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Best Practices for Soil Restoration at post-ASGM Sites

Participatory Guideline for the Guiana Shield and Tropical Regions

September 21, 2026

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It is important to acknowledge that the development of this manual would not have been possible without the invaluable input of stakeholders and the local community of Compagnie Kreek. Their active involvement and collaboration have been instrumental in shaping the direction of the project and ensuring its relevance to community needs.

Together, these collective efforts and contributions have paved the way for a comprehensive and impactful project aimed at addressing the environmental challenges associated with ASGM (Artisanal and Small-Scale Gold Mining). The commitment and cooperation of all involved demonstrate the power of collective action in tackling complex issues and creating positive change for local communities and the environment.

Disclaimer

This document provides general guidelines for restoring topsoil on abandoned ASGM sites. It is not intended to replace the guidelines of the Minamata Convention, national regulations, or professional advice. Rather, it should be regarded as a supplement to existing initiatives by EMSAGS and others that aim to make the ASGM sector safer and more sustainable. Users of this manual are responsible for verifying its applicability to their specific circumstances and act at their own risk when following these guidelines.

Request for Feedback and Data

The authors have based the information in this manual on their experience gained at ASGM sites in Suriname, including Compagnie Kreek in the Brokopondo District, and on selected experiences from Lombok and Sumbawa in Indonesia and other soil restoration projects worldwide. Examples from other tropical regions should be interpreted with caution, as soil parent material, weathering intensity, nutrient status and water-holding capacity may differ substantially from the highly weathered, acidic and nutrient-poor soils commonly found in the Surinamese interior.

Users of this manual are encouraged to provide feedback on its contents so that it can be improved. To further enhance this guide, the authors call upon field practitioners and professionals to share sample analysis data within the context of soil restoration in ASGM areas.

For suggestions, data sharing, and inquiries, please contact TAUW bv at info@TAUW.com, mentioning this guideline in the subject line

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Summary

Introduction and Context

Artisanal and Small-Scale Gold Mining (ASGM) is a global phenomenon supporting millions of livelihoods, yet it remains a primary driver of environmental degradation, particularly in the Guiana Shield. While the region is characterized as a High Forest Cover, Low Deforestation landscape, ASGM activities result in the complete destruction of soil profiles, severe compaction, and the loss of productive capacity. This physical degradation is frequently compounded by chemical contamination, specifically the release of mercury, which poses severe health risks to miners and downstream communities.

This document presents a comprehensive, community-focused guidance for site rehabilitation with a focus on the restoration of the soil functions for agriculture and forestation of abandoned ASGM sites. It posits that a pure environmental approach ignoring livelihood needs will fail, while a purely economic approach overlooking ecological costs is unsustainable. The objective is to transform abandoned ASGM sites from environmental liabilities into safe, productive assets for local communities.

Community-Led and Science-Based

The foundation of this guidance is that successful restoration must be community-led, science-based, and pragmatic.

- **Community-Led:** Restoration is viewed as a social process. It moves beyond token consultation to co-design and co-management, grounded in the principles of Free, Prior, and Informed Consent (FPIC). Community aspirations (e.g., safe drinking water, agriculture, risk of flooding) define the project goals rather than external technical mandates

- **Science-Based:** The technical goal is to recover five critical soil functions: nutrient cycling, water regulation, biodiversity habitat, carbon sequestration, and contaminant immobilization
- **Pragmatic and Low-Cost:** The guidance prioritizes locally sourced materials and adaptable techniques suitable for resource-constrained environments

Key Findings: The Compagnie Kreek Pilot

A central component of this guidance is the provisional data derived from the soil restoration pilot project at Compagnie Kreek in Suriname. The pilot tested various soil amendments to determine the most effective "recipe" for rehabilitation.

- **Success of Simplicity:** The application of a 10 cm layer of locally salvaged topsoil proved to be the most successful method for kick-starting ecosystem recovery. This method introduced necessary organic matter and seed banks, far surpassing complex attempts to engineer soil using imported clay and humus, which were costly and did not result in more plant growth
- **Revegetation:** The use of the local leguminous cover crop *Mucuna sp.* ('Okra Pesí') was highly effective in stabilizing the site and initiating nutrient cycling
- **Lesson Learned:** While top-soil application is effective, very coarse soils may require additional measures to improve water-holding capacity, such as shading or thicker soil layers

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The Seven-Step Restoration Framework

The guidance outlines a modular, step-by-step framework for practitioners to navigate from assessment to long-term governance.

Step 1: Baseline Assessment

A successful plan relies on understanding site-specific conditions through a tiered approach:

- Participatory Mapping: The process begins by leveraging local knowledge to map historical land use, mining history, and hydrology. This ensures technical surveys focus on community priorities
- Site Characterization: The site is mapped into distinct "domains" such as mining pits, overburden dumps, processing areas, mud plains, and site drainage pattern
- Soil Sampling: A stratified random sampling approach is used to assess physical (texture, compaction) and chemical (pH, organic matter) properties
- Contaminant Screening: A tiered screening protocol is employed, utilizing handheld XRF analyzers for rapid "hotspot" identification, followed by laboratory confirmation for mercury speciation if necessary

Step 2: The Decision Framework

Practitioners are guided by a risk-based decision tree that prioritizes interventions based on safety and health before productivity, and includes decisions based on contaminations levels, physical hazards, soil health, and the preferred final state.

Step 3: Soil Restoration Plan

This step details the "building blocks" of technical restoration:

- Contaminant Management: Strategies include immobilization of mercury in the soil using biochar or compost or using plants like *Vetiver* grass to stabilize contaminants (i.e., phytostabilization)
- Physical Restructuring: Sites must be re-profiled to stable gradients (generally <3:1 slopes) to prevent erosion and allow safe access
- Soil Fertility: The primary recommendation is the "direct return" of salvaged topsoil (10-30 cm). Where topsoil is unavailable, organic amendments like compost and biochar are critical
- Biological recovery: The use of nitrogen-fixing leguminous cover crops (e.g., *Mucuna sp.*) and soil inoculants (mycorrhizae) is essential to rebuild the soil food web

Step 4: Nature Development and Livelihood Integration

Restoration is designed to support sustainable income generation, ensuring long-term stewardship.

- Nature Development: Instead of expensive full-scale reforestation, the guidance suggests "Applied Nucleation", planting islands of fast-growing framework species to attract wildlife and sometimes humans, which then disperses seeds and accelerates natural succession
- Livelihood Integration: Technologies such as Agroforestry (e.g., alley cropping) integrate trees with crops to build soil health while providing food and income. Other options include community nurseries and aquaculture in detoxified, backfilled pits

Step 5: Implementation

To move from planning to action, the guidance provides project management tools:

- SOPs: Standard Operating Procedures ensure consistency in tasks like topsoil application or slope grading
- Resource Planning: Budgets should use unit-based costing (e.g., per hectare) and include contingency funds
- HSE: A Health, Safety, and Environment plan is mandatory, covering risk assessments, Personal Protective Equipment (PPE) requirements, and emergency response procedures

Step 6: Monitoring, Evaluation, and Adaptive Management

Monitoring is not just for reporting; it is an active management tool.

- Key Performance Indicators (KPIs): A hierarchy of indicators is proposed, ranging from simple community-monitored metrics (e.g., seedling

survival, erosion rills) to technical measurements (e.g., soil pH, organic matter %)

- Adaptive Management: The project uses a "Plan-Do-Monitor-Learn-Adapt" cycle. Specific triggers (e.g., survival rate <60%) are established to prompt immediate corrective actions, such as replanting or adding amendments

Step 7: Governance and Funding Alignment

Sustainability requires alignment with national and international frameworks.

- Roles: A RACI matrix is recommended to clarify responsibilities among NGOs, government agencies, and communities
- Funding: Diversified funding strategies are encouraged, including Global Environment Facility (GEF) grants, Carbon Credits, and Payment for Ecosystem Services (PES)

Ultimately, this guidance serves as a roadmap to convert the deteriorated landscapes of ASGM into ecosystems that support the health, safety, and economy of local communities.

Samenvatting

Introductie en Context

Artisanale en kleinschalige goudwinning (ASGM – *Artisanal Small Scale Goldmines*) is een wereldwijd fenomeen dat voorziet in het levensonderhoud van miljoenen mensen, maar tegelijkertijd een belangrijke oorzaak blijft van milieuaantasting, onder andere in het Guyanaschild. ASGM-activiteiten leiden tot de volledige vernietiging van bodemprofielen, ernstige verdichting en het verlies van productiecapaciteit. Deze fysieke degradatie wordt vaak verergerd door chemische verontreiniging, specifiek de uitstoot van kwik, wat ernstige gezondheidsrisico's met zich meebrengt voor mijnwerkers en gemeenschappen stroomafwaarts.

Dit document presenteert een gemeenschapsgerichte leidraad voor de revalidatie van deze locaties, met een focus op het herstel van de bodem functies voor landbouw en herbebossing van verlaten ASGM locaties. Het stelt dat een puur ecologische benadering die de behoeften in levensonderhoud negeert zal falen, terwijl een puur economische benadering die voorbijgaat aan ecologische kosten onhoudbaar is. Het doel is om verlaten ASGM-locaties te transformeren van milieulasten naar veilige, productieve activa voor lokale gemeenschappen.

Gemeenschapsgestuurd en wetenschappelijk onderbouwd

De basis van deze leidraad is dat succesvol herstel gemeenschapsgestuurd, wetenschappelijk onderbouwd en pragmatisch moet zijn.

- Gemeenschapsgestuurd: Herstel wordt gezien als een sociaal proces. Het gaat verder dan symbolische raadpleging en richt zich op co-ontwerp en co-beheer, gebaseerd op de principes van Free, Prior, and Informed Consent (FPIC). De ambities van de gemeenschap (bijvoorbeeld veilig drinkwater, landbouw, overstromingsrisico) bepalen de projectdoelen in plaats van externe technische mandaten
- Wetenschappelijk onderbouwd: Het technische doel is het herstellen van vijf kritieke bodemfuncties: de nutriëntenkringloop, waterregulering, habitat voor biodiversiteit, koolstofvastlegging en immobilisatie van verontreinigingen
- Pragmatisch en financieel haalbaar: De leidraad geeft prioriteit aan lokaal verkregen materialen en aanpasbare technieken die geschikt zijn voor omgevingen met beperkte middelen

Belangrijkste bevindingen: De Compagnie Kreek Pilot

Een centraal onderdeel van deze leidraad bestaat uit de voorlopige gegevens afkomstig van het bodemherstel-pilotproject bij Compagnie Kreek in Suriname. De pilot testte verschillende bodemverbeteraars om het meest effectieve "recept" voor rehabilitatie te bepalen.

- Succes van eenvoud: Het aanbrengen van een laag van 10 cm lokaal gewonnen bovengrond bleek de meest succesvolle methode om ecosysteemherstel op gang te brengen. Deze methode introduceerde noodzakelijke organische stof en zaadbanken en overtrof complexe

pogingen om bodems te construeren met geïmporteerde klei en humus, die kostbaar waren en niet leidden tot meer plantengroei

- Herbegroeiing: Het gebruik van het lokale vlinderbloemige dekgewas *Mucuna sp.* ('Okra Pesí') was zeer effectief in het stabiliseren van de locatie en het initiëren van de nutriëntenkringloop
- Geleerde les: Hoewel het aanbrengen van bovengrond effectief is, kunnen bij zeer grove bodems aanvullende maatregelen nodig zijn om het waterhoudend vermogen te verbeteren, zoals schaduwvoorziening of dikkere bodemlagen

Het zevenstappenplan voor herstel

De leidraad schetst een modulair, stapsgewijs kader voor uitvoerders om van beoordeling naar langetermijnbeheer te navigeren.

Stap 1: Nulmeting (Baseline Assessment)

Een succesvol plan steunt op inzicht in locatie-specifieke omstandigheden:

- Participatieve kartering: Het proces begint met het benutten van lokale kennis om historisch landgebruik, mijnbouwgeschiedenis en hydrologie in kaart te brengen. Dit zorgt ervoor dat technische onderzoeken zich richten op de prioriteiten van de gemeenschap
- Karakterisering van de locatie: De locatie wordt in kaart gebracht in afzonderlijke "domeinen" zoals mijnputten, stortbergen van deklagen, verwerkingslocaties, moddervlaktes en drainagepatronen
- Bodemonsters nemen: Een gestratificeerde steekproefaanpak wordt gebruikt om fysische (textuur, verdichting) en chemische (pH, organische stof) eigenschappen te beoordelen
- Screening op verontreinigingen: Er wordt een gelaagd screeningsprotocol gehanteerd, waarbij gebruik wordt gemaakt van handheld XRF-analysers

voor snelle identificatie van "hotspots", indien nodig gevolgd door laboratoriumbevestiging voor kwikspeciatie.

Stap 2: Het beslissingskader

Uitvoerders worden geleid door een op risico gebaseerde beslisboom die prioriteit geeft aan interventies op basis van veiligheid en gezondheid vóór productiviteit, en beslissingen omvat op basis van verontreinigingsniveaus, fysieke gevaren, bodemgezondheid en de gewenste eindtoestand zoals die is afgestemd met de lokale gemeenschap.

Stap 3: Bodemherstelplan

Deze sectie beschrijft de "bouwstenen" van technisch herstel:

- Beheer van verontreinigingen: Strategieën omvatten immobilisatie van kwik in de bodem met behulp van biochar of compost, of het gebruik van planten zoals vetivergras om verontreinigingen te stabiliseren.
- Fysieke herstructurering: Locaties moeten worden geherprofileerd naar stabiele hellingen (doorgaans <3:1) om erosie te voorkomen en veilige toegang mogelijk te maken.
- Bodemvruchtbaarheid: De primaire aanbeveling is de "directe terugplaatsing" van geborgen bovengrond (10-30 cm). Waar bovengrond niet beschikbaar is, zijn organische toevoegingen zoals compost en biochar essentieel.
- Biologisch herstel: Het gebruik van stikstofbindende vlinderbloemige dekgewassen (bijv. *Mucuna sp.*) en bodem-entstoffen (mycorrhiza) is essentieel om het bodemvoedselweb opnieuw op te bouwen.

Stap 4: Natuurontwikkeling en integratie van bestaansmiddelen

Herstel is ontworpen om duurzame inkomstenverwerving te ondersteunen en langdurig beheer te waarborgen.

- Natuurontwikkeling: In plaats van kostbare volledige herbebossing suggereert de leidraad "Toegepaste Nucleatie": het planten van eilanden van snelgroeiende 'framework'-soorten om wilde dieren aan te trekken, die vervolgens zaden verspreiden en natuurlijke successie versnellen
- Integratie van inkomstenbronnen: Technologieën zoals Agroforestry (bijv. strokenteelt/alley cropping) integreren bomen met gewassen om de bodemgezondheid op te bouwen en tegelijkertijd voedsel en inkomen te verschaffen. Andere opties zijn gemeenschapskwekerijen en aquacultuur in ontgiftigde, gedempte putten

Stap 5: Uitvoeringsprotocol

Om van planning naar actie over te gaan, biedt de leidraad tools voor projectmanagement:

- SOP's: Standaard Operationele Procedures zorgen voor consistentie bij taken zoals het aanbrengen van bovengrond of het egaliseren van hellingen
- Resourceplanning: Budgetten moeten gebruikmaken van kostenberekening per eenheid (bijv. per hectare) en voorzieningen voor onvoorziene uitgaven bevatten
- HSE: Een plan voor Gezondheid, Veiligheid en Milieu (HSE) is verplicht en omvat risicobeoordelingen, vereisten voor persoonlijke beschermingsmiddelen (PBM) en noodprocedures

Stap 6: Monitoring, Evaluatie en Adaptief Beheer

Monitoring is niet alleen voor rapportage; het is een actieve beheertool.

- KPI's: Er wordt een hiërarchie van indicatoren voorgesteld, variërend van eenvoudige, door de gemeenschap gemonitorde meetgegevens (bijv. overleving van zaailingen, erosiegeulen) tot technische metingen (bijv. bodem-pH, % organische stof)
- Adaptief Beheer: Het project hanteert een "Plan-Do-Monitor-Learn-Adapt"-cyclus. Er worden specifieke triggers vastgesteld (bijv. overlevingspercentage <60%) om onmiddellijke corrigerende maatregelen, zoals herbeplanting, in gang te zetten

Stap 7: Governance en afstemming van financiering

Duurzaamheid vereist afstemming op nationale en internationale kaders.

- Rollen: Een RACI-matrix wordt aanbevolen om verantwoordelijkheden tussen NGO's, overheidsinstanties en gemeenschappen te verduidelijken
- Financiering: Gediversifieerde financieringsstrategieën worden aangemoedigd, waaronder subsidies van de Global Environment Facility (GEF), koolstofkredieten en betaling voor ecosysteemdiensten (PES)

Uiteindelijk dient deze leidraad als een routekaart om de aangetaste landschappen van ASGM om te zetten in ecosystemen die de gezondheid, veiligheid en economie van lokale gemeenschappen ondersteun

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As	Arsenic	GC-MS	Gas Chromatography-Mass Spectrometry
ASGM	Artisanal and Small-Scale Gold Mining	GEF	Global Environment Facility
BFSC	Boudewijn Fokke Soil Consultancy	GCF	Green Climate Fund
Cd	Cadmium	GPS	Global Positioning System
CELOS	Centre for Agricultural Research in Suriname	HFLD	High Forest Cover, Low Deforestation
CN	Cyanide	Hg	Mercury
CoC	Contaminant of Concern	Hg ⁰	Elemental Mercury
CO ₂	Carbon Dioxide	Hg ²⁺	Inorganic Mercury
CSR	Corporate Social Responsibility	HSE	Health, Safety and Environment
Cu	Copper	ICP-MS	Inductively Coupled Plasma Mass Spectrometry
CVAAS	Cold Vapor Atomic Absorption Spectroscopy	ICP-OES	Inductively Coupled Plasma Optical Emission Spectrometry
DEM	Digital Elevation Model	KPI	Key Performance Indicator
DSM	Digital Surface Model	LiDAR	Light Detection and Ranging
DTM	Digital Terrain Model	LOI	Loss on Ignition
EIA	Environmental Impact Assessment	NAP	National Action Plan
EMSAGS	Improving Environmental Management in the Mining Sector of Suriname, with Emphasis on Artisanal and Small-Scale Gold Mining	NGO	Non-Governmental Organization
FPIC	Free, Prior and Informed Consent	OM	Organic Matter
		Pb	Lead
		PBM	Persoonlijke Beschermingsmiddelen

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PES	Payment for Ecosystem Services
PPE	Personal Protective Equipment
PPK	Post-Processed Kinematic
PSB	Phosphate Solubilizing Bacteria
RACI	Responsible, Accountable, Consulted, Informed
RBD	Randomized Block Design
REA	Rapid Ecological Assessment
RGB	Red, Green, Blue
RTK	Real-Time Kinematic
SER	Society for Ecological Restoration
SOM	Soil Organic Matter
SOP	Standard Operating Procedure
SRCE	Standardized Reclamation Cost Estimator
TAUW	Consulting and Engineering Company TAUW bv
ToC	Theory of Change
TOC	Total Organic Carbon
UAV	Unmanned Aerial Vehicle
UNDP	United Nations Development Programme
VOX	Volatile Organic Compounds
WWF	World Wide Fund for Nature
XRF	X-Ray Fluorescence

1 Introduction

1.1 Challenges of ASGM Across the Guiana Shield

Artisanal and Small-Scale Gold Mining (ASGM) is a global phenomenon, providing direct income for nearly 20 million people and indirectly supporting over 100 million more across more than 80 countries (Dossou-Yovo et al., 2024). In the unique context of the Guiana Shield — a vast, Precambrian geological formation spanning Suriname, Guyana, French Guiana, and parts of Brazil, Venezuela, and Colombia — ASGM is both a cornerstone of rural economies and a primary agent of environmental change (Ecologic Institute, 2015). This region, characterized as a High Forest Cover, Low Deforestation (HFLD) landscape, holds one of the largest remaining pristine tropical forests on Earth, playing a critical role in global climate regulation and biodiversity conservation (World Wide Fund for Nature, 2022).

However, the expansion of ASGM, driven by poverty and the rising price of gold, poses a significant threat to this ecological integrity (Dossou-Yovo et al., 2024). The environmental footprint of ASGM is extensive and multifaceted. It is a leading driver of deforestation in the region. At the end of 2018, the historical cumulative deforestation caused by gold mining reached 213,623 ha across the Guiana Shield (Rahm et al., 2021). At a local level, the mining process itself transforms landscapes. The removal of vegetation and topsoil, excavation of pits, and creation of vast deposited tailings (“Bakka Santi” in Suriname) result in complete soil profile destruction, severe compaction, and the loss of all productive capacity (Watson et al., 2020).

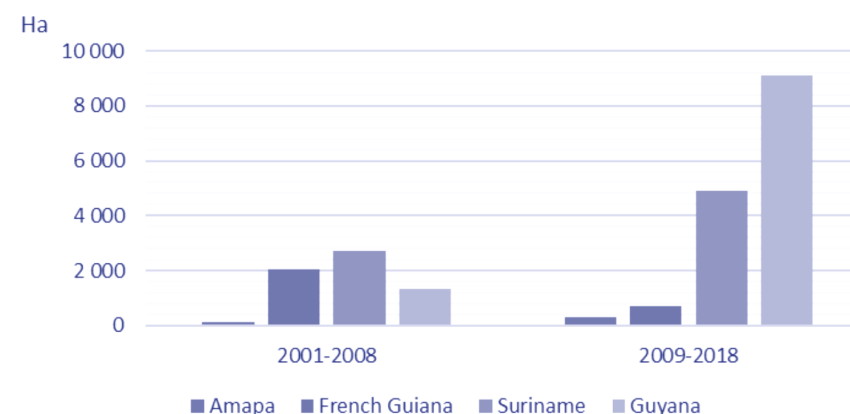


Figure 1.1 Comparison of average annual deforestation between 2001-2008 and 2009-2018 among the four territories (Rahm et al., 2021)

This physical degradation is often aggravated by chemical contamination and contamination of creeks and rivers with fine sediments. The ASGM operations are also, often deregulating the natural drainage causing flooding in the rainy season and lack of clean water the dry season. The widespread use of mercury to amalgamate gold results in the release of an estimated 1,400 tonnes of mercury into the environment annually, making ASGM the single largest source of anthropogenic mercury emissions globally (Douine et al., 2025). This mercury contaminates soil and water, where it can be converted into highly toxic methylmercury, which bioaccumulates in the food web, posing severe

neurological health risks to miners and downstream communities that rely on fish for protein (EMSAGS, 2025a).

This complex web of environmental degradation, and socio-economic dependence create, together with the lack of future land-use planning, a formidable challenge. A purely environmental approach that seeks to halt ASGM without providing viable alternatives is destined to fail, as it ignores the fundamental livelihood needs of millions (Watson et al., 2020). Conversely, a purely economic approach that overlooks the long-term environmental and health costs is fundamentally unsustainable. This Guidance does not cover all these aspects of ASGM site rehabilitation but focuses on the restoration of the topsoil of mined areas to allow for agricultural use or nature development. It intends to provide a pathway to repair ecological damage in a way that simultaneously builds new, sustainable livelihood opportunities, thereby contributing to breaking the destructive cycle of ASGM practices in Suriname as described in the following section.

1.2 ASGM Practices in Suriname

Most of the ASGM in Suriname is focused on secondary deposits known as placer accumulations. These accumulations consist of colluvial, and alluvial deposits derived from weathered material in terraces (Kioe-A-Sen et al., 2016). According to Brinck (1955), these gold-bearing placer deposits are found within gravel layers of foothill and terrace soils. The practices of ASGM in Suriname have been extensively documented in various publications, including those by Kioe-A-Sen et al. (2016), Seccatore et al. (2017), and Arets et al. (2006). Soil materials, either the entire soil or specific layers, are displaced within the landscape or carried away by run-off and are discharged in creeks and finally

end up in rivers. As such, the outcomes of ASGM practices can be viewed as a redistribution of soil materials. The details of these ASGM practices are summarized in the cross section of an ASGM site presented in Figure 6.1. The main distinct ASGM site components are:

1. **Unaffected upland:** This component comprises soils of the Bronsweg series (De Boer Soil Classification System Surinam 1980) and serves as a potential source of litter and seeds for soil restoration efforts



Figure 1.2 Mining pit

2. **Mining Pit:** To create a mining pit (see Figure 1.2), subsoil and saprolite are excavated using excavators and high-pressure water jets and pumped to the sluice box as a slurry. This mining method is known as 'land-dredging' (Veira, 2005)
3. **Overburden dumps:** In larger mining operations, the excavated topsoil may be set aside for potential reuse



Figure 1.3 Remnants of a sluice box

4. **Processing area:** Slurry from the mine is pumped up into a sluice box (see Figure 1.3) and from there washed down on sloping structures, the “daal”, that is lined with a mesh. Heavy particles, including gold, are trapped in the mesh through gravity separation. The rest of the sediment is deposited on the ground. The heavy particles, trapped in the mesh, are harvested and treated with mercury (Hg) to form an amalgam with gold. Panning is then used to further remove sediments and concentrate the gold-mercury amalgam. The amalgam is burned to extract gold, often in a miner's camp usually located near the sluice box
5. **Mine tailings:** The processed sediments are discharged downhill from the sluice box. The particles settle along the slope based on their mass,

resulting in a distinct downhill gradient: gravel and coarse sand precipitate first, followed by sand and fine sand, and finally silt and clay.

These deposited tailings cover the original topsoil, leading to a loss of fertile land. Further downstream, the finer particles of silt and clay settle in natural depressions, forming mud pits (see Figure 1.4 left). If no depressions are available or if a mud pit overflows, these fine mine tailings spread out, creating a mud plain (see Figure 1.4 right)



Figure 1.4 Mud pit (l) and mud plain (r)

6. **Waterbodies:** ASGM activities significantly alter natural waterbodies, which are used as a primary water source and are subsequently polluted by fine tailings and mercury-laden runoff. ASGM operations require substantial water for pumping and sluicing sediments from mine-pits. Natural water bodies (streams and creeks) often serve as the primary source. To ensure a steady supply, miners frequently construct dams to block local streams or creeks, a practice that leads to the loss of fertile topsoil by inundation and construction. Depending on the volume of runoff, the fine fraction of mine tailings can enter downstream watercourses

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(see Figure 1.5).

This results in turbidity (murky water), which is often contaminated with mercury. The contaminated water is then transported to larger rivers, and the sediments (silt and clay) can settle on the floodplain when the creek or river overflows (inundates)

each other, and mine tailings are often reprocessed, resulting in complex landscape.



Figure 1.5 Downstream watercourses with murky water

The above discussed ASGM site components (Mining pits, Overburden dumps, Processing area, Mine tailings and Water bodies) often overlap and may not be distinct at ASGM sites. Several mining pits are often constructed close to

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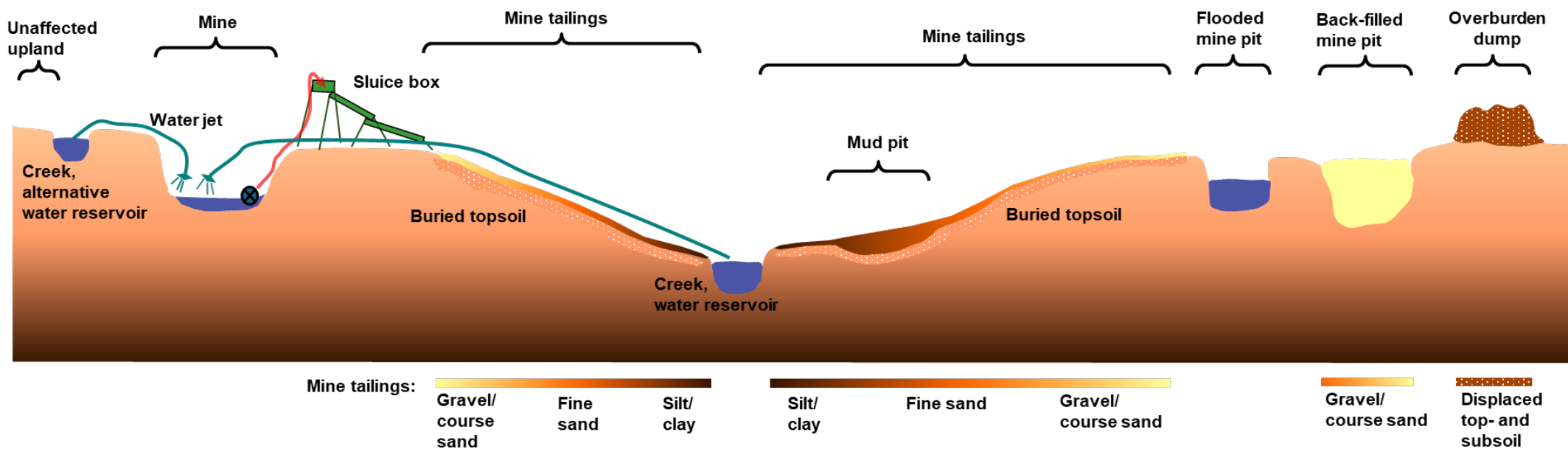


Figure 1.6 Cross section summarizing ASGM site elements

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1.3 Community-Focused Vision for Site Rehabilitation

A Community-Focused Vision for Rehabilitation of ASGM sites is the essential principle for defining local rehabilitation goals. Site rehabilitation is not merely a technical exercise in soil science and botany; it is, first and foremost, a social process. The long-term success of any rehabilitation project is contingent upon its alignment with the needs, values, and aspirations of the local communities who will live with its outcomes. This principle shifts the focus from an externally-imposed vision of what a "rehabilitated" landscape should be, to a collaborative process of defining what the community needs it to become.

The foundation of this approach is a genuine commitment to partnership, built on trust and mutual respect. This requires moving beyond token consultation to a model of co-design, co-management and collective decision making. The process must begin by asking the community: "What problems has the mining activities created for you, and what would a rehabilitated landscape allow you to do?" The answers to these questions define the true objectives of the restoration project.

This community-centred approach must be formalized through the principles of **Free, Prior, and Informed Consent (FPIC)**. FPIC is more than a checklist; it is a process that ensures that indigenous peoples and local communities have the right to give or withhold their consent to projects that affect their lands, territories, and resources (UNDP, 2022). It is a fundamental tenet of international human rights law, enshrined in the UN Declaration on the Rights of Indigenous Peoples, and a non-negotiable prerequisite for ethical and effective restoration work (UNDP, 2022).

Example - Defining goals of the soil restoration of the deserted ASGM mining area bordering Compagnie Kreek.

During the initial engagement for the pilot project at Compagnie Kreek, Suriname, the project team, facilitated by the EMSAGS project, held extensive dialogues with the traditional authority and community members. The community did not frame the problem in terms of "low soil organic matter" or "lack of biodiversity." Instead, they identified concrete, lived challenges: the creek they once relied upon was no longer safe for drinking water; the land was so infertile that agriculture was impossible; and the abandoned, water-filled pits posed a safety hazard and caused flooding, preventing the village from needed expansion. These community-defined problems became the project's core objectives: to create safe, stable land suitable for agriculture, reforestation and future village expansion. This immediately grounded the technical restoration work in tangible human benefits.

Key Definition: Free, Prior, and Informed Consent (FPIC)

- **Free:** Consent is given voluntarily, without coercion, intimidation, or manipulation
- **Prior:** Consent is sought sufficiently in advance of any authorization or commencement of activities, allowing communities adequate time for their own decision-making processes
- **Informed:** Communities receive comprehensive, objectives, and understandable information about the proposed project, including its nature, scale, potential impacts (positive and negative), and risks.

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This information must be provided in a culturally appropriate manner and language

- **Consent:** The collective decision made by the rights-holders to agree to or withhold agreement for the proposed project, reached through their own customary decision-making processes

By embedding these principles from the outset, ASGM site rehabilitation projects can transform from external interventions into community-owned initiatives, dramatically increasing their legitimacy, relevance, and long-term sustainability.

1.4 Objectives of this Guidance

The Objectives of this Guidance are:

- Providing instructions to restore soil functions and develop productive, stable land uses for nature development and, where feasible, agricultural use as part of the rehabilitation of abandoned ASGM sites
- Embed community participation and livelihood resilience in every phase of soil restoration
- Ensure compliance with relevant national/international regulations (e.g., Minamata Convention)

This guidance is written for all practitioners working on community-based mine-site rehabilitation, these are among others:

- Local NGOs working on community-based mine-site rehabilitation
- Municipal/provincial government officers (environment, land-use planning, agriculture, public health)

- Private environmental consultancy firms and contractors involved in restoration projects

1.5 Scope of this Guidance

This guidance provides a comprehensive, practitioner-focused protocol for the terrestrial restoration of deserted ASGM sites that will not be again subjected to ASGM.

The core philosophy of this protocol is that successful, scalable, and sustainable rehabilitation must be:

- **Community-Led:** Grounded in the aspirations, knowledge, and active participation of local communities, respecting the principles of FPIC
- **Science-Based:** Focused on recovering fundamental soil functions—physical, chemical, and biological—as the engine of ecological recovery
- **Pragmatic and Low-Cost:** Prioritizing the use of locally sourced materials and adaptable, cost-effective techniques suitable for the resource-constrained environments where ASGM is prevalent

Throughout this document, the **Soil Restoration Pilot at Compagnie Kreek in Suriname** is used as a detailed, recurring case study. This project, a collaboration between the EMSAGS project, local communities, TAUW Foundation, and technical partners, provides an example of the principles outlined herein (TAUW, 2024). The provisional central lesson from Compagnie Kreek is one of powerful simplicity:

the application of a mere 10 cm layer of salvaged¹ local topsoil proved to be a low-cost method for kick-starting ecosystem recovery on severely degraded land, while additional measures should be taken to ensure the soil water holding capacity or evaporation (e.g., shading using tree pits) or thicker soil layer with finer textured soils. More complex and expensive soil interventions (e.g., importing clay and organic matter) did not showcase increased plant growth. This experience underscores the Guidance's emphasis on leveraging local resources.

By synthesizing a broad base of scientific literature with practical field experiences, this participatory guideline offers a modular, step-by-step approach, from baseline assessment to implementation to long-term monitoring. It provides a decision-making framework to help users select the most appropriate soil restoration pathway based on site-specific risks (e.g., contaminant levels) and community-defined goals (e.g., agriculture, conservation). Ultimately, this Guidance serves as a practical roadmap to assist transforming the hazardous and unusable abandoned ASGM sites into safe, productive, and resilient ecological and socio-economic assets for the communities that depend on them.

¹ The application of local topsoil should not lead to soil degradation at other sites. Therefore the soil restoration preferably uses set-aside topsoil from the mining sites. This demands upfront planning of the

ASGM operation. Such ASGM planning should be in consultation and agreement with the community and its leaders taking in to account the desired future land use of the site.

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2 Conceptual Framework

2.1 Key Soil Functions to Recover in Degraded Soils

Effective soil restoration moves beyond the superficial goal of "making it green again" to the fundamental task of re-establishing a living, functioning soil ecosystem. ASGM activities do not just remove vegetation; they dismantle the very engine of terrestrial life. In the highly weathered, often nutrient-poor soils of tropical regions like the Guiana Shield, this engine is particularly fragile, and its recovery is the central technical challenge of restoration. A successful project must therefore focus on recovering five (5) interconnected categories of soil functions:

- **Nutrient Cycling:** Tropical forest ecosystems are famously efficient at recycling scarce nutrients. This process is driven by the high organic matter content in the topsoil from which nitrogen, phosphorus and other nutrients may become available for plant uptake after mineralization by soil microorganisms. ASGM physically removes this vital organic layer, breaking the nutrient cycle (PlanetGOLD, 2024). The remaining subsoils are often acidic, devoid of essential nutrients like nitrogen and phosphorus, and may have toxic concentrations of heavy metals mobilized by the mining process. Restoring chemical functions requires rebuilding the soil's stock of organic matter and restarting the processes of nutrient cycling, often using leguminous, nitrogen-fixing, plants and/or the application of compost and/or biochar
- **Water Regulation:** Healthy topsoil has a granular or aggregated structure with a network of pores that allows it to perform two critical functions: rapidly absorb rainwater to prevent erosion and keep that water available for plants during dry periods. ASGM obliterates this structure. The removal of topsoil and the use of heavy machinery and excess of water compact the subsoil into a dense, impermeable layer (Wortel, 2020). Deposited tailings are often composed of coarse sand and gravel with no structure, allowing water to drain away instantly, while processing ponds can become lined with fine clay that is permanently waterlogged. The result is a dysfunctional landscape that either sheds water, causing erosion and flooding, or becomes a barren desert or swamp. Restoring physical functions means de-compacting subsoils and re-establishing a topsoil
- **Biodiversity Habitat:** Soil is not inert dirt; it is a complex habitat teeming with life. A single gram of healthy soil can contain billions of microorganisms—bacteria, fungi, protozoa—and a vast network of larger creatures like worms and insects. This soil food web is the engine of nutrient cycling, breaking down organic matter and making nutrients available to plants. Mycorrhizal fungi, for example, form symbiotic relationships with plant roots, vastly extending their reach for water and nutrients. ASGM effectively sterilizes the soil, destroying this biological community through physical removal and compaction. Restoring biological functions involves re-introducing organic matter to provide food for

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microbes and, in some cases, inoculating the soil with beneficial fungi and bacteria to accelerate the recovery of the soil food web

- **Carbon Sequestration:** Soil is the largest terrestrial pool of carbon, holding more carbon than the atmosphere and all vegetation combined. Healthy soils continuously sequester atmospheric carbon dioxide (CO₂) in the form of stable organic matter. Land degradation from mining reverses this process, releasing vast amounts of carbon. Restoration, by focusing on rebuilding soil organic matter, turns these degraded lands from a carbon source back into a carbon sink (Society for Ecological Restoration, 2021)
- **Contaminant Immobilization:** A critical soil function in the context of ASGM sites is the soil's ability to act as a filter and buffer. Healthy soil with sufficient organic matter, and clay content (the soil adsorption complex or soil colloidal complex), and a near-neutral pH can adsorb heavy metal contaminants like mercury and arsenic. This process, known as immobilization or stabilization, locks the contaminants within the soil matrix, reducing their bioavailability and preventing them from being taken up by plants, leaching into groundwater or entering the food chain

2.2 Theory of Change

To translate the principles of community-led, science-based soil restoration into a plannable and measurable project, a clear Theory of Change (ToC) is essential. A ToC is a roadmap that articulates the causal pathway from project inputs and activities to the desired long-term impacts.

It makes the project's underlying assumptions explicit and provides a framework for monitoring and evaluation. The flow diagram on next page

illustrates a generalized Causal Pathway **for soil restoration** and is explained as follows:

- **Inputs to Activities:** The project begins by an (A) initiative to restore the ASGM area and secure (B) funding and resource to do so. This should be followed by combining other external resources such as (C) Community Partnerships (D) Local knowledge and (E) Technical Expertise. These inputs enable the project activities
- **Activities to Outputs:** When nature development and/or agriculture land-use are part of the site rehabilitation project, the activities include (F) baseline assessment, (G) soil restoration planning, (H) soil restoration and (I) implementation, with involvement of the community on all facets. The outputs are the immediate, measurable results of the project's work, such as a certain number of hectares being re-profiled and planted, or a specific number of community members where actively involved
- **Outputs to Outcomes:** This is the most critical and often most challenging transition in a rehabilitation project. Outputs alone do not guarantee success. A stabilized (J) restored soil only leads to lasting success if they successfully trigger the recovery of (K) improved soil functions This rehabilitation of underlying ecosystem processes is the pivotal event that allows the planted vegetation to thrive and evolve into a self-sustaining system. Once soil function is restored, it enables further positive outcomes: Increased (L) biodiversity and ecosystem services as the site becomes more complex, and the establishment of new, sustainable livelihood streams as agroforestry or horticultural systems become productive

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- **Outcomes to Impact:** The achievement of these intermediate outcomes leads an (M) increased area of farmland for food production and/or nature all contributing to a (N) healthier, more stable local environment and diversified and the rehabilitation of ecosystem services, such as the immobilization of contaminants and the provision of clean water. This all leads (O) improved livelihood of the villagers that are confronted with the negative impact from ASGM. **Impacts:** The impact is the project's ultimate goal, the long-term more (P) sustainable community and (Q) and environmental recovery of ASGM site

This framework demonstrates that soil restoration is not a simple linear process. The feedback loop between restored soil functions and the health of the vegetation is crucial. Without recovering the soil's ability to retain water, cycle nutrients, and support life, the initial outputs will fail to translate into sustainable outcomes, and the investment in restoration will be lost.

INPUTS TO ACTIVITIES



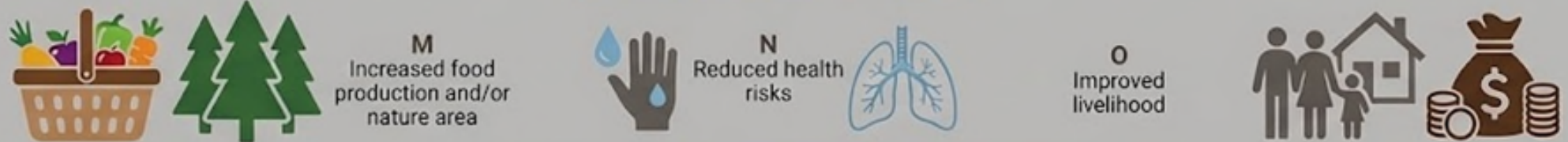
ACTIVITIES TO OUTPUT



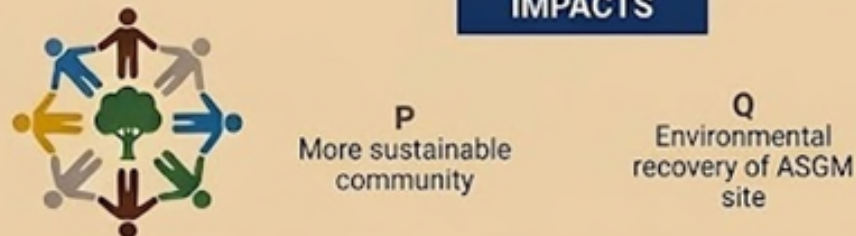
OUTPUTS TO OUTCOMES



OUTCOMES TO IMPACTS



IMPACTS



3 Baseline Assessment

A successful soil restoration plan is built upon a thorough understanding of the site's specific conditions. Rushing into implementation without a proper assessment can lead to wasted resources, failed plantings, and even unintended harm. This section outlines a pragmatic protocol for baseline assessment that integrates community knowledge with scientific measurement, prioritizing low-cost and accessible baseline assessment methods.

3.1 Participatory Mapping with Local Communities

Before any technical sampling begins, the first step is to engage with the community to co-create a map of the rehabilitation area. This process leverages the invaluable, fine-grained knowledge that local residents possess about their environment (World Agroforestry Centre, 2024). It is a powerful tool for building trust and ensuring the rehabilitation plan is grounded in local realities.

The process involves facilitating a workshop where community members—elders, miners, farmers, women, and youth—draw a map of the area on preferably a large scale aerial orthophoto map, or otherwise a large sheet of paper or on the ground. Using a checklist of questions, facilitators can guide the discussion to capture crucial information that technical surveys might miss (World Agroforestry Centre, 2024):

- **Historical Land Use:** Where were the old forest trails, farming plots, or sacred sites before mining began?
- **Mining History:** Which areas were mined first? Who worked there? What techniques were used (e.g., hydraulic mining, mercury use)?
- **ASGM site components:** Where are the (deepest and filled) mine-pits? Which tailings piles are known to be unstable? Where are the processing areas where mercury was burned?
- **Hydrology:** Where does water flow during heavy rains? Which areas are prone to flooding? Where were the local springs, water sources, water fronts and creeks located before mining started and are these located now?
- **Social Landscape:** Who claims ownership or uses rights over different parts of the land? What are the community's aspirations for the future use of the area (e.g., new farms, housing, a community forest)? Are there any socially or culturally significant sites (e.g., sacred groves, burial grounds). Where are the problem areas (e.g., "This pit is dangerous for children," "This stream is polluted")?

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Example: Baseline assessment at Compagnie Kreek

The partnership with the community was fundamental to the baseline assessment at Compagnie Kreek. Through dialogue, the community identified the specific pits that posed the greatest safety and flooding risks and delineated the areas they hoped to use for future agriculture and village expansion. This local knowledge directly guided the subsequent technical sampling, ensuring that the investigation focused on the areas of highest priority to the community. The resulting map became a shared planning tool, integrating technical data with community aspirations.

The result is a layered map that represents the community's collective understanding and vision for the future land use of the former ASGM mining area, providing an invaluable foundation for the rehabilitation plan (BCcampus, 2022).

Best Practice: Acquisition of Orthophoto and Digital Elevation Model (DEM)

Secure an up-to-date, high-resolution geospatial base layer for the entire ASGM site. The preferred approach is to conduct a low-altitude Unmanned Aerial Vehicle, (UAV or drone) survey with RTK (Real-Time Kinematic) control and PPK (Post-Processed Kinematic) process the imagery via structure-from-motion photogrammetry (or LiDAR, where available). This should yield:

- An orthorectified Red, Green, Blue (RGB) mosaic with a ground-sample distance ≤ 5 cm;
- A DEM (Digital Surface Model (DSM) and/or Digital Terrain Model (DTM)) with vertical accuracy ≤ 10 cm;
- Full metadata, including acquisition date, flight parameters, ground-control-point accuracy, and the coordinate reference system.

If a drone survey is not feasible, purchase commercial satellite or airborne imagery (e.g., WorldView, Pleiades) at ≤ 50 cm resolution. As a last resort, draw on freely accessible products (Sentinel-2, Google Earth, OpenTopography), while clearly noting their lower spatial and vertical resolution and the implications for micro-topography analysis.

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3.2 Identifying ASGM site components

Building on the participatory map, the technical team should conduct a systematic walkover to characterize and delineate the distinct site components created by mining, please refer to Section 1.2 for a more detailed description of the ASGM practices and site components. Each site component has different physical and chemical properties and will require a different rehabilitation approach. Please be aware that these site components can overlap. Using Global Positioning System (GPS), these areas should be mapped as distinct "domains":

1. **Unaffected upland:** Area undisturbed by ASGM and a potential source area for harvesting topsoil and seed bank
2. **Mining pit:** Excavated area, often filled with water and sometimes backfilled with coarse mine-tailings. Key characteristics to note are depth, water quality (e.g., turbidity, pH), and the stability of the side walls or backfill height and quality
3. **Overburden dumps:** Piles of the original topsoil and subsoil that were removed to access the gold-bearing layer. These can be a valuable source of material for soil restoration
4. **Processing areas:** These areas are characterized with remains of the construction supporting the sluice box. The miner's camp was often within the near vicinity of the sluice box. This is also the location where mercury was stored, and the gold amalgam is burned
5. **Mine tailings:** Close to the processing area, these deposited tailings are typically composed of coarse sand and gravel, are extremely low in organic matter and nutrients, have poor water-holding capacity, and may be contaminated with mercury and/or other heavy metals. One should also

look out for **mud pits**, downstream depressions or old mining pits where clay and silt particles precipitated out of the processing water. These areas can be unconsolidated and form a high drowning dangerous for people and animals entering

6. **Mud plains** are areas inundated by mud, direct from the mine or overflow from a tailing pond
7. **Water Bodies:** Ponds, creeks, water reservoirs or drainage channels that have been created or altered by mining. Fine tailings run-off eventually ends up in down-stream creeks, turning the original clean surface water into coloured water affecting the aquatic environment resulting in "dead" creeks
8. **Site Accessibility:** Another element that may be looked out for is access roads determining the accessibility with heavy equipment of the site



Figure 3.1 Site Layout on a High-resolution RGB Aerial Photograph at Compagnie Kreek

The result is a multi-layered map that summarizes the site's layout and principal geophysical site components. All deliverables must be georeferenced to the national grid and supplied as GeoTIFF (or equivalent) files. The resulting base map must include a north arrow and a scale bar. Figures 3.1 is the resulting map of the baseline assessment carried out in Compagnie Kreek.

3.3 Soil Sampling & Analysis

A tiered analysis for texture, organic matter, pH, and a risk-based suite of heavy metals is proposed to characterize the ASGM site components and other site

components. Once the site is mapped into distinct domains, a targeted soil sampling campaign is needed to quantify the key limiting factors for restoration. A robust soil assessment is critical for understanding the site conditions and designing effective restoration interventions (Watson et al., 2020).

Before defining the sampling locations, the rehabilitation area should first be subdivided through a rapid soil survey into clearly distinguishable soil or substrate units, such as coarse mine tailings, fine tailings, humic topsoil, clayey or loamy material, lateritic subsoil and water-affected sediments. Each unit should be described in terms of texture, colour, compaction, organic matter, drainage condition and existing vegetation. This step is essential because different materials may require different restoration measures and because the most important implementation decisions, including the selection of future topsoil material, compost requirements and planting strategy, depend on the interpretation of these units.

3.3.1 Sampling Design

A stratified random sampling approach is often most effective. This involves dividing the site into its specific ASGM site components and other site components and then collecting a number of random samples from within each site component. To reduce costs, **composite samples** can be created by collecting soil from up to 8 sub-locations within a single site component and mix them thoroughly in a clean bucket to create one representative sample for that site component (Karam et al., 2012). In case a site component is likely contaminated, composite samples should not exceed 4 sub-samples since hotspots will be diluted using this approach, also, the sub-samples should be preserved so individual samples could be tested in case elevated

concentrations are detected. Composite samples are only recommended for analyses of non-volatile components. Mercury is volatile, therefore individual samples should be used for mercury analysis.

Composite samples should only be prepared within homogeneous units and the protocol should be documented before sampling starts. As a minimum, the sampling plan should specify the number of subsamples per composite sample, the sampling depth, the tools used, the person responsible for sampling, the laboratory parameters to be analysed and the specialist responsible for interpreting the results. Where the future topsoil source is unclear, separate samples should be taken from each potentially reusable material. If organic matter is absent and only infertile sand, loam or clay is available, the project team should explicitly assess whether compost, forest litter, locally available organic residues or other soil amendments can realistically be supplied in sufficient quantities.

Aside from soil sampling, open mine pits and downstream stream systems might be targeted to assess environmental risks and inform the remediation design. Open Pit Sampling targets both water and fine sediments. Pit water samples require a water safety assessment to determine the suitability for agricultural irrigation. Fine pit sediments should be sampled to evaluate their suitability for soil restoration.

The stream sampling design evaluates off-site impact and contaminant transport using strategically selected locations. An upstream/background point establishes the unimpacted baseline data. The mixing/discharge zone captures

the maximum immediate contamination where mine runoff enters the stream. Finally, downstream transect points (e.g., at 50m, 200m, 500m) track contaminant attenuation. Stream Sediment Samples from the streambed are also collected to determine the concentration of total heavy metals, as sediments act as a sink for long-term pollutant risk to the floodplain during inundation.

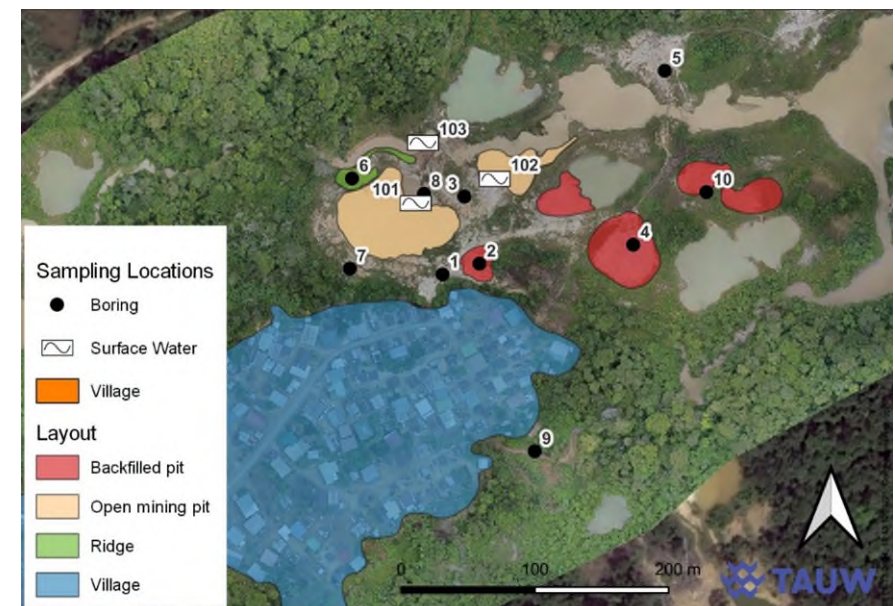


Figure 3.2 Sampling plan for the Rehabilitation Planning of the Compagnie Kreek.

Water samples should always be collected prior to sediment sampling and from downstream to upstream to minimize the suspension and inclusion of

extraneous particulate matter in the water column, thereby ensuring the water analysis accurately reflects its original condition and turbidity.

3.3.2 Soil Sampling Method

Soil samples must be collected from the representative layer and handled carefully to prevent evaporation or cross-contamination. Sampling must occur per soil horizon and contaminant level, typically collecting a maximum of 50 cm of soil per sample jar. Three types of samples are distinguished based on disturbance, with tools like augers and coring systems employed for collection:

- **Undisturbed Samples:** Essential for volatile compounds analysis, like mercury, taken without delay using specialized equipment (e.g., coring kits) and stored immediately under cooled conditions ($< 6^{\circ}\text{C}$) in a tightly sealed jar with no headspace
- **Semi-undisturbed Samples:** Inner cuttings are immediately transferred to a jar after removing the exposed surface (note: suitable for most contaminants)
- **Disturbed Samples:** Suitable for most non-volatile chemical analyses, obtained using augers

Shallow soil for non- and semi-volatile chemical analyses can also be sampled directly from the walls of pits using a spatula.

Clean chemical resistant gloves are mandatory when sampling. All filled sample jars must be stored cool ($< 6^{\circ}\text{C}$) and transported under a cold chain to the laboratory as soon as possible. The analytical laboratory must extract the samples within the specified holding time (e.g., 24 h for VOX, 5 days for

Total Mercury). All sample codes and corresponding depths are recorded on the borehole log (see example in Appendix 1) that are made in the field as essential part of the soil sampling.

3.3.3 Analytical Investigation and interpretation

The soil sample analyses should focus on key indicators of soil health that are relevant to restoration (International Society for Ecological Restoration, 2019b).

- **Physical:** Soil Texture (percentage of sand, silt, clay), Bulk Density (a measure of compaction)
- **Chemical:** pH (acidity/alkalinity), Soil Organic Matter (SOM), Cation Exchange Capacity (CEC), and primary nutrients (Nitrogen, Phosphorus, Potassium)
- **Nutrient limitations:** On highly weathered tropical soils, phosphorus and potassium may remain critically low even when nitrogen-fixing plants are introduced. Nitrogen-fixing legumes can improve nitrogen availability, but they do not add other nutrients that are absent from the soil. Therefore, nutrient analysis should include at least nitrogen, phosphorus and potassium, and the interpretation should consider whether targeted amendments are required to support vegetation establishment and long-term soil development

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Mercury as a Natural Occurring Contaminant

When interpreting site analysis results, particularly those from Artisanal and Small-Scale Gold Mining (ASGM) areas, all data must be compared against the local background soil sample analyses. Research indicates that the natural weathering process can residually concentrate Hg in the topsoil up to a range of 200–300 µg/kg and occasionally up to 800 µg/kg at Guiana Shield (Kroonenberg et al. 2022). This concentration occurs alongside other immobile elements, notably iron, chromium, and vanadium, and can result in Hg values a hundred times higher than those in the unweathered parent rock.

Crucially, Kroonenberg et al. (2022) concluded that natural soil and saprolite Hg values are often within the same order of magnitude as published mine tailings and stream sediments. Therefore, these natural background concentrations cannot generally be used as a standalone indicator to differentiate areas polluted by ASGM activities from unpolluted materials.

Beside soil health, understanding the nature and extent of chemical contamination is essential for assessing risks and selecting the right site management strategy. The primary Contaminants of Concern (CoCs) in ASGM are Mercury (Hg), Arsenic (As), Lead (Pb), Cadmium (Cd), and Cyanide (CN) (Douine, 2025).

The screening approach should be used to identify anthropogenic (mercury) contamination, such as processing areas and mud plains.

A tiered Screening Approach can be, as follows, and is presented in Table 3.1:

- **Tier 1: On-Site Field Screening:** This provides rapid, preliminary data to identify hotspots and guide further investigation.
 - Portable X-Ray Fluorescence (XRF): A handheld XRF analyser can provide instant, on-site readings for heavy metals like Hg, As, Pb, and Cd. While less precise than lab analysis, it is invaluable for quickly mapping the distribution of contamination (Karam, 2012). (See textbox below with remarks use of an XRF)
 - Low-Cost Field Test Kits: Simple, colorimetric test kits are available for screening soil and water for mercury, arsenic, and cyanide. These are affordable and can be used by trained community members, though they are typically semi-quantitative (see Annex B for a guide) (Satish et al., 2024).
- **Tier 2: Laboratory Confirmation:** Based on the field screening results, a targeted subset of samples (e.g., from the most contaminated hotspots) should be sent to an accredited environmental laboratory for precise, quantitative analysis using standard methods like EPA Method 6010B for metals (Raskin & Osborn, 2019).
- **Tier 3: Advanced Laboratory Testing**
 - Mercury Speciation: Mercury speciation analysis is crucial for determining the environmental risk and required remediation strategy. Total mercury concentration alone is insufficient; speciation analysis identifies the specific chemical forms (species) of mercury (Hg) present, as their toxicity and mobility vary widely. The analysis typically focuses on quantifying:
 - Elemental Mercury (Hg⁰): The least toxic form, which is volatile.

- Inorganic Mercury (Hg^{2+}): Highly reactive, commonly binds to soil or sediment particles.
- Organic Mercury (CH_3Hg^+): Predominantly methylmercury, the most toxic form, which readily bioaccumulates up the food chain.
- Ecotoxicity Bioassays: Chemical concentration data alone does not tell the whole story. Ecotoxicity bioassays measure the actual biological effect of the contaminated soil on living organisms, providing a more holistic assessment of risk (Raj et al., 2025). Best Practice: Use Simple, Low-Cost Bioassays.
 - Earthworm Avoidance Test: This simple test involves placing earthworms in a container with potentially contaminated soil on one side and clean control soil on the other. After 48 hours, the number of worms on each side is counted. If the worms actively avoid the potentially contaminated soil, it indicates toxicity (Worldwide Fund for Nature, 2022).
 - Seed Germination Test: Plant seeds of a common, fast-growing species (like lettuce, radish, or a local crop) in pots with potentially contaminated soil and in pots with clean control soil. Compare the germination rate and seedling growth after 7-14 days. Stunted growth or low germination in the potentially contaminated soil indicates phytotoxicity (Worldwide Fund for Nature, 2023).

Best Practice: Handheld XRF analyser

For projects with limited laboratory access, the handheld X-Ray Fluorescence (XRF) analyser offers a promising, field-portable alternative for rapid screening of contaminants. A crucial limitation to note is that the detection limit for mercury (Hg) via handheld XRF is often above the human health risk level relevant for local communities, particularly those relying on subsistence consumption (e.g., eating "out of a single food basket").

Therefore, XRF should be used primarily as a screening tool to identify hotspots, with laboratory confirmation required for fine-tuning risk assessment. Additionally, XRF can be used to determine the elemental composition of soil and sediment samples, which provides valuable insight into the local mineralogy, helping to characterize the natural background concentrations of elements like iron, chromium, and vanadium.

Our reference R003-1291225IKR-V03-sss-NL

Table 3.1 Tiered Soil Analyses Protocol

Parameter	Tier 1 Method (Field/Low-Cost)	Tier 2 Method (Standard Lab)	Tier 3 Method (Advanced Lab)	Decision-Making Threshold*
Texture	Hand Texturing (Ribbon Test) and Sand Ruler	Particle Size Analysis (Hydrometer Method)	-	If Clay<5%, the soil's ability to retain nutrients is critically limited; amendment with fine soil or clay-rich material is required. If Sand>90%, water-holding capacity is critically low; amendment with fine soil fraction and/or organic matter is required. Amend soil toward a Loam (Sandy Loam/Silt Loam) texture, targeting a combined Silt + Clay content of ≥15-25% for optimal structure and function.
Compaction	Penetration Resistance (Metal Rod/handheld penetrometer)	Bulk Density Measurement	-	If a penetration rod cannot penetrate >15 cm (or penetration resistance exceeds 200 psi), deep ripping/subsoiling is required to restore root growth.
pH	pH-strips or Field Meter	Laboratory pH Meter (in water and CaCl ₂)	-	If pH<4.5, soil acidity is extreme; liming is required (Ca/Mg amendment) to raise the pH to a plant-supportive range (≥5.5).
Organic Matter	Soil Colour (Munsell Chart)	Loss-on-Ignition (LOI) or Walkley-Black	Total Organic Carbon (TOC) Analysis	If OM<2%, the soil is low in fertility and structure; significant amendment with compost, manure, or biochar is needed.
Total Mercury (Hg)	Handheld XRF screening to detect Hg hotspots	Cold Vapor Atomic Absorption Spectroscopy (CVAAS)	Mercury Speciation (Methylmercury)	If Total Hg>1 mg/kg AND exceeds the established local Background Concentration, the site is classified as anthropogenically contaminated. This condition mandates Hg speciation analysis, specific risk assessment, and/or potential engineering controls (e.g., capping) or phytoremediation.
Cyanide (CN)	-	Spectrophotometry (Colorimetric Method) (e.g., using ASTM D6888).	Cyanide Speciation (Gas Chromatography-Mass Spectrometry (GC-MS))	If Total Cyanide (CNT) in water exceeds <0.02 mg/L in the stream, the site is classified as posing an acute ecological risk. This condition mandates a specific risk assessment to prevent off-site transport and downstream contamination.
Other Heavy Metals (As, Pb, Cd)	Handheld X-Ray Fluorescence (XRF) Screening	Inductively Coupled Plasma (ICP-MS or ICP-OES)	Bioavailability/Leaching Tests	If contaminant levels exceed National Soil Quality Guidance, a formal, site-specific quantitative risk assessment is needed to determine safe future land use and mandatory remediation.

*The concept of a single decision-making threshold for successful vegetation and safe future site use is inherently highly variable. Such thresholds depend critically on the local climate, the specific plant species selected, existing soil and site characteristics, and the intended future land use. However, the provided guidelines and decision rules remain valuable as a generic, initial tool for soil interpretation, assessing contamination risks, and defining preliminary restoration requirements.

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3.4 Water Quality Assessment

Water quality assessment should be included in the baseline assessment where surface water, former mining pits, creeks or downstream drainage routes may influence soil restoration, site safety or future land use. The assessment should describe the relevant water bodies, expected flow direction, visible sources of turbidity, sediment accumulation, stagnant water and potential interaction with restored soils. Field measurements, laboratory analyses and interpretation should be linked to the intended management question (WHO and UNEP, 1996; UNEP, 2025). At each sampling location, a cross-section of the water body should be recorded to describe the channel or pond geometry and to support the interpretation of discharge, storage volume and water level fluctuations.

Where flowing water is present, discharge can be estimated using the constant-rate injection dilution method where conventional velocity-area measurements are not reliable due to irregular cross-sections, shallow water, high flow velocity or difficult access, please refer to Figure 3.3.

This method consists of pumping a tracer solution, such as a salt solution, with a known high concentration (C_1) into the stream at a constant injection rate (q) until a stable downstream plateau concentration (C_2) is reached. The background tracer concentration of the stream water (C_0) should be measured before injection. Stream discharge (Q) is then calculated using Formula 3.1.

Concentrations should be derived from calibrated electrical conductivity measurements or laboratory-confirmed tracer concentrations. The method is

based on mass conservation and requires full lateral and vertical mixing of the tracer before the downstream measurement point (Kilpatrick and Cobb, 1985; USGS, 2024).

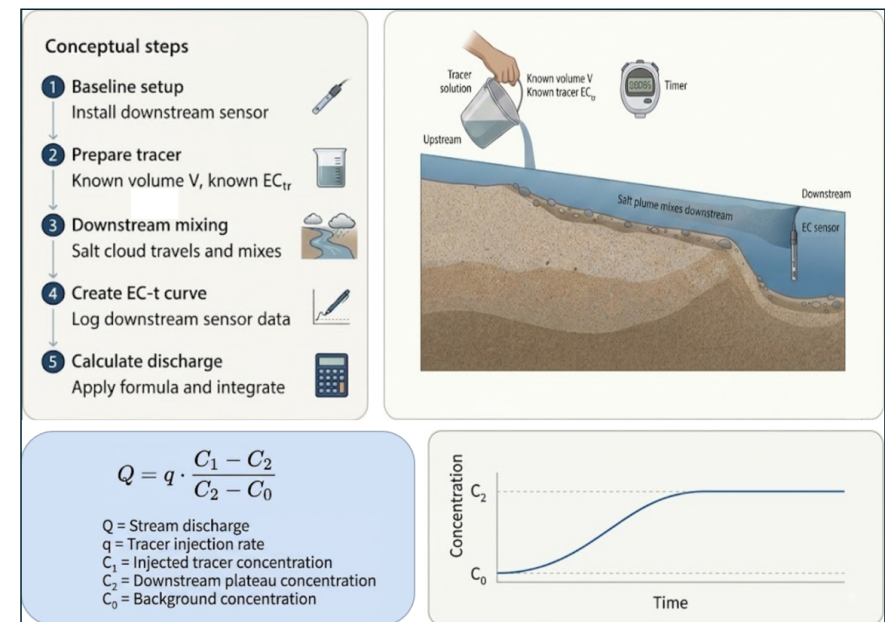


Figure 3.3 Example of a stream cross-section including discharge measurements

Formula 3.1

$$Q = q \times \frac{C_1 - C_2}{C_2 - C_0}$$

Where Q is the stream discharge, q is the injection rate of the tracer solution, C1 is the concentration of the tracer in the injected solution, C2 is the downstream plateau concentration and C0 is the background tracer concentration of the stream water.

No tributaries, seepage inflows, abstractions or losses should occur between the injection point and the downstream measurement point, as these would affect the calculated discharge. Background conductivity should be measured before injection, and the relation between tracer concentration and conductivity should be checked or calibrated for the water used during the measurement.

In addition, a measuring pole or water level beacon should be installed at a stable location to allow repeated readings of water depth during the monitoring period, including after extreme rainfall events. To account for seasonal variation in both water quality and water quantity, at least two monitoring rounds are recommended: one at the end of the wet season and one at the end of the dry season.

3.5 Socio-Economic Baseline

A thorough socio-economic baseline is essential for designing a project that meets community needs, avoids unintended negative consequences, and

allows for the measurement of social impact over time. This assessment should be conducted through a combination of household surveys, focus group discussions (separating men, women, and youth), and key informant interviews with community leaders and local officials. Toolkits from organizations like the World Bank and Anglo American provide excellent frameworks (EMSAGS, 2025c).

Key Areas of Inquiry are:

- **Livelihoods and Economy:** What are the primary, secondary, and seasonal sources of income? What percentage of households rely on ASGM? What are the local market dynamics?
- **Land Tenure and Access:** Who formally or customarily owns the degraded land? Are there existing land use rights or conflicts? This is a critical factor for the long-term sustainability of any rehabilitation effort (PlanetGOLD, 2024)
- **Gender Dynamics:** What are the different roles, responsibilities, and decision-making powers of men and women regarding land, income, and community projects? How might the project affect them differently?
- **Social Organization:** Identify existing community groups, leadership structures (formal and informal), and social cohesion

3.6 Ecological Quick Scan

A Rapid Ecological Assessment (REA) provides a quick snapshot of the site's current biological conditions, which is crucial for setting realistic rehabilitation goals and identifying valuable on-site resources:

- **Remnant Vegetation:** Carefully map any patches of surviving native vegetation on or near the site. These patches are invaluable as they can act as natural seed sources for regeneration and provide a reference for which species are adapted to the local conditions
- **Fauna:** Look for signs of wildlife, such as animal tracks, droppings, burrows, or bird calls. This helps establish a baseline for biodiversity and can indicate the level of ecosystem functions (e.g., the presence of pollinators or seed dispersers)

3.7 Data Interpretation for Intervention Planning

The data collected from the assessment is not an end in itself; it is a tool for making informed decisions. The final step of the assessment protocol is to synthesize the participatory map, the site characterization, and the soil analysis results to formulate a preliminary rehabilitation strategy.

This process should be transparent and collaborative, involving a feedback session with the community to discuss the findings and their implications. For example, the technical team might present the findings as follows:

- "The community map showed this area is a priority for agriculture. Our soil tests confirm that the soil here is very sandy and low in nutrients (Organic Matter < 2%). Therefore, to make this land productive, we will need to add a significant amount of compost and plant leguminous cover crops."
- "The soil samples from the old processing area show mercury levels above the background values and are higher than 1 mg/kg. Therefore, this specific area is not suitable for agricultural purposes and should be planted with trees for conservation."

This interpretive step directly links the "what is there" (the assessment data) to the "what we will do" (the rehabilitation plan), ensuring that every intervention is justified by evidence and aligned with community goals. The Compagnie Kreek investigation provides a clear model: the finding of low mercury contamination but severe physical degradation and nutrient deficiency led directly to a plan focused on physical soil amendments (topsoil application) rather than costly contaminant remediation (TAUW bv & EMSAGS, 2024).

4 Development of Restoration Plan

4.1 Purpose

This section explains how to use the decision framework to select the most appropriate strategy based on the baseline assessment results, community goals, and available resources. After completing the baseline assessment, project teams are faced with the following critical question: What is the most appropriate soil restoration strategy for this specific site? A one-size-fits-all approach is ineffective and can be dangerous. A site with low contamination but severe erosion requires a different set of interventions than a site with high mercury levels intended for future community use.

The decision tree presented below is a conceptual tool designed to guide practitioners, in close collaboration with community stakeholders, through a logical, risk-based process. It uses the data gathered during the baseline assessment as inputs to navigate a series of key decision points. The purpose of the tree is to ensure that the selected strategy is:

- **Risk-Appropriate:** Prioritizing human health and environmental safety by first addressing contamination risks before moving to other ecological or productive goals
- **Site-Specific:** tailoring soil restoration to the site's unique physical conditions (contamination, soil quality, topography)
- **Goal-Oriented:** Aligning soil restoration with the community's desire which can be nature, agriculture land use or recreation
- **Resource-Efficient:** Directing limited resources towards the most critical limiting factors, avoiding the misapplication of costly or unnecessary techniques

By following the tree, a project team can move from a complex set of baseline assessment data to a clear, defensible suite of "Building Blocks" (detailed in Section 5) that form the basis of their soil restoration.

Best Practice: A Participatory Process

The Decision Framework should not be used by technical experts in isolation. It is most effective when used as a tool in a community planning workshop. By walking through the logic of the framework together, all stakeholders can understand why a particular strategy is being chosen, which builds consensus and ownership of the final restoration plan.

4.2 The Decision Framework

The most fundamental decision in any ASGM soil restoration project is the initial risk stratification. The presence of significant contamination fundamentally changes the objectives, methods, and costs of rehabilitation. The decision framework therefore begins with this critical question on contamination status; afterwards, it will focus on ecological and productive recovery. The Compagnie Kreek pilot, with its low mercury levels, focussed on soil health (TAUW, 2024).

4.3 Defining End-State

Before any earth is moved or any trees are planted, a clear and shared vision of success must be established. This process translates the broad aspirations of the community into specific, measurable targets that will guide

implementation and allow for an objective evaluation of the project's success. This is a critical step for aligning stakeholder expectations and ensuring accountability (International Society for Ecological Restoration, 2019b).

Drawing from international standards for soil restoration, success criteria should be developed collaboratively and framed using the SMART methodology (Society for Ecological Restoration, 2021). SMART stands for:

- **Specific:** Clearly state what will be achieved (e.g., "Establish a vegetative cover of native grasses and legumes")
- **Measurable:** Define quantitative or qualitative indicators (e.g., "Achieve 80% ground cover")
- **Achievable:** Be realistic given the site's limitations and the project's resources
- **Relevant:** Directly relate to the community's desired end-state and the recovery of key ecosystem functions
- **Time-bound:** Specify a timeframe for achievement (e.g., "within three years of planting")

Success criteria should address multiple ecosystem attributes, including the long-term stability of the landform, the functionality of the soil and hydrology, and the composition and structure of the plant community (International Society for Ecological Restoration, 2019b).

The process includes the facilitation of a community visioning workshop to share and explain the Decision Framework results, review the participatory maps and baseline data, and discuss what the community wants the land to be used for in five (5) and twenty (20) years, including what a healthy and safe

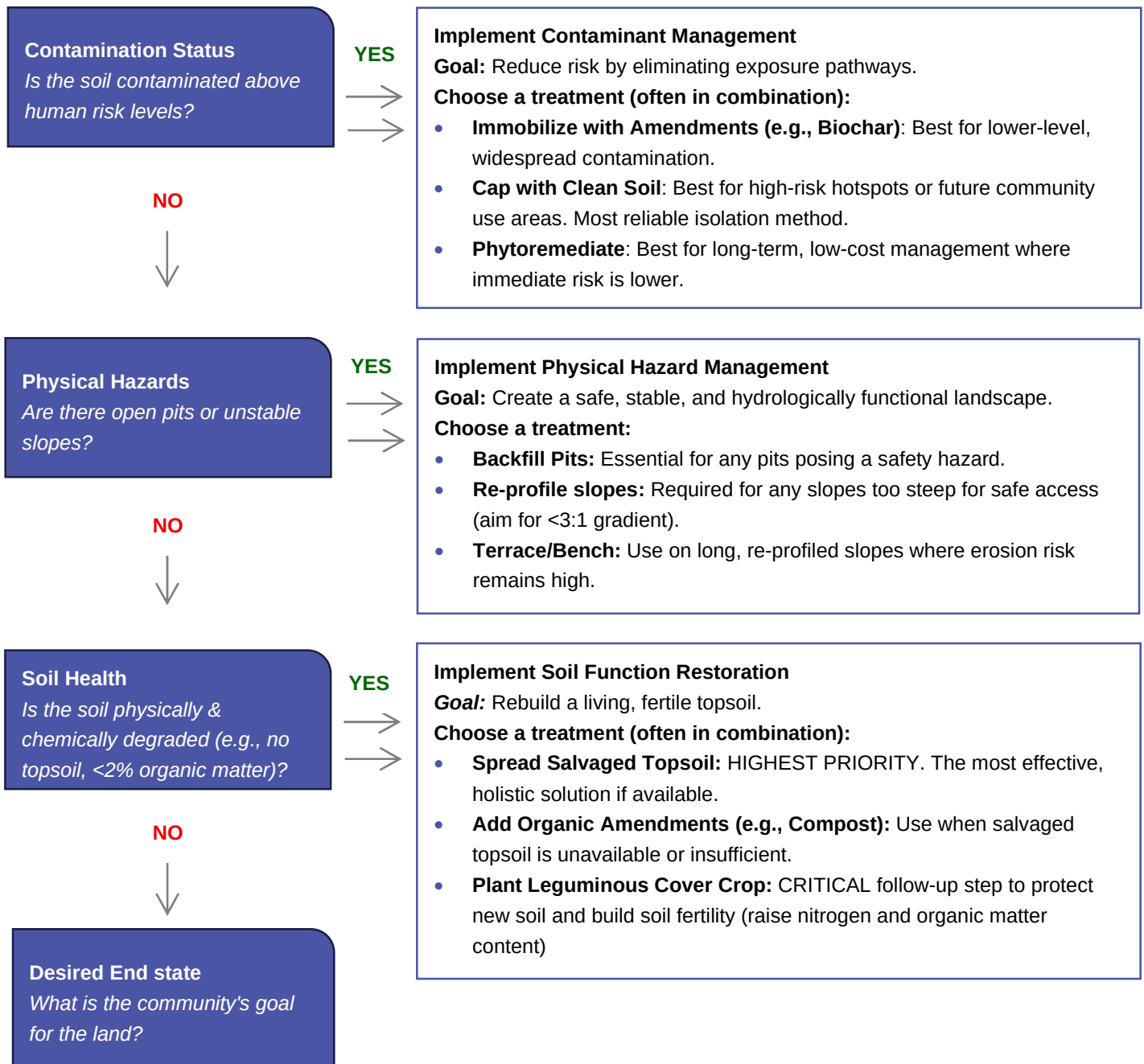
landscape should look like. Translate these aspirations into broad goals, such as making the land safe for children, growing food for families, or restoring birds and animals, and then defining measurable success criteria for each goal together with the community, linking the vision directly to the technical monitoring that will follow.

Illustrative Example: Success Criteria for Compagnie Kreek

Based on the community's goal of using the restored land for agriculture and agroforestry, SMART success criteria could include the following:

- **Soil Function:** Within one growing season, soil organic matter and key nutrients in the topsoil of the agroforestry plot show measurable improvement compared with baseline conditions.
- **Vegetative Cover:** Within three (3) months after planting, cover crops or planted vegetation achieve at least 70% ground cover to reduce erosion, suppress weeds, and support soil development.
- **Site Safety and Water Management:** Former mining pits and drainage features will be stabilized to reduce safety risks and improve controlled water flow, with no longer signs of erosion within one (1) year after the earth works

Decision Framework Soil Rehabilitation ASGM Sites



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5 Implementation Protocol

A well-designed rehabilitation strategy is only as good as its execution. This section provides a suite of practical tools and protocols to support effective, safe, and accountable project implementation in the field.

5.1 Project Management

Effective project management requires breaking down a complex rehabilitation plan into a series of manageable tasks and scheduling them over time.

- **Work-Breakdown Structure (WBS):** A WBS is a hierarchical decomposition of the total scope of work to be carried out by the project team (Smartsheet Inc., 2025). It starts with the major deliverables (e.g., "Site components Stabilized and Revegetated") and breaks them down into smaller work packages and finally into individual tasks (e.g., "Procure *Mucuna Sp.* seed," "Conduct slope re-grading"). A WBS template helps ensure that all necessary tasks are accounted for and provides a clear framework for assigning responsibilities and estimating costs
- **Gantt Chart:** A Gantt chart is a visual timeline that displays the project schedule (ProjectManager.com, 2024). It lists tasks on the vertical axis and time on the horizontal axis. Each task is represented by a bar whose length corresponds to its duration. Gantt charts are invaluable for visualizing task dependencies (e.g., "Topsoil Spreading" cannot begin until "Slope Re-grading" is complete), tracking progress against the schedule, and communicating the project plan to stakeholders

5.2 Standard Operating Procedures

To ensure consistency, quality, and safety in field operations, clear Standard Operating Procedures (SOPs) should be developed for all key technical activities. SOPs translate the general guidance from the activities into simple, illustrated, step-by-step instructions that can be easily followed by field teams. A generic SOP template is provided in Appendix 4, which should be adapted for each specific task.

Example SOP: Topsoil Application

Objective: To evenly apply a 10-15 cm layer of salvaged topsoil onto a prepared subgrade.

Materials & Equipment: List of required tools (e.g., shovels, rakes, wheelbarrows) and machinery (e.g., front-end loader).

Pre-requisites: Confirm that subsoil has been de-compacted and is at the correct elevation. Confirm topsoil stockpile has been tested and approved for use.

Step-by-Step Procedure:

- Step 1: Lightly moisten the substrate to reduce dust and improve bonding
- Step 2: Use a loader to place small piles of topsoil at regular intervals across the site
- Step 3: Use hand tools (rakes, shovels) to spread the topsoil evenly between the piles
- Step 4: Use a measuring stick to check for a consistent depth of 10-15 cm

- Step 5: Avoid walking on or driving over the freshly spread topsoil to prevent re-compaction

Safety Precautions: List required Personal Protective Equipment (PPE) (e.g., gloves, boots, dust masks).

Quality Control Check: Final visual inspection for even coverage and correct depth.

5.3 Resource Planning

Accurate budgeting is critical for project success. Rehabilitation costs can vary dramatically based on site conditions, labour rates, and the chosen interventions. This section provides guidance on building a realistic budget.

Cost Categories: Budgets should be broken down into major categories:

- **Personnel:** Staff salaries, community labour wages, technical consultant fees
- **Equipment:** Rental or purchase of heavy machinery (excavator, bulldozer), vehicles, and field tools
- **Materials:** Purchase of seeds, seedlings, soil amendments (lime, compost), fencing, etc
- **Overheads:** Project administration, office costs, travel
- **Unit Costing:** The most effective way to estimate costs is on a per-unit basis (e.g., cost per hectare, cost per seedling planted, cost per cubic meter of earth moved). This allows the budget to be scaled and adapted to different site sizes. Tools like the Standardized Reclamation Cost Estimator (SRCE) used in the mining industry provide a model for this type of first-principles cost estimation

- **Contingency:** All project budgets should include a contingency fund (typically 10-15% of the total cost) to cover unforeseen challenges or delays

5.4 Community Engagement Toolkit

Sustaining community support throughout the project lifecycle requires a structured and transparent engagement process.

- **FPIC Protocol:** While FPIC is a principle, its implementation requires a practical process. This toolkit provides a step-by-step guide for project teams, adapted from established resources (UNDP, 2022):
 - **Preparation:** Identify all relevant rights-holders and their customary decision-making structures
 - **Information Sharing:** Develop culturally appropriate materials (e.g., visual aids, radio programs) to explain the project in the local language. Hold multiple community meetings to present information and answer questions
 - **Consultation & Participation:** Facilitate community-only meetings where they can discuss the project among themselves, according to their own traditions
 - **Decision-Making:** Respect the community's timeline and process for reaching a collective decision
 - **Documentation:** Formally document the outcome of the consent process in a written or recorded agreement

- **Participatory Monitoring:** Involve community members in tracking project progress. This builds ownership and provides valuable, real-time feedback. Methods include training local monitors to use simple tools like photo points, measuring seedling height and survival, and identifying signs of erosion (U.S. State Department, 2015)
- **Conflict Resolution:** Conflicts can arise in any community project, often related to benefit sharing, land use decisions, or leadership. Having a clear, pre-agreed process for resolving disputes is essential
 - **Establish a Community Rehabilitation Committee:** This committee, with diverse representation (elders, women, youth, landowners), should be the first point of contact for any grievances
 - **Develop Ground Rules:** At the start of the project, have the community agree on ground rules for meetings and decision-making
 - **Focus on Interests, Not Positions:** Train facilitators to help parties move beyond their stated demands ("positions") to understand their underlying needs and concerns ("interests"), which often opens up space for creative, mutually agreeable solutions
 - **Grievance Redress Mechanism:** Establish a clear, simple, and accessible process for community members to raise concerns or complaints about the project. This can prevent small issues from escalating into major conflicts

5.5 Health, Safety & Environment (HSE)

Rehabilitation work, particularly on former mine sites, involves inherent risks. A systematic HSE plan is essential to protect workers and the community.

- **Risk Assessment:** For each major activity (e.g., operating machinery, handling soil, working near water), conduct a risk assessment to identify

potential hazards. A simple risk matrix can be used to score the likelihood and severity of each hazard

- **Mitigation Measures:** For each identified hazard, define specific mitigation measures. Examples include:
 - **Physical Hazards:** Mandatory use of PPE (hard hats, steel-toed boots, live jacket); daily safety briefings; procedures for working on unstable slopes; securing pits and deep-water bodies
 - **Chemical Hazards:** If working with contaminated soils, require the use of dust masks and gloves; implement dust suppression measures (e.g., watering); establish decontamination procedures for workers and equipment leaving the site
 - **Biological Hazards:** Awareness and prevention measures for vector-borne diseases like malaria, which can be prevalent in mining areas

A site-specific HSE plan is mandatory to protect workers and the community. HSE Plan Template must include:

- **Site Control:** Procedures for delineating work site zoning (e.g., Exclusion Zone, Contamination Reduction Zone) and controlling access to prevent community members, especially children, from entering hazardous areas during active work
- **Hazard Communication:** Clear communication of site hazards to all workers and the community through meetings and signage
- **Task-Specific Risk Assessments:** For each major task (e.g., operating an excavator, handling contaminated soil, applying amendments), identify the specific hazards and the control measures to mitigate them

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- **Personal Protective Equipment (PPE):** A matrix specifying the mandatory PPE for each task (e.g., hard hats, safety glasses, dust masks, gloves, steel-toed boots and live jacket)
- **Emergency Response Plan:** Clear, simple procedures for medical emergencies (first aid, transport to clinic), and fire. Post emergency contact numbers prominently on site

All workers must receive training on the HSE plan before commencing work.

The local community is often interested in the activities being carried out as part of this project, and should therefore be part of the risk assessment and should be informed. Establish clear agreements regarding where community members are allowed and not allowed to go, and clearly identify who they can contact with questions or concerns.

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6 Soil Restoration

This section provides the technical details for the strategies identified by using the Decision Framework and provides the practical overview to restore the soil.

6.1 Contaminant Management

For site components identified as contaminated above the human health risk target level, managing contaminants is the primary objective. In the context of ASGM, this usually means addressing mercury (Hg) contamination. While active remediation (e.g., excavation and disposal) is prohibitively expensive for most projects, several low-cost, passive techniques can effectively reduce risk.

Technical Guidance:

Biochar and compost can have different functions depending on the restoration objective. When applied for contaminant management, their primary role is to bind or immobilize mercury and other metals and reduce bioavailability. When applied as soil amendments, their primary role is to improve organic matter supply, nutrient retention, water retention and microbial habitat. These functions should be distinguished in the restoration plan, because the required material quality, application rate and performance indicators may differ.

- **Access restriction:** In general, this may be the first containment option which involves physically limiting or eliminating human and ecological entry to a contaminated site to prevent direct contact with, or exposure to, pollutants. This is typically achieved through security fencing, posting

warning signage, or implementing institutional controls that prohibit specific activities like farming or water use

- **Immobilization with Amendments:** One of the most effective strategies is to reduce the bioavailability of mercury, preventing it from being taken up by plants or converted to methylmercury. Mixing amendments like biochar or compost into the soil can achieve this. These materials have a high surface area and chemical reactivity, which allows them to bind strongly to mercury particles, locking them in the soil matrix
 - **Biochar:** A charcoal-like material made from heating biomass (e.g., crop waste, wood) in a low-oxygen environment. Its porous structure and surface chemistry are highly effective at adsorbing heavy metals like mercury and arsenic (OHIO EPA, 2021)
 - **Application Rate:** Typically, 1-5% by weight (e.g., 1-5 kg per m² for a 10 cm incorporation depth). Start with a lower rate (e.g., 1%) and monitor effectiveness (OHIO EPA, 2021)
 - **Method:** Spread evenly on the soil surface and incorporate into the top 10 - 20 cm of soil using hand tools or a rototiller
 - **Compost:** Well-decomposed organic matter is rich in humic substances that can form strong complexes with heavy metals, effectively immobilizing them (World Agroforestry Centre, 2024)
 - **Application Rate:** 2-5 kg per m²
 - **Method:** Apply and incorporate in the same way as biochar. Often used in combination with biochar for synergistic effects

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- **Capping:** For areas with very high contamination or where direct human contact is planned, capping is the most reliable option. This involves placing a physical barrier (e.g., a geotextile liner) over the contaminated material, followed by a thick layer (e.g., >50 cm) of clean soil. This effectively isolates the contamination and provides a safe medium for establishing vegetation
- **Phytoremediation:** This technique uses specific plants to contain by extraction or stabilization of the contaminants. For mercury, two main pathways are relevant (Danasla et al., 2024; Mosquera Chaverra et al., 2024):
 - **Phytoextraction:** Certain plants, known as hyperaccumulators, can absorb mercury through their roots and translocate it to their shoots and leaves. These plants can then be harvested and safely disposed of, gradually removing mercury from the site. Research in tropical regions has identified promising native species, including the legume tree *Acacia mangium* in Ghana and the sedge *Cyperus rotundus* in Indonesia (Liu, J., et al., 2020). While some studies show in certain cases accumulation of mercury, the efficacy of phytoextraction for large-scale remediation of mercury remains a subject of ongoing scientific debate
 - **Key Species:** Research has identified plants with potential for Hg and as uptake, such as certain species of ferns (*Pteris vittata* for arsenic), Indian mustard (*Brassica juncea*), and sunflower (*Helianthus annuus*). Local research is crucial to identify native species with accumulation potential (EMSAGS, 2025d). Nutsedge (*Cyperus rotundus*) has shown significant potential for mercury uptake in soil (Australian Government, 2019)
- **Method:** Plant the selected species densely in contaminated areas. Once mature, the above-ground biomass must be harvested and disposed of safely (e.g., in a designated, lined pit on-site or through controlled incineration if facilities are available) to permanently remove the contaminants from the site. This process may need to be repeated for several growing seasons
- **Phyto-stabilization/containment:** Other plants can absorb mercury into their root systems but do not translocate it to their shoots. This helps to stabilize the contaminant in the soil, reducing leaching into groundwater or becoming airborne
 - **Key Species:** Vetiver grass (*Chrysopogon zizanioides*) is exceptionally effective due to its deep, dense, fibrous root system and tolerance to a wide range of contaminants and soil conditions (UN Environment Programme, 2025)
 - **Method:** Plant vetiver slips in dense hedges along contours to create living barriers against erosion
 - **Materials & Equipment:**
 - Biochar, compost, or other amendments
 - Spreader (manual or mechanical)
 - Rototiller or hand tools for incorporation
 - Planting materials (seeds, slips) for phytoremediation species
- **Estimated Timeline:** Chemical stabilization provides immediate benefits upon application. Phytoremediation is a longer-term process,

often requiring multiple years to achieve significant reductions in contaminant levels

6.2 Physical hazard management

For many ASGM sites, particularly those created by hydraulic mining, the most critical intervention is physical restructuring. The goal of earthworks is to transform unstable, and dysfunctional landscape into one that is safe, geotechnically stable, and hydrologically functional.

Technical Guidance:

- **Backfilling open mine Pit:** Where possible, pits should be backfilled to eliminate safety hazards and create a continuous land surface. Coarse tailings and waste rock can be used as bulk fill in the lower portions of the pit, but the final surface layer must be composed of finer material capable of supporting soil development
 - **Procedure:** Safely backfill pits using available waste rock and subsoil. Place coarser, non-acid-generating rock at the bottom to ensure good drainage, followed by finer subsoil material. The final surface should be capped with restored topsoil (see Section 5.4 Soil Restoration). The surface should be slightly mounded to prevent water from ponding and promote runoff
 - **Safety:** Before backfilling, ensure pits are free of standing water and that the pit walls are stable
- **Re-profiling Slopes:** Steep, unstable slopes on tailings and overburden piles must be re-graded to a stable angle of repose. This reduces erosion risk and allows for safe access for planting and maintenance
 - **Procedure:** Use an excavator or bulldozer to pull material from the top of the slope to the bottom, reducing the overall gradient
 - **Specification:** The final slope should generally not exceed a gradient of 3:1 (horizontal: vertical) and preferably be closer to 4:1 or 5:1 for long-term stability and ease of revegetation
- **Terracing and Benching:** On longer slopes, constructing terraces or benches can break up the flow of water, reduce its velocity, and trap sediment, further minimizing erosion
 - **Procedure:** Create a series of level or gently sloping steps across the slope parallel to the slope contour. The terrace edges can be stabilized with vetiver grass or rock walls
- **Drainage Integration:** The redesigned landform must incorporate a sustainable drainage system
 - **Procedure:** Create small ditches or depressions (swales) and mounds of soil (berms) along the contours of slopes also known as tied-rigids. These site components intercept surface runoff, slowing it down, reducing its erosive force, and allowing more water to infiltrate the soil

Best-Practice: Managing Soil Loss at ASGM Sites

Years of excavation have stripped topsoil and left steep-walled pits that continue to silt up streams; even though backfilling of mining pits improves the likelihood of natural regeneration (Timsina, et al., 2022), backfilling is neither affordable nor technical feasible at the scale of this issue, because most material has been washed away. Importing borrow soil from another location would merely transfer the environmental disturbance rather than resolve it.

Therefore, regrade pit rims and tailings in place to gentler 3:1 slopes or stepped benches, then seed with fast-rooting grasses and native pioneers while installing simple erosion controls such as brush layers or straw wattles. Deeper voids can be repurposed as fishponds with stabilised overflow channels, and the surrounding terraces converted to agroforestry or seasonal crops.

Illustrative Example: Landform Design at Compagnie Kreek

The rehabilitation plan for Compagnie Kreek includes the partial backfilling of remaining mining pits to reduce safety risks and improve drainage (TAUW, 2025). The surfaces of existing deposited tailings ("Bakka Santi") will be re-profiled to create gentle, stable slopes. This is a prerequisite for the subsequent topsoil application, as placing valuable topsoil on an unstable slope would result in its immediate loss to erosion. The design aims to create a landscape that could be safely used for the community's planned agricultural activities.

Development of Soil Balance

The rehabilitation plan must include a Soil Balance that comprehensively summarizes all proposed soil movement across the site. The Soil Balance is a register detailing every cut and fill operation, with each entry assigned a unique identifier that correlates to a precise location on the site map.

This Soil Balance must specify the estimated quantity (volume) and the quality (chemical/physical properties) for the material involved in each cut and fill. The Soil Balance functions as a critical management tool, allowing the rehabilitation plan to be adjusted based on the actual quantity and usability of the available soil. The central objective is to minimize the import of external soil material and minimize on-site soil transport.

Materials & Equipment:

- Excavator or Bulldozer (for large-scale work)
- Manual labour with shovels and wheelbarrows (for smaller sites or refining slopes)
- Surveying equipment (e.g., A-frame level, laser level) for laying out contours

Estimated Timeline: Highly variable. Major earthworks can take several weeks to months depending on the site size and equipment availability.

6.3 Soil Restoration

The installation of the new topsoil follows earthworks. Its goal is to rebuild a living topsoil capable of supporting productive vegetation. The lessons from the

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Compagnie Kreek pilot are central to this section, demonstrating the power of simple, locally-sourced solutions.

Technical Guidance:

- **Spreading Salvaged Topsoil:** The original topsoil is a precious, non-renewable resource containing seeds, organic matter, and microbes. If any topsoil was salvaged and stockpiled during mining, its proper management is paramount (see Figure 6.1)
 - **Procedure:** If fresh topsoil is being stripped from an adjacent area for concurrent restoration, it should be moved and spread immediately ("direct return") to preserve its biological activity. If stockpiled, piles should be low (<2 meters) and long to maximize aeration and prevent anaerobic conditions which kill beneficial microbes. Stockpiles should be seeded with a cover crop (like a local legume) to prevent erosion and maintain soil health (Bastiansz et al., 2023)
 - **Spreading:** For restoration, a layer of 10-30 cm of this salvaged topsoil is spread evenly over the re-graded subsoil. Avoid using heavy machinery in wet conditions to prevent compaction
- **Organic Matter Amendments:** Where salvaged topsoil is unavailable or insufficient, organic matter must be added
 - **Compost:** Locally produced compost from agricultural waste or community organic waste can be an excellent source of stable organic matter and nutrients, but its availability, quality, volume, labour requirements and maturation time must be assessed during project preparation. If sufficient compost is not available, the project should consider whether compost production can realistically be

established with local partners such as CELOS before relying on it as a core restoration measure

- **Biochar:** A form of charcoal produced by heating biomass in a low-oxygen environment. As a soil amendment, it can improve water retention, nutrient holding capacity and microbial habitat. In contaminated areas, biochar may also contribute to immobilization of mercury or other metals, but this contaminant-management function should be evaluated separately from its role as a general soil improver
- **Application:** Apply generous amounts of compost and/or biochar and incorporate into the surface layer

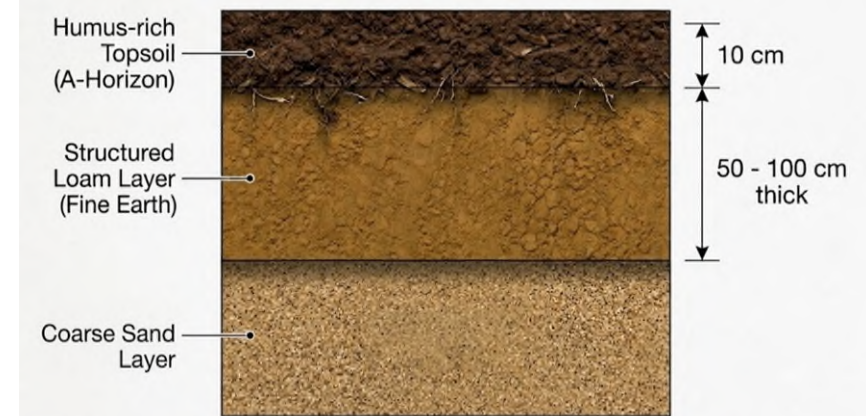


Figure 6.1 Topsoil restoration on top of backfilled mine pits or on top of mine tailings

- **Leguminous Cover Crops:** Planting a fast-growing, nitrogen-fixing cover crop is a highly effective biological amendment for early stabilization. These plants can convert atmospheric nitrogen into plant-

available forms when effective rhizobia are present, rapidly protect the soil surface, suppress weeds and add organic matter as they die back. However, nitrogen fixation does not resolve broader nutrient limitations such as phosphorus, potassium or micronutrient deficiencies. On newly exposed or biologically poor substrates, inoculation of seeds or planting material with appropriate rhizobia is recommended, and the effectiveness of nodulation should be checked in the field. Inactive root nodules are white or pale inside; active nitrogen-fixing nodules are pink or reddish inside

- **Application:** When using seeds use three per plant hole. The planting distance depends on the type but should be short to have the plant cover the soil in a minimum of time. Planting is preferably carried out just before the rain starts. These leguminous should be growing for at least one season. Better is to grow leguminous for multiple seasons to increase the organic matter content, improve the soil structure and have a maximum improvement of the soil fertility
- **Improving Soil Biology (Inoculation):** Kick-starting the soil food web is essential for nutrient cycling and soil structure development
 - **Biofertilizers:** These are products containing living microorganisms that enhance plant growth. Key types include:
 - *Rhizobium* inoculants for legume species (to fix atmospheric nitrogen)
 - *Azospirillum* or *Azotobacter* for non-legumes (to fix smaller amounts of nitrogen)
 - Phosphate Solubilizing Bacteria (PSB) to make soil phosphorus available to plants

- **Mycorrhizal Inoculants:** These are beneficial fungi that form a symbiotic relationship with plant roots, vastly extending their reach for water and nutrients, particularly phosphorus
 - **Application Methods:** Inoculants are most effective when applied directly to the seed or root zone. Common low-cost methods include:
 - Seed Coating: Mix powdered inoculant with a sticky solution (e.g., a weak sugar or jaggery solution) and coat seeds before planting
 - Root Dipping: For seedlings, create a slurry of inoculant and water and dip the bare roots before transplanting
 - Soil Drenching: Mix liquid inoculant with water and apply directly to the soil around the base of plants
 - **Compost Tea:** This is a low-cost, locally-producible method to introduce a diverse array of beneficial microbes
 - Method: Steep a bag of high-quality compost in aerated, non-chlorinated water for 24-48 hours. The resulting "tea" can be diluted and applied as a soil drench or foliar spray
 - **Materials & Equipment:**
 - Salvaged topsoil
 - Compost, biochar, manure
 - Biofertilizer and mycorrhizal inoculants
 - Equipment for brewing compost tea (bucket, air pump, compost bag).
 - **Estimated Timeline:** Initial improvements can be seen within one growing season, but rebuilding a truly healthy soil profile is a multi-year process
- To assist the user of this guidance in selecting soil amendments Table 5.1 provides a comparative Analysis of Soil Amendments.

Illustrative Example: The Core Lesson from Compagnie Kreek

The Compagnie Kreek pilot shows that successful soil restoration depends on both a fertile topsoil layer and sufficient water-holding capacity in the rooting zone. The application of a 10 cm layer of locally salvaged topsoil was the most effective treatment for initiating plant growth, while the use of a local leguminous cover crop, such as *Mucuna* sp. ('Okray Pesi'), helped stabilize the surface and support early nutrient cycling. However, the dry season highlighted an important limitation: where the underlying material consisted mainly of very coarse sand and gravel, the soil could not retain enough water to sustain plant growth without additional support, such as irrigation, shading, or thicker/finer-textured soil layers. The core lesson is therefore that restoration designs should not focus only on adding organic matter at the surface but must also ensure adequate water retention below the topsoil.

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Table 6.1 Comparative Analysis of Soil Amendments

Amendment Type	Key Function	Typical Application Rate	Sourcing	Relative Cost	Pros	Cons	Compagnie Kreek Finding ²
Salvaged Topsoil	Provides organic matter, nutrients, seed bank, and microbial community.	A minimum of 10-15 cm layer as topsoil.	Stripped from pre-mining site or borrowed from adjacent areas.	Low (if on-site)	Most holistic solution; introduces all key soil components at once.	Limited availability; can be costly to transport if off-site.	Highly effective. The most successful and practical treatment (so far) ³ .
Leguminous Cover Crop	Nitrogen fixation, erosion control, weed suppression, organic matter addition.	10-20 kg/ha of seed	Local seed suppliers or community seed banks.	Low	Actively builds soil fertility; rapid ground cover.	May require specific rhizobia inoculants; can be invasive if non-native.	Highly effective (<i>Mucuna Sp.</i>)
Compost	Provides stable organic matter and slow-release nutrients.	20-50 tons/ha	Local agricultural waste, community composting programs.	Low to Medium	Excellent for improving soil structure and water retention.	Can be bulky to transport; quality can be variable.	Not explicitly tested, but a standard best practice.
Biochar	Improves water/nutrient retention; immobilizes contaminants; long-term carbon storage.	5-20 tons/ha	Produced locally from agricultural or forestry waste.	Medium	Very high persistence in soil; co-benefits for contaminant management.	Requires specific production equipment (kilns); can be costly.	Not tested, but high potential for contaminated sites.
Imported Clay	Intended to improve texture and organic matter.	N/A	Commercial suppliers (often distant).	High	-	Expensive, logistically difficult, ineffective at raising organic matter.	High cost, less effective.

² This statement is based on the first results of the pilot project in Compagnie Kreek and will be reviewed when the final results of the pilot are available in the next version of this Guidance

- **Armouring and bank stabilisation:** Boulder walls, vegetated soil lifts, coir structures or other natural materials may be required where flow velocities or unstable banks create erosion risks
- **Riparian and wetland vegetation:** Vegetation should be introduced to resist erosion, provide shade, regulate stream temperature, enhance biodiversity and create habitat for terrestrial and aquatic species. Species selection should reflect local riparian conditions and wet-tolerant native vegetation

Sedimentation pools or sediment traps are particularly relevant where disturbed soils and fine tailings continue to enter surface water. Their function is to reduce flow velocity, allow suspended sediment to settle and prevent further transport of turbid water downstream. They should be located where they can be safely maintained and where accumulated sediment can be removed or stabilized if needed. Where local materials are available, simple permeable structures made from timber, branches, stones or other natural materials may be used, provided that they do not obstruct flood flows or create new erosion risks.

These measures should be selected based on the site layout, expected water levels, soil texture, slope stability and community use of the watercourse.

6.4.2 Wetland and Water-Retention Areas

In some cases, former mining pits, low-lying areas or disturbed floodplains can be integrated into the rehabilitation design as wetland or water-retention areas. The objective is not only to manage water, but also to support nature

development, increase water storage capacity, reduce flood risk and create habitat for aquatic and riparian species. Where water quality is suitable and risks are controlled, such areas may also support future community uses, such as controlled water access, fish habitat or small-scale aquaculture.

Wetland development should only be considered where the area can be made safe, where water quality does not pose unacceptable risks, and where stagnant water will not create health or nuisance risks. Measures may include controlled excavation, partial backfilling, bank profiling, creation of shallow margins, stabilization of steep slopes, and planting of suitable wetland or riparian vegetation. The design should avoid steep, unsafe pit edges and should include safe access points only where these are needed by the community.

Relevant building blocks for wetland and water-retention areas include excavation, partial backfilling, profiling, slope stabilization, vegetated margins, sedimentation zones, controlled inlets and outlets, and monitoring of water quality and water levels. These measures should be combined with the soil restoration plan so that surrounding restored soils are protected against erosion, flooding and excessive drying.

6.5 Nature development

Nature development can be described as ecosystem rehabilitation. This is accomplished by techniques for enrichment planting and fostering natural regeneration on restored soils. For site components designated for conservation or as part of a larger ecological corridor, the goal is to re-establish

a resilient, biodiverse native ecosystem. In tropical regions, full-scale reforestation by planting rows of trees over an entire site can be prohibitively expensive and may result in a low-diversity plantation rather than a functional forest. More cost-effective and ecologically sound approaches focus on catalysing natural succession (Elliott et al, 2023).

Technical Guidance:

- **Natural Regeneration (Passive Rehabilitation):** In some cases, the most cost-effective approach is to create the right conditions and let nature do the work. This is most applicable where:
 - The site is adjacent to a healthy, intact forest or grassland that can provide a natural source of seeds
 - Soil conditions have been sufficiently improved to allow seeds to germinate and grow
 - Methods to assist natural regeneration:
 - Protect the site: Fence the area to exclude grazing animals that would eat young seedlings
 - Control invasive species: Remove aggressive, non-native weeds that can out-compete native seedlings
 - Install bird perches: Erect simple poles or dead trees throughout the site. Birds will use these perches and deposit seeds from the surrounding landscape in their droppings, effectively "planting" a diverse mix of species
- **Enrichment Planting (Active Rehabilitation):** In areas that have some level of natural regeneration but lack diversity or key species, enrichment planting can be used. This involves planting seedlings of desired species

(often valuable timber or fruit trees) in small gaps or along cleared lines within the regenerating forest (Tiwari et al., 2025). This enhances the ecological and economic value of the recovering forest without the cost of clearing and planting the entire site.

- **Applied Nucleation (or Tree Islands):** This technique involves planting dense islands or clusters of trees rather than covering the entire area (BC Campus, 2022). These islands act as "nuclei" of forest recovery
 - **Species Selection:** The islands should be planted with a mix of "framework species"—fast-growing, hardy native species that produce fleshy fruits or other resources attractive to seed-dispersing wildlife like birds and bats (Karam et al., 2012)
 - **Mechanism:** As these trees grow, they create a favourable microclimate, suppress weeds, and attract wildlife. The animals, in turn, perch in the trees and disperse the seeds of many other native species from the surrounding forest into the rehabilitation area, effectively "planting" the next generation of trees for free. This accelerates natural succession and results in a more diverse and structurally complex forest

Best Practice: Selecting Framework Species

The key to successful applied nucleation is choosing the right species. Ideal framework species for tropical restoration should (Karam et al., 2012):

- Be native to the local ecosystem.
- Be tolerant of open, sunny conditions and grow relatively quickly.
- Produce resources (e.g., fleshy fruits, nectar) that attract a wide range of seed-dispersing animals within a few years of planting.
- Have a canopy structure that suppresses invasive grasses and weeds.

6.6 Livelihood Integration

Rehabilitation should not be seen as an end to productive land use, but as the beginning of a new, sustainable form of it. Therefore, integrating terrestrial-based opportunities like agroforestry and horticulture directly into the rehabilitation design generates opportunities and is crucial for securing long-term community buy-in and ensuring the rehabilitated landscape is valued and maintained. Agroforestry is a particularly powerful tool for achieving this synergy (Awazi et al., 2024).

Technical Guidance:

- **Agroforestry Systems:** Agroforestry is the intentional integration of trees and shrubs with crop and/or animal systems (Raj et al., 2025). On rehabilitated mine sites, this provides multiple benefits: the trees help to continue building soil fertility, prevent erosion, and create a more resilient

microclimate, while the crops provide food and income for local families (Center for Agroforestry, 2024)

- **System Design:** Several designs are suitable for post-mining landscapes:
 - **Alley Cropping:** Rows of trees (e.g., nitrogen-fixing legumes, fruit trees, or timber species) are planted with wider "alleys" in between where annual crops like cassava, maize, or vegetables can be grown (Raj et al., 2025)
 - **Multi-strata Systems:** These systems mimic the structure of a natural forest, with a canopy of tall fruit or timber trees, a mid-layer of smaller trees like coffee or cacao, and a ground layer of shade-tolerant crops
- **Species Selection:** The choice of species should be based on a combination of ecological suitability and market opportunities. A mix of short-term cash crops, medium-term fruit and nut trees, and long-term timber species can provide a diversified and resilient income stream
- **Community Nurseries:** The need for large numbers of native tree and grass seedlings for the rehabilitation project itself creates a business opportunity
 - **Model:** Support the establishment of a community-run nursery to produce the planting materials for the project. Provide training in seed collection, propagation, and business management. The nursery can then sell seedlings to other rehabilitation projects in the region, creating a sustainable enterprise

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- **Horticulture and Market Gardens:** On safely capped or remediated areas with good soil, support the development of intensive vegetable gardens for household consumption and sale at local markets
- **Aquaculture:** Backfilled mine pits that are geotechnically stable and hold clean water (verified through testing) can be repurposed as ponds for aquaculture
 - **Model:** Introduce fast-growing, hardy fish species (e.g., tilapia). This can provide a valuable source of protein for the community and a marketable product
 - **Caution:** This is only suitable where water quality is confirmed to be safe and there is no risk of contaminated water entering the pond
- **Recreation:** Recreation facilities are often sparse in rural communities. Providing these (e.g., a football pitch) as part of the project could fulfil the wishes of the community
- **Materials & Equipment:**
 - Seeds and seedlings for agroforestry trees and crops
 - Nursery supplies (poly-bags, soil medium, shade cloth)
 - Fish fingerlings and feed for aquaculture
- **Estimated Timeline:** Livelihood benefits can begin within the first year (e.g., from vegetable gardens). Agroforestry systems begin to yield significant returns after 3-5 years as trees mature

Example: CELOS Agroforestry Project at Compagnie Kreek

At Compagnie Kreek, agroforestry is being implemented as an integral component of the larger participatory rehabilitation demonstration project funded by EMSAGS and implemented with support from CELOS. As part of this demonstration project, restored areas are being prepared for productive land use by combining soil improvement, site stabilization, planting, and community involvement. The agroforestry plot demonstrates how rehabilitation can move beyond ecological repair alone and create a practical pathway toward food production, alternative income, and long-term stewardship of restored land. The example also highlights that livelihood integration should be built into the restoration design from the start, with clear attention to soil fertility, water availability, crop and tree selection, community roles, and maintenance responsibilities.

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7 Monitoring, Evaluation & Adaptive Management

Monitoring and Evaluation (M&E) is not simply a reporting requirement to be completed at the end of a project. It is an active management tool that provides the information needed to learn, adapt, and improve the rehabilitation process in real-time. An effective M&E system is the foundation of adaptive management, which is essential for navigating the inherent uncertainties of ecological rehabilitation.

7.1 Key Performance Indicators

A robust M&E plan uses a balanced set of Key Performance Indicators (KPIs) to track progress towards the project's goals and success criteria. These KPIs should be organized in a hierarchy, from simple metrics that can be tracked by community members to more complex indicators requiring technical expertise. Table 7.1 provides an overview of monitoring KPIs. This allows the M&E system to be adapted to the capacity and budget of any given project.

7.2 Monitoring Plan

The KPIs from the table on the next page needs to be integrated into a formal Monitoring Plan. This plan is the operational guide for all M&E activities. A template for the plan should include:

- **Indicator Definition:** A precise definition for each KPI (from Table 7.1)
- **Data Collection Method:** A step-by-step description of how the data will be collected (e.g., "Establish ten 5m x 5m permanent plots randomly located within the rehabilitated area...").

- **Frequency and Timing:** When and how often each indicator will be measured
- **Responsibilities:** Clearly state who is responsible for collecting, managing, and analysing the data (e.g., "Community monitors will collect seedling survival data; the project officer will compile and analyse it."). When the community has the responsibility for a domain it is important that the responsible persons are involved from the start so that they come on board and see the progress. Their involvement is crucial for the continued adaptation of the plan once the machinery and all other parties involved have left
- **Data Management:** A plan for how data will be stored, quality-checked, and shared. Simple tools like Excel or Google Sheets can be effective.

Our reference R003-1291225IKR-V03-sss-NL

Table 7.1 Hierarchy of Monitoring KPIs

Domain	KPI	Method	Frequency	Responsibility
Physicochemical	% Bare Ground	Visual estimation using quadrats	Quarterly (Year 1-2), Annually (Year 3+)	Community Monitor
	Presence of Erosion (Rills/Gullies)	Visual inspection along transects	After major rain events	Community Monitor
	Soil Organic Matter (%)	Laboratory analysis (LOI)	Annually (Year 1-3), then every 3 years	Technical Team
	Soil pH	Field meter or laboratory analysis	Annually (Year 1-3)	Technical Team
Ecosystem functioning	Seedling Survival Rate (%)	Counting surviving seedlings in permanent plots	6 months, 1 year, 3 years post-planting	Community Monitor
	Seedling Height/Girth Growth	Measurement in permanent plots	Annually	Community Monitor
	Native Plant Species Richness	Species count in permanent plots	Annually (starts after Year 2)	Technical Team
	Wildlife Sightings (esp. birds)	Standardized observation log	Ongoing	Community Monitor
Socio-economic	# of People Trained	Project records	Per training event	Project Team
	Household Income from Agroforestry Products	Household surveys	Annually (after first harvest)	Project Team
	Community Perceptions of Project	Focus group discussions	Annually	Project Team
	Adoption Rate of New Techniques	Farmer interviews/surveys	Biennially	Project Team

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7.3 Adaptive Management

Adaptive management is a structured process of "learning by doing." It treats soil restoration actions as experiments and uses the results from monitoring to systematically improve the approach over time. This moves a project away from a rigid, linear plan and towards a flexible, iterative cycle of planning, doing, monitoring, and adapting:

- **Plan:** Develop the initial rehabilitation plan based on the best available information (the baseline assessment). Define clear objectives and success criteria
- **Do:** Implement the planned rehabilitation activities
- **Monitor & Evaluate:** Systematically collect data on the KPIs defined in the monitoring plan. Analyse the data to evaluate progress against the success criteria
- **Learn & Adapt:** This is the critical step. Compare the actual results with the expected results. Why were there differences? Based on this new knowledge, decide how to adapt the plan. This could involve changing a technique (e.g., switching to more drought-tolerant species), adjusting the intensity of an activity (e.g., applying more compost), or reallocating resources. The cycle then begins again with a revised plan

To make the "Adapt" step systematic rather than arbitrary, it is useful to define decision thresholds or "triggers" in advance. These are pre-agreed values for specific KPIs that, if crossed, automatically trigger a specific management response. Table 7.2 gives examples of adaptive management triggers and corresponding corrective actions.

Table 7.2 Examples of an Adaptive Management Triggers

Monitoring Indicator	Threshold / Trigger	Corrective Action / Management Response
Plant Survival Rate	If survival rate is < 60% after the first rainy season.	1. Investigate cause (e.g., drought, pest, soil issue). 2. Re-plant affected areas during the next rainy season. 3. Consider introducing more resilient species or improving water harvesting techniques.
Soil pH	If soil pH remains < 5.0 one year after initial lime/biochar application.	1. Re-sample and test soil to confirm pH. 2. Apply a second, targeted application of lime or wood ash.
Community Participation	If participation in communal workdays drops by > 50% for two consecutive months.	1. Hold a community meeting to understand the reasons for the decline. 2. Re-evaluate incentive structures or work schedules. 3. Reinforce communication about project benefits.

This framework creates a feedback loop that forces the project team to respond to data in a timely and systematic way, rather than waiting until the end of the project to discover that the initial strategy was not working. It is an essential tool for managing risks and increasing the likelihood of long-term project success.

8 Governance & Funding Alignment

Successful soil restoration projects do not happen in a vacuum. They must be aligned with national laws and international commitments, supported by clear institutional arrangements, and financed through sustainable funding mechanisms. This section provides guidance on navigating the governance and financial landscape.

8.1 Regulatory Compliance

Projects must operate within the legal framework of the host country. This requires an understanding of national laws related to environmental protection, mining, land tenure, and community rights: A compliance checklist for alignment with national laws and international treaties should be developed at the start of the project, covering:

- Environmental Impact Assessment (EIA) requirements
- Mining and closure regulations
- Obligations of International Convention(s)
- Water quality and soil contamination standards
- Forestry and biodiversity protection laws
- Land tenure and community property rights

Alignment with the Minamata Convention on Mercury:

The Minamata Convention is a global treaty to protect human health and the environment from mercury pollution (Douine et al., 2025). Article 7 of the Convention specifically addresses ASGM, requiring countries where ASGM is "more than insignificant" to develop and implement a National Action Plan (NAP) to reduce and, where feasible, eliminate mercury use (Douine et al., 2025).

Soil restoration projects are a powerful tool for helping countries meet their Minamata obligations. By soil restoration of mercury-contaminated sites, restoration directly addresses a key legacy of ASGM. Furthermore, by integrating livelihood alternatives like agroforestry, projects can help reduce the economic pressure that drives miners to use mercury in the first place. Project proposals should explicitly state how their activities will contribute to the goals of the host country's NAP. For example, Suriname acceded to the convention in 2018 and finalized its first NAP in 2023, which includes objectives for reducing mercury release and enhancing awareness (Government of Suriname, 2023). Soil restoration projects can directly support these national commitments.

8.2 Roles & Responsibilities

Site rehabilitation projects involve multiple actors/stakeholders, including NGOs, community leaders, government agencies, and technical experts (see Figure 8.1 for an overview of typical Stakeholder related to ASGM Sites). A lack of clarity about who is responsible for what can lead to confusion and inefficiency. A RACI matrix is a simple but powerful tool for clarifying roles and responsibilities.

RACI Definitions:

- Responsible: The person(s) who do the work
- Accountable: The one person ultimately answerable for the correct and thorough completion of the task(s)

- Consulted: People who provide input and whose opinions are sought
- Informed: People who are kept up-to-date on progress



Figure 8.1 Overview of Typical Stakeholder related to ASGM Sites

8.3 Post-project Stewardship and Site Ownership

Rehabilitation projects do not end when the physical works are completed. Long-term success depends on continued stewardship of the rehabilitated site and the willingness of local stakeholders to maintain and protect the investments that have been made. Experience from post-ASGM rehabilitation projects shows that physical restoration measures can rapidly deteriorate if responsibilities for maintenance, monitoring and future land use are not clearly defined before project closure.

A post-project stewardship plan should therefore be developed during the implementation phase and agreed upon by the relevant stakeholders. This plan should clearly identify who is responsible for routine maintenance, monitoring, protection of the rehabilitated area and decision-making regarding future land use. Whenever possible, responsibilities should be embedded within the local community to strengthen ownership and long-term commitment.

Equally important is the creation of incentives that encourage communities and stakeholders to continue protecting and maintaining rehabilitated areas after project completion. These incentives may include improved agricultural opportunities, agroforestry production, safer living conditions, access to land, community facilities or other livelihood benefits. Rehabilitation efforts are generally more sustainable when local stakeholders perceive the restored area as a valuable community asset rather than an externally funded project.

Clear agreements on responsibilities, expected benefits and long-term management arrangements should therefore be established before project closure to increase the likelihood of lasting environmental and social outcomes.

8.4 Funding

Securing adequate short and long-term funding is a major challenge for rehabilitation. Practitioners should look beyond single-source grants and explore a diversified funding strategy. Below are the aspects listed as guidance on developing budgets and accessing co-financing:

- Public and Multilateral Funds:
 - Global Environment Facility (GEF): is a major financial mechanism for international environmental conventions, including Minamata. It funds projects related to chemicals and waste, biodiversity, and land degradation, all of which are relevant to ASGM rehabilitation. The EMSAGS project in Suriname is a GEF-funded initiative (Government of Suriname, 2023)
 - Green Climate Fund (GCF): For projects that can demonstrate significant climate change mitigation (carbon sequestration) or adaptation benefits, the GCF is a potential source of large-scale funding
 - Bilateral Development Aid: Many national development agencies fund environmental and livelihood projects in the Guiana Shield region
 - Communal in-kind funding like labour and local available building materials
- Private and Blended Finance:
 - Corporate Social Responsibility (CSR): Large-scale mining companies operating in the region may have CSR funds or foundations that can support rehabilitation of legacy ASGM sites
 - Payment for Ecosystem Services (PES): As rehabilitated sites begin to generate measurable ecosystem services, opportunities for PES may arise
 - Carbon Credits: Reforestation and agroforestry projects can sequester significant amounts of carbon. By measuring and verifying this sequestration, projects may be able to sell carbon credits on the voluntary market, creating a long-term revenue stream for the community (EMSAGS, 2025d)
- Biodiversity Offsets: In some regulatory contexts, developers who impact biodiversity in one area are required to fund conservation or restoration in another. Rehabilitated ASGM sites can be ideal recipients for such offset funds
- Nature-Positive Enterprises: The most sustainable funding model is one where the rehabilitated landscape generates its own revenue. Supporting the development of community-based enterprises to process and market products from agroforestry systems (e.g., fruit, nuts, specialty coffee, timber) can create a self-sustaining economic engine for long-term landscape stewardship (EMSAGS, 2025d)

9 Case studies

9.1 The Compagnie Kreek Pilot in Suriname

The Compagnie Kreek work in Suriname's Brokopondo District provides a practical case study for applying this guideline under real post-ASGM conditions. The work started with a smaller soil restoration pilot using a Randomized Block Design (RBD) to compare four soil amendment options with an untreated control. The aim was to identify a technically feasible and cost-effective approach for restoring severely degraded mine tailings so that they could support vegetation growth. The findings from this pilot were subsequently used to inform a larger participatory rehabilitation demonstration project at Compagnie Kreek, in which soil restoration, water management, site safety, agroforestry, and community livelihood objectives are addressed together.

The most important technical lesson from the Compagnie Kreek work is that successful plant establishment depends not only on adding fertile material at the surface, but also on creating a rooting zone with sufficient water-holding capacity. The application of locally salvaged topsoil proved effective for initiating vegetation growth, particularly where it improved organic matter, nutrient availability, and biological activity in the topsoil. However, where the underlying material consisted mainly of very coarse sand and gravel, plant growth remained vulnerable during dry periods because the subsurface retained too little water. This highlights the need to consider both the quality of the applied topsoil and the physical properties of the underlying material when designing soil restoration measures.

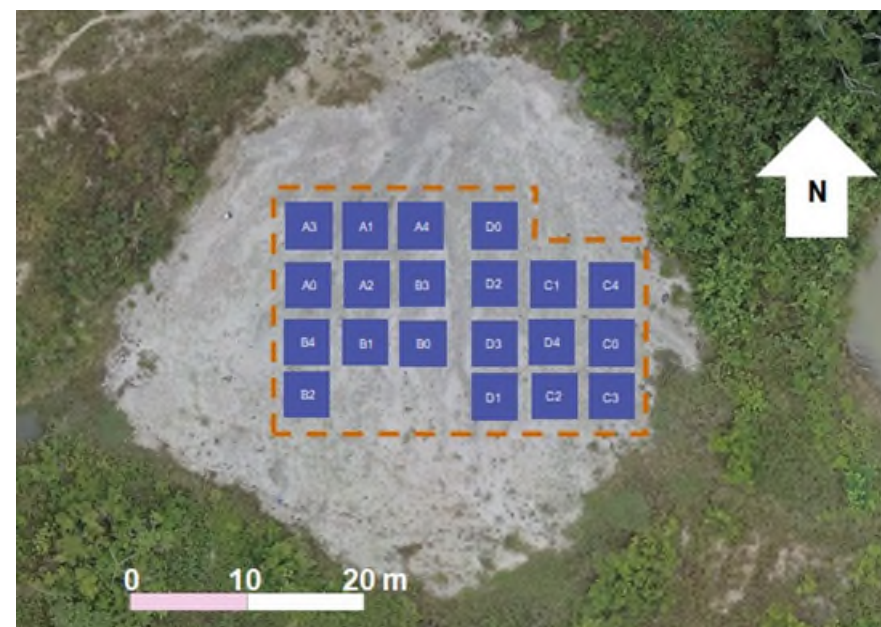


Figure 9.1 A map with the experimental pilot to test feasible recipes to rehabilitate the soils at ASGM sites in the direct vicinity of Compagnie Kreek.

9.1.1 Project Context and Partnership

The Compagnie Kreek work was developed within the broader “Improving Environmental Management in the Mining Sector of Suriname, with Emphasis

on Artisanal and Small-Scale Gold Mining” (EMSAGS) project, funded by the Global Environment Facility (GEF), with additional support from the TAUW Foundation. Technical and implementation partners included TAUW bv, Boudewijn Fokke Soil Consultancy, Wageningen University and Research, and the Centre for Agricultural Research in Suriname (CELOS). This partnership combined international soil restoration and environmental expertise with local knowledge, community engagement, agricultural experience, and field implementation capacity.

The later demonstration project expanded the scope from testing soil restoration options to demonstrating how a degraded post-ASGM landscape can be rehabilitated for safer and more productive future land use. The project included earthworks, drainage improvements, preparation of an agroforestry plot, stabilization of unsafe areas, construction of safer waterfront access, and continued community engagement. As such, Compagnie Kreek now functions not only as a soil restoration pilot, but also as an example of how rehabilitation can be linked to livelihood development and long-term land-use planning.

9.1.2 Community Engagement and Goal Setting

Community engagement was central to the Compagnie Kreek approach. Through regular presence in the area and consultation with local stakeholders, the project team worked in line with the principles of Free, Prior, and Informed Consent (FPIC). Discussions with community leaders, farmers, and residents showed that the main concerns were not limited to loss of vegetation. The community also highlighted unsafe mining pits, poor water quality, disrupted drainage, flooding, limited opportunities for agriculture, and constraints on future village expansion.

These concerns shaped the project objectives. Rather than focusing only on ecological recovery, the desired end state was a safer, more stable, and more productive landscape that could support agriculture, agroforestry, improved water management, and future local use. The demonstration project therefore integrated technical restoration measures with community priorities, including the preparation of land for agroforestry and the improvement of site safety around water bodies and former mining pits.

9.1.3 Baseline assessment Findings

- The baseline assessment combined participatory information, field observations, drone-based mapping, soil sampling, sediment sampling, and surface-water assessment. The site contained typical ASGM landforms, including open and partly backfilled mining pits, redirected drainage features, deposited tailings locally known as “Bakka Santi,” and areas with poor or absent vegetation. The assessment showed that the main restoration challenge was the severe loss of soil function rather than widespread mercury contamination

Key findings included:

- **Limited mercury concerns:** Soil, sediment, and water investigations did not identify mercury as the main limiting factor for restoration at the pilot site. Water samples had mercury concentrations below detection limits, and soil and sediment concentrations were generally within acceptable limits for the intended restoration approach
- **Severe physical and chemical soil degradation:** Many mine tailings and backfilled areas consisted of coarse sand and gravel with very low organic

matter, poor structure, low nutrient availability, and limited natural regeneration. These conditions strongly limited plant growth

- **Low water-holding capacity:** The coarse-textured subsurface was a critical constraint. Even where topsoil and cover crops supported initial establishment, the dry season showed that insufficient water retention in the rooting zone can limit plant survival and growth without additional support
- **Drainage and safety issues:** Former mining pits, altered creek flow, unstable slopes, and blocked drainage features created water-management and safety concerns. These issues needed to be addressed as part of the broader rehabilitation design
- **Localized copper and zinc concerns:** Some sediment and water-related observations indicated elevated copper and zinc in specific areas, requiring attention in water management and future monitoring



Figure 9.2 Movement of fine-textured soil towards Agroforestry Area

9.1.4 Restoration Strategy and Key Learnings

The restoration strategy focused on rebuilding basic soil functions while addressing community priorities for safety, drainage, agriculture, and agroforestry. The original pilot tested different soil amendment approaches, while the larger demonstration project applied lessons from these trials at a more practical scale.

The main lessons learned are:

- **Locally salvaged topsoil is a strong starting point:** A relatively thin layer of locally salvaged topsoil can provide organic matter, nutrients, microbial life, and a seed bank. In the Compagnie Kreek pilot, this proved more practical and effective than more complex and costly approaches using imported materials
- **Water-holding capacity is essential:** The pilot demonstrated that topsoil application alone is not sufficient where the subsurface consists of very coarse material. Restoration designs must ensure that the rooting zone can retain enough water during dry periods, for example by using thicker or finer-textured soil layers, incorporating organic matter, reducing evaporation through shading or cover crops, and considering irrigation during establishment where needed
- **Surface application may be preferable to dilution:** Applying fertile material as a concentrated surface layer can be more effective than mixing it through a thicker layer of poor substrate, because mixing may dilute organic matter, clay, and nutrients. However, the suitability of either approach depends on the underlying soil texture and water-retention capacity
- **Cover crops support early stabilization:** The use of a local leguminous cover crop such as *Mucuna sp.* ('Okra Pesi') helped stabilize the surface, suppress weeds, protect the soil from erosion, and support early nutrient cycling. Its effectiveness depends on seasonal timing, moisture availability, and the presence or introduction of suitable nitrogen-fixing soil organisms
- **Soil restoration is a slow and staged process:** The monitoring data of soil organic matter, nutrients and plant growth at the site clearly show that the soil rehabilitation follows the expected pattern of first improving soil structure and organic matter, secondly increasing soil moisture and nutrient retention capacity, and lastly nutrient content of the soil. Throughout, vegetation can establish with proper maintenance. This means that soil nutrient content increases and spread of vegetation beyond the replanted area is not to be expected in the short term, but will take years to be noticeable
- **Drainage and safety must be integrated from the start:** Rehabilitation of post-ASGM sites should not focus only on topsoil restoration. At Compagnie Kreek, disrupted drainage, former pits, unstable slopes, and water access were important design drivers. Future projects should map drainage patterns and water-related risks early in the baseline assessment
- **Seasonal planning is critical:** Planting, soil amendment, and monitoring should be planned around wet and dry seasons. Unrealistic deadlines can reduce the effectiveness of restoration trials and increase the risk of plant failure
- **Livelihood integration strengthens long-term relevance:** The larger demonstration project shows how soil restoration can be linked to agroforestry, productive land use, and community stewardship. This connection helps ensure that restored land becomes locally useful rather than only technically rehabilitated

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Figure 9.3 Reprofiling the open-mining pit to ensure slope stability and safer access

9.2 Community-Based Land Restoration and Governance in Ghana

Context: Ghana has a long and complex history of ASGM, known locally as "Galamsey." The sector operates within a different socio-political context than the Guiana Shield, with customary land tenure managed by traditional chiefs playing a significant role alongside state regulations. The environmental impacts are similar, including widespread land degradation and water pollution

(Watson et al., 2020). Ghana's National Action Plan under the Minamata Convention acknowledges these challenges and seeks to formalize the sector and reduce mercury use (Biodiversity Research Institute, 2025).

Challenge: How to implement restoration in a context of complex, overlapping land tenure systems and where state enforcement capacity is limited, requiring strong community-level governance to ensure success.

Intervention and Outcomes: A case study of an NGO-initiated, community-based restoration project in Ghana explored the conditions necessary for local communities to lead successful rehabilitation efforts (Pure Earth, 2024). The study found strong community support for reclaiming former mining lands using communal labour. However, the success of such initiatives was highly dependent on several key factors:

- **Role of Traditional Authorities:** Chiefs were identified as the most influential actors, with the power to enact and enforce local by-laws regarding land management and sanction non-compliance. Securing their active support and leadership was critical for mobilizing community actions and ensuring the long-term protection of rehabilitated areas
- **Land Tenure Security:** Community members were more willing to contribute labour and resources to restoration on land where their tenure rights were secure. In areas with insecure or contested tenure, there was less incentive for long-term investment in restoration
- **Community Organization:** While there was general support for restoration, the study highlighted a need for better organization among landowners and community members to align different land use priorities and collectively manage rehabilitated landscapes (Pure Earth, 2024)

Key Lesson: In contexts with strong traditional governance structures, restoration projects must work through and strengthen these institutions. The technical "Building Blocks" of restoration are necessary but not sufficient; success depends on embedding them within a robust framework of local governance, clear land tenure, and shared community rules.

9.3 Phytoremediation of Mercury-Contaminated Sites in Indonesia

Context: Indonesia is a global hotspot for ASGM and associated mercury contamination. Many sites have significant levels of mercury in both soil and processing water, posing a direct threat to the environment and human health. This context places these sites firmly in the "High-Risk Pathway" of the Decision Framework, requiring a primary focus on contaminant management.

Challenge: How to remediate soil and water with high mercury concentrations using low-cost, sustainable, and scalable technologies suitable for rural communities.

Intervention and Outcomes: A laboratory-scale study at an ASGM site in South Lampung, Indonesia, investigated the potential of phytoremediation using locally available plants (OHIO EPA, 2021). Initial assessments found mercury concentrations far exceeding national limits, with 0.367 mg/L in water and 74.8 mg/kg in soil. The study tested three plant species:

- **Water Remediation:** The aquatic plants water hyacinth (*Eichhornia Crassipes*) and water lettuce (*Pistia Stratiotes*) were used. Water hyacinth

was exceptionally effective, achieving 100% mercury removal from contaminated water within nine days. A combined treatment of both species also achieved complete removal, demonstrating a synergistic effect

- **Soil Remediation:** The terrestrial sedge nutsedge (*Cyperus Rotundus*) was planted in contaminated soil. Over 21 days, the plant reduced soil mercury concentrations by 61.8%. The plant accumulated mercury primarily in its roots but also translocated it to its leaves, indicating its potential for phytoextraction (removal of the contaminant by harvesting the plant biomass) (OHIO EPA, 2021)

Key Lesson: For highly contaminated sites, phytoremediation using carefully selected, locally adapted native plants can be a powerful and cost-effective component of the restoration strategy. This approach directly addresses the root cause of the risk (bioavailable mercury) and provides an accessible, nature-based solution that can be managed by local communities, turning a contaminated liability into a managed remediation system.

9.4 Integrating Mercury-Free Technology and Reforestation in Madre de Dios, Peru

Context: The Madre de Dios region in the Peruvian Amazon has experienced some of the most extensive forest destruction from ASGM globally, with tens of thousands of hectares of rainforest converted to barren, mercury-contaminated landscapes (Pure Earth, 2022). The region is a priority for both conservation and sustainable development interventions.

Challenge: How to link the adoption of cleaner mining technology directly with the restoration of legacy sites, creating a holistic model that addresses both ongoing pollution and past damage.

Intervention and Outcomes: A project led by the NGO Pure Earth from 2019-2022 worked with the AMATAF mining association in Madre de Dios on a dual-track program (Pure Earth, 2022).

Technology Transfer: Miners were trained on the health risks of mercury and provided with hands-on training in mercury-free processing techniques. The project helped repair and calibrate a gravimetric separation table owned by the association, enabling them to recover gold based on its density without using mercury.

Community-Led Restoration: Simultaneously, the project trained the same miners in reforestation techniques. This included hands-on training in species selection, planting, and the generation and application of soil amendments to restore the degraded soil. The project directly led the restoration of 5 hectares, and the empowered miners independently initiated the restoration of an additional hectare. The project successfully linked the miners to a responsible jewellery market, achieving the first sale of their certified mercury-free gold (Pure Earth, 2022).

Key Lesson: Restoration is most effective when it is part of a broader transition towards a more sustainable local economy. By directly linking training in cleaner production methods with training in ecological restoration, the project empowered miners to become agents of both pollution prevention and

environmental repair. This created a powerful new identity for the miners as stewards of the land and producers of responsible gold, providing a clear economic and social incentive to break from the destructive practices of the past.

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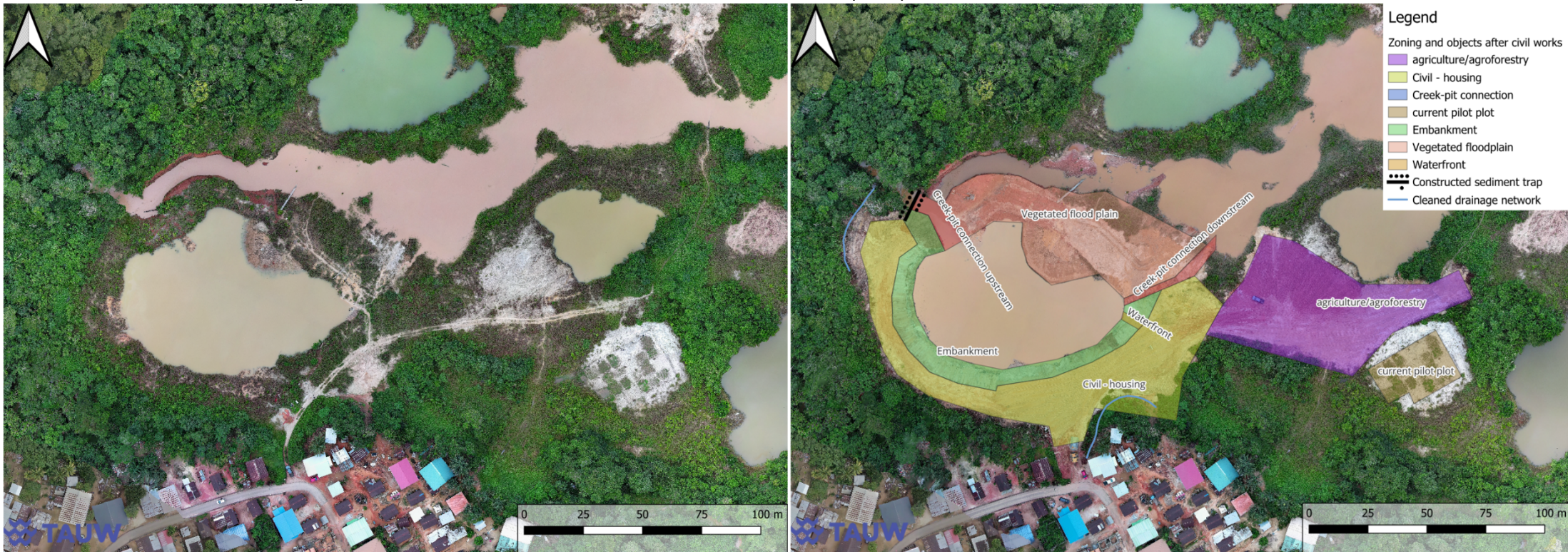
Appendix 1 Example Borehole log

Name of the village and site		Example of bore log		Site description	Near sluice box on tailings sloping west
Soil profile no	01	Longitude		Foreman	
Date started	dd/mm/yy	Latitude		Width sample pit	20 x 20 cm
Date completed	dd/m/yy	Height		Total depth soil observation	30 cm sample pit and 150 by soil auger
Surface	Bare	Vegetation	None	Weather	dry
Groundwater depth	Not detected	Nearby surface water	Open mine pit	Equipment used	Shovel, sampling spoon and hand auger
Soil layer depth in cm	Sample		Soil texture	Organic %	Soil colour
	Depth cm	Code			
00 - 10	00	C01-01	Coarse sand	0	Light gray
	10				
10 - 30	10	C01-02	Medium coarse sand	0	Pale yellow
	30				
30 - 100			Fine sand	0	Yellow
100 - 120	100	C01-03	Sandy loam	2 - 3	Dark brown
	110				
120 - 150			Clay loam	1	Dark reddish brown

Appendix 2 Example Site Maps

To illustrate the mapping process, this annex will provide two maps from the Compagnie Kreek pilot after the completion of the ESMAGS Demonstration Pilot to be completed in 2026.

- **Figure B1: Baseline Site Map.** An orthophoto map generated from the initial drone survey of the Compagnie Kreek site. It clearly shows the extent of the degraded area, including the location of mining pits, deposited tailings (“Bakka Santi”), and the diverted creek. This serves as an example of a high-quality baseline map
- **Figure B2: Conceptual Rehabilitation Plan Map.** A map overlaying the baseline photo with the proposed rehabilitation design. It delineates the different management site components: areas for backfilling and re-profiling, plots for topsoil application, the location of the CELOS agroforestry trials, and areas designated for natural regeneration. This illustrates how assessment data is translated into a spatial plan



Appendix 3 List of locally sourced materials and plants

This annex provides a model for how project teams can develop a list of locally appropriate and available resources for their rehabilitation work, reducing costs and increasing sustainability. The list is based on materials and species used or considered for the Compagnie Kreek project.

- Soil Amendments:
 - Topsoil: Sourced from adjacent, deserted shifting cultivation plot (with appropriate permissions).
 - Compost: Sourced from local agricultural producers (e.g., rice husks, chicken manure).
 - Biochar: Potential for local production using waste wood from site clearing.
- Revegetation Species:
 - Pioneer Cover Crop: *Mucuna Sp.* ('Okray Pesi') - A fast-growing, nitrogen-fixing vine.
 - Agroforestry Crops (CELOS Project): Cassava (*Manihot esculenta*), Banana (*Musa spp.*), Pineapple (*Ananas comosus*).
 - Framework Tree Species (for enrichment planting): A list of fast-growing, fruit-bearing native trees known to attract birds and other wildlife in the Guiana Shield region (e.g., species from the *Inga*, *Cecropia*, and *Ficus* genera).

Appendix 4 Template Standard Operating Procedure

A standard operating procedure should contain the following information:

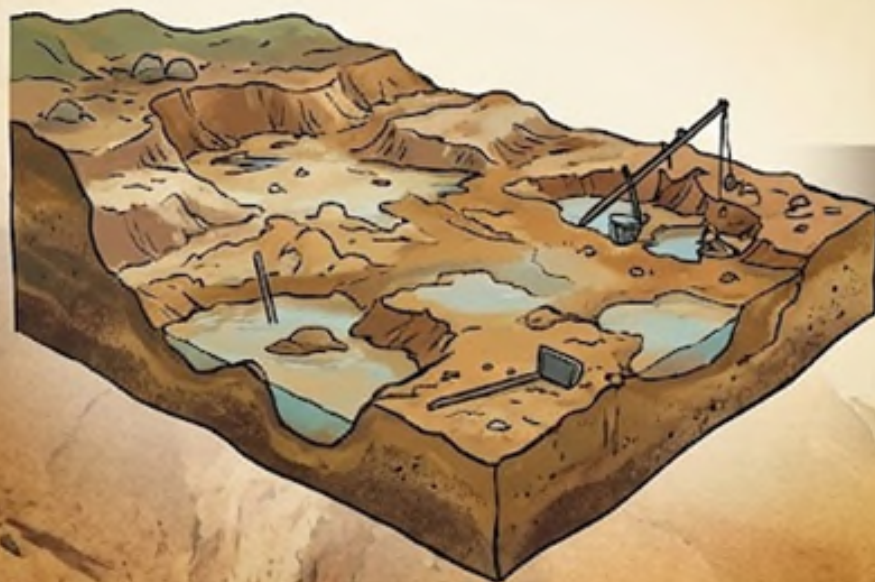
- SOP Title & ID: (e.g., "SOP-001: Application of Biochar").
- Purpose: A brief statement of the SOP's objective.
- Scope: Where and when this SOP applies.
- Responsibilities: Who is responsible for carrying out the procedure.
- Hazard Assessment: A list of potential hazards associated with the task (e.g., dust inhalation, manual handling).
- Required PPE: A specific list of Personal Protective Equipment required (e.g., N95 dust mask, gloves, safety boots).
- Materials & Equipment: A checklist of all necessary tools and materials.
- Step-by-Step Procedure: A clear, numbered list of actions from start to finish. This should be written in simple language and include illustrations or photos where possible.
- Waste Disposal: Instructions for managing any waste generated.
- Emergency Procedures: What to do in case of an accident or spill.

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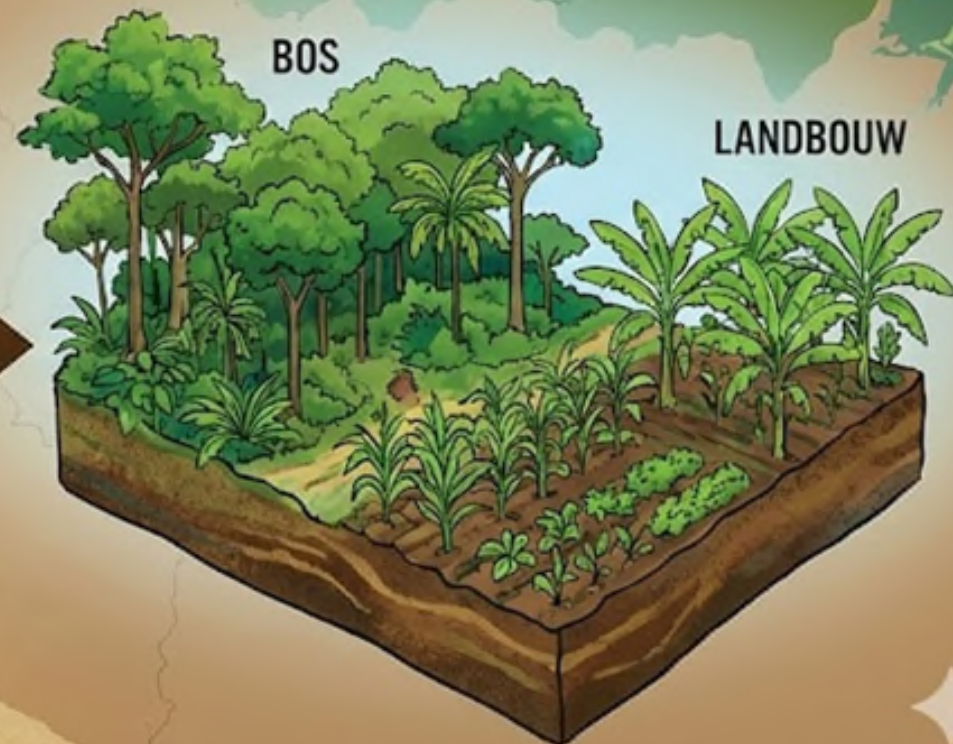
Appendix 5 Summary for Community Rehabilitators

PRAKTISCHE RICHTLIJN: HERSTEL VAN BODEM EN NATUUR OP VERLATEN GOUDMIJNLOCATIES (ASGM)

Een handleiding voor de gemeenschap
en uitvoerders in het Guyanaschild



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Deze handleiding is mogelijk gemaakt door de steun van de TAUW Foundation en EMSAGS, wiens initiële financiering de basis heeft gelegd voor dit initiatief. De projectpartners, waaronder TAUW bv, Wageningen University and Research, CELOS en Boudewijn Fokke Soil Consultancy, hebben allen een cruciale rol gespeeld door niet alleen financiële en materiële bijdragen te leveren, maar ook door hun uitgebreide kennis en expertise te delen. Het is belangrijk te erkennen dat de realisatie van deze handleiding niet mogelijk zou zijn geweest zonder de onschatbare input van de belanghebbenden en de lokale gemeenschap van Compagnie Kreek. Hun actieve betrokkenheid en samenwerking zijn bepalend geweest voor de koers van het project en het waarborgen van de relevantie voor de behoeften van de gemeenschap. Samen hebben deze collectieve inspanningen en bijdragen de weg vrijgemaakt voor een veelomvattend en impactvol project dat zich richt op de milieu-uitdagingen die gepaard gaan met ASGM (kleinschalige goudwinning). De inzet en samenwerking van alle betrokkenen onderstrepen de kracht van collectieve actie bij het aanpakken van complexe vraagstukken en het creëren van positieve verandering voor lokale gemeenschappen en het milieu.

Disclaimer

Dit document biedt algemene richtlijnen voor het herstellen van de bovenlaag van de bodem op verlaten ASGM-locaties. Het dient niet als vervanging voor de richtlijnen van het Minamata-verdrag, nationale regelgeving of professioneel advies, maar moet worden gezien als een aanvulling op bestaande initiatieven van EMAGS, en anderen om de ASGM-sector veiliger en duurzamer te maken. Gebruikers van deze handleiding zijn zelf verantwoordelijk voor het verifiëren van de toepasbaarheid ervan en handelen op eigen risico in overeenstemming met deze richtlijnen.

Verzoek om Feedback en Gegevens

De auteurs hebben de informatie in deze handleiding gebaseerd op hun ervaring opgedaan bij ASGM-locaties in Suriname (zoals Compagnie Kreek in het district Brokopondo), op Lombok en Sumbawa in Indonesië en bij andere bodemherstelprojecten wereldwijd. Gebruikers van deze handleiding worden uitgenodigd om feedback te geven op de inhoud, zodat deze handleiding kan worden verbeterd. Met het oog op de verbetering van deze handleiding roepen de auteurs professionals uit de praktijk op om gegevens over monsteranalyses te delen binnen het kader van bodemherstel in ASGM-gebieden. Neem voor suggesties, het delen van gegevens en vragen contact op met TAUW bv via info@TAUW.com onder vermelding van deze richtlijn in het onderwerp.

Inleiding: Van Verlaten Mijn naar Productieve Grond

Kleinschalige goudwinning (ASGM) zorgt voor inkomen, maar laat vaak een landschap achter dat onveilig en onvruchtbaar is. De bodem is verdicht, de productieve toplaag is weggespoeld en krekken zijn vervuild.

Het doel van deze richtlijn is simpel: Hoe maken we van een verlaten mijnlocatie weer een veilig gebied waar voedsel verbouwd kan worden en/of waar het bos terugkeert?

De 3 Pijlers van Herstel

- **Gemeenschap gestuurd:** De lokale bevolking staat centraal in elke fase van bodemherstel, en is cruciaal voor het lange termijnbeheer.
- **Wetenschappelijk:** We gebruiken methodes die bewezen werken om de bodem weer "levend" te maken.
- **Praktisch:** Het bodemherstel is gericht op haalbare en kostenefficiënte oplossingen.

Dit document is een praktische samenvatting en richtlijn in het Nederlands. Deze is speciaal herschreven voor de gemeenschap en uitvoerders van locatie herontwikkeling naar natuur en agrarische doeleinden, gebaseerd op het Englestalig document met de titel “**Best Practices for Soil Restoration at post-ASGM Sites**” en met de subtitel “**Participatory Guidance for the Guiana Shield and Tropical Regions**”



Boven: Depositie van mijnafval (tailings); Onder: verlaten ASGM-locatie

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Het 7 Stappenplan voor Herstel

Hieronder leggen we stap voor stap uit hoe we het werk aanpakken. Het proces bestaat uit zeven (7) fases:



Stap 1: Onderzoek



Stap 2: Het plan maken



Stap 3: Grondwerk



Stap 4: Bodemherstel



Stap 5: Natuurherstel of Voedselbos



Stap 6: Onderhoud en Monitoring

Stap 1: Onderzoek – Wat komen we tegen?

Voordat we beginnen met herstel, moeten we precies weten hoe het terrein erbij ligt. We combineren hierbij de kennis van de omwonenden en mijnbouwers met technische metingen.

Samen de kaart tekenen (Participatory Mapping)

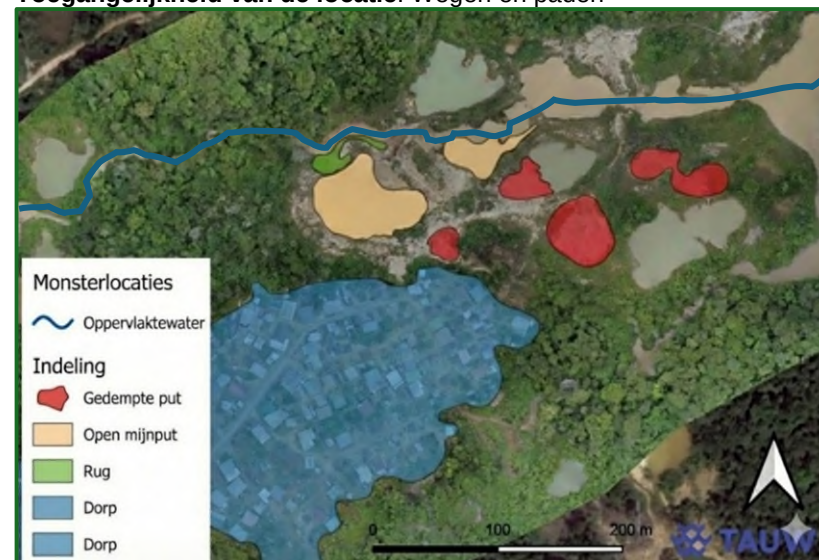
We beginnen met een sessie waarbij de gemeenschap een kaart tekent en invult. De lokale kennis is onmisbaar voor vragen als:

- Waar liepen vroeger de krekens?
- Welke plekken zijn het meest vervuild? Waar werd kwik uitgekookt?
- Wat is de gewenste toekomst voor dit stuk land (landbouw, wonen, bos)?

Het terrein indelen: schematische dwarsdoorsnede

Op basis van de kaart en een rondgang over het terrein verdelen we het gebied in verschillende zones ("landschapselementen"):

1. **Onaangetast bos:** Dit is een mogelijke bron voor zaden en grond.
2. **De mijnputten:** Diepe gaten, vaak gevuld met water, maar eveneens kunnen deze opnieuw zijn aangevuld met (grof) zand.
3. **Toplaag:** Locaties waar de toplaag is neergelegd, de bovengrond deels aanwezig is, of sprake is van een fijnere bodemtextuur.
4. **De verwerkingslocaties:** Locaties waar sluiceboxen stonden en goud met kwik werd geëxtraheerd.
5. **De locaties met mijnafval:** Bergen met grof zand en grind (weinig voeding) 'Bakka Santi', onderaan kunnen modderpoelen ontstaan.
6. **Waterlichamen:** Putten, krekens en rivieren vervuild met sediment.
7. **Toegankelijkheid van de locatie:** Wegen en paden



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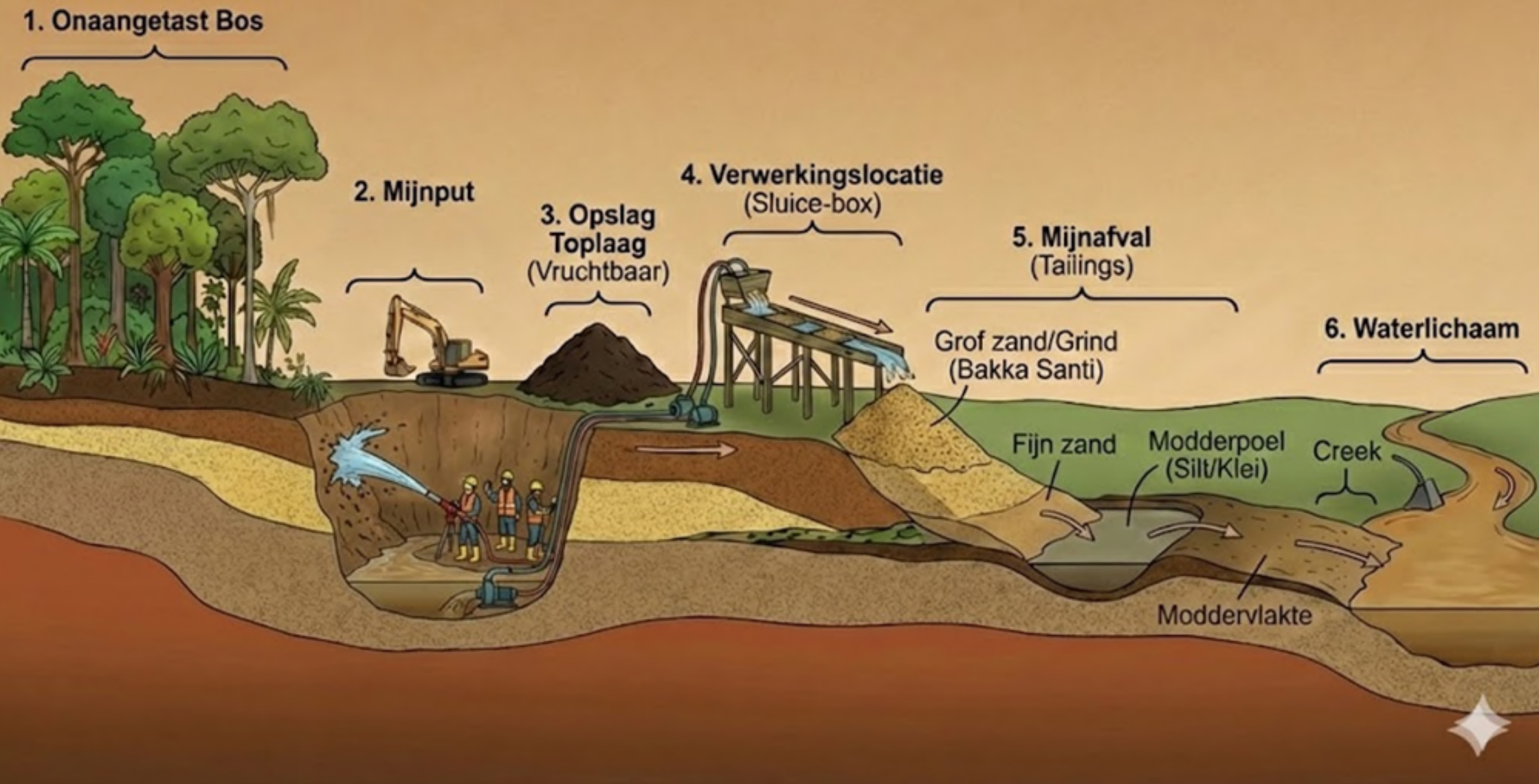
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*Ingetekende kaart op drone afbeelding
met landschapselementen*

Dwarsdoorsnede van een ASGM-locatie: Landschapselementen



Bodemmonsters nemen: Hoe gezond is de grond?

Om te bepalen of de grond veilig en productief is, moet onderzoek gedaan worden. Verdeel de site in verschillende componenten, zoals verschillende hopen met tailings, toplagen, ondergrond, fijn materiaal etc. De volgende activiteiten moeten worden uitgevoerd:

1. Kijken (Visuele Inspectie)

Graaf een 'mini-pit' van maximaal 50 cm en beschrijf de bodemkwaliteit:

- Structuur: Fijnere grond (klei/leem) is vruchtbaarder dan grof zand.
- Kleur: Donkere grond bevat doorgaans meer organische voeding dan lichtgele grond.

2. Meten (Het Labmonster)

Gebruik een grondboor om verstoring te minimaliseren en bemonster de bodemlagen tot 50 cm diepte direct na de visuele inspectie; zo voorkom je dat vluchtige stoffen (zoals kwik) ontsnappen.

- Vullen: Doe de grond direct in een glazen pot. Vul deze tot de rand (geen lucht) en sluit hem luchtdicht af.
- Koelen: Transporteer de potten direct in een koelbox (< 6 °C).
- Analyse: Laat het laboratorium testen op zware metalen, organische stof en textuur.

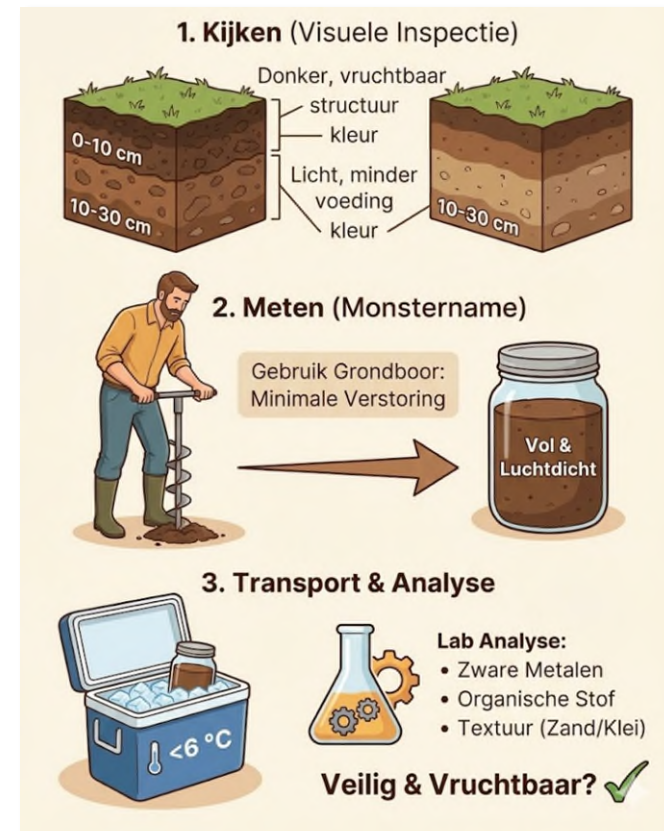
Stap 2: Het Plan Maken

Niet elk stuk grond heeft dezelfde behandeling nodig. We gebruiken een logische volgorde om te bepalen wat we doen. Veiligheid en gezondheid gaan altijd voor op opbrengst.

De 4 vragen om tot een plan te komen:

1. **Is het giftig?** (Kwikconcentratie > norm). Zo ja: eerst isoleren of saneren.
Geen voedsel verbouwen!

2. **Is het fysiek gevaarlijk?** (Diepe putten, instortingsgevaar). Zo ja: gaten vullen en hellingen afvlakken.
3. **Is de bodem 'dood'?** (Geen organische stof). Zo ja: bodemleven herstellen met compost en planten.
4. **Wat willen we ermee?** (Landbouw of Natuur) → Dit bepaalt welke planten we kiezen.



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Praktische Richtlijn: Keuzeschema Herstel ASGM Locaties



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Ontwerp

Een succesvol herstel begint met een goed plan dat past bij de wensen en behoeften van de lokale gemeenschap. Willen we hier over 5 jaar voedsel verbouwen, of over 20 jaar weer een gezond bos zien? Op basis van deze wensen en behoeften maken we een zoneringskaart (zie figuur rechts) waarin elk stuk grond een bestemming krijgt, zoals landbouw, wonen, recreatie of waterberging.

Dit ontwerp wordt in overleg met de gemeenschap gemaakt: eerst als concept, daarna aangepast met de feedback van de gemeenschap, tot er een definitief plan ligt waar de machines mee aan de slag kunnen.

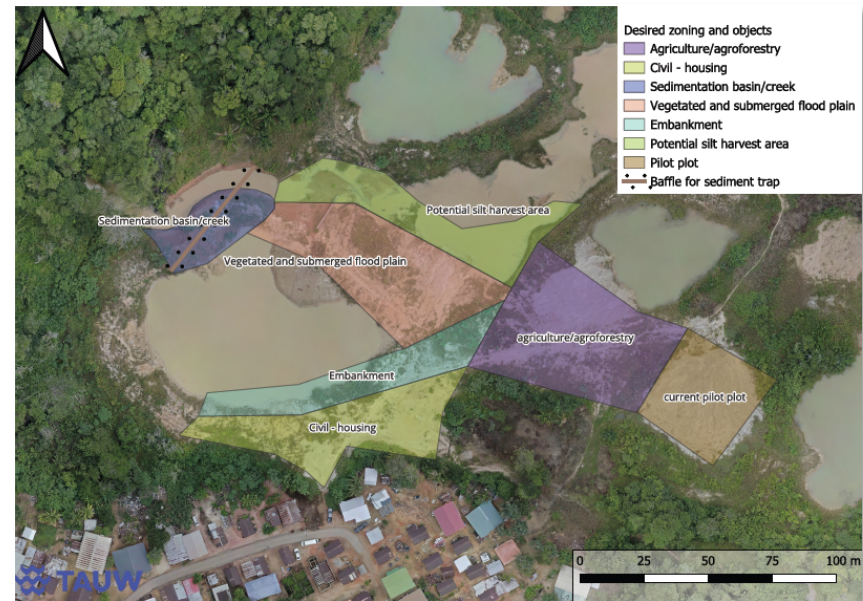
Hoe werkt de Grondbalans?

Om dit ontwerp uit te voeren, moeten we de grond verplaatsen. Hiervoor gebruiken we de Grondbalans. Dit is het technische hart van het plan (zie linkerkant van het figuur op de volgende pagina). Het werkt als een weegschaal:

- Inventarisatie (Cut): We berekenen precies hoeveel zand, grind of 'tailings' we op bepaalde plekken moeten weghalen (afgraven) om de gevaarlijke gaten en hellingen veilig te maken, en de kreekloop te herstellen. We kijken hierbij goed naar de kwaliteit (is het schoon of vervuild?) en het volume (hoeveel m³?).
- Bestemming (Fill): De grond die we afgraven, gebruiken we direct om andere delen van het terrein op te vullen en te egaliseren.

- De Toplaag (Topsoil): De kostbare, productieve toplaag (de bovenste 10 tot 30 cm) houden we apart in de berekening. Deze komt pas als allerlaatste laag terug over het terrein om plantengroei mogelijk te maken.

Het Doel: Een gesloten balans: Het doel van de grondbalans is efficiëntie. We willen voorkomen dat we dure grond van buitenaf moeten aanvoeren of dat we onnodig veel met grond moeten slepen. Wat we op locatie afgraven, gebruiken we op locatie weer nuttig.



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*Zoneringskaart met het Eindbeeld in
Compagnie Kreek, Suriname*

GRONDBALANS BEREKENING



AFGRAVEN (Cut)

AANVULLEN (Fill)

Volume
 $X \text{ m}^3$

Volume
 $Y \text{ m}^3$

Kwaliteit
A

Kwaliteit
A

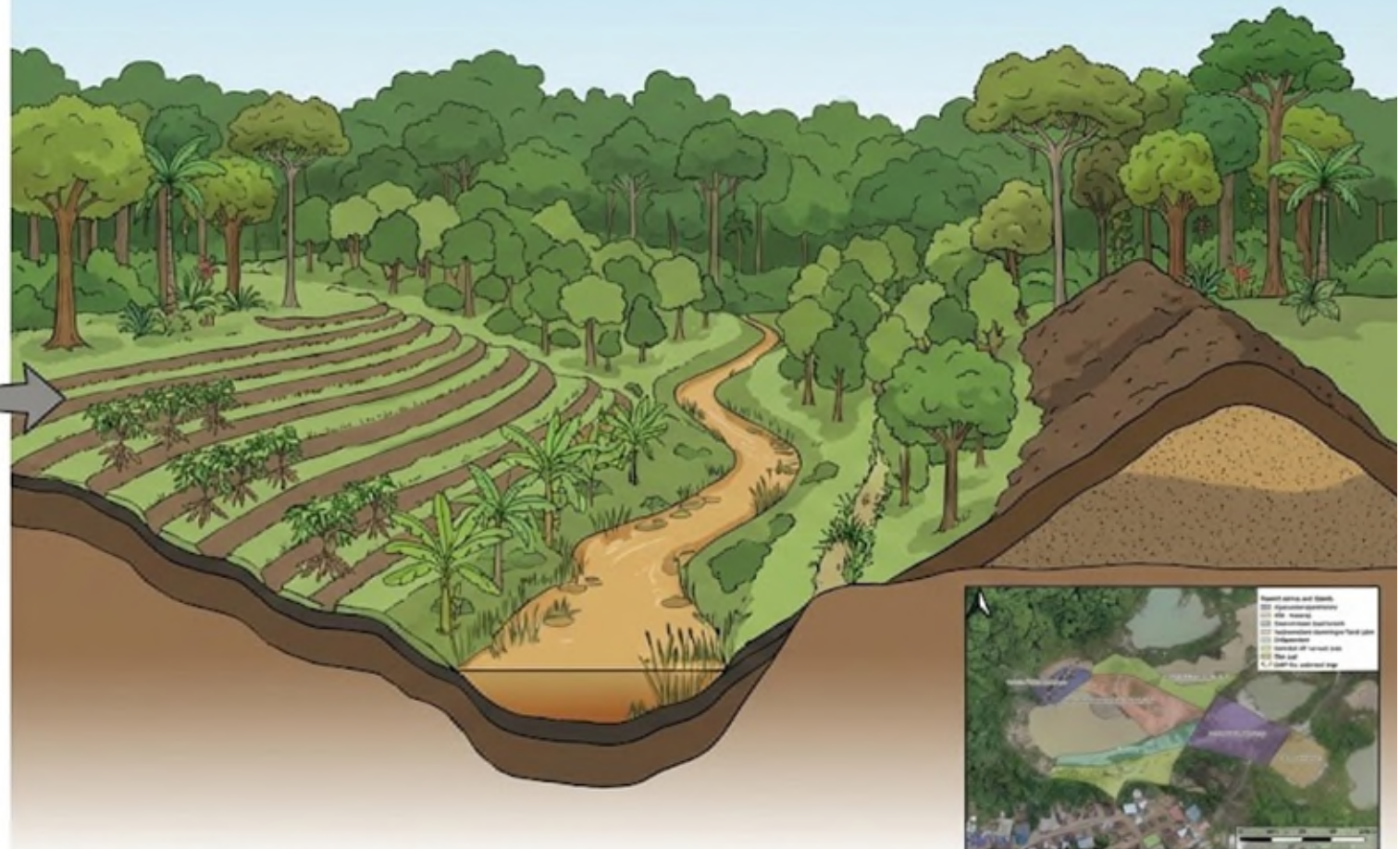
TOPLAAG AANBRENGEN
(Topsoil)

Volume
 $W \text{ m}^3$

Kwaliteit
B

Volume
 $Z \text{ m}^3$
(ca. 10 cm)

UITVOERINGSPLAN & EINDBEELD



DOEL: MINIMALISEER EXTERN TRANSPORT,
MAXIMALISEER LOKAAL HERGEBRUIK.

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Stap 3: Het Grondwerk

Dit is de kern van de uitvoering. Dit is het zware werk. De machines (graafmachines/bulldozers) gaan aan de slag. De volgende werkzaamheden moeten over het algemeen uitgevoerd worden om de locatie klaar te maken voor het beplanten (Stap 4).

Gaten en Hellingen:

- Diepe putten moeten worden gedicht of de steile oevers moeten afgevlakt worden.
- Steile bergen zand spoelen weg bij de eerste regenbuien. We maken de hellingen afgevlakt (maximale ratio 1 op 3). Dat betekent: voor elke meter omhoog of omlaag, moet de helling minimaal 3 meter lang zijn.
- Toplaag van 50 tot 100 cm bestaande uit fijn zand tot silt moet worden aangebracht, zodat de bodem voldoende water kan vasthouden.

Erosie en waterbeheer:

- Bij langere hellingen kunnen we het terrein terrasseren om de waterstroom te breken en verdere afspoeling te voorkomen.
- We kunnen ook greppels en walletjes langs de hoogtelijnen maken. Dit zorgt dat regenwater de grond *in* zakt in plaats van dat het de grond wegspoelt.

Kreekherstel:

- Richt een smalle laagwatergeul in die het water rustig door het gebied leidt. Gebruik meanders, ondiepe stroomversnellingen en diepere poelen

om erosie te beperken. Laat overstromingsvlaktes tijdelijk water opvangen bij hoge afvoer.

Stap 4: Bodemherstel

De belangrijkste les uit de praktijk is het succes van de "Direct Return" methode. Breng een laag van 10 tot 30 cm lokale, humeuze bovengrond aan over de geëgaliseerde toplaag van fijn zand tot silt. Haal dit van een nabijgelegen plek die ontgonnen wordt, of gebruik bewaarde hopen grond ('overburden dumps'). Als er geen bovengrond is, gebruik dan compost of biochar, maar dit is arbeidsintensiever.

Stabiliseer kwetsbare oevers van de herstelde kreek met stenen, kokosvezel of beplanting. Plant lokale, natte-soorten voor schaduw, biodiversiteit en minder afspoeling.



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Stap 5: Natuurherstel of Voedselbos

Levensonderhoud – Voedsel en Inkomen

Herstel is pas geslaagd als de gemeenschap er iets aan heeft. We kiezen vaak voor **Agroforestry** (Voedselbos). Dit is een mix van bomen en gewassen. Ook behoeftes als recreatie kunnen hierin meegenomen worden.

Beplanting in 3 Fases

Fase 1: De Eerste Hulp (Maand 1-6) We planten direct na het grondwerk om erosie te stoppen en de bodem te voeden.

Doel: Bodem bedekken en 'mulch' (organisch materiaal) maken.

Gewassen:

- **Mucuna (Okray Pesi):** Groeit razendsnel, bindt stikstof aan de bodem.
- **Banaan:** Snelle schaduw en biomassa.
- **Pinda & Cassave:** Korte termijn voedsel en bodembedekking.

Fase 2: Voedselproductie (Jaar 1-4) Tussen de bodembedekkers planten we struiken en kleine bomen die geld of voedsel opleveren.

Gewassen: Ananas, Gember, Peper, Papaja.

Fase 3: Het Toekomstbos (Jaar 5-20) Grote bomen die hout leveren, CO₂ opslaan, en met diepe wortels nutriënten uit de diepe grond kunnen opnemen.

Gewassen: Ceder, Bacuri.

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Natuurherstel: Laat de natuur het werk doen

We hoeven niet elke boom met de hand te planten. Dat is duur en veel werk. Met deze 3 slimme methodes helpen we het oerwoud sneller terugkomen:

- De Vogels als Planters (Natuurlijke groei): Als er nog bos in de buurt is, laat de natuur dan zelf werken.
 - o Wat te doen: Zet hoge palen of dode bomen neer in het open veld. Vogels gaan hierop zitten en poepen zaden uit van bomen uit de buurt.
 - o Resultaat: De vogels planten het bos gratis voor ons! (Zorg wel dat vee de jonge boompjes niet opeet).
- Boomeilanden (Slim planten): Je hoeft niet het hele veld vol te zetten.
 - o Wat te doen: Plant groepjes bomen ("eilanden") met lekkere vruchten.
 - o Resultaat: Deze eilanden trekken dieren aan. De dieren brengen weer nieuwe zaden mee, waardoor de eilanden vanzelf naar elkaar toe groeien tot één groot bos.
- Rijkdom Bijplanten (Verrijking): Groeit er al struikgewas of 'capuweri'?
 - o Wat te doen: Hak het niet weg, maar plant er waardevolle bomen tussen (zoals fruitbomen of hardhout).

Resultaat: Je maakt het bestaande groen waardevoller voor gebruik en natuur.



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Monitoring met behulp van prestatie-indicatoren

WERKPAKKET	INDICATOR	METHODE	FREQUENTIE	DOOR
				
Grondwerk	%  Verschijnselen bodemerosie bovengrond	 Oog  Bodem-monster	 Wekelijks  Na regen buien	 Opzichter
Aanleg groen	%  % ontkiemde zaden	 Tellen  Rolmaat	 Eerste 2 maanden  Jaarlijks	 Team gemeenschap
Informatie voorziening	 Getrainde groep 	 Logboek boek  Tellen?	 Per training  Jaarlijks	 Trainer  Boer

Stap 6: Onderhoud and Monitoring – Houden we het vol?

Wanneer de machines vertrekken en de rust op de locatie wederkeert, is het werk nog niet gedaan. Sterker nog: nu begint de belangrijkste fase. Hoewel de natuur uiteindelijk het werk zal overnemen, is de start kwetsbaar. Zeker in de eerste jaren vraagt het herstel – en met name een voedselbos – om **actief onderhoud en monitoring**. Jonge aanplant moet worden beschermd, water krijgen en worden bijgestuurd. De gemeenschap kan dit zelf doen, maar moet hier wel actief en constant bij betrokken zijn om eigenaarschap te creëren.

Wat meten we?

- **Overleving:** Hoeveel van de geplante boompjes leven nog? (Als minder dan de helft leeft, moeten we bijplanten).
- **Kleur:** Wordt de plant geel? (Dan is er tekort aan voeding of water).
- **Erosie:** Zien we geulen ontstaan na een regenbui? (Dan moeten we die dichten).

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Veilig en Slim werken

Een goed plan op papier is waardeloos als de uitvoering onveilig of rommelig verloopt. We werken op een oude mijnlocatie; dat betekent dat er altijd onverwachte gevaren zijn, voor de werkers maar ook de gemeenschap. Daarom hanteren we de volgende regels:

Veiligheid (HSE) – We gaan 's avonds allemaal weer gezond naar huis

Veiligheid is geen optie, maar een verplichting. De volgende Persoonlijke Beschermingsmiddelen (PBM) moeten worden gedragen:

- **Altijd:** Stevige veiligheidslaarzen (tegen scherpe stenen/slangen) en werkhandschoenen.
- **Zichtbaarheid:** Iedereen draagt een felgekleurd veiligheidsvest (oranje/geel). De machinist van de graafmachine *moet* je kunnen zien.
- **Lucht:** Bij stoffig werk (droge tijd) of bij het werken met potentieel vervuilde grond dragen we stofmaskers (type FFP2/3) om inademing van fijnstof en eventuele kwikdeeltjes te voorkomen.
- **Water:** Werk je binnen 2 meter van een diepe put of kreek? Dan is een reddingsvest verplicht, ook als je kunt zwemmen. De oevers kunnen instabiel zijn en afbrokkelen.
- **Hoofd:** Helmplicht in de buurt van de graafmachine en bij kapwerkzaamheden (vallende takken).

Hygiëne & Gezondheid:

- **Handen wassen:** Op een ASGM-locatie kan kwik in de grond zitten. Was *altijd* je handen met water en zeep voordat je eet, drinkt of rookt. Zo krijg je het niet binnen.

- **Hitte:** Het is zwaar werk in de zon. Zorg voor voldoende drinkwater op de locatie en neem op tijd pauze in de schaduw.

Werken met Zware Machines

De graafmachine is de grootste vriend van het project, maar ook het grootste gevaar.

- **De 'Oogcontact'-regel:** Loop nooit achter een draaiende machine langs. Zoek altijd oogcontact met de machinist voordat je de machine nadert. Steek je duim op als teken van begrip.
- **Veiligheidszone:** Houd minimaal 5 meter afstand van de draaicirkel van de graafmachine, inclusief giek en bak.
- **Duidelijke signalen:** Spreek van tevoren af welke handsignalen jullie gebruiken (bijv. voor 'stoppen', 'hier storten', 'pauze').
- **Afspraken met de lokale gemeenschap:** De lokale gemeenschap is vaak geïnteresseerd in wat er gebeurt voor dit project. Maak goede afspraken waar ze wel en niet mogen komen, en wie ze aan kunnen spreken.



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Tot slot: Het Begin van Nieuw Leven

Het inrichten van het terrein is slechts de eerste stap. Nu begint de cirkel van herstel: vallende bladeren voeden de bodem, bodemleven keert terug, en dieren (en soms mensen) brengen nieuwe zaden. Dit is de cirkel van herstel.

Om deze cirkel niet te doorbreken, is het cruciaal dat we de herstelde locatie nu beschermen tegen nieuwe verstoringen. Hierin speelt de gemeenschap en het traditioneel gezag een belangrijke rol. Daarnaast nemen we een belangrijke les mee voor toekomstige mijnbouw: Bewaar altijd de bovengrond! Wie tijdens het mijnen de productieve toplaag apart houdt in plaats van wegspoelt, heeft het halve werk voor herstel al gedaan. Die grond is het startkapitaal voor nieuw leven.

De weg van kaal zand naar een zichzelf in standhoudend bos duurt jaren tot decennia. Maar met de maatregelen uit deze richtlijn hebben we de bodem een 'vliegende start' gegeven. Hoe meer we deze lessen toepassen en het land beschermen, hoe sneller we het eindresultaat bereiken: een gezonde, levende bodem voor de toekomst.



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