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Follow-up of a road building scheme in a fragile environment

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Abstract

Serra do Mar, in Southeastern Brazil, is an extremely diverse and rich environment characterized by intense rainfall and steep slopes covered by tropical rainforest. A number of roads, highways, railways, pipelines, and transmission lines cross this zone. A new highway that has been approved by the São Paulo State environment authorities is currently under construction.

During the approval phase, the issue of ensuring proper implementation of mitigation measures arose as a significant concern. As a consequence, an innovative institutional arrangement has been set up for following-up, by which a multi-institutional multi-disciplinary team performs weekly inspection tours, whereas the project owner hired its own consultant to oversee the construction, putting the contractor under strict scrutiny. Among the most significant issues addressed, the following are particularly relevant: (1) erosion and sediment yield; (2) river siltation; (3) slope stability; (4) excavated soil and rock disposal; (5) management of water pumped from tunneling; and (6) minimizing habitat loss.

Results show that strict environmental supervision can effectively ensure that environmental impacts can be maintained within the limits of predicted impacts or legal requirements. Furthermore, this case showed that careful review of environmental impact studies and the establishment of detailed terms and conditions to be fulfilled by the

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proponent during the construction phase are necessary conditions for a successful follow-up.

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1. Introduction

The follow-up phase of environmental impact assessment process (EIA) is considered as a major shortcoming in many jurisdictions (Arts, 1998; Arts et al., 2001). The effectiveness of mitigation measures and management plans often goes unchecked, whereas the proper implementation of such measures and plans remains largely unverified. In Brazil, empirical evidence suggests weak implementation records and low adherence to terms and conditions established under the environmental licensing procedure (Dias and Sánchez, 2000, 2001; Prado Filho, 2001). In particular, previous experience with environmental assessment of highways in São Paulo had showed major gaps in implementing mitigation measures (Fruehauf et al., 1995). On the other hand, a few documented cases show that strict environmental supervision during the construction phase of civil engineering undertakings can lead to high levels of environmental performance and adherence to environmental license terms and conditions (Küller and Machado, 1998).

The Imigrantes highway project, whose construction ended in December 2002 in a highly sensitive environment in São Paulo State, is a case where follow-up has been particularly emphasized by the environmental regulatory bodies. This paper reviews the institutional arrangements made and the results of the follow-up activities aiming at identifying positive aspects of this experience that could possibly be employed or adapted for other large civil engineering projects.

2. The Serra do Mar and the highway project

Serra do Mar is a mountain range that follows the coastline along most of Southern Brazil, separating the narrow coastal plain from interior plateaus. In the São Paulo zone, the highlands are situated at about 750 m above sea level, but in other sectors, peaks reach up to 1800 m. The ridge has always been a hindrance in communicating the coast with the inland.

As the most important Brazilian seaport, Santos demands quick and efficient transportation links with São Paulo, the biggest metropolitan region. A railroad has been built as early as in the 1850s, whereas the first highway was operating in the 1920s. In 1947, a modern four-lane motorway had been built, crossing the Serra do Mar by a series of tunnels and bridges, but 20 years later, it was already unable to convey both the freight and the growing flow of cars transporting tourists to the beaches in weekends.

Therefore, a new three-land ascending roadway was built in the 1970s. However, the project for a descending roadway had been postponed due to the high costs of the scheme. By the late 1980s, the initiative has been revived, but it was only in the late 1990s, after a regulatory reform, that a private consortium won a bid to build the new highway.

Technical difficulties and high costs are a consequence of the geomorphologic conditions. Serra do Mar features steep slopes and intense rainfall, posing risks of landslides that can threat any structure built upon it. Moreover, the ridge is covered by remnants of Atlantic rainforest, an extremely rich and diverse ecosystem reduced to only 8% of its original area. Water resources from Serra do Mar are important for public supply and industrial use in the coastal lowlands.

The growing concern about preserving biodiversity, the need to protect the relatively scarce water resources of both São Paulo metropolitan region and the coastal lowlands, and the high visibility of the Imigrantes project rank among major reasons that concurred to make follow-up a particularly important part of the impact assessment process.

3. Impact assessment and environmental licensing

This project has a relatively long history since its inception in the 1970s. In terms of environmental implications, four major stages may be identified: (1) the early project designed in the 1970s; (2) a project update submitted for environmental review in the late 1980s; (3) a revised project submitted for obtaining a building license in the late 1990s; and (4) the executive project. Such stages of project upgrade led to a number of technical improvements that in turn reduced environmental impacts. On the other hand, a better understanding of environmental issues led the negotiation of a revamped mitigation plan that greatly contributed to further reducing impact magnitude and significance.

Under environmental impact assessment practice in Brazil, a proponent files an environmental impact statement (EIS) usually considering basic design characteristics. If approved, the project is granted a previous license where terms and conditions are established. A building license is granted under environmental law only if the proponent demonstrates that those terms and conditions, as applied, have been fulfilled. Such conditions for this stage usually include preparing detailed projects that could further reduce harmful impacts, such as drainage and siltation control. On the other hand, compensation for loss of natural vegetation must be detailed and negotiated with interested parties, particularly the State Parks Branch.

The life of Imigrantes project, however, was in many aspects different from the theoretical model, as the original project antedates environmental licensing regulations (which came into effect in 1986) and a 10-year gap exists between the previous license that had been issued and effective project implementation. Such a gap is due to a shift in government priorities, since a government department was supposed to build the scheme but, due to budgetary restrictions, all major road projects have been transferred to a private initiative in the 1990s. Thus, when a private consortium won the bid for building the Imigrantes scheme, the project underwent a major technical and financial review, as well as an environmental updating.

This review and the time gap itself allowed for cheaper and more efficient technical solutions to be found, such as rerouting the road under longer tunnels instead of constructing several smaller tunnels and viaducts. On the other hand, as the project suffered significant changes, a new environmental license was sought; hence, the original terms and conditions have been modified. Table 1 synthesizes the major project modifications that led to a reduction in environmental impacts.

Table 1
Imigrantes descending roadway major project characteristics

Issue	Original project[a]	Environmental impact statement[b]	Building permit[c]	Executive project[d]
Alignment and art works	17 viaducts, 10 tunnels	14 viaducts—4920 m, 5 tunnels—5570 m, earthworks—3850 m	10 viaducts—4417 m, 4 tunnels—7538 m, earthworks—3855 m	9 viaducts—4270 m, 3 tunnels—8231 m, earthworks—4623 m
Viaduct building method	Precast beams	Precast beams with 63 pillars (only in the ridge zone), out of which 33 needed new access roads	Pillar span increased from 45 to 90 m due to a shift to the free cantilevering construction method, thus reducing the number of pillars to 23, out of which 11 in need of new access	Reduced to 18 pillars, out of which 9 in need of new access
Location of ancillary installations	Not considered	16 sites, all located in previously disturbed areas	Only two sites, located in previously disturbed areas inside the State Park	One site will be maintained for Park installations
Resettlement	Not necessary	Not necessary	12 houses, 1 commercial unit (total 48 people)	13 houses, 1 commercial unit

Sources: Environmental impact statement (TTC, 1998), Consema deliberations 38/89, 28/99, Environmental Impact Assessment Branch (DAIA, 1999), JGP (1998, 1999).

[a] Prepared in the 1970s in conjunction with the project for the ascending roadway.

[b] Project as described in the EIS, prepared from 1986 to 1988 and submitted in 1988.

[c] Project as described in the documents presented for requiring a building permit in 1999.

[d] Project reviewed after further geotechnical information was obtained.

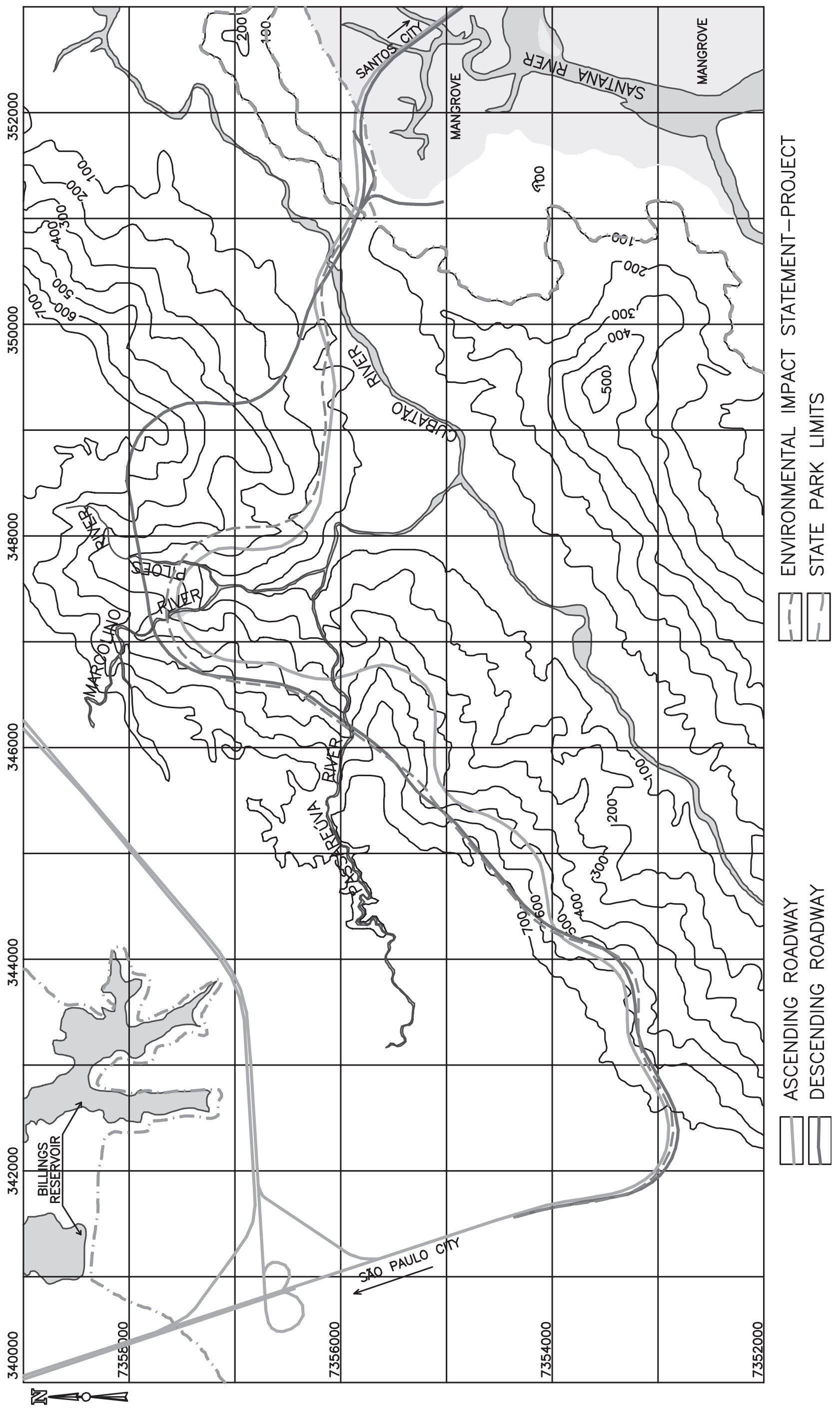
Figs. 1 and 2 show a topographic map and a section along the proposed roadway, evidencing the steep slopes of Serra do Mar.

Table 1 shows that the original 1970s project was almost silent about environmental impacts. In fact, the building of the ascending roadway caused many visible negative impacts upon the soil, vegetation, and water resources. Twenty years after project completion, un-rehabilitated landfills and eroding slopes subsisted. In 1977, the region was declared a State Park, and in 1986, the National Council on the Environment (Conama) issued regulations for environmental impact assessment. Therefore, as the government decided to go ahead with the project in 1986, it commissioned an EIS (TTC, 1998). The project considered in the EIS brought, as the main change in relation to the first project, a new alignment, dislocating the road to the body of the rock mass, through longer tunnels, thus reducing surface works. Such a change had many positive environmental implications such as a reduction of natural vegetation removal and a reduction in soil disturbance. As a consequence, the project resulted in less significant environmental impacts over surface waters, on the landscape, and on natural habitats. On the other hand, the longer tunnel stretch was expected to cause less animal road kills. Moreover, the EIS included proposals for environmental control of ancillary installations that were overlooked in the engineering design for the original project. This proposal has been approved by the Environment Department in December 1989, but several conditions were imposed, mostly related to the construction phase (Consema, 1989).

As a result of the time gap referred above, a new building license was sought in 1998 (JGP, 1998) and granted in 1999 (Consema, 1999). Now, the project proponent was the private consortium. After a thorough review of the engineering design, the consortium decided to make several major modifications, as explained in Table 1. Although most changes were motivated by cost savings, they also had positive environmental implications. The most significant modification was to reroute the road alignment. Instead of excavating five tunnels totaling 5570 m, four tunnels totaling 7538 m were proposed, thus reducing vegetation removal and exposure of naked soil to erosion and potential landslides. Moreover, the number of viaducts decreased from 14 to 10 and the method used for building them was changed to allow bigger spans, thus reducing the number of pillars, hence, again decreasing the need for vegetation removal.

On the other hand, changing environmental and social conditions imposed the need to adopt new measures, two of which are worth mentioning. (1) An unauthorized settlement for low-income families was established outside the limits of the State Park, making necessary the removal and resettlement of 12 households. (2) A major landslide took place in December 1999 upstream of a planned viaduct, resulting in a debris flow that modified the bottom of a narrow valley; it also severely affected the 1947 road.

Other modifications followed when construction began. As detailed engineering design proceeded and feedback from early workings was received by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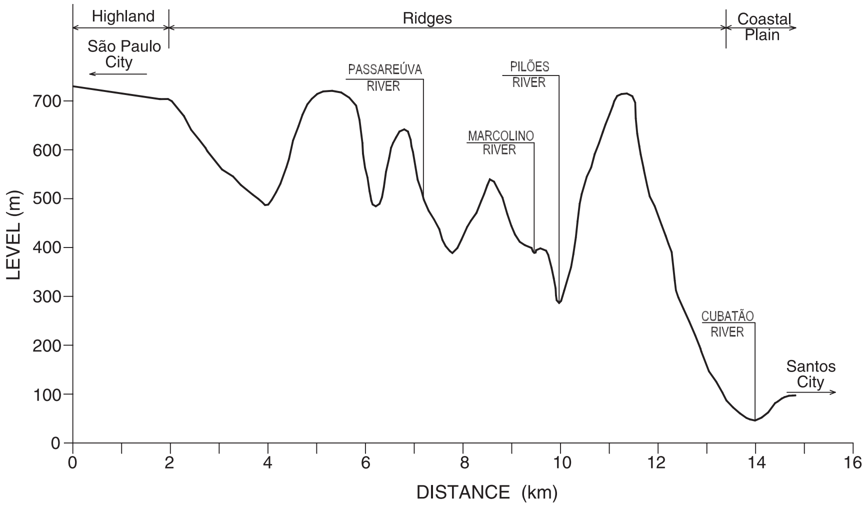

Fig. 2. Topographic section along the proposed roadway. Base maps: IGG topographic maps 1:50 000, sheet Riacho Grande SF-23-T-III-4-NE and IBGE topographic map 1:50 000 sheet Santos-SF-23-Y-D-IV-3/SF-23-V-B-1-1.

project engineers, other modifications were introduced, including a further increase in tunnel length and another review of viaduct projects. Due to unfavorable geotechnical characteristics of a talus body, the lower tunnel has again been rerouted and placed deeper inside the rock mass, thus resulting in a longer tunnel, but creating a more stable condition. This change also resulted in less surface disturbance.

4. Mitigation and monitoring

Mitigation and monitoring evolved as the project has been modified. Although the EIS (TTC, 1998) was rather vague about management measures, the approval document (Consema, 1989) imposed many conditions. These conditions were reviewed (Consema, 1999) as the project underwent modifications.

The most significant environmental issues to be addressed by the contractor during the construction phase were: (1) erosion and sediment yield; (2) river siltation; (3) slope stability; (4) excavated soil and rock disposal; and (5) minimizing habitat loss. As a consequence, mitigation measures included,

Fig. 1. Localization map showing the existing roadway, the proposed descending roadway, and State Park limits, UTM coordinates. Base maps: IGG topographic maps 1:50 000, sheets Riacho Grande SF-23-T-III-4-NE and IBGE topographic map 1:50 000 sheet Santos-SF-23-Y-D-IV-3/SF-23-V-B-1-1.

among others, (i) using topographic benchmarks to constrain vegetation removal to the strict minimum, (ii) immediate planting in excavated slopes to prevent erosion and instability processes, (iii) constructing sediment traps, (iv) periodical clean up of drainage system, (v) protection of natural creek slopes to prevent margin erosion, (vi) rainwater retention and controlled release, and (vii) dust emission control. At least one major impact has not been properly identified in the environmental review process as explained below; hence, no mitigation was planned.

A detailed monitoring program was part of the terms and conditions of the environmental license, compiled in a monitoring manual produced by the proponent's environmental consultant (JGP, 1999). The most important monitoring items are listed in Table 2. A number of control points have been previously established for each item, as well as the tasks to be performed on each one, they are described in the above-mentioned manual. The very same points are usually visited by the government inspection teams.

Table 2
Imigrantes descending roadway main monitoring guidelines[a]

Issue	Main indicators/ parameters	Frequency	Location
Erosion	Dimensions of gullies	Weekly	Potentially affected slopes and streams
Slope stability Landslides	Slope strike Dimension		
Water quality	Sedimentation (extension) pH, turbidity, color	Weekly Monthly	Affected creeks
Vegetation loss	Number of individuals	Prior to vegetation cut down	Every point where vegetation is to be removed
Fauna	Number of species	Prior to vegetation cut down	Every point where vegetation is to be removed + 200 m buffer zone
Noise	Sound pressure level	Not specified	Construction zone Proximity of urban zone
Air quality	Total suspended particle fume emissions	Weekly	Construction zone

Sources: Environmental impact statement (TTC, 1998), Consema deliberations 38/89, 28/99, Environmental Impact Assessment Branch (DAIA, 1999), JGP (1998, 1999).

[a] The inspection program is much more detailed. This table shows only the most significant items included in the monitoring program.

5. Environmental follow-up

Since the first project had been submitted for environmental review in 1988, the need to find mechanisms to ensure proper implementation of management measures designed to reduce harmful impacts was clear. By then EIA procedures were new and all stakeholders were learning by their own practical experience. When the project has been resubmitted in 1998, previous experience had shown that implementation of mitigation plans was by no means automatic once they had been incorporated into an environmental license terms and conditions: some formal built-in mechanism should be devised if these plans were to be successful.

The fragility of the affected environment and the high visibility of the Imigrantes project provided ideal conditions to impose formal arrangements. Hence, an innovative institutional arrangement has been set up, by which a multi-institutional multidisciplinary team, coordinated by the Environment Department (Secretaria do Meio Ambiente), performs weekly inspection tours. Responsibilities have been assigned to different government branches according to their respective attributions. The Parks Department (Instituto Florestal) should ensure that disturbance to natural habitats would be kept at a minimum. The pollution control agency (Cetesb) should check any pollution source such as the construction yard, rock crushing, and ready mix installations. In order to supervise all civil works that could impact on the physical environment, a contract has been granted to the Institute of Technological Research-IPT, a State government research institution. IPT was to play a very significant role in the supervision process, as a team of engineers and geologists performed weekly inspections of the totality of the works. IPT prepared monthly progress reports. The proponent was then obliged to correct any non-conformity.

On the other hand, the proponent hired its owns consultant to execute the monitoring program and to oversee the construction, thus putting the contractor under strict scrutiny. The consultancy team had to fulfill a detailed inspection and sampling program (JGP, 1999). Most inspections must be performed every week, but a number of tasks (such as inspecting the service road, waste dumps, and tunnel portals) were repeated every 3 days, whereas other tasks were made on a daily basis (such as inspecting vegetation cut downs, or landslides, if any). Reports were regularly submitted to the proponent.

Finally, the contractor hired two environmental professionals as well, whose tasks were to oversee all works on an everyday basis, and find solutions to any unforeseen problems. Having proved to play a pivotal role in other projects, such as the Bolívia-Brasil gas pipeline (Küller and Machado, 1998), the continuous presence of an internal environmental supervisor seems definitively to contribute to prevent harmful impacts beyond those predicted. Furthermore, the environmental professionals hired by the Imigrantes contractor were former officials of the Parks Department, thus sharing a culture of environmental conservation.

Besides providing a framework for effective follow-up, this arrangement generates a wealth of information about project impacts that can be both explored for applied research and maintained as a record of baseline data.

6. Results

Construction took place between August 1998 and December 2002, with remaining activities to be done in 2003, such as decommissioning construction yards. As the project was being built, supervision and monitoring progressed and first results were available to evaluate compliance with environmental regulations as well as with terms and conditions of licenses.

Despite detailed review of the EIS, at least one major problem had not been properly addressed in the planning phase. Water draining from tunneling presented high levels of solid particles and turbidity. Initially discharged into surface waters, these effluents substantially altered the quality of Cubatão river (Fig. 1) used for public supply. As soon as the deterioration was detected by the water supply company, the pollution control agency Cetesb moved to forbid any further discharge, prompting the contractor to quickly find a solution. Four treatment plants have then been built aiming at removing solids, so as to discharge wastewater only if complying with effluent standards. In spite of such moving, compliance with these standards has proved to be difficult due to the high alkalinity of water draining from the tunnels (all tunnels have been concreted). A number of monitoring samples revealed that receiving waters had higher than expected pH and turbidity. Moreover, high calcium contents in wastewater caused carbonate deposition on the stony floor of two creeks. After fixing the treatment stations, the contractor had to clean-up the creeks, a task that had to be manually accomplished.

Apart from this significant unpredicted impact, other data collected by the inspection and monitoring teams indicate that, as a general rule, the management plan has been fully implemented, with minor adaptations, leading to a satisfactory environmental performance.

Moreover, the arrangements for follow-up designed for this project led to the reduction of some harmful impacts to an extent greater than expected in the EIS. Such environmental gains were meaningful in at least two sectors:

- Deforestation. Careful planning and in-depth review of viaduct projects led to a 34% reduction in forest clear cutting; this also contributed to reduce the chances of slope instabilities;
- Construction and inspection teams jointly devised an opportunity to rehabilitate a former landfill left abandoned since the construction of the ascending roadway. The site—which was under intense water erosion, featuring one big and several small gullies—had been used to dispose soil removed from earthmoving in the plateau. Rehabilitation actions included regrading, construction of surface drains, and protecting slopes by grass seeding. Further

action is planed to plant native tree seedlings. Different from the conditions imposed on a similar landfill located in the lowlands, the environmental license had not established any obligation to rehabilitate this site. Hence, follow-up has been able to address another issue overlooked in the review phase.

7. Conclusions

The environmental impact assessment process of the Imigrantes project provides many positive lessons that can be used to improve the assessment of other projects. First are considerations about project alternatives, both technological and positional: as the project has been successively detailed, new solutions have been found that effectively contributed to reduce negative impacts. A careful assessment of significant issues resulted in solutions not only to prevent significant environmental deterioration but also to correct past mistakes, such as the choice to locate new waste dumps in areas formerly degraded by the construction of the ascending roadway.

Why have follow-up arrangements been effective in the construction of Imigrantes highway? Apart from the context described above (sensitiveness of the affected environment, existence of a State Park, and the high visibility of the project), it can be argued that a detailed statement of duties and responsibilities has proved to be of paramount importance to undertake such a complex follow-up. The absence of such a detailed statement had been identified elsewhere (Dias and Sánchez, 2001) as one major shortcoming of the EIA process in São Paulo State, an aspect deserving careful attention. In other words, too often the terms and conditions of environmental licenses were simply not verifiable or auditable because they have been written using vague and imprecise vocabulary. The Imigrantes follow-up scheme overcame this limitation.

The Imigrantes project experience shows that it is possible to establish a framework for effective follow-up through intense supervision and reporting. The complementary roles played by the contractor's environmental professionals, by the consultancy hired by the project owner, and by the government supervision teams proved effective. Although such a complex arrangement has been made necessary due to the fragility of the environment, adaptations can be made to fit the needs of most projects. Nevertheless, this is a costly arrangement where the costs are supported by both the project owner and the government. In this sense, the Imigrantes experience is difficult to be transposed to smaller projects whose proponents do not have strong financial resources. Moreover, it can also be argued that the state government does not have the financial and human resources to undertake this kind of supervision for most projects submitted to the EIA process.

In any case, independent of project size or potential impacts, the Imigrantes case teaches that follow-up activities must be based on a robust protocol, clearly stating duties and responsibilities of each party engaged, a protocol that must be fully auditable or verifiable.

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