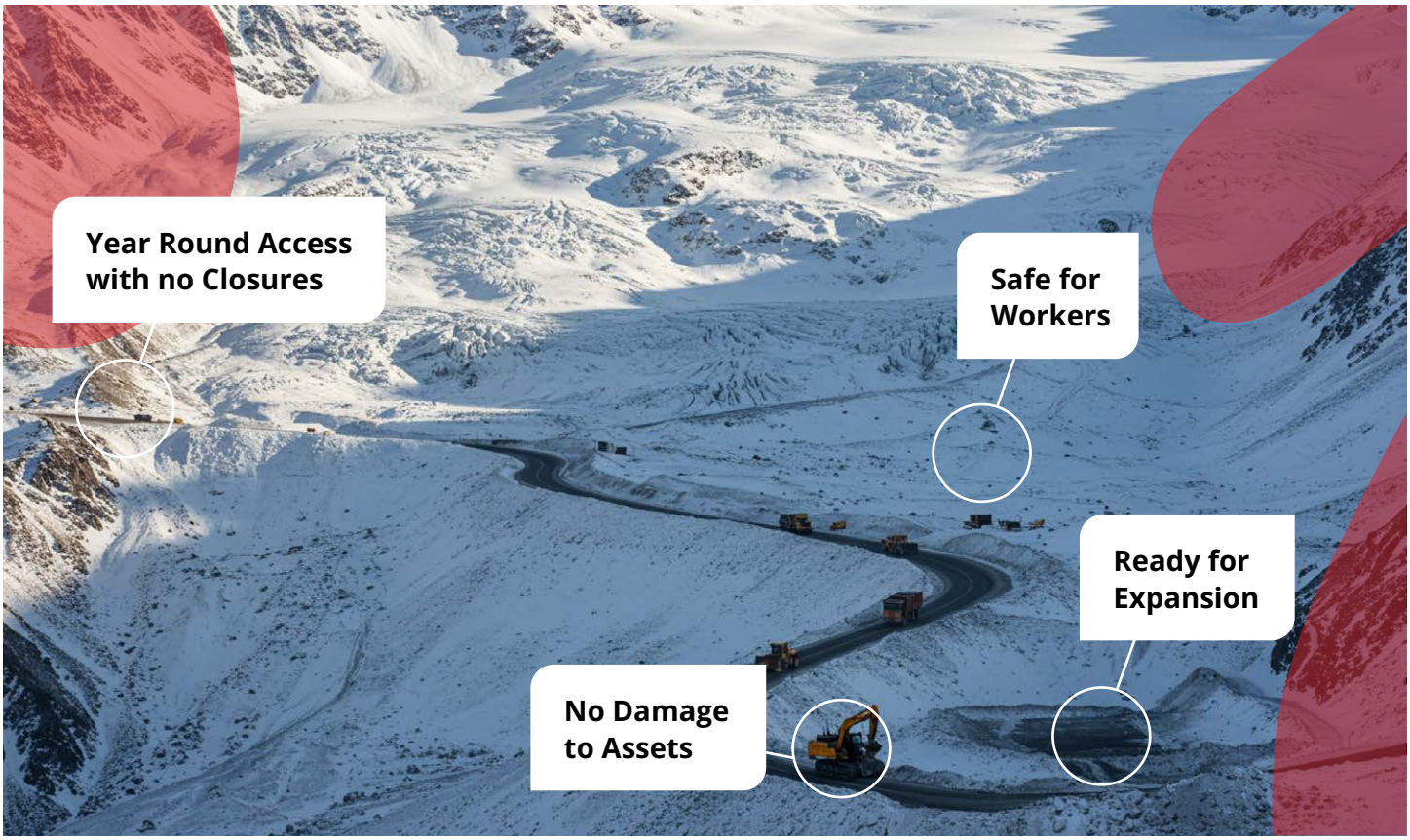
TIME SCALE NEEDED	TOLERANCE FOR CLOSURES	EXAMPLES OF SHORT TERM MITIGATION OPTIONS
Days/weeks	Flexible timeline	• Work restrictions based on set hazard matrix • On-site avalanche technician for duration of the work
All winter season/ multiple seasons	Flexible	• Work restrictions based on set hazard matrix • Remote avalanche forecasting • On-site avalanche technician for duration of higher hazard • Avalanche explosives control during higher hazard • Worker avalanche rescue training
All winter season/ multiple seasons	Low tolerance for closures	• Full season avalanche program optimizing allowable work days • Avalanche mapping • On-site avalanche technicians monitoring daily avalanche, snowpack and weather conditions. • Tailored avalanche bulletins • Frequent avalanche explosives control • Worker avalanche rescue training • Use of Remote Avalanche Control Systems

Each unique industry: Mining, Construction, Forestry, Transportation, Ski Hills, Guiding and more will have unique project needs and tailored short term mitigation strategies. A successful mitigation strategy optimizes operational goals during avalanche season.

Successful Avalanche Mitigation

A cost-benefit analysis determined that a combination of long-term and short-term mitigation measures effectively reduces avalanche hazard to the operation, minimizing the risks of closures, damage, or liability. This approach is optimized for an operation with near-zero tolerance for closures or damage to property/life due to its significant economic output, ensuring its readiness for sustained operations and future expansion.

Successful Reduction of Avalanche Zones



Avalanche Zone