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BRITISH GEOLOGICAL SURVEY

COMMISSIONED REPORT CR/03/50N

Alluvial mining of aggregates in Costa Rica

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Costa Rica; aggregates; alluvial mining.

Front cover

Peñas Blancas river, Costa Rica. Site of alluvial extraction of sand and gravel for construction of hydroelectric scheme.

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Preface

Throughout the developing world river sand and gravel is widely exploited as aggregate for construction. Aggregate is often mined directly from the river channel as well as from floodplain and adjacent river terrace deposits. Depending on the geological setting, in-stream mining can create serious environmental impacts, particularly if the river being mined is erosional. The impacts of such mining on farmland, river stability, flood risk, road and bridge structures and ecology are typically severe. The environmental degradation may make it difficult to provide for the basic needs (water, food, fuelwood, communications) of communities naturally located in the river valleys.

Despite the importance of this extractive industry in most developing countries, the details of its economic and environmental geology are not fully understood and therefore do not adequately inform existing regulatory strategies. The main problem is therefore a need to strengthen the general approach to planning and managing these resources. Compounding the problem is the upsurge of illegal extractions along many river systems. There is therefore a need to foster public awareness and community stewardship of the resource.

The project 'Effective Development of River Mining' aims to provide effective mechanisms for the control of sand and gravel mining operations in order to protect local communities, to reduce environmental degradation and to facilitate long-term rational and sustainable use of the natural resource base. This project (Project R7814) has been funded by the UK's Department for International Development (DFID) as part of their Knowledge and Research (KAR) programme. This programme constitutes a key element in the UK's provision of aid and assistance to less developed nations. The project started in October 2000 and terminates late in 2004.

Specific objectives of the project include:

- Resource exploration and resource mapping at the project's field study sites (Rio Minho and Yallahs rivers in Jamaica)
- Analysis of technical and economic issues in aggregate mining, particularly river mining
- Determination and evaluation of the environmental impacts of river mining
- Evaluation of social/community issues in the context of river mining
- Investigation of alternative land and marine aggregate resources
- Review of the regulatory and management framework dealing with river mining; establishment of guidelines for managing these resources and development of a code of practice for sustainable sand and gravel mining.

The 'Effective Development of River Mining' project is multidisciplinary, involving a team of UK specialists. It has been led by a team at the British Geological Survey comprising David Harrison, Andrew Bloodworth, Ellie Steadman, Steven Mathers and Andrew Farrant. The other UK-based collaborators were Professor Peter Scott and John Eyre from the Camborne School of Mines (University of Exeter), Dr Magnus Macfarlane and Dr Paul Mitchell from the Corporate Citizenship Unit at the University of Warwick, Steven Fidgett from Alliance Environment and Planning Ltd and Dr Jason Weeks from WRc-NSF Ltd. The research project is generic and applicable to developing countries worldwide, but field studies of selected river systems have been carried out in Jamaica and review studies have been undertaken in Costa Rica. Key participants in these countries have included Carlton Baxter, Coy Roache and Larry Henry (Mines and Geology Division, Ministry of Land and Environment, Jamaica) and Fernando Alvarado-Villalón (Instituto Costarricense de Electricidad, Costa Rica).

The authors would like to thank the many organisations in Jamaica and Costa Rica who have contributed to the project. In addition to the collection of data, many individuals have freely given their time and advice and provided the local knowledge so important to the field investigations.

This report forms one of a series of technical Project Output Reports listed below:

- *Geology and resources of the lower Rio Minho and Yallahs Fan-delta, Jamaica, 2003*. AR Farrant, SJ Mathers and DJ Harrison, British Geological Survey.
- *Aggregate production and supply in developing countries with particular reference to Jamaica, 2003*. PW Scott, JM Eyre (Camborne School of Mines), DJ Harrison and EJ Steadman, British Geological Survey.
- *Assessment of the ecological effects of river mining in the Rio Minho and Yallahs rivers, Jamaica, 2003.* J Weeks, WRc-NSF Ltd.
- *Scoping and assessment of the environmental and social impacts of river mining in Jamaica, 2003*. M Macfarlane and P Mitchell, Warwick Business School, University of Warwick.
- *Alternative sources of aggregates, 2003*. DJ Harrison and EJ Steadman, British Geological Survey.
- *Alluvial mining of aggregates in Costa Rica, 2003*. Fernando Alvarado-Villalón (Costa Rican Institute of Electricity), DJ Harrison and EJ Steadman, British Geological Survey.
- *Planning guidelines for management of river mining, 2003*. S Fidgett, Alliance Environment and Planning Ltd.

Details of how to obtain these reports and more information about the 'Effective Development of River Mining' project can be obtained from contacting the Project Manager, David Harrison at the British Geological Survey, Keyworth, Nottingham, UK, email: djha@bgs.ac.uk

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Summary

Much of the demand for aggregates in Costa Rica has traditionally been met with supplies of crushed volcanic rock aggregate from numerous small quarries located close to the main urban centres in the Great Metropolitan Area. In recent years, however, land-use conflicts, environmental restrictions, resource depletion and a desire for consistent supplies of high quality aggregates have resulted in changes to the pattern of supply of aggregates, with increased contributions of alluvial sand and gravel from instream extraction (alluvial mining).

In Costa Rica, alluvial mining represents a source of good quality sand and gravel with wide distribution, practically inexhaustible resources, easy extraction, and simple processing requirements. However, their generally distant location from the Great Metropolitan Area and the high costs of transportation, limit resource development. Nevertheless, there are many rivers which supply sand and gravel, particularly in the Atlantic region. Distribution is mainly by lorry, but some material from the Barranca river is also transported to San Jose by the recently re-opened railroad system.

Alluvial extraction in Costa Rica is carried out by numerous small companies using unskilled or semi-skilled labour. Quarry operations have a short life involving simple extraction and processing procedures. In recent years, the environmental effects of alluvial extraction have been of concern and have been rigorously investigated in order to prevent or minimise negative environmental impacts. This report describes the environmental impacts associated with the mining, processing and transportation of alluvial sand and gravel in Costa Rica.

An understanding of alluvial dynamics is necessary in order to predict how the river will react to excavation of aggregates from the river channel and the associated effects on river morphology, scour, flood-risk and the sediment budget. As a preventative measure some developed countries have opted for a total prohibition of alluvial mining, but in many developing countries this is not possible due to economic reasons, or to a lack of alternative sources of aggregate supply. In Costa Rica, a specified volume of material may be extracted from a river, based on calculations of the material that potentially could be replenished, a concept termed the 'replacement volume' or 'dynamic reserves' of the river. However, currently a standardised systematic procedure for calculating such volumes does not exist.

The concept of 'environmental recovery' is considered as a means of systematic control of the river mining operations. Mineral licences should identify and execute mitigation measures which favour processes of natural regeneration or recovery, diminishing negative impacts on the environment. However, in areas of alluvial mining activity in Costa Rica, restoration schemes are uncommon. The most relevant experiences of alluvial recovery have been developed by the Costa Rican Institute of Electricity (ICE) during the construction of hydroelectric power plants. Based on these experiences, ICE specialists have listed a number of activities which need consideration and whose prioritisation depends on the stage of the development (before extraction, during extraction, and post extraction) and on the particular environmental conditions of each river section.

The report also presents a review of current mining and environmental legislation in Costa Rica including specific alluvial mining legislation, the management structure regarding alluvial mining licences, and the requirements for environmental impact studies. Recommendations propose future regulatory reform and improved management practices in order to promote the alluvial extraction industry.

This report is one of a series of Technical Reports on alluvial mining in developing countries, most of which relate to Jamaica (see Preface for details). They are the output from the 'Effective Development of River Mining' project which aims to provide effective mechanisms for the control of sand and gravel mining operations in order to protect local communities, to reduce environmental degradation and to facilitate long-term rational and sustainable use of the natural resource base. The work was carried out under the Department for International Development Knowledge and Research programme, as part of the British Government's programme of aid to developing countries. The project was undertaken in collaboration with key organisations in Jamaica and Costa Rica, who provided field guidance and local support.

1 Introduction

The supply of aggregates in Costa Rica has historically been from many small volcanic rock quarries, located close to the urban centres of the Great Metropolitan Area (GAM). In recent years, land-use conflicts, exhaustion of reserves and a desire for supplies of consistent high quality aggregate, has resulted in a change in the pattern of supply of aggregates, with a growing importance of supplies from alluvial sources.

The environmental impact of alluvial mining (instream extraction) is a controversial topic. In some developed countries it is prohibited, but this is not usually possible in less developed countries, due to economic reasons. In Costa Rica, alluvial mining represents a source of good quality sand and gravel, with practically inexhaustible resources, easy extraction and simple processing requirements. Alluvial resources have a wide distribution thanks to geological, topographical and climatic conditions that have favoured the development of a wide hydrographic net.

In order to prevent and control the environmental impacts of alluvial mining it is important to understand the aggregates industry in Costa Rica, to investigate the quality of alluvial aggregates, their methods of extraction and processing and the prevailing legislation and regulatory regime.

2 Aggregate Production and Construction

2.1 Annual Production

The main source of published information on non-metallic mining production of the country, including construction materials, results from the Anglo-Costa Rican Industrial Minerals Project (Berrangé and others, 1989).

In the last decade the consumption of aggregates and derived products has fluctuated. Market growth is thought, by construction industry forecasters, to be 3% per annum for the next five years (Velasco, 2002). Few reliable statistics exist, but it is estimated that the national production of aggregates in 2001 totals around 4.5 million cubic metres, of which 3 million cubic metres are used in concrete mixtures for the Great Metropolitan Area and 1 million for rural areas. The remaining 0.5 million cubic metres of aggregates are used in highways at national level (Alvarado, 2001). Additional estimates of production, based on analyses of the mining industry in the GAM (Castro and Calvo, 2002), also comment on the lack of reliable production data and estimate national production between 4.1 and 5.6 million cubic metres for 1999, based on an estimate of annual national construction and cement consumption. This estimate is likely to be relatively precise, as the statistics supplied by the cement industry are thought to be more reliable.

The estimates carried out by public institutions probably tend to underestimate aggregate production figures due to:

- An imprecise data gathering system which is not applied systematically by the regulatory organisations
- Manipulation of the required information by the licensees, in attempts to avoid sales taxes.
- Unknown volumes of production from illegal mining (Castro and Calvo, 2002).

The construction industry makes a significant contribution to the national economy, but, the analysis systems and gathering of statistical information established by the state entities, estimate the contribution from the mining sector to the Gross National Product (GNP) to be just 0.1%.

2.2 Available Aggregates

Costa Rica originated from a proto-continental crust, and only recently (in mid-Tertiary times) developed from an oceanic arc system. The geology consists of a basement of oceanic basaltic rocks (mid-Jurassic to early-Tertiary age), overlain by varied sedimentary and volcanic sequences ranging in age from mid-Cretaceous to the present (Figure 1).

The country is divided into two tectonic domains by a transform fault trending E-W across the country. To the North of this fault, a chain of active strato-volcanoes is present with andesitic-basaltic, andesitic and dacitic lavas, ash-flow tuffs, some rich in pumice, and air-fall deposits, including pumice, scoria and ashes with a varied degree of consolidation (Berrangé, and others,1989). This wide range of variable character volcanic rocks in a tropical climate with high humidity, suggests that aggregates produced from the rocks would be generally of a relatively low quality. These volcanic rocks are broadly exposed in small but multiple quarries especially in the Great Metropolitan Area, from where most of the demand has historically been supplied for the construction industry. At the present time around 70-85% of aggregate production comes from the processing of volcanic rocks extracted in these quarries (mainly lavas, scorias and tuffs). Such operations require a higher level of initial capital investment and more complex and more extensive processing operations than are typically required for alluvial mining.

In the South of the country, deeper crustal rocks are developed characterized by the granitic rocks of the Talamanca Range. For reasons of distance, access and environmental restrictions, commercial quarries have not been developed in these rocks, despite their widespread occurrence, and potential for high quality aggregate production.

2.3 Alluvial Extraction

Erosion of the volcanic and granitic mountain ranges in Costa Rica, produces enormous resources of fluvial aggregate material (Figures 2 and 3). Deposits of sand (+1/16mm) and gravel (+4mm) are poorly sorted and consist of a diverse mix of volcanic rocks, intrusive igneous rocks, sandstones, shales and limestones. These unconsolidated materials are easily loaded by machinery directly from the riverbed and transported to the processing plant or directly to the point of use.

The alluvial sources can be divided into three main groups based on their distribution and characteristics (Figure 1 and Table 1).

In the **Atlantic Region**, there are many rivers which supply sand and gravel, with distribution by lorry. Of particular importance are:

- The Reventazón and Grande de Orosi rivers in the central region of the country, which contributes volcanic sands and gravels of good quality for the Cartago and San José regions (Figure 4).
- The Chirripó River in Limon where intrusive rocks prevail, but with contributions from volcanic rocks. Here aggregates of premium quality are exported through the nearby port of Limon.
- The Sucio, Toro Amarillo and other rivers in the Guápiles area, supply very good quality aggregates. Volcanic rocks prevail, but with minor contributions from intrusive igneous rocks (Figure 5). This area supplies the GAM by lorry, with sand for concrete and almost all of the aggregates used for asphaltic mixtures. It is anticipated that this area will become an increasingly important source of supply.

The **South Pacific Region** is characterised by lower quality materials. Significant points of supply are not developed.

The **North Pacific Region** is characterized by a general mix of diverse quality alluvial materials, due to the prevalence of relatively weak volcanic and sedimentary rocks. However, areas of particular interest for aggregate resources include;

- The Barranca River, Central Pacific Region – here moderate quality sands and gravels are important where lavas prevail and also, to a smaller degree, where sandstones occur. The area supplies the Puntarenas and San José regions by lorry, and also supplies San Jose by the recently re-opened railroad system.The over-exploitation of the river sediments has caused serious scour to a major bridge on the Interamerican Highway.
- The Tempisque River in Guanacaste drains a large basin (955km^2). Extraction of the volcanic sands (Figures 7 and 8) is mostly by a co-operative of about 120 small scale miners that supplies local markets in Liberia, Conchal and the western part of the Nicoya peninsula.

Figure 1 Geology of Costa Rica and principal alluvial extraction areas

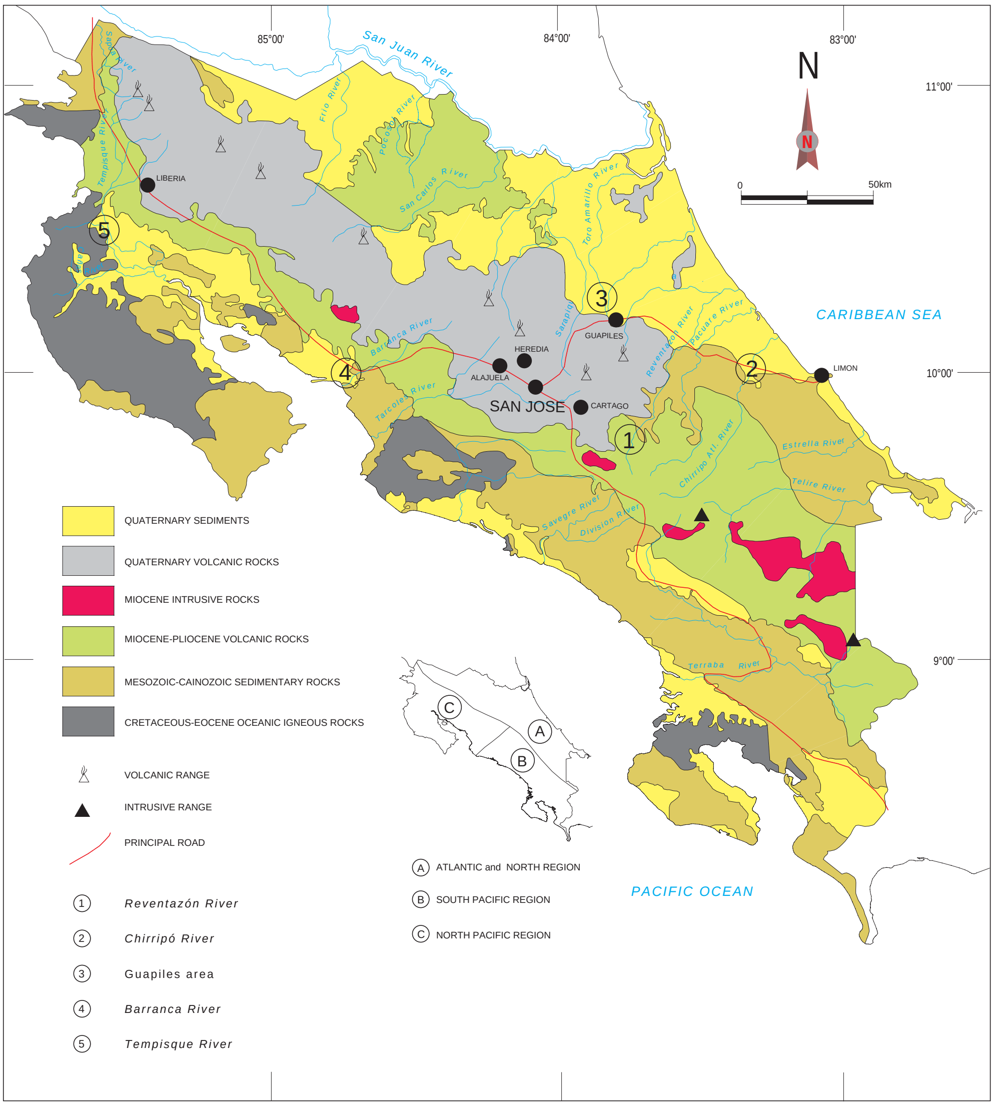


Table 1 Characteristics of alluvial mining in different regions of Costa Rica

	Atlantic Region	South Pacific Region	North Pacific Region
Dry season Wet season	Indefinite, reduced rainfall (mostly all year round)	December — May (6 months) June — November (6 months)	December—June (7 months) July—November (5 months)
Maximum/minimum rain per month	1287mm (Guápiles) 39mm (Guápiles)	1159mm (Playón Parrita) Zero (Playón Parrita)	662mm (Bagaces) Zero for several months (Bagaces)
Annual rain rate	6434mm (Guápiles)	3660mm (Playón Parrita)	1378mm (Bagaces)
Example river	Río Toro Amarillo ($138Km^2$)	Río Parrita ($422\ Km^2$)	Río Tempisque ($955\ Km^2$)
Discharge regime	Minimal contrast of discharge between dry and rainy season	Major contrast of discharge between dry and rainy season	Major contrast of discharge between dry and rainy season
Specific discharge (litres/sec/km$^{2)}$	112 (Toro Amarillo River)	66 (Parrita River)	27 (Tempisque River)
Geology and aggregates present in the region	Strong uplifting and erosion. Predominance of volcanic and intrusive rock aggregates	Strong uplifting and erosion. Predominance of volcanic and intrusive rock aggregates	Little uplifting and erosion. Predominance of volcanic and intrusive rocks, of mainly sand size
Available aggregate materials	High quantities of available aggregates for transportation	High quantities of available aggregates for transportation	Small quantities of available aggregates for transportation
General slope	Steep	Steep	Gently sloping
Flow velocity	High ranges	High ranges	Low ranges
Transport distance	Significant	Medium	Significant
Morphology of the river	Predominance of braided rivers. Numerous abandoned channels that migrate over previous thick deposits	Braided rivers. Abandoned channels that migrate over previous thick deposits	Straight rivers. Rivers controlled by bedrock outcrops
Dynamics of the river	Frequent lateral migration, re-activation of old channels	Frequent lateral migration, re-activation of old channels	Well defined channels with little lateral migration
Particular river characteristics	Narrow and deep channels, with small flood plains. High energy floods with strong erosive power	Narrow and deep channels, with small flood plains. High energy floods with strong erosive power	Wide and shallow channels, with major flood plains. Low energy floods with small erosive power
Other characteristics	Abundant riparian vegetation, shaded riverbanks, medium evaporation, abundant biodiversity	Riparian vegetation present, shaded riverbanks present, medium evaporation, medium biodiversity	Minor riparian vegetation, sunny riverbanks, medium evaporation, medium biodiversity
State of environmental degradation (of the basin)	Medium or minimal	Major or medium	Major
Available aggregate resources	Enormous resources, readily replenished	Enormous resources, readily replenished	Minor resources, sporadically replaced
Deposit characteristics	Wide grain-size range, from large boulders to silt	Wide grain-size range, from large boulders to silt	Narrow grain-size range, with predominance of sand and silt
Aggregate quality	Very high quality in terms of strength. Crushing may be required.	Variable quality materials (strength and durability) depending on the region. Crushing may be required	Sand and silt only, of moderate quality
Trade	Transport to the Metropolitan Area, international export	Local distribution only	Local distribution only, mainly for tourism infrastructure
Frequent mining problems	Lateral instability of the river and its tributaries, flow re-directions, intense erosion of bordering lands and infrastructure	Lateral instability of the river and its tributaries, flow re-directions, intense erosion of bordering lands and infrastructure	Over-extraction of resources, impacts on bordering wells, changes in the river longitudinal profile, damages in bordering lands and infrastructure
Recommendations for environmental extraction management	Management should aim to maintain natural conditions, specifically to establish lateral stability of the river and its tributaries	Management should aim to maintain natural conditions, specifically to establish lateral stability of the river and its tributaries	Management should aim to keep natural conditions, with regard to maintaining the available resources of aggregate materials

Figure 2 Peñas Blancas river, Atlantic Region. Extraction of sand and gravel for hydroelectric project. Note the small ponds constructed to trap sand from the river (which is flowing at the foot of the cliff).

Figure 3 Peñas Blancas river, Atlantic Region. Extraction of sand from the sand traps after a flood event during the rainy season.

Figure 4 Rio Tempisque, Guanacaste, North Pacific Region. A-frame screen for simple processing of sand and gravel.

Figure 5 Toro Amarillo river, Guapiles, Atlantic Region. Large scale instream mining of sand and gravel, producing high quality aggregates for the principal market of San Jose and the GAM.

Figure 6 Rio Guayabo, San Carlos, Atlantic Region. Extraction of sand and gravel directly from the river channel.

Figure 7 Rio Reventazon, Turrialba, Atlantic Region. Mobile sand and gravel processing plant.

Figure 8 Rio Zapote, Guanacaste, North Pacific Region. Extraction of river sand by small scale miners from low energy river systems.

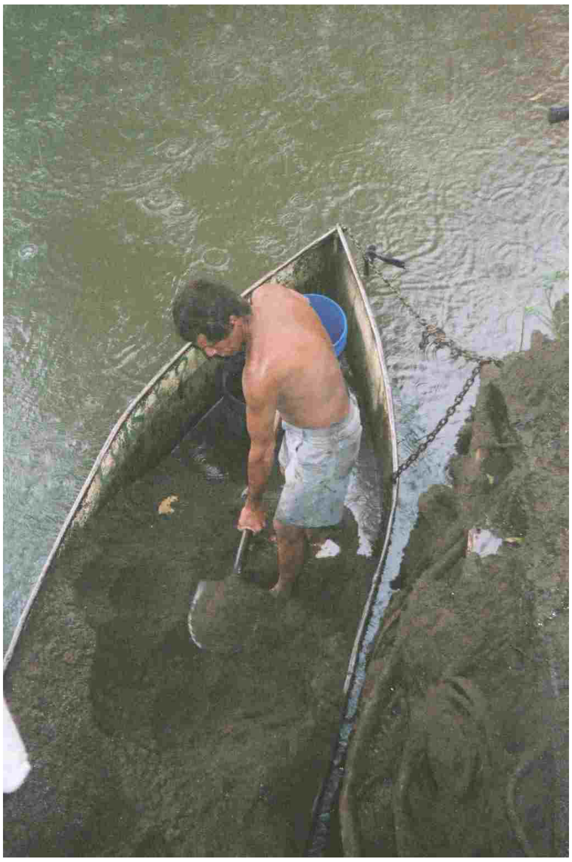


Figure 9 Rio Zapote, Guanacaste, North Pacific Region. Hand-loading river sand into trucks to supply the local aggregates market.

Small-scale/artisanal river mining is undertaken in several regions of Costa Rica. These operations are typically conducted by small groups of individuals or co-operative ventures, who will hand-dig sand from mid-stream shoals. The sand is loaded on to small, steel-hulled boats which are towed to shore. These are then unloaded, again by hand, on to a stockpile at a convenient point on the river bank (Figure 8). From here, the sand is allowed to drain, until it is loaded on to trailers or ox-carts for further transportation to the side of a main highway. Sales are then made at the roadside, where material is mechanically loaded on to 10-20 tonne trucks. Each truck will often make several stops to pick-up small loads from several producers in order to make up a full load (Figure 9).

At the present time it is not possible to carry out a precise calculation of the relative contribution of alluvial mining to regional or national production. Conservative estimates suggest that alluvial mining contributes around 15% of total aggregate production, that is to say around 750 000 cubic metres per annum of aggregate. Around 50% of this production is dedicated to asphalt mixtures (especially medium granulometries) and the remainder is used in concrete (particularly the sand fraction). However, more realistic estimates may be appropriate (up to 30% contribution from alluvial sources) due to additional recurrent requirements of up to 500 000 cubic metres of alluvial aggregates per year for infrastructure projects, particularly for electricity generation schemes of the Costa Rican Institute of Electricity (ICE) in rural areas. All the available evidence suggests that alluvial mining is rapidly growing in importance, particularly from the Guápiles area.

2.4 Quality

The quality of aggregate materials in terms of strength and durability, is one of the most important requirements when considering the performance of an aggregate in mixtures of concrete or asphalt. In Costa Rica the standards of the American Society for Testing and Materials (ASTM) are used, although in many cases the specifications and testing procedures are not applied rigorously, but are used as general guidance for the assessment of an aggregate for a particular purpose.

The most commonly used aggregates in Costa Rica are those derived from crushing andesitic-basaltic lavas. However, these are characterized by their ease of alteration, their variable porosity, their chemically metastable composition and their highly variable physical properties (such as specific gravity, water absorption). These characteristics indicate a relatively poor aggregate performance and added costs when used in mixtures of concrete and asphalt. In contrast, the intrusive granitic rocks of medium and coarse grain size are not used as intensively for aggregates despite their minimal alteration, their high strength, low porosity, chemical stability and homogeneity. Most sedimentary rocks used as aggregates are clastic rocks composed of fragments of volcanic rock (greywackes) with variable degrees of alteration and cement types, and limestones with varied crystallinity and degree of cementation. Sedimentary rocks only contribute a small proportion of aggregates in Costa Rica.

Due to the variable and complex volcanic lithostratigraphy, and to inadequate quality control in the quarrying methods, it is usual that the volcanic rock aggregates supplied to the GAM are of diverse quality, including excessive fines and organic matter contents that impact on the the properties of the aggregates. In contrast, the alluvial sources present deposits with mixtures of rocks of varied type, depending on the geology of the basin, where the reworking force of the water selects the most resistant materials. The presence of water during the extraction process, facilitates the separation of fines, clays and other undesirable materials, reducing the need for additional washing processes. Alluvial aggregates, therefore, generally form good quality raw materials for construction. Nevertheless, occasionally the alluvial sources may become contaminated as a consequence of natural phenomena such as landslides and floods or by anthropogenic activities such as deforestation or by the waste from former mining activities. In addition, the high degree of roundness and sphericity of the gravel may require crushing to give best performance in asphalt and concrete, but this can lead to more plant wear and high processing costs.

Most of the smaller companies producing aggregates in Costa Rica lack appropriate systems of quality control. There are, however, frequent controls on the performance of the final products (concrete, blocks, asphalt mixtures), and these are applied by the larger manufacturing companies which have specialized laboratories or the services of private or academic laboratories. These controls on quality are extending towards the extraction sector, including the processing plant and the handling of stockpiles. For example, from 1996, as a consequence of the serious deterioration of the road infrastructure, a better quality control of aggregates has been maintained by the formulation of higher quality asphalts, using almost exclusively alluvial aggregates composed of mixtures of better quality intrusive and volcanic rocks. These aggregates are cheaper to produce, but attract higher transport costs.

The ex-works prices of aggregates are currently considered to be US\$ 8/m^3 for crushed stone, US\$ 7-8/m^3 for clean (classified as 'good') sand and US\$ 7/m^3 for unprocessed ('poor') sand. Typical costs of production are thought to be US\$ 4-5/m^3 for crushed stone; US\$ 4/m^3 for good sand and US\$ 3/m^3 for poor sand. The concern for the provision of a quality product is beginning to have a growing influence on the amount of processing required and hence on the price of the aggregates to the consumer (Alvarado, 2001).

In the future, it is anticipated that there will be greater interest for the respect of norms, nomenclatures and standardized constructive procedures, and a more rigorous role on behalf of the regulatory regime for quarrying, and other organizations involved with the construction industry, particularly with regard to operations of smaller scale. There is a Government Bill pending approval, which states that the regulatory bodies of mining would require the mining licensees to undergo controls of quality. The growing development of investigations about the quality and availability of aggregates required for each specific use, will allow a more rational use of aggregates, assuring the preservation of the resources of better quality for the most demanding applications.

2.5 New Patterns of Supply

In recent years, several factors favour a major change in the pattern of supply of aggregates for the construction industry, with a growing contribution from alluvial mining (Alvarado, 2001):

- Many small quarries developed in volcanic rocks in the proximity of the Great Metropolitan Area, face a rapid depletion in reserves, increasing the complexity and the costs of extraction. This situation results from the sterilization of valuable resources by unplanned urbanisation, and by an increase in the price of land, serious conflicts in the use of land and environmental restrictions. It is therefore foreseeable that in the near future aggregates will be sourced outside the GAM, by fewer, but larger quarries from alluvial and volcanic rock sources. Such quarries will have larger reserves, although they will be characterised by a significant increase in transport distances and cost. Nevertheless, the quarries will be connected to a wider market and have a more efficient operational capacity. The quarrying companies will be better equipped financially and technically and will produce a wider range of products, with the versatility to adjust to the demands of the market, particularly with regard to stricter requirements for environmental protection and quality of the products.
- The demand for constructional raw materials in the GAM is increasing, especially for aggregates of good quality for certain specific uses. Almost all of the medium grained, sand-sized aggregate for asphalt is supplied by lorry from alluvial deposits in the Atlantic Area (Guápiles), in substitution for fine aggregate from the volcanic rock quarries of the GAM. In addition, an increasing volume of the sand for concrete also comes from this source.

- The Atlantic Area has enormous resources of alluvial aggregates with wide distribution, and deposits readily replenished in the frequent storm events. However, their distant location from the GAM and the high costs of transportation to the main markets, limit their commercialisation. This situation could radically change if the former railroad is re-opened, as it will reduce transportation costs, as well as lead to a reduction in the damage to roads caused by lorry traffic. Almost all overland cargo is transported by lorry on the 7,000km of provincial highway and 16,000km of rural roads. Transport costs range from 12 cents/km/m^3 to 30 cents/km/m^3 according to the age of the vehicle and the condition of the road.
- The shortage of aggregates of high quality in some parts of the east coast of North America and on certain Caribbean islands, gives rise to a potential market for alluvial aggregates from the Atlantic Area, due to the existence of a large, deep water port at Limon. The profitability of exports of a product of such low unitary cost requires shipment in bulk. Substantial improvements in the local highway and port infrastructure are required before this becomes feasible, although small amounts of aggregates have been exported over the past decade. In addition, a small but well placed export market for construction materials, may exist between the Guanacaste region and Nicaragua.

3 Environmental Impact Of Alluvial Mining

In Costa Rica, alluvial mining is an increasing activity carried out mainly by numerous small companies using unskilled or semi-skilled labour. Extractive operations have a short life involving simple extraction and processing procedures, with minimal requirements for waste disposal or storage. In the past 20 years, the environmental effects of alluvial extraction have become of greater concern and have been more rigorously investigated, in order to control, mitigate or prevent the environmental impacts.

3.1 Alluvial Dynamics

The active river transports sediments as bottom load (gravel and sand) and in suspension (silts and clays) from higher mountainous areas to the point of deposition. The capacity of the river for transportation is a function of multiple hydraulic conditions of the riverbed (size of the material in the channel, speed of the flow, hydraulic and geometric properties of the channel, etc). In a certain section of the river, if the incoming flow of sediments is similar to the outflow of sediments, the river is in balance. In very simple terms, this balance can be described mathematically in an “Equation of Balance” - where the flow of the river (Q) x slope of the river (S) is proportional to the load of sediments (Qs) x the average diameter of the sediment material (D_{50}):

(Q x S) is proportional to (Qs x D_{50}).

Alluvial mining in an active river channel (instream mining), implies interruption of the transportation of sand and gravel, and the construction of a cut or “incision” in the drainage channel by means of two mechanisms that alter the balance between sediment supply and transporting power:

1 – Excavation of aggregates in the channel of the river works as trap for the sediments transported as bottom load, while the water continues flowing downstream exerting an excessive dragging capacity. This water (sometimes described as “hungry water”) is deprived of its sediments and tries to recover part of its original load of sediments by eroding the channel bed and to a lesser degree, the banks of the river downstream of the extraction site.

2 – Excavation also results in a locally steeper gradient, with increased stream power and channel erosion creating a headcutting or 'knickpoint' which may migrate progressively upstream, causing incision of the riverbed.

3.2 Potential for Replenishment

Most rivers during and after aggregate extraction, adjust to the removal of a portion of their load of sediments without serious effects, provided the scale of extraction does not exceed the amount replenished, particularly in the rainy season. Under these conditions, it is assumed that alluvial mining does not have a significant impact on the morphology of the riverbed. However, in the medium term, a minor lowering of the level of the river channel will be evident, due to the propagation of the incision along the channel.

When alluvial mining exceeds the rate of normal sediment replenishment, then major changes in channel morphology may result, both upstream and downstream of the extraction site, including variations in the general slope of the riverbed, and in the depth and shape of the channel, due to lateral instability. In some extreme cases, it may also result in lowering of the levels and flows in nearby water wells, drying of the root systems in the surrounding vegetation, and lead to the destruction of wetland habitats.

In efforts to minimise these effects, sheetpile structures have been used to limit the degree of the incision and the migration of the knickpoint upstream. The profile of the river may recover by gradual accumulation of sediments (agradation). However, downstream, the effect of unstability in the profile of the river persists, due to the impact of 'hungry water'. In such cases, downstream of the sheetpile, scouring of structures (eg bridges) and the exposure of conduction lines buried in the channel of the river (pipelines and aqueducts) are possible.

As a preventative measure, some developed countries have opted for the total prohibition of alluvial mining, but in many developing countries this is not possible due to economic implications or a lack of alternative options for aggregates supply. In Costa Rica, a specified volume of material may be extracted from a river, based on calculations of the replacement volume or 'dynamic reserves' of the river. However, currently a standardised, systematic procedure for calculating such volumes does not exist.

Ideally, the appropriate extraction rate and volumes should be defined with reference to specific data that consider:

- The transport of sediments of each river and of each tract of the river under consideration.
- A rigorous recording of the extracted volumes.
- Verification of the evolution of marked river traverse profiles, ideally supplemented with sequential aerial photographs.
- A careful and periodic analysis of the evolution of the effects of extraction.

Nevertheless, in tropical areas, the rivers are characterized by major variations of flow from one year to other, as well as from seasonal variations. Since the transport of sediments is in great measure a function of the flow of the rivers and streams, the replenishment of extracted materials is a very variable and highly episodic process.

In conclusion, any estimates of the volumes which may be safely extracted from a river are plagued by uncertainty and are associated with errors and assumptions, as a result of the difficulty of obtaining appropriate data, the complexity of the scientific factors, and the limitations of the countless equations and existing calculation methods. The only real measure of variations in the dynamics of the riverbed, is the systematic measurement of the deepest point in the channel in a transverse section (or thalweg) in several sections of the river. Even if the extraction volumes are kept below those of supply, changes in the conditions of the channel bed will result in changes in the channel morphology. Only a rigorous monitoring scheme that records and interprets changes from once the extraction starts, will allow the necessary adjustments for the establishment of an appropriate volume of extraction designed to minimise environmental and – ultimately – social impacts.

3.3 Grain Size Changes

As a result of the instream extraction process a quantity of fine sediment is introduced into suspension, creating turbid conditions. This effect may be minimised by means of construction of dykes and channels (see Figures 2 and 3) to manipulate the flow of water, isolating extraction areas from the main current. This requires a river bed of sufficient width to accommodate the engineering schemes. These works are usually carried out during the dry season, when the riverbeds of the rivers are in their period of low flow. The excavation areas separated from the main current, act as sedimentation traps during periods of peak flow, accumulating new materials particularly sandy sediments.

The construction industry usually requires aggregates rich in sand from alluvial sources, due to its high quality (preferred grain sizes and grain shape, and mechanical strength), low production costs, and the technical difficulties involved in obtaining alternative manufactured sand from crushed rocks. It is common practice to preferentially select sandy sediment and discard the coarser-grain size materials. This results in a substantial coarsening of the riverbed sediments at the extraction site. When the percentage of cobbles is very high, there is significant reduction in efficiency of the extraction operation and an increase in equipment maintenance costs.

The increased grain size of the riverbed sediments, typically leading to a channel lined with cobbles and coarse gravels, has a serious negative effect on aquatic habitats. A river is typically ecologically diverse, associated directly or indirectly with fish spawning, and with the distribution of seeds, and is directly linked to the phreatic levels of swamps, flood areas, and the dynamics of the forest. Nevertheless, the negative effects could be minimised if the larger boulders (>60cm) were isolated during extraction and used to armour the riverbanks and provide stabilisation.

3.4 Socio-Economic Impacts

Before extraction takes place, it is important to consider the socio-economic aspects of alluvial sand and gravel extraction. These aspects include impediments in the activities and the movement of the population; interference to traditional local social activities of recreation and tourism; changes to social, cultural and economic patterns in the community; modification in the use of land and land tenure; expropriations; changes in the infrastructure and the transport; displacement and affluence of families and manpower; changes in conditions of life; employment opportunities; training in new skills; construction of secondary and new roads; changes in the cost and the availability of goods and services; change in aspects of occupational health; physical risks in working conditions; increase in the danger and risk of accidents.

3.5 Other Environmental Impacts

Other positive and negative environmental impacts associated with the activities of alluvial extraction, processing and transportation of the material, need to be considered. Some of the most important impacts are:

- Disturbance of the surface and topography of the riverbanks
- Destruction or modification of habitats during land clearance operations
- Generation of solid waste materials
- Extraction, compaction, contamination, erosion and destabilization of soils

- Contamination of surficial and ground waters for oil spills
- Restriction of water for human consumption or amenity
- Deterioration of local air quality
- Increase in the levels of noise, dust and vibration from the processing operations and transportation
- Increase in road traffic with the additional risk for traffic accidents and road damage
- Improved local road networks with access to isolated natural areas
- Visual intrusion by infrastructure, equipment and vehicles
- Conflicts for resource use, especially water
- Potential for entrance of exotic species to the river
- Increase or decrease in the productivity of species

4 Environmental Recovery

In the context of land-use planning, alluvial aggregate mining should be considered as a temporary use of land. Mineral permissions (licences) should identify and execute mitigation and/or correction measures which favour processes of natural regeneration or recovery, diminishing negative impacts on the environment.

Plans which include requirements for environmental recovery, will involve many parameters including:

- The deposit type to be worked
- The scale of development of the work
- The design and the work method
- The excavation depth, particularly its relationship with the local phreatic level
- Scheduling of the works
- The nature and volume of any waste materials generated at the site
- The original conditions of the site prior to development
- Schemes for after-use of the site.

The concept of environmental recovery in alluvial mining has generally been restricted to recovery at the extraction site. However, the impacts of extraction are not limited simply to the exact mined site or to the period of activity. While the site is operational, and even for a considerable time after extraction, the active channel of the river responds to the incision and disturbance, causing substantial changes in the hydrological, fluvial, hydrogeological and biological regimes of the river. Once natural readjustments have been initiated, the dynamic processes of the river, will adjust the profile of the river, eliminating and distributing the excavations or incisions along the riverbed. It is therefore not realistic to presume that mining in an active channel can avoid environmental impacts by means of initiating “recovery " once the mining has been concluded.

4.1 Fundamental Principles

An appropriate “Plan of Recovery” for a particular alluvial mining scheme begins before extraction starts, adopting work practices and technologies that reduce the major adverse long-term environmental impacts, and favour site recovery assuring appropriate and beneficial future use of the area. The minimization of environmental impacts must be given full attention during the extraction operation. Recovery will only be possible by means of systematic control of the mining operation based on a theoretical and practical knowledge of potential impacts. The following aspects are relevant for an appropriate understanding of the processes of environmental recovery (from Gonzalez and Garcia, 1998):

1- Connection river - basin: The environmental recovery in a section of river will be poor if the alluvial mining is associated with other regional effects, including abrupt oscillations of flow, dry periods, frequent floods, retention of sediments in an upstream dam, excessive sediment discharge from erosion in the basin, and uncontrolled use of the riverbanks (by mining activity, overpasturing, waste disposal, etc.).

2- Flow regime vs. fluvial ecosystem: The effects of alluvial mining on environmental modifications in the riverbed and its marginal lands can only be evaluated if the pre- and post-mining situation is compared in the context of that particular mining extraction. The process of recovery of the riverbed is influenced by, among other variables, the duration and rhythm of flood events, the sedimentation of fine particles, and the cleaning of the riverbed by excessive macrophytes.

3- Variations in the morphology of the riverbed: Sediment extractive activities may destabilise the balance between the flow régime and the sediments generated within the basin causing erosion, both in the channel (incision) and in the banks of the river (as outlined above). Mining also tends to concentrate and increase the speed of the flow, affect the flora, fauna and the micro-organisms of the river, causing a progressive lowering of the phreatic level in the riverlands, and leads to a reduction in the frequency of floods. The recovery process, should tend to retard or to accelerate the rate of re-adjustment of the river to its natural condition. This process should favour the development of vegetation, improve the temperature conditions of the river, stabilise the biodiversity of the whole fluvial system, and recover the overall morphological relationship between the riverbed and the floodplain. Sheetpile structures used in some schemes tend to diminish the slope of the riverbed, establish a shallower riverbed and a lower phreatic level of the adjacent flood plain.

4- Biodiversity of a river is a product of heterogeneous habitats: Biological diversity depends on the maintenance of the complex trophic chain of the ecosystem, where the vegetable matter of the flood plain, added to the primary production in the river, is used by the consumers of the river (organic carbon is vital for the macroinvertebrates), creating a mutual dependence between the river and the flood plain, with a fundamental exchange of matter and energy. The riverside vegetation exercises other numerous functions. It diminishes the effects of flooding, retaining and absorbing great quantities of water and associated sediments; it acts like a natural filter when retaining sediments and nutrients, separating the riverbed from contamination originated in the hillsides or flood plain, or associated with human activities; it diminishes the speed of runoff to the riverbed, diminishing erosion of the riverbanks and of the river channel; it facilitates the movement of species and the connection between different habitats required by the different states of development of certain species.

Restoration of rivers should tend to increase the habitat's heterogeneity with an appropriate balance between the flow regime and the morphology of the riverbed.

5- Individual nature of fluvial systems: Each river possesses individual characteristics resulting from its particular hydrological regime and the history of human intervention in the drainage basin. In consequence, even when faced with a wide range of problems, the design of environmental restoration projects needs to be specific to each case, considering the morphology, the intensity of the fluvial processes, the biological individuality, the objectives of the restoration and the conditions of the landscape, in an attempt to diversify the ecological conditions, with reference to those areas which at the present time are in a better state of conservation.

6- Working with nature is more effective than working against it: Restoration work should respond to the natural dynamics of the river during periods of flooding. Many existing problems in rivers are associated with: 1- the presence of obstructions to water flow (both natural and man-made), 2- erosion of the banks due to a lack of vegetation cover and, 3-excessive growth of micro-organisms (macrophytes). The periodic flood events remove the obstacles naturally from the riverbed, reducing the need for expensive dredging. Also, the riverbank vegetation of the river gives force and cohesion to the flows, impedes erosion, improves its aesthetic appearance, gives shade to the waters, regulates the temperature and entrance of light, controls the massive growth of macrophytes and reduces the need for expensive construction of bank reinforcement structures.

7- Prevention can be less expensive than restoration: Alluvial mining projects should rigorously consider all environmental aspects in order to avoid the high cost associated with remediation. A full knowledge of the river system is required for the design of integrative solutions that respond to fluvial dynamics and that avoid any deterioration of the fluvial system, thus avoiding costly restoration and maintenance.

8- Restoration requires investment: The amount of investment required depends on the level of environmental deterioration. It is preferable to have a slower rate of restoration, but which is durable in time, affecting a limited section of river, and based on the dynamic operation of the river, than a restoration scheme that will be ruined by the first flood event. Continuity of the restoration should be assured, including the development of riverbank vegetation, the stability of any designed structures, and the payment of grants to the riverside communities. It is of vital importance to have specialized personnel managing, undertaking and promoting the recovery process. Restoration works should respect local interests and the traditional users of the river, since the success or failure of the scheme depends on the community support.

9- Restoration and hydrological planning of the basin: The restoration of a certain tract of river should be in accordance with a Hydrological Plan for the basin. There are many activities that affect riverbeds and adjacent lands, and the environmental performance of all such activities need to be monitored and controlled. Such programmes include conservation of soils, appropriate husbandry practices and a knowledge of water resources (quantity and quality). Control is necessary to avoid conventional engineering works for the stabilisation of river banks (dams, canalisations, longitudinal dykes or lateral reinforcements of the riverbeds), in order to re-establish the hydrological connections between the riverside habitats and the flood plain.

4.2 Alluvial Recovery in Costa Rica

In contrast with many other types of mining, environmental recovery related with the extraction of alluvial aggregates usually involves the solution of relatively simple problems which does not require large budgets. In areas of alluvial mining extraction in Costa Rica, restoration schemes are uncommon. The most relevant experiences in this field have been developed during the last decade by employees in charge of the supply of aggregates for the construction of civil works of the Costa Rican Institute of Electricity (ICE).

A methodology for specific systematic restoration for an alluvial aggregate operation does not exist in Costa Rica. Experience has shown that each mining restoration should be analysed and resolved in a site-specific way, considering various alternatives in connection with those responsible in the area. The general approach involves the substitution of “active care” restoration schemes with maintenance and additional control, for a scheme of “passive care", with minimum control and little maintenance in reforestation, drainage, etc.

Based on these experiences, ICE specialists, have listed a number of activities which need consideration and whose prioritisation depends on the stage of development of the project and of the particular conditions at each river section. Such activities may be adjusted, even after the project has started, due to the need to:

- Assure the supply of suitable materials available in the river,
- Offer appropriate protection to public health in the operations area of influence,
- Maintain to an acceptable level, or to minimise, the environmental damage at the site.

4.2.1 Before extraction

Planning an alluvial extraction and processing operation should first involve an evaluation of aggregate resources. Geotechnical sampling and definition of the geometry, thickness and quality of the alluvial deposit is necessary to establish the feasibility of the mining operation.

The environmental recovery process of an alluvial extraction begins by giving special attention to the investigation of the riverbed and its surroundings, in order to establish with clarity the natural conditions existing before any disturbance (reports from local people, photographic information, documents, etc). The results of future environmental evaluations of the river can then be compared with this baseline data.

The project planning process should also embrace local knowledge of river behaviour, looking to find a favourable location that minimises any environmental impacts associated with future extraction, particularly those relating to access to the river and transportation routings for the materials.

A favourable project location should additionally consider the determination of the property limits adjacent to the river; the general state of flora and fauna species; the morphology and the general behaviour of the riverbed, especially during flooding; the level and quality of water in nearby wells; the existence of adequate space for the processing equipment and for stockpiles, as well as the installation of the basic infrastructure for the workforce.

At the same time, it is important to establish the availability of basic services including; fresh water for the personnel; industrial water for processing; a consistent electricity supply for the crushing and processing equipment (440 volts); the selection of favourable roads for transportation; the potential damage to public roads (including bridge capacity); the availability of local workers; the potential impact of migrant workers; the existence of transportation services and communication for the personnel; the potential impact of solid and liquid waste generation.

Any social impact of alluvial mining should be limited and a close relationship should be established with the local community that lives and works in the area or that requires access to the river. The opinion of diverse groups that normally have free access to the river (fishermen, cattlemen, farmers, sportsmen, etc) should be considered, including those that potentially could form part of the local workforce required for the project. Public relations should be maintained during the planning, development and conclusion of the project, fostering the growth of public confidence and promoting a better knowledge of the industry; limiting potential conflicts and offering long term competitive advantages.

The project planning process usually involves the identification of a substantial and secure site adjacent to the riverbank. A first step in the environmental recovery of the site should be in the protection of a band of vegetation, the width of which will depend on local conditions along the margins of the riverbed, particularly in areas of greater erosion, such as at the outsides of meanders. This vegetation favours the stability of the riverbed and allows isolation of the potentially polluting mining activities from the adjacent floodplain, preserves the landscape and simplifies future actions of recovery. The extraction operations should have at least two points of access to the riverbed, facilitating logistics and allowing a quick evacuation of personnel and machinery during sudden floods or emergencies.

4.2.2 During extraction

Alluvial mining should try to minimise any alterations in the structure of the river to aid the return of the riverbed to a state similar to that existing before extraction. The daily work should be based on an extraction methodology aimed to reduce:

- Negative impacts on the morphology of the river,
- Radical changes in the substrate type (grain size and shape, stability of the channel and banks),
- Changes in the hydraulic conditions of the current, and
- Effects on the biological communities of the river, its riversides and the flood plains.

Alluvial extraction usually implies changes in the physical layout of the river and incision processes, with the riverbed tending to become deeper and narrow. During extraction topographical control should be emphasised since lateral instability of the riverbed as a product of erosion in narrows and elongated sections, can lead to damage requiring substantial compensation payments to landowners.

During the processing of the sand and gravel, substantial quantities of silt and clay waste may be generated. This should not be allowed to freely enter the river system, but should be directed into sedimentation ponds for cleaning, before water is returned to the river. All lorry traffic should be sheeted, and haul roads should be sprayed with water, to reduce dust.

In order to reduce noise from the site the processing plant should be sensitively located and work schedules should be put in place that aim to limit noise generation, particularly at night. Appropriate maintenance of machinery, particularly that related with transportation of the aggregates, is fundamentally important in minimising noise and dust, as well as maintaining security in the nearby communities.

4.2.3 Post-extraction

Alluvial mining schemes generally only last for a few years and, therefore, following completion of the works, a prompt restoration of the river and riverbanks should be assured. Site restoration plans should include dismantling all constructions and structures (pipes and site drainage, power supply lines, etc), the removal of site machinery and equipment and the appropriate treatment of all waste systems.

Using heavy machinery the restoration program can accelerate the natural dynamic processes, copying the primitive state of the riverbed, when aerial photographs or other types of old documentation are available.

River mining tends to increase the slope of the riverbanks (depending on the characteristics of the locally available sediments), which is unsatisfactory for the successful establishment of vegetation. An improvement which is an initial step in the recovery of the river, will be to decrease the slope of the banks, to stabilize the riverbed, to facilitate the lateral displacement of the river and the gradual connection with the flood plain. Also, this leads to a reduction in the speed and water transportation capacity, and a dissipation of river energy leading to sedimentation of the river load. Hydraulically, the river moves from channel erosion processes to sedimentation processes, elevating the riverbed and the phreatic level of the flood plain, connecting the riverside with the riverbed, and facilitating the occasional flood, and absorbing the energy associated with floods.

The river will, therefore, tend to become more meandering (sinuous), favouring pool formation and the development of sluggish flow in the bends where the riverbed becomes deeper and narrower.This, in turn, will lead to a finer-grained, less stable substrate, which will become subject to scour, especially in periods of low waters, and the formation of rapids in sections where the riverbed is wider and shallower. A greater physical variability in the river, favours the appearance of different habitat types for aquatic organisms.

When the new riverbed has become established, the morphological conditions should allow some freedom for the lateral displacement of the river. In this sense, to make the necessary allowances in the restoration plans, it is of vital importance to determine the potential level of flooding in the river system, and to anticipate the possible deterioration from extreme events (earthquakes, droughts, floods, etc.), always using a much broader timescale than that of the extractive operation.

When a suitable topographic configuration has been defined, the restoration scheme should concentrate on the location of a substrate of stable soils on a shallow bank slope, facing away from the river. Usually, restoration to promote the growth of vegetation will include native species of rapid growth to accelerate the natural vegetation process and the consolidation of soils. In the final phase of restoration, small depressions are generated in the flood plain, where standing waters are renewed periodically by floods, and where vegetation is developed. The formation and maintenance of these areas is not usually expensive, and only demands enough space in the flood plain.

5 Mining and Environmental Legislation

5.1 Generalities

Mining legislation in Costa Rica has been guided by the regulations developed for the extraction of metallic minerals (principally, gold). The prevailing Mining Code published in October 1982, ratified that mineral resources are State property, and that mining is possible only by means of an authorization of ownership called a "Mining Concession". This is subject to rigorous procedures for approval, including an Environmental Impact Study (EIS), a requirement which was later extended to other development activities, inspected by the Environmental National Technical Secretariat (SETENA).

State control of mining began in 1947, and has depended on several state organisations. However, in 1986, as a consequence of a large increase in the demand for aggregates, due to an ambitious program of housing development, control was centralised in what is today called the Geology and Mines Direction (DGM), of the Environment and Energy Ministry (MINAE). Together with other government and academic entities, the DGM carries out the functions of a national Geological Survey or Mines Bureau.

Legislation has evolved through time, in response to the needs of society. The environmental legislation which has arisen around the mining industry is not focused specifically on alluvial mining, but it contains an important number of laws, ordinances, regulations, codes, dispositions and resolutions of varying range, character and origin that regulate mining, public health, land planning, protected wild areas, marine and coastal resources, biological diversity, forest resources, air, water, soils, energy resources, archaeological patrimony, etc. The Environment Law published in 1995 is intended to be unified in normative environmental matters.

With the country's rising interest in 'green' policies and emphasis on sustainable developments there has been increasing pressure to balance mining interests with ecological concerns. There is therefore a policy of balancing the need to promote economic development with the necessity of conservation of natural resources.

In efforts to clarify the effective legal panorama, relating to the most recent and relevant environmental regulations for the mining industry: -the Political Constitution of the State (1949, with later amendments) indicates in Article 50: "Any person is entitled to a healthy and ecologically balanced environment. For it is legitimate to denounce the acts that infringe that right and to claim the repair of the damage caused. The State shall guarantee, shall defend and shall preserve that right". In connection with this Constitutional precept, the Judicial Power has emitted an important number of dispositions of environmental protection:

- Any citizen is entitled to claim a healthy environment,
- Any individual can claim for the protection of the environment,
- Being the Environmental Right, any lesion to the particular interests of a citizen, injures the interests of the Community,

The environment is defined as being for the good of all citizens, it does not belong particularly to anybody.

With the intention of speeding up a great variety of procedures before the agencies of State, in 1996 the principle of Positive Silence was established, which states that the institutions of the State are required to peremptorily resolve matters that the citizens raise with them. However, in environmental matters this principle doesn't operate. In 1998, the Principle of Prevention established that, if an event is likely to cause some environmental damage, then caution should prevail and the activity should be postponed.

The General Law of Health (1973) states clearly that the state has the obligation of protecting public health, and therefore, the lack of material means cannot argue for the lack of attention to the matters of its competition “...especially, when it has become a widespread excuse of the public entities, for non action in the fields of its competition".

The Law of Biodiversity (1998) defines the protection of living organisms of any source, whether they are found in terrestrial, air, marine, or aquatic ecosystems or in other ecological complexes. Regarding the protection of forests, it is important to note that almost a quarter of the Costa Rican territory is protected by law. The Forest Law (1996) prohibits the cutting or the use of the forests in national parks, biological reserves, swamps, protected areas, refuges of wild life and forest reserves which are the property of the State. Regarding the quality of the environment, the Organic Law of the Environment (1996) establishes that the air and its quality should satisfy, at least, the permissible levels of contamination fixed by the corresponding norms.

Territorial planning, as set down in law, is the responsibility of the State through Regulators Plans dictated at Municipal level.

5.2 Alluvial Mining Legislation

Alluvial mining extraction is regulated by an increasingly rigorous environmental legislation which is applicable to both applications for a new operation, as well as to the continuation of existing ones.

The Code of Mining (1982) does not establish special guidance for alluvial mining, but a specific regulation ‘Alluvial Mining of Riverbed of Public Domain’ was established in 1993, and modified in 2001. This was in response to the massive (500%) increase in applications for alluvial extraction, related with the developments associated with growth of the banana sector in the Atlantic Area of the country (1992).

In order to minimise the environmental risks associated with mining operations, since 1982, mining laws and the regulatory organisations demand Environmental Impact Studies (EIS) as part of the requirements of an application for a mining concession. The Mining Code and all the later regulations that modify it, as well as the diverse environmental guidelines, tend to be quite normative when defining procedures, terms and restrictions. They define the maximum length of mining concessions (2km), their minimum separation (2km), and the financial sum as an Environmental Guarantee (up to 1% of the investment involved in the project) that is renewed year after year. In the event of environmental damage, that sum will be used as compensation to the State. In June 2002, the most recent modifications were published to the Code of Mining that basically modernises the procedures, and for the first time in alluvial mining, it establishes a procedure for the payment of taxes to the local government for the sale of aggregates (30% of tax on sales dedicated to local government).

The juridical ordination in mining and environmental matters, as well as the intricate procedure for obtaining a mining concession (Figure 10), generates conflict among diverse elements, with a range of interpretations that result in uncertainty and controversy. Also, with growing importance, the local population's position implies conflicts of interest between local and national needs. These difficulties may be increased by abuse, on behalf of groups or by an individual, and which can retard a project, by the mere presentation of a mining or environmental accusation that forces the administration to consider it, even if lacks foundation. Due to the regulatory character of the legal norms, many of the denounced cases are readily resolved by SETENA, an Administrative Environmental Tribunal, or by the Constitutional Chamber. The concerns of civil society need to be resolved, however, with arguments based on technical factors and not using a merely legalistic focus on environmental matters. Some controversial mining projects have failed, due to their poor conception, planning or presentation before the public, and some have even been closed after years of operation. The lack of security for the operator considerably increases the risk implied for their activities.

5.3 Environmental Impact Studies (EIS)

An EIS is a technical, comparative, multidisciplinary, economic, and legal analysis, that allows estimations to be made of the repercussions of a certain work or project on the environment. It supposes the proposition of measures and actions to prevent, to correct, or to minimize such effects.

In alluvial mining, the EIS presents several particular characteristics:

Many investigations tend to evaluate short-term impacts such as river turbidity and spills of fuel. However, they often fail to characterise the original physical and environmental conditions of the site and do not value the potential cumulative impacts of the extraction activities on the riverbed,

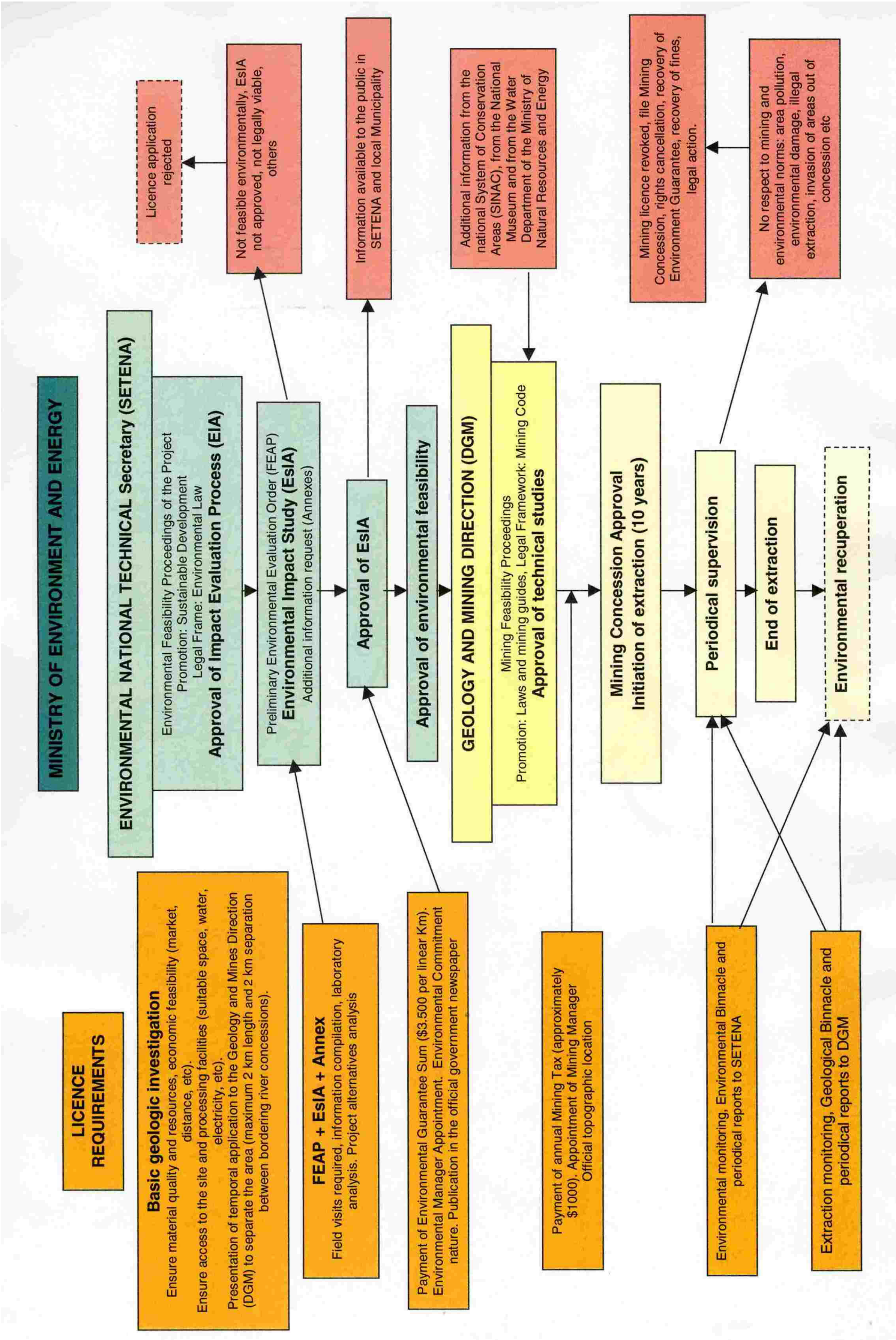
The absence of precise environmental data in tropical rivers, implies that there will be a requirement for much more field work to collect new information. This makes the studies more interesting and valuable, but it implies additional problems of cost, interpretation and time,

The environmental costs of extraction and restoration are becoming increasingly important, but many costs are difficult to quantify or they may be intangible,

It is essential to apply the previous experience of environmental specialists to avoid the generation of encyclopaedic works of enormous volume and variable quality, that mean a loss of resources for both the industry and the authorities.

A good EIS is a useful tool for the process of decision making for the developer, gathering all the information and identifying the flaws and potential weaknesses of the project, allowing considerations of less harmful alternatives to the environment, which may not necessarily be more expensive. Unfortunately, for some operators the production of an EIS, supposes an increase of costs associated with lengthy administrations, additional recruitments (consultants), detailed investigations and a progressive interference of civil society in the extractive industry, since the environmental regulations establish that the EIS should be available to the public.

Figure 10 Management structure for mining licences in rivers



6 Future Reforms

6.1 Contractor Strategy

In Costa Rica the mining industry has shown a remarkable increase in acceptance of its responsibilities to carry out environmentally acceptable extraction operations. Sometimes, however, this implies going beyond the execution of strict legal requirements, to satisfy the, wider interests, striving to establish a balance between the environmental alterations, the recovery measures and the economic benefits.

In environmental matters the best entrepreneurial politics aim to prevent adverse environmental effects by adopting a proactive attitude, instead of trying to subsequently correct or to counteract impacts. It is therefore of fundamental importance to communicate all available information to employees, especially that relating to the potential environmental effects of their activities. Raising the level of awareness and changing attitudes, will lead to savings in the high costs of corrective measures which in general, are exponentially higher than those of preventive measures.

Mining companies tend to be reserved when providing information to the public, which only serves to engender suspicion and distrust. It will be of great advantage to establish consultation systems which regulate, with the participation of local resident's representatives, the mining and environmental authorities.

6.2 Change of Attitudes

Most of the public in Costa Rica are not well informed about the mining industry and do not associate the mining industry with the essential activities required to maintain a modern economy. There is often general opposition to mining, guided particularly by objection to open-pit metal mining, and supported by small but multiple organizations that censor mining and promote conflict situations, even before a mining project is formally presented.

The public's opposition to mining will decrease if they are informed on:

The environment and the mining development may be compatible and need not be mutually exclusive

The enormous economic and social benefits that mining brings to society at large

The mineral operator will assure that any adverse environmental effects of its operation will be at a minimum

Programmes of environmental recovery will try to reduce any adverse environmental impacts.

The best available option to the mining industry now seems to be the one of taking the offensive, lifting the levels of communication and of the debate, and trying to diffuse these ideas among the regulatory authorities, the non-governmental organizations and the public.

6.3 Mining Regulations

Multiple agencies, regulators of the State, are in charge of enforcing the mining and environmental legislation and carrying out the control of environmental impacts. There usually prevails a marked emphasis toward the handling of environmental impacts, trying to create assurances that the environmental damages are minimized. State organizations, however, usually have limited budgets with a high turnover of staff who are overworked and poorly paid. These organisations are also poorly equipped and lack appropriate control systems and, therefore, do not gather systematic data for the taking of appropriate and opportune decisions. It is evident that there is an urgent necessity for an effective institutional coordination for the handling of the scarce resources for mining and environmental regulation, to allow for efficient processing of mining concessions.

Many of the existing regulations present numerous obstacles to development, with an important loss of time and money for the mining concessionaires, but without necessarily making sure that the environmental impacts of the mining will be prevented. It is therefore necessary to improve regulations, particularly with respect to the required limits of alluvial extraction. For example, SETENA has established a standardized norm that regulates alluvial extraction to a depth of 1.5 metres below the riverbed. This, however, is not sensible, since the baseline of the riverbed is increased as the excavation progresses. The depth of extraction should be defined in particular terms, as an absolute elevation for each section of the riverbed. Environmental conditions vary greatly along the diverse river sections and therefore, each alluvial mine site should be treated individually and starting from a detailed documentation of the adjustments of the channel.

Mechanisms should be developed to assure that any increase in mining and environmental restrictions will apply equally to all operators located along the riverbed.

6.4 Land Planning

The environmental recovery of alluvial extraction projects will be strengthened by means of:

- A recognition of the regional nature of the impacts,
- Consolidation of the process of application for mining permits to evaluate, in an integrated and coherent way, environmental and mining aspects,
- Establishment of mechanisms of control of the extraction volumes, (which are evaluated periodically) and in the light of the environmental impacts. Extraction should be interrupted if negative effects are apparent,
- The establishment of restrictions to alluvial mining in potentially problematic river sections, for example, down stream of dams or in rivers where incision of the channel is a problem,
- The development of administrative aggregate resource development plans at a local government level, with technical support of the State, striving to avoid illegal mining often related with alluvial extraction, particularly in rural areas,
- Incorporation of environmental costs in the price of aggregates.

At the present time the costs of environmental damages produced by alluvial mining extraction, are externalised, such that alluvial sources appear to be a cheaper and more attractive alternative than other sources To a certain extent this subsidises alluvial mining activities. The construction industry depends on an appropriate and stable supply of aggregates. Plans for the supply of aggregates, aiming to establish an appropriate balance between the consumption and the production at regional level, should establish both the economic importance and the environmental impact of alluvial mining from each source, valuing the quality and final use of the materials with considerations of alternative supply options (deposits in inactive terraces, dredging tailings, crushed rock quarries, etc).

Unfortunately, as with many other aspects related with the national mining industry, the analysis systems and data gathering established by the state entities, underestimate the contribution of the aggregates industry to the economy, with the result that necessary data (occurrence, availability, technical quality, production statistics, end use data, etc), for the taking of decisions are not available. Such information is fundamental if the government is to develop a strategy for establishing areas of mining resources, to increase the benefits of the mining projects and reduce any undesirable environmental effects.

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