Environmental problems of placer gold mining in the Zaamar Goldfield, Mongolia

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ABSTRACT

Between August and December 1999 five site visits were made to the Zaamar gold mining area, located on the Tuul River, western Tov Aimag, in northern Mongolia's Lake Baikal and Arctic Ocean drainage. Large-scale placer gold mining operations began in Zaamar in 1992, and gold production in 1998 was 4,080 kg (Dallas 1999). Environmental impacts observed were large and mostly avoidable, regarding: 1. extraction of gold-bearing gravels and sands; 2. pumps and wash plants; 3. settling pond design, operation and location; 4. tailings and topsoil storage; 5. multi-tracking; 6. mine restoration; 7. river diversions; and 8. annual environmental protection plans and reclamation bonding. Recommendations are given for measures to alleviate the environmental damage, and further investigation is required. Examples are illustrated of new mines using old technology incapable of recovering fine gold that have very high water demand, poor waste water treatment, poorly-designed setting ponds, and inadequate site management. Attention is drawn to the unnecessary loss of stands of willow (*Salix* spp.) that are a crucial element of the riparian ecosystem. The Ministry of Nature & Environment lacks the resources to properly monitor and enforce existing legislation concerning environmental impacts of mining.

Introduction

The Zaamar placer gold mining district is located on the Tuul River, western Tov Aimag at latitude/longitude N48°17’50”, E104°24’65” in northern Mongolia's Lake Baikal and Arctic Ocean drainage. Large-scale placer gold mining operations began in the Zaamar region in 1992, and the soum's gold production in 1998 was 4,080 kg (Dallas 1999). Gold production continues to increase annually, and new mines are expected to open in the Zaamar Goldfield each year for the foreseeable future.

Fig.1: *Typical gold recovery system in the Zaamar Goldfield, using old technology with a low % gold recovery rate and large water demand, Shijir Alt Mine of Mongolrosvestmet JSC.*
(Photographer: John Farrington, August 2000).

Between August 1999 and December 1999 the author made five site visits to the Zaamar Soum gold mining areas as a United States Peace Corps volunteer attached to the Mongolian Ministry of Nature and the Environment's Zaamar Soum environmental inspector's office. Site visits varied from 1 to 5 days in duration. The environmental inspector's office is located in the soum centre, Bat Olzit, 40 km west of the mining district, and the individual mines are spread out along an approximately 50 km long stretch of the Tuul river valley. Since neither the volunteer nor the soum environmental inspector had access to a vehicle, visits were conducted in shared vehicles at the vehicle operator's convenience. Consequently, no single visit provided a thorough overview of the entire region's mine operations at any given point in the mining season, and made consistent enforcement of Mongolian environmental regulations concerning mining virtually impossible. However, the 5 site visits did provide a good overview of environmental problems affecting the area, and are a good basis for proposing methods to improve the environmental performance of placer mining operations in the region.

Photographs illustrating Environmental Issues

Fig.2: *A relatively undisturbed section of the Tuul river, with dense willow thickets that preserve channel bank stability and provide important habitat. Note the 35m high overburden mounds to right, from draglines that eliminate scarce prime grazing lands (Photographer: John Farrington, August 2000).*

Fig.3: *Large Mongolrosvestmet gold dredge, in a deep artificial dredge pond on the floodplain of the Tuul river. Note the narrow neck of land between the 7m deep dredge pond and the 1.5m deep river channel, that has a high risk of a breach by the river when in spate. Breaching of the neck would result in channel capture and the release of large volumes of silt and mud into the river. (photographer: Jeff McCusker, October 1999).*

Fig.4: *Poor environmental mine management at Ikh Alt Ltd., where an idle water monitor jetting water has been turned towards the tailings mounds, causing gullying and washing of sand and mud into watercourses and ponds. The water is pumped from the Tuul river. The water monitors are frequently left on for extended periods, due to the inherent difficulty of priming water pumps of traditional design when restarting them. This can be overcome by switching to water pumps of modern design. (Photographer: Jeff McCusker, October 1999).*

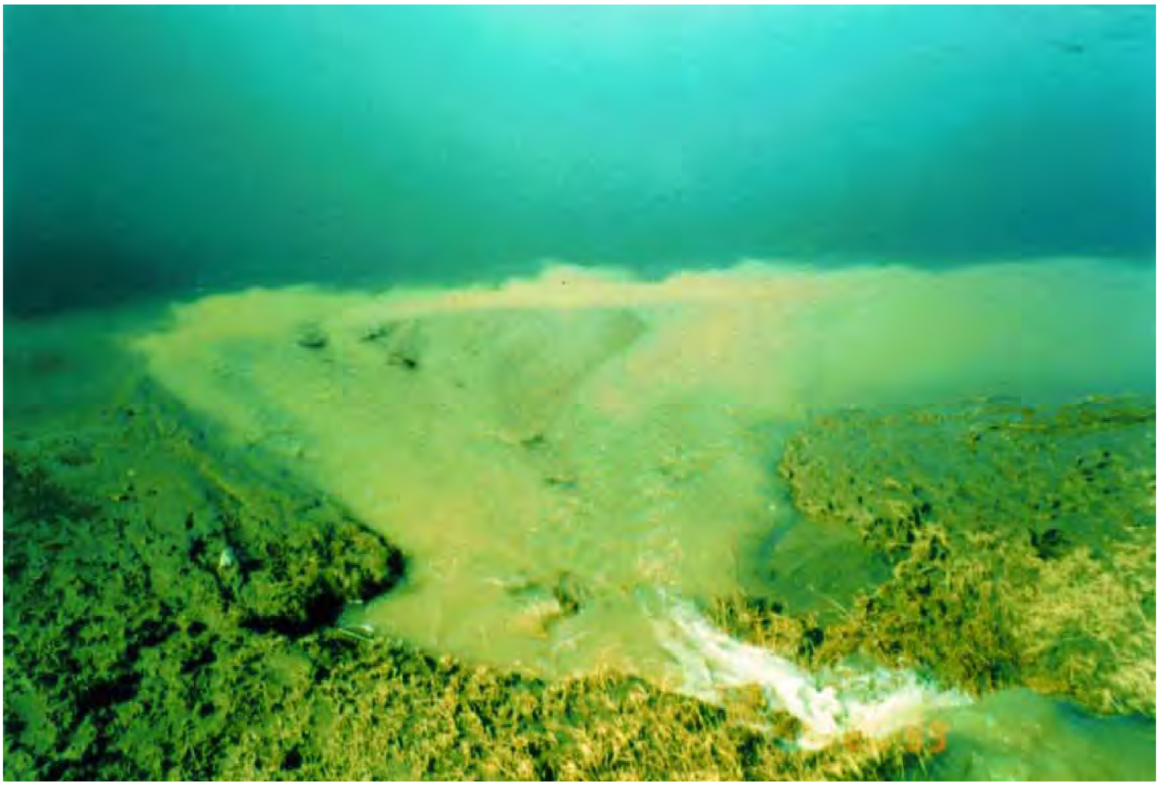

Fig.5: *Ultimate result of poor environmental mine management at Ikh Alt Ltd. where mud-laden water created by the idle water monitor in Fig.4 is discharging directly into the clear water of the Tuul river. The idle water jet conveys mud from the tailings into the river untreated due to a settling pond having been allowed to become full of sediment (Photographer: Jeff McCusker, October 1999).*

Fig.6: *Example of inefficient technology, a traditional style sluice that is incapable of recovering fine gold, and requires excessive use of water, which rapidly fills settling ponds with sediment, and causes inadequately treated waste-water to overflow in an uncontrolled manner due to the large volumes of water used. (Photographer: John Farrington, August 2000).*

Fig.7: *Example of bad environmental mine management at Tomin Co. Ltd. gold mine, with settling pond allowed to become completely choked with sediment, including the outlet pipe, allowing mine waste sediment to escape directly into the Tuul river. (Photographer: Jeff McCusker, October 1999).*

Fig.8: Two drag lines active in the Hailaast Valley, a minor tributary of the Tuul river. Note steep-sided mounds of overburden dumped close to hillside on left. (Photographer: John Farrington, August 2000).

Destruction of Riparian and Grassland Ecosystems

The largest environmental problems resulting from gold mining activities in Zaamar Soum are the widespread destruction of the Tuul river valley's riparian ecosystem, natural meandering river channel, and adjacent floodplain, river terrace, and alluvial fan grassland ecosystems. Damage results from both open pit extraction of gold-bearing sand and gravel deposits on the valley's floodplain, terraces, and alluvial fans, and also from injection of large amounts of silt and suspended sediment into the Tuul river from improperly operated mine washing plants and process water settling ponds. Other sources of suspended sediment entering the Tuul river include runoff from improperly designed open mine pits, mine roads, and unreclaimed and improperly reclaimed areas where mining is finished. While the only remedy for rehabilitation of habitats destroyed by digging of open mine pits is proper ecosystem restoration based on an integrated, interdisciplinary approach, damage caused by improperly operated wash plants, settling ponds, and poor mine design and management can, and should, be prevented.

Placer gold mining is potentially a relatively "clean" industry, not producing the highly toxic ore separation chemical effluent, acid drainage, and smelter emissions common to the mining and processing of other metal deposits. However, open pit placer mining and the subsequent injection of vast amounts of silt into the Tuul river watershed is nevertheless highly destructive to the riparian ecosystem. Possible effects of siltation of the Tuul river include:

1. destruction of fish spawning habitat by burial of spawning gravels and fish eggs with fine silt;
2. physical abrasion of fish, particularly young fish;
3. suffocation of fish by clogging of gills with sediment;
4. instability and braiding in the presently single meandering channel;
5. increased channel and bank erosion, and subsequent loss of riparian vegetation;
6. filling of pools favoured by insects and algae;
7. channel incision, increased flood potential, and channel capture by mine pits on the floodplain;
8. reduced floodplain groundwater levels;
9. proliferation of invasive plant, insect, and invertebrate species;
10. lowered water quality for downstream users;
11. contribution to the eutrophication of Lake Baikal, a UNESCO world heritage site.

Other Pollution Sources arising from Placer Mining

Other mine-related environmental problems which at present are minor issues with respect to ecosystem destruction, but which nevertheless require periodic monitoring and regulation, include:

1. high levels of airborne dust from open mine pits and unsealed mine and camp roads;
2. hydrocarbon spills from improper storage and disposal of fuel, lubricants, and solvents;
3. handling, and disposal of mercury used in gold concentration processes (if used);
4. sewage and solid waste disposal;
5. coal and wood smoke emissions from mine camps.

Overgrazing and Deforestation Issues

Further exacerbating the problems of ecosystem destruction due to mining activities are the large number of grazing animals owned by local herders, which form the basis of Zaamar Soum's traditional pastoral economy. Mine operations are generally conducted on large tracts of prime grazing land beside the river, and have forced herders onto a reduced grazing area with lower grass productivity. Local herd numbers, already enlarged due to privatisation of the former socialist system collectives, have been further swollen by the presence of upwards of 2,000 mine employees, who, owing to the remote location of Zaamar Soum, are fed in part by meat from herds owned by the mines and managed by local herders. The effects of increasing grazing pressures in Zaamar Soum are clearly visible in summer months by the vast areas of trampled, overgrazed, bare, and highly eroded pasture lands in the upper tributary drainages east of the Tuul river.

Another Zaamar Soum environmental issue exacerbated by the mines is the cutting of trees for firewood used in the smaller mine camps. In 1989 a large soum wide forest fire destroyed most of Zaamar's upland birch forests. No replanting programme has been undertaken, and in winter livestock herds browse on new shoots emerging from burnt stumps. Thus no regeneration of the soum's forests is occurring. Zaamar Soum's permanent residents in Bat Olzit heat exclusively with wood, and are already cutting the remaining forest at unsustainable rates. Increased use of forest resources by mining camps only further accelerate the process of deforestation in the soum.

Analysis of Environmental Problems of Major Mining Activities

The following analysis of primary mining activities in Zaamar Soum is by no means exhaustive, and may not be applicable in whole or in part to each of the 20 active mining operations in the area. However, the analysis does address many of the major shortcomings of mine operations in Zaamar Soum with respect to environmental protection, and should serve as a good starting point for reducing the environmental impact of the mines. Eight main categories of mine activities and their environmental problems are dealt with below:

1. extraction of gold-bearing gravels and sands;
2. pumps and wash plants;
3. settling pond design, operation and location;
4. tailings and topsoil storage;
5. multi-tracking;
6. mine restoration;
7. river diversions;
8. annual environmental protection plans & reclamation bonding.

1. Extraction of Gold-bearing Gravels and Sands

PROBLEM	REMEDIAL ACTION
Runoff from mine pits and work areas with high silt and suspended sediment content.	Simultaneous reclamation, mining according to a panel mining plan, proper mine layout with drainage to a settling pond, armoring of exhausted pits with coarse tailings.

There are variety of methods being used for the extraction of gold-bearing placer deposits in the Zaamar gold fields. These include:

1. the use of heavy earth moving equipment to extract and load material onto dump trucks for transportation to washing plants;
2. the use of draglines to extract sediments from water filled mine pits dug below the groundwater table (Figs.8 & 25);
3. in one case, the use of a 4-storey high river dredge and washing plant which floats on an artificial pond dug into the Tuul river's active flood plain (Figs. 3 & 25).

The vast majority of mining operations active in Zaamar Soum use bulldozers, loaders, backhoes, and dump trucks to extract gold-bearing sediments from pits that typically range from 2 to 20 metres in depth. The open pits themselves can be hundreds of metres across, and freely draining pits cut into terrace banks are highly susceptible to erosion by the short, but at times intense, summer rains, creating silt-laden runoff.

One method to reduce the amount of silt laden runoff entering the Tuul River from freely draining mine pits would be to require mining according to a "panel" mining plan, working the claim in a series of narrow strips, with simultaneous "preliminary" reclamation of finished panels by backfilling them with mine tailings (Fig.10). At the very minimum, open pit bottoms can be armoured with coarse tailings to reduce erosion until reclamation is undertaken, and any pit runoff can be channelled to settling ponds.

2. Pumps and Wash Plants

PROBLEM	REMEDIAL ACTION
Creation of silt-laden runoff from idle wash plant jets.	Turn off pumps when jets aren't in use, or install a return pipe to the river for unused water.
Digging of open, erosion-prone ditches for water pipes.	Lay water pipes across the existing land surface.

Gravel wash plants are operated using water from pumps located on or near the banks of the Tuul river. Pump intakes are placed directly in the river, and sometimes a minor channel diversion is constructed to enhance flow to the intake. Water is pumped uphill through pipelines, sometimes up to several hundred metres in length, to wash plants where water jets are used for washing of gravels and sediment in order to gravimetrically separate gold from tailings. Because of the difficulties in priming pumps, starting pump engines, and generating enough suction head to transport water long distances, many pumps are left running continuously all day but are only used to wash sediments for a small portion of that time. Idle jets are typically pointed at tailing piles beside wash plants where the freshly pumped "clean" river water erodes the tailing pile, picking up a large suspended sediment load. The water then flows to settling ponds, unnecessarily filling the pond with water and sediment, or returns directly to the river as newly silt laden water, never actually having been used in the mining process (Figs. 4 & 5). One solution to this extremely wasteful practice would be to simply turn off the pump for the long hours when the jet may be idle, or if this is problematic, a return pipe should be installed to deliver the unused water to the river clean.

Another observation was that, in one case, a pipe rose out of the river directly up a terrace bank, at the top of which a large ditch 1m in depth had been dug to hold the pipe. While reducing the lift required by the pump marginally, the ditch now forms a prefabricated erosion gully which is likely to be another source of topsoil loss and silt in the river. A better practice would be to simply lay the pipes across the existing contours of the land.

3. Settling Pond Design, Operation and Location

PROBLEM	REMEDIAL ACTIONS
DESIGN: Large amounts of silt and suspended sediment exit from the mine settling ponds due to poor design.	DESIGN: Design ponds with: • U-shape or circulation barriers; • Presettling ponds with coarse tailing filters; • angled outflow pipes + energy dissipation structures; • armoured outflow channels; • recycle pump to reuse treated wash plant water.
OPERATION: • settling ponds operated full of sediment; • no cleaning of ponds; • no monitoring of effluent sediment load.	OPERATION: Operational goal must be ZERO DISCHARGE, with: • scheduled daily to weekly cleaning of settling & presettling ponds; • daily monitoring of pond effluent suspended sediment load; • re-use of treated pond water.
LOCATION: Settling and dredge ponds constructed with unreinforced earthen dikes on floodplains where they are susceptible to destruction by flood waters.	LOCATION: Selection of pond sites on river terraces above the river floodplain or reinforcement and rip-rapping of earthen dikes on the floodplain.

Improper wash plant settling pond design, operation, and location are among the primary reasons for the large volumes of silt and suspended sediment entering the Tuul River, and should be some of the easiest problems to correct.

A common design used in Zaamar consists of several open ponds in series, built on the ground surface by construction of hemispherical earthen dikes up to several meters in height, which are backed by river terraces or mine cuts. Ponds are drained by horizontal culverts placed just below the top of the dikes, draining into each other and typically into a dug earthen channel that flows directly to the Tuul river.

While the ponds do remove a fair amount of sediment, the effluent that reaches the Tuul river is generally opaque brown in colour and at best has a transparency of only a few millimetres. The first step to reducing the amount of sediment exiting these ponds would be to improve pond design. Ponds typically are simply round to hemispherical basins with uncontrolled inflow and outflow, which can lead to short-circuiting and a very short residence time for silt-laden water in the pond. Better designs include the construction of U-shaped ponds or ponds with median dikes to increase the flow path length of process water, thereby increasing the residence time of water in the pond and increasing settling of suspended solids (Figs.11,12 & 13).

A second improvement would be the construction of a presettling pond with a sediment filter constructed from coarse rock and gravel tailings (Figs.14&15). Pre-settling ponds can improve performance of settling ponds by removing up to 95% of the sediment before even reaching the main settling pond, but require frequent, daily to weekly cleaning (Hanneman

1987). Coarse tailing filters could also be placed in intermediate settling ponds to increase residence time and enhance sediment removal (Fig.16).

A third design problem is the uncontrolled outflow from these ponds. Final pond outflow typically passes through a horizontal culvert pipe placed in the top of the final pond dike, and cascades up to several metres to the ground below before entering a dug earthen ditch. No flow energy dissipation structures are used, and effluent ditches are unarmoured. Thus, although the water quality improves in the settling ponds, it degrades again by picking up sediment in eroding a large hole at the bottom of the outflow cascade and in eroding the unlined effluent ditch. Better outflow design would include angling the outflow pipe downward through the dike to prevent cascading, placing large rocks and boulders at the pipe outflow to dissipate flow energy, and armouring of effluent canal with rock to reduce erosion (Figs.17&18). However, BETTER METHODS OF EFFLUENT DISPOSAL ARE AVAILABLE AND SHOULD BE IMPLEMENTED.

American and Canadian placer mining operations strive for and often achieve ZERO DISCHARGE, as required by stringent western environmental regulations (Henkins 2000). Zero discharge should be the goal of mine and settling pond design in Mongolia's placer gold fields. Zero discharge can be achieved by processing water to the point where it can be recycled by simply pumping it out of the final treatment pond and back to the mine wash plant (Figs.9&13). Other possible disposal options which would reduce the sediment inflow to the Tuul river include draining treated water to ground water recharge basins dug into coarse sediments, disposing of treated water by running it over gently sloping undisturbed grasses, or irrigation of areas suitable for haying. The key to implementing these methods however, is to reduce water use in the first place, so that excess water does not have to be drained directly into the Tuul river.

The second category of problems with settling ponds used in Zaamar's placer mines is improper operation. Site visits were made late in the season, and many ponds observed were nearly or completely filled with sediment, and in one case even the final outflow pipe of a pond was over half filled with sediment (Fig.7). Settling ponds completely full of sediment quickly develop stream channels through the soft sediments, eroding them, and leaving the ponds with residence times measured in minutes, not in terms of the multiple days required for fine silt and suspended sediment removal. In order for settling ponds to operate properly, they must be of sufficient depth and must have that depth maintained by frequent removal of deposited sediments.

Both the Province of British Columbia and the State of Montana require that ponds have MINIMUM POND LIQUID DEPTHS OF 1.5 m, and that ponds never be more than 50% full of sediment. British Columbia requires a half metre of freeboard and implementation of stringent pond dike design safety criteria, while the State of Montana requires 1.25 metres of freeboard, and recommends that ponds be dug into the ground to enhance percolation (McCulloch 1993, Ford 1997). In Zaamar Soum, some ponds were observed to be completely full in late August, and were operated in such a condition for at least the final 2 months of the mining season, but probably longer. In order to maintain a minimum liquid depth of 1.5 metres, ponds must be cleaned of sediment on a daily to weekly basis. Removed silt and fine sediments are a valuable reclamation resource in themselves, and should be stockpiled and protected from rain erosion for later placement beneath restored topsoil layers.

Pond operation and performance should also include frequent monitoring of effluent suspended sediment load reaching the Tuul river. One simple method used by the United States Environmental Protection Agency (US EPA) and recommended by the state of Alaska is the Imhoff cone, a plastic graduated cone costing about US $15 (Henkins 2000). A known volume of pond effluent is placed in the cone and the suspended sediment allowed to settle. Settled sediment volume is then read using the cone graduations, and suspended sediment levels are reported as the volume of settleable solids per litre of effluent. The current US EPA standard for permissible settleable solids in placer mine effluent as measured by the Imhoff cone is 2 ml/l

(Hanneman 1987). Another test routinely performed on effluent water is a turbidity test using a nefelometric turbidity meter. US EPA standards allow effluent to be 5 nefelometric turbidity units (NTU's) above source background turbidity, a barely visible amount (Henkins 2000).

The third category of problems with settling ponds used in placer mines, and also dredge and drag-line ponds, operated in Zaamar Soum is location. The Province of British Columbia requires that all structures in a sedimentation pond system be built to withstand a 200 year flood (Ford 1997). The dikes of numerous ponds in Zaamar lie on the active river flood plain, and in one extreme case even form an artificial bank of the river (Fig.3). However, although all observed dikes on the flood plain were constructed of loose earth fill, none were rip-rapped nor in any other way reinforced to withstand fast-moving, high flood waters. When asked about flood protection measures, one mine engineer replied that it was unnecessary because the Tuul river never flooded. In the event of a flash flood, such as those that shaped the alluvial fans of the area, these earthen dikes and dams are likely to fail, resulting in the introduction of extremely large volumes of sediment into the main river channel.

Obviously flood stage level frequency analysis needs to be performed based on the flood stage gages located on the Tuul, and the information distributed to mine operators for proper planning. Furthermore, settling ponds should not be built on the floodplain to begin with. The floodplain is the most productive part of riparian ecosystem, is an important summer grazing resource, and has an extremely shallow water table. Because of the danger from flooding and the reduced percolation capacity due to the high ground water table, it would be better if ponds were dug into the river terrace in zones of coarse substrate to enhance percolation, and had dikes built from excavated material used only to retain extreme amounts of runoff, not to retain water from daily operations. A second consideration that needs to be made is location of the ponds in an area where they can easily be cleaned, and the removed material safely stored. Locating the ponds on boggy ground where machines used in removing pond sediment might become stuck should be avoided. By the very nature of dredge and dragline ponds, these will be located on or near the floodplain. Thus for these operations minimum standards must be developed and implemented for reinforcement of pond dike structures to reduce the risk of these structures being destroyed in a flood. Coarse rock tailing piles from wash plant operations are one source of rock that could be used to reinforce earth dikes.

4. Tailings and Topsoil Storage

PROBLEM	REMEDIAL ACTION
Release of sediment from uncovered soil and tailing storage piles, reduction of stored topsoil fertility, invasion of stored topsoil by weeds.	• Cover storage piles with rocks or erosion blankets, • build sediment traps down gradient of piles, • place storage piles away from streams, • perform simultaneous reclamation of mined areas.

All topsoil saved for reclamation, removed overburden, and wash plant tailings observed on site visits were stored in uncovered piles, with no erosion control measures whatsoever. In such a state, piles were left exposed to erosion by wind and rain, and quickly overgrown by invasive weeds. Topsoil left in such a condition will quickly have its fertility diminished. Simple measures to prevent erosion of storage piles and siltation of runoff include:

1. covering finer materials with coarse tailings;
2. building sediment traps on the down gradient side of piled materials (described in section 6 under mine reclamation);
3. covering irreplaceable topsoil piles with erosion blankets that could later be used to prevent erosion on reclaimed areas;
4. selection of storage sites where eroded materials are least likely to enter water courses;
5. simultaneous reclamation of mined areas.

5. Multi-tracking

PROBLEM	REMEDIAL ACTION
Soil erosion and grasslands ecosystem destruction due to excessive number of motor vehicle roads and tracks.	Road maintenance, road barriers, single river access roads, building of erosion control structures, driver education.

A common environmental problem in Zaamar Soum is **multi-tracking**, – the creation of multiple vehicle tracks by driving vehicles off main roads to avoid potholes and ruts, or simply to take the shortest path to one's destination across open grasslands. This is a particularly acute problem in the mining areas where heavy vehicles are used in all operations. Multi-tracking results in the destruction of terrace and floodplain grasslands, and can be the source of chronic erosion and siltation of runoff. Solutions to this problem include:

1. performing frequent maintenance and repairs on heavily used mine roads with road grading equipment;
2. placing vehicle barriers across subsidiary tracks paralleling main mine roads;
3. limiting mines to single river access roads;
4. placing erosion control structures where needed (see section 6: mine reclamation);
5. encouraging mine drivers to only drive on existing roads.

6. Mine Reclamation

PROBLEM	REMEDIAL ACTION
Lack of revegetation and woody plant replacement.	Store cleared trees and shrubs in protective nurseries.
Lack of erosion control.	Erosion control using rock and hay bale check dams, erosion blankets, berms, and furrows.
Lack of control of vehicles and over-grazing.	Installation of fences around reclaimed areas.
Lack of fill compaction.	Compact replaced fill using heavy machinery.
Lack of acceptance of responsibility for reclamation.	Hold mine operators responsible for all mine reclamation activities.
Generally inadequate ecosystem restoration.	Thoroughly document topography, plant, and animal life on the mine site with maps and photos before mining to serve as a guide in restoration.

Mine reclamation in Zaamar Soum, if even performed, generally consists of simply backfilling mine pits with tailings and overburden, contouring the fill, and spreading a thin layer of topsoil over the replaced materials. "Reclaimed" areas are readily identifiable as the large tracts of land covered by tall invasive weeds that can be seen along the Tuul river. Little or no attention is paid to:

1. replacing destroyed elm trees, willows, and grasses;
2. preventing wind, rain splash, and runoff erosion on bare replaced soils in stream gullies and other areas;
3. preventing the thousands of cows, sheep, goats, and horses that graze in the valley from trampling the sensitive reclaimed areas;
4. proper compaction of replaced fill materials to prevent excess settling and associated erosion-prone settling cracks.
5. operators who neglect to even refill their pits.

One common reason given for not performing reclamation is that the tailings will be re-mined at a later date, using as yet unobtained "improved" technology. In the meantime the health of ecosystems in the valley continue to degrade. Pits and tailing piles continue to erode, fertility of stored topsoil decreases, weeds invade the area, silt laden runoff from unvegetated areas enters the Tuul river, and less ground is available for grazing, having been left in a state unsuitable for plant or animal habitation (Fig.25). Under these circumstances, it might be wise to require operators to see how they can improve their gold take given the technology available to them, by optimising pay gravel separation, classification, and wash plant feed and flow rates (Silva 1986, Clarkson 1990). Otherwise, if the operator fails to obtain the improved technology in a reasonable amount of time, the site should be reclaimed according to reclamation standards.

The other common reason given by mine operators for inadequate restoration is that they are not responsible for reclamation since they have paid a contractor to carry out the reclamation work. However, the mine operators should be held responsible for the work of their reclamation subcontractors. There is clearly a lack of understanding in the Zaamar area that mine reclamation and ecosystem restoration are not simply matters of refilling mine pits and spreading topsoil over them, but a process taking a minimum of 5 years to complete which requires, among other things:

1. adequate compaction of replaced materials to prevent settling and formation of erosion prone settling cracks;
2. erosion control measures such as placement of sediment traps made from hay bales and rock dams on steep slopes, in gullies, and in streams; placement of biodegradable erosion control blankets on unvegetated topsoil; and construction of slopeside berms and furrows (Figs.19, 20, 21, 22, 23);
3. planting of native grasses, shrubs, and trees;
4. weed control;
5. fences to keep out grazing livestock and vehicles;
6. continuous long term monitoring of the site so that corrective action can be taken if the site is not regenerating itself properly.

Ideally, progressive continuous reclamation, the reclaiming of a pit area as soon as soon as it is exhausted, should be performed at each mine so that storage time for topsoil and exposure of open mine pits to wind, rain, and runoff is minimised.

Some simple reclamation measures that are within the capabilities of all mine operators in Zaamar Soum, and which will greatly enhance reclamation as practised in Zaamar, include:

1. salvaging cleared shrubs and trees in protected nursery areas for later replanting on restored areas, or at the very minimum establishing willow nurseries from cuttings of removed willow plants (Fig.24);
2. fencing of reclaimed areas to prevent grazing and trampling of new plants and grasses by goats, sheep, cows, and horses;
3. the spreading of hay on reclaimed areas to reduce rain splash and wind erosion on unprotected topsoil;
4. erosion control in loose replaced fill materials by placement of rock and hay bale check dams along the channel bottoms of restored ephemeral creeks and gullies, and construction of berms and sediment traps along hill slopes (Figs.19,20,21,22,23);
5. adequate compaction of replaced fill materials;
6. weed control;
7. enforcement of long-term grazing moratoriums on reclaimed lands.

However one of the most useful and important tools for conducting proper reclamation is to thoroughly survey, map, and photograph the mine site BEFORE MINING COMMENCES.

Thorough surveys should be made of topography, paying particular attention to original stream channel dimensions, and to determine the distribution and condition of plant and animal species. Such documentation will prove invaluable to restoring an area to maximum productivity, and should be required of all mining operations.

7. River Diversions

PROBLEM	REMEDIAL ACTION
Unregulated large scale diversions of the Tuul river.	Institute a permitting process for river diversions.

At present, one mine operator, Shijur Alt, has permanently diverted an approximately 1.5 km long stretch of the Tuul river so that the gold-bearing sediments beneath the present river bed can be mined to a depth of 7 metres using Shijur Alt's floating dredge rig. While this clearly violates Article 14, Section 5 of the 1995 Mongolian Law on Water, which prohibits permanent alteration of natural river channels, the diversion project nevertheless proceeded due to the economic value of the gold beneath the present river channel.

Although a large enterprise like Shijur Alt may have the technical expertise and equipment to alter the course of the Tuul River with a minimal environmental impact, the unlicensed diversion of a large river sets a bad precedent for smaller operations without adequate expertise and equipment that may want to perform similar diversions of the river. In the future, such river diversions should be subject to a special permitting process beyond the mineral extraction license, and should require creation of new channels that retain the hydraulic and ecological characteristics of the channel destroyed.

8. Annual Environmental Protection Plans & Reclamation Bonding

PROBLEM	REMEDIAL ACTION
Failure of mine operators to submit annual EPP's and reclamation bonds.	Prohibit mines from opening before EPP's and bonds are submitted.

Before the beginning of mine operations each year, mine operators are required by law to file annual environmental protection plans (EPP's) and post a reclamation bond amounting to half the anticipated costs of reclamation for the year. In practice, the majority of mines operating in Zaamar neither file EPP's nor post a reclamation bond. EPP's that are filed tend to be vaguely worded, inadequately address pertinent environmental issues, and greatly underestimate reclamation costs, thus lowering the size of the reclamation bond that needs to be posted. Standards requirements for EPP statements and a reclamation cost schedule should be developed to regulate EPP's and bonding.

Sketches illustrating Good Mine Management Practise

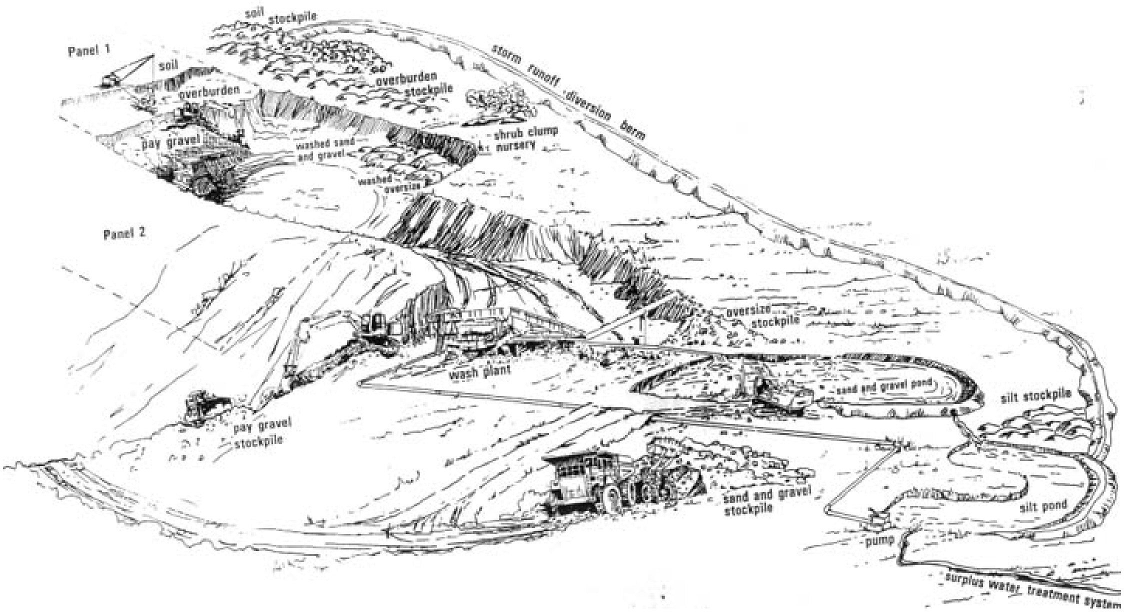

Fig.9: *Mining according to a "panel plan". Note that exhausted portions of the pit are being protected with coarse tailings, both panels 1 and 2 will drain to a common settling pond, the settling pond is U-shaped to increase water residence time, and that a recycle pump has been installed to reuse all wash plant water. Also note that silt cleaned from the silt pond and shrubs in the protective nursery, which were removed from panel 1, have been saved for final reclamation (from McCulloch 1993).*

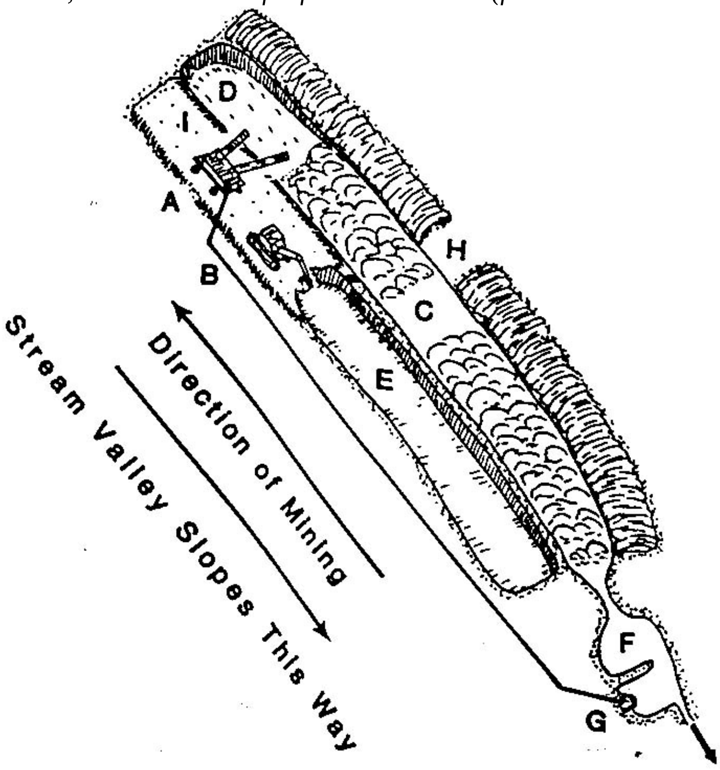

Fig.10: *Mining according to a panel plan with simultaneous reclamation. Note that the first panel excavation is being filled with the tailings from the second panel excavation. Also note the use of a recycle pump to reuse all water and the settling pond's U-shape which increases residence time (from Hanneman 1987).*

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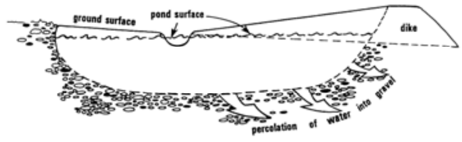


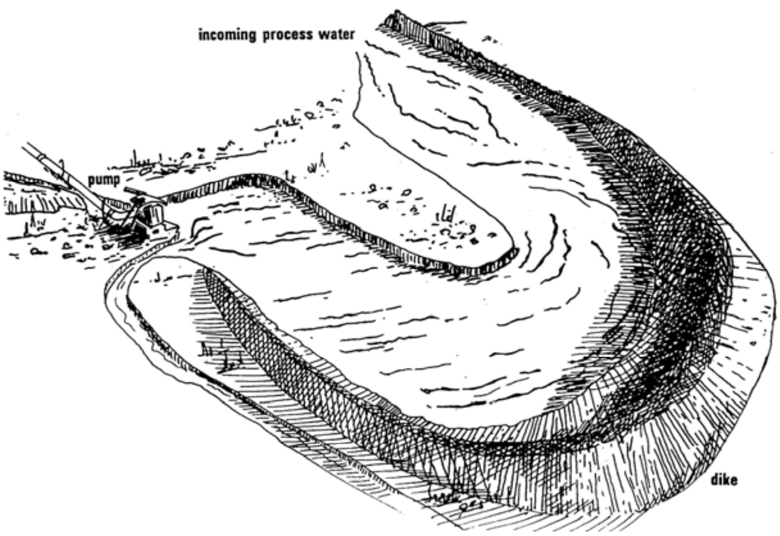


Fig.11: *U-shaped settling pond design. Note that the Pond is U-shaped to increase water residence time, the pond outflow exit is at the furthest end of the pond from the inflow, and that a recycle pump has been installed to reuse water. Also note that the pond is dug below the ground surface in gravel layers to enhance percolation and that the pond dike will only retain water during large storm events (from McCulloch 1993).*

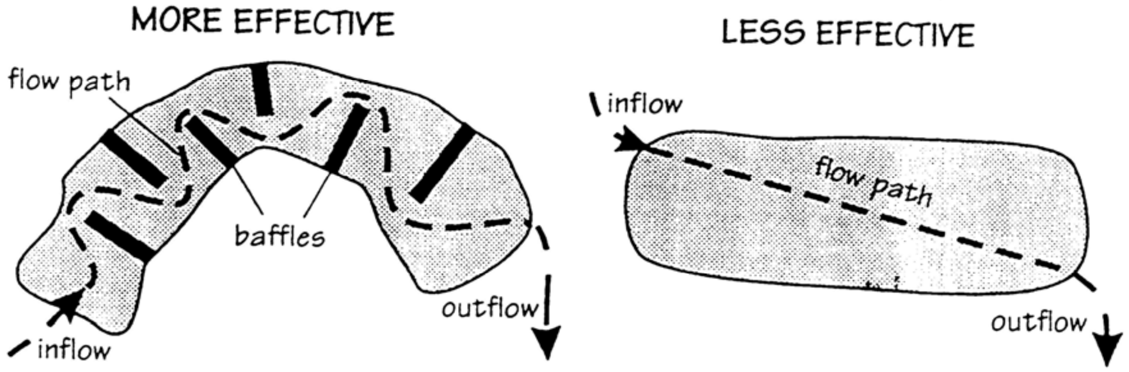


Fig.12: *U-shaped settling pond with flow baffles. Note that the flow baffles of this pond further increase flow path length and pond residence time (from Norman 1997).*

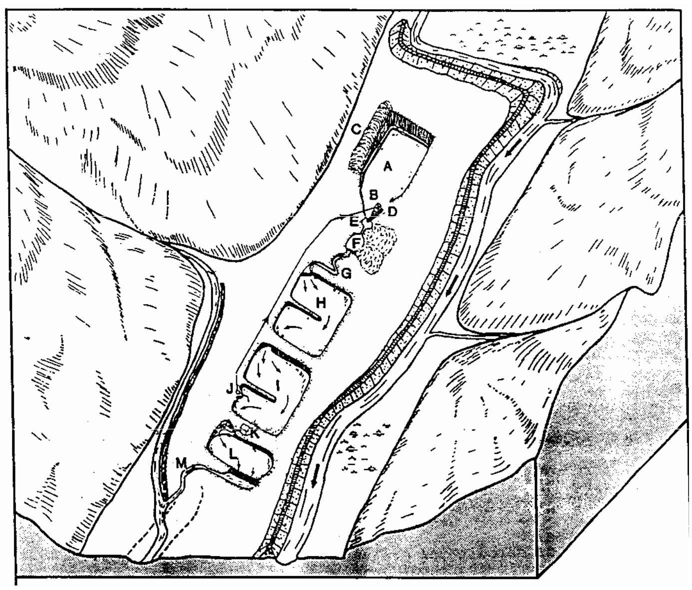


Fig.13: *Overview of mine operation settling ponds. Note that the 2 main ponds are U-shaped to increase residence time and a recycle pump has been installed to reuse water. Also note that the silt cleaned from the presettling pond has been saved next to the pond for later use in reclamation and that a flocculent addition system has been added to the polishing pond to remove suspended clay and reduce water turbidity (from Hanneman 1987).*

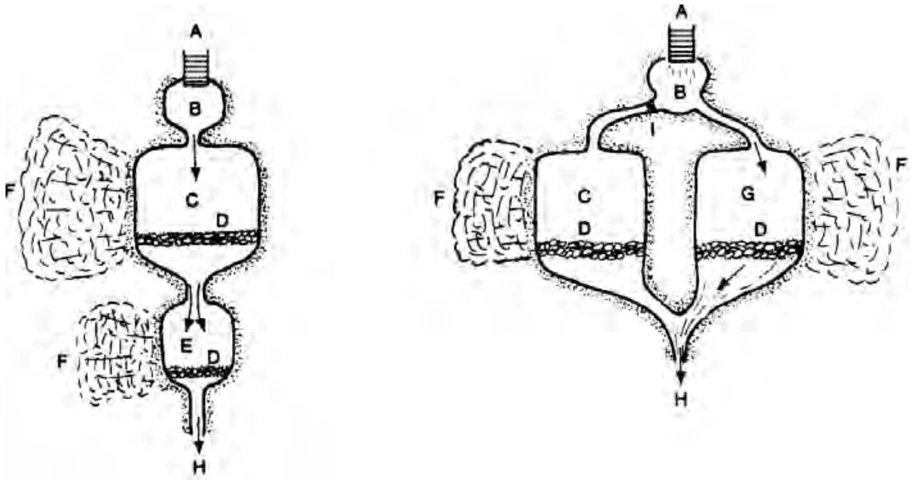


Fig.14: *Two presettling pond designs. Note the sediment filters made coarse tailings should remove the majority of wash plant sediment before water reaches the main settling ponds. Also note that presettling ponds are much smaller than the main settling ponds and will require daily to weekly cleaning (from Hanneman 1987).*

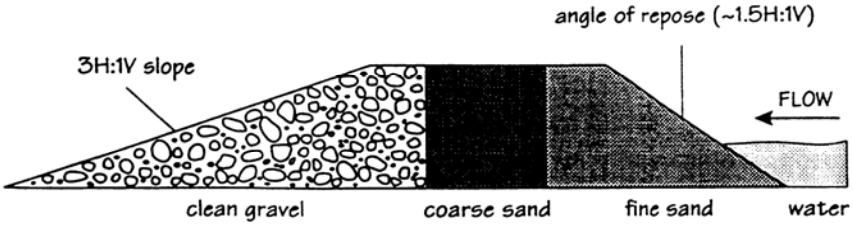


Fig.15: *A design for a sediment filter using coarse mine tailings to remove sediment from mine outflow (from Norman 1997).*

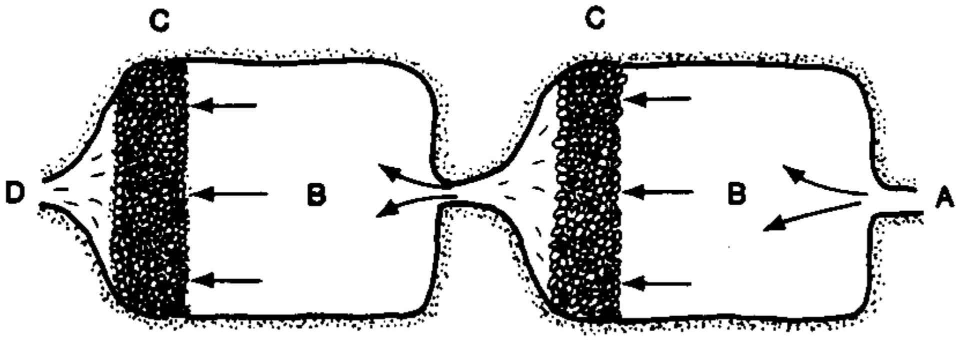


Fig.16: *Settling ponds with coarse tailing filters (from Hanneman 1987).*

Fig.17: ***A)*** *Poor settling pond outflow culvert design. Note that clean pond water cascades out of horizontal culvert pipes, sometimes falling up to 3 m, eroding a large hole at the base of the pond dike.*
B) *Cross-section view of a proper settling pond outflow design. Note that the culvert pipe is angled downward through the dam and large rocks and boulders have been placed at the culvert outlet to dissipate flow energy.* ***C)*** *front view of pond dam (from Hanneman 1987).*

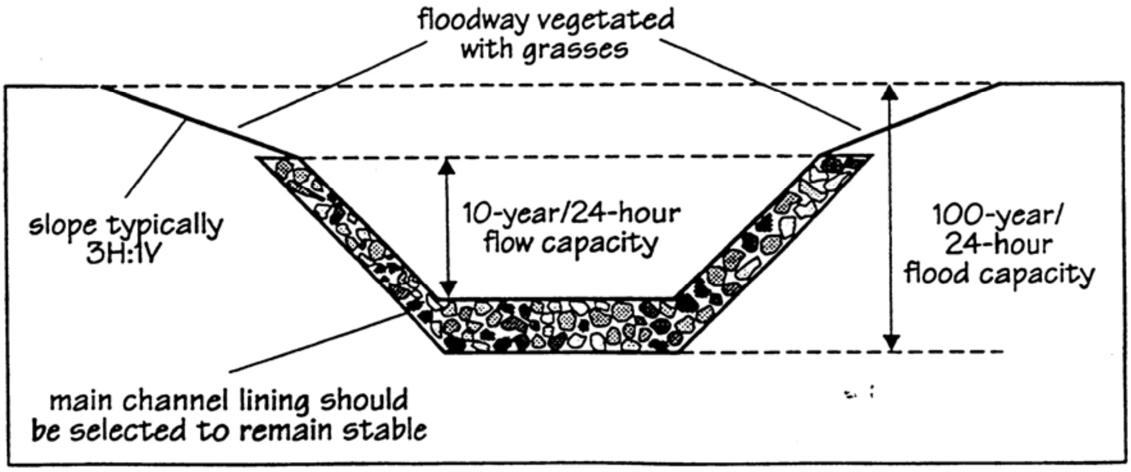


Fig.18: *Improved pond outflow channel. Note that the dug earth channel has been carefully lined with coarse rock tailings to reduce channel erosion (from Norman 1997).*

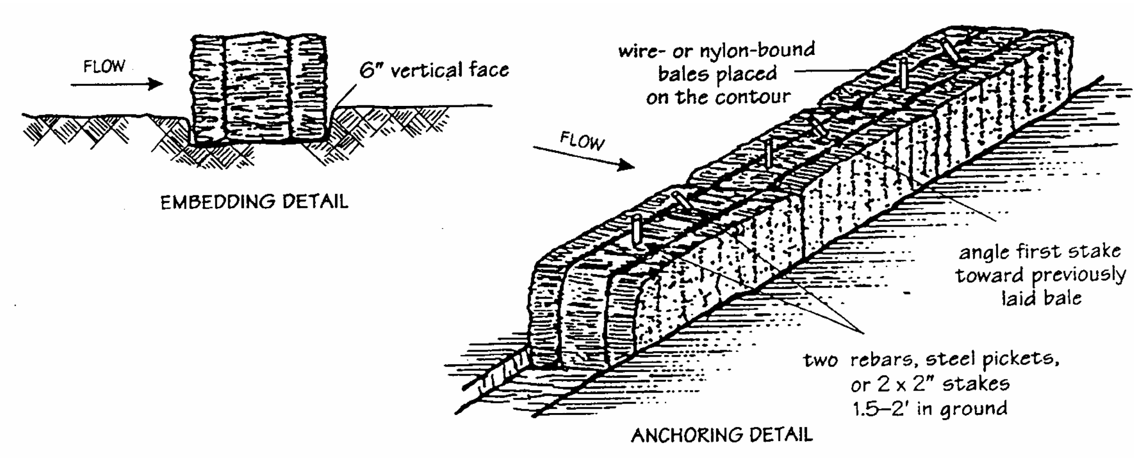
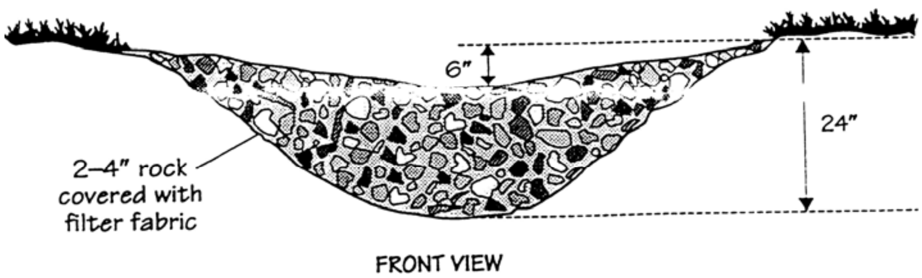


Fig.19: *Erosion control check dam made from hay bales (from Norman 1997).*



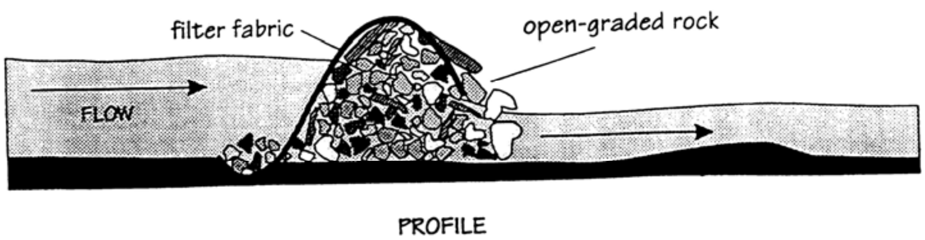


Fig.20: *Erosion control check dam made from coarse tailings (from Norman 1997).*

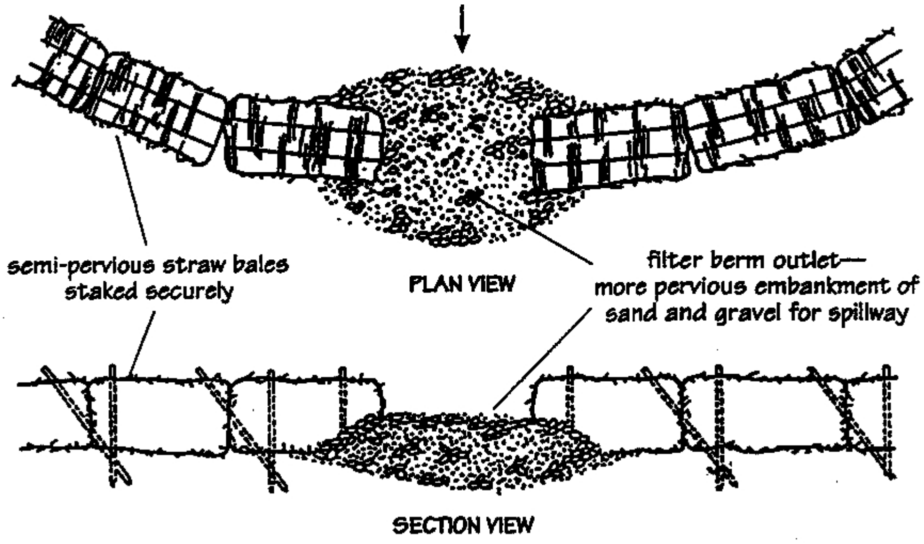


Fig.21: *Erosion control check dam made from hay bales and coarse tailings (from Norman 1997).*

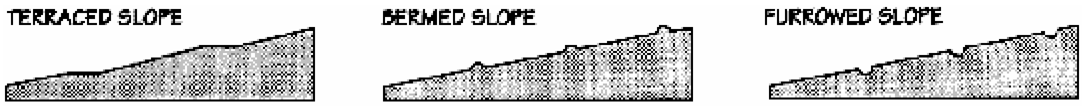


Fig.22: *Erosion control on slopes by construction of slope terraces, berms and furrows (from Norman 1997).*

SEE ANNEX

Fig.23: *Erosion control on slopes using erosion blankets (from Norman 1997).*

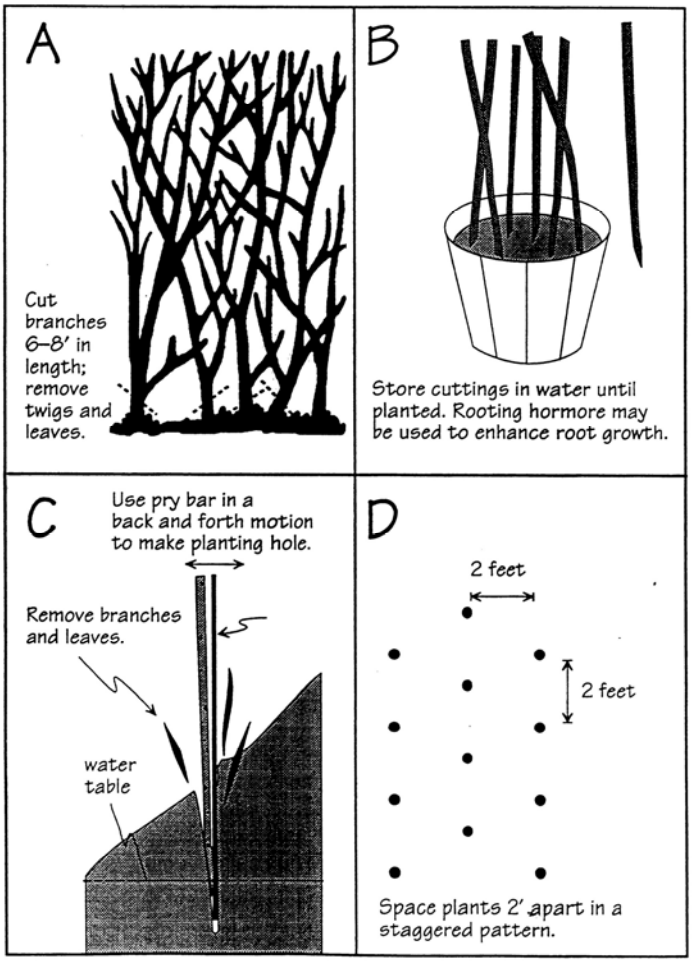


***Fig.24:** Steps in planting willows from cuttings. Note that the optimal annual planting period will vary with regional climate (from Norman 1997).*

***Fig.25:** As yet unreclaimed stretch of Tuul river floodplain, severely damaged by dragline (left) and dredge (right). Note that the active river channel is barely visible behind the overburden mounds (Photographer: John Farrington, August 2000).*

Recommendations

1) Enforcement of Existing Environmental Laws

Existing environmental laws relevant to the mining situation in Zaamar Soum should be consistently enforced. One notable environmental law that goes entirely unenforced is the law on water which requires commercial ventures to pay water use fees (1995 Mongolian Law on Water and Mineral Water Use Fees, Article 3, Section 1). No water fees are collected from the Zaamar Soum mines, although collection of fees might serve as motivation to curtail wasteful water use practices. At present enforcement is extremely limited, due to the Zaamar Soum environmental inspector's lack of a vehicle. Thus inspections are infrequent, and the environmental inspector stays in mining company quarters when inspections are made, which may affect professional objectivity.

Several times a year inspectors from the Ministry of Nature and the Environment travel from Ulaanbaatar to make inspections, issue fines, and shut down mine operations violating environmental laws. However, fines go unpaid for lack of a collection mechanism, and closed mines reopen as soon as the inspection team returns to the capital, whether or not they have corrected their violations. A vehicle should be obtained for the inspector and an inspector's residence built in the mining area so that a minimum of weekly inspections can be carried out during the mining season. To further discourage harmful practices, fines imposed by environmental laws should be increased to be commensurate with the damage being caused, and the profit being earned. Reclamation bonding and EPP preparation should be completed before a mine is permitted to commence the season's operations.

2) Introduction of Operational and Reclamation Standards

Stringent operational and reclamation standards should be introduced for placer mines. Such standards should address:

1. mine waste-water contaminant levels;
2. waste-water disposal methods;
3. requirements for wash plant technology with minimum gold recovery capabilities to eliminate the need for remining tailings;
4. setting a goal of zero discharge for mine operations in the area;
5. a requirement that reclamation not be considered complete until restored ecosystems are completely functional and self-regenerating.

To ensure that a site is properly restored, regulations should also require thorough documentation of a site's pre-mine topography, plant and animal life, using photos and maps. Furthermore, these standards should mandate channel and flood plain protection measures, such as setting a minimum floodplain buffer zone between mine operations and the active channel, and require assessment of the "real" costs of mining operations to the local economy, such as the loss of grazing lands, probably for decades, the reduced productivity from forced overgrazing on un-mined lands, and the long term costs of maintaining a viable riparian ecosystem during mining operations. Mining laws should also attach a rider on the sale of mines requiring that new owners be financially responsible for reclamation of lands unreclaimed by the previous mine owners.

3) Licensing of Mine Operators

In order to ensure that mine operators have the technical expertise to extract gold in a manner that minimises the impact to the local environment, a placer mining exam and licensing process should be developed for chief engineers of placer mines. Such an exam should include sections on placer mining technology, mine operation protocol, mining impacts, and relevant environmental protection laws and standards.

4) River Water Quality Monitoring

A long-term monitoring programme of Tuul river suspended sediment should be implemented above and below the mining district as well as at numerous intermediate points, particularly downstream of the largest mines. Such a monitoring program would assess the long term impact of the mines on river water quality, and assist in establishing goals for improving the environmental performance of mines in Zaamar Soum.

Conclusions

Although the mine revenues from the Zaamar placer gold deposits are of vital importance to the national economy of Mongolia, placer mining as presently practiced in Zaamar Soum has caused extensive damage to the Tuul, and probably the Orkhon and Selenge river ecosystems. Yet many environmental problems arising from the mines can be curtailed at a minimum cost by implementation of sensible mine design and operational practices as described above. While the environmental impact of any given placer mining operation is fairly limited, the cumulative environmental impacts of the 20 active mine operations is large, and will continue to negatively impact the local grazing economy long after mining has ceased. Thus mining should be conducted with consideration of the long term impact on the local herding economy as well as on the ecology of Northern Mongolia's watersheds. At present the local soum government does not receive any revenue from mining operations. With evaluation of the real costs of placer mining, e.g. for restoration of damaged ecosystems and income lost to herders due to long term damage of traditional grazing lands, a more equitable programme for protection of local ecosystems and sharing of mine revenues with the local community can be developed.

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