RE-383

Ex post Evaluation of the Impact of the Environmental Mitigation Measures for the Porce II Hydroelectric Power Plant Project

Office of Evaluation and Oversight, OVE

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ABBREVIATIONS

BOD	Biological oxygen demand
CEPIS	Pan American Center for Sanitary Engineering and Environmental Sciences
Cj	Jaccard index of similarity
CORANTIOQUIA	Corporación Autónoma Regional del Centro de Antioquia [Autonomous Regional Corporation of Central Antioquia]
D	Simpson's dominance index
DO	Dissolved oxygen
EPM	Empresas Públicas de Medellín [public utility]
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EIUs	Environmental impact units
EMM	Effect of Mitigation Measures
EMP	Environmental Management Plan
EQI	Environmental quality index
H'	Shannon diversity index
IEA	International Energy Agency
IVI	Importance value index
LVQI	Landscape visual quality index
MAVDT	Ministry for the Environment, Housing and Territorial Development
MCP	Monitoring and Control Program
MFI	Multilateral Financial Institutions
OVE	Office of Evaluation and Oversight
PIUs	Parameter Importance Units
PUC	Public Utility Company
SBU	Strategic Business Unit
TC	Total coliform (bacteria)
TP	Total phosphorus
TSS	Total suspended solids
UPME	Unidad de Planeación Minero Energética [Mining and Energy Planning Unit]
WB	World Bank
WCD	World Commission on Dams

I. INTRODUCTION

1.1 **Ecosystems are characterized by deep complexity** (Munda, 2003). The evaluation, delimitation, attribution and compensation of impacts arising from human activities and projects on their components must consider the limitations of simplifying this complex reality.[1] The Environmental Impact Assessment (EIA) is one of the tools used to monitor impacts on the ecosystem and the effectiveness of mitigation measures adopted (Ortolano L. and May, C.L., in Morrison-Saunders A. et al, 2004; Feldmann, F., 1999).

1.2 The literature focuses on the heavy concetration of **environmental assessment experience on project prefeasibility studies, whereas monitoring after project approval is the weakest point in the process** (Arts et al, 2001). A thematic review by the World Commission on Dams (WCD) in 2000 drew attention to the "surprisingly small number of ex post evaluations of completed dam projects—as compared with the many studies that estimate the potential effects of planned projects." Similarly, the analysis focuses on predicting the impacts of projects under construction rather than the long-term impacts of completed projects.[2] Consequently, a gap in the EIA processes becomes a barrier to linking ex ante predictions to actual environmental performance of project's ex post (Dunsire, 1978 in Arts et al, 2001).

1.3 Other studies reviewed EIA practices of the leading multilateral financial institutions, again pointing to the need for moving away from the limited scope of processes focused on the project preparation phase.[3] World Bank studies further reaffirm these conclusions. The Environmental Assessment Sourcebook, prepared by the World Bank's Environment Department in 1993, called attention to the lack of ex post analysis to evaluate compliance with the recommendations in ex ante environmental studies. A later review by the same department in 1997 again underscored the limitations of Bank supervision to determine environmental

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[1] Not only are complex systems complicated, but their very nature implies deep uncertainty and a plurality of legitimate perspectives. Hence, in this context, traditional experimental science methodologies are of limited effectiveness (reductionist approach to ecosystems) (Del Moral *el al*, 2002).

[2] For example, Wescoat, J., 1999. Ex-Post Evaluation of Dams and Related Water Projects. WCD, Prepared for Thematic Review IV.5: Operation, Monitoring and Decommissioning of Dams, states that in the case of hydroelectric projects, useful lessons can be drawn from ex post evaluations of dam projects if the studies are *comprehensive, integrated, adaptive, long-term, and cumulative*. In other words, if the evaluation includes the full array of environmental, social, economic, and institutional impacts; examines the interactions between different types of impacts; continuously assesses and adjusts dam related decisions within the context of changing environmental and social conditions; monitors impacts that occur over time scales of several decades or more; and considers how the impacts of one dam are related to the impacts of other dams in the same river basin.

[3] Kennedy, W.V., 1999, based on the review of publicly available information on EIA at the World Bank, the African Development Bank, the Asian Development Bank, the European Bank for Reconstruction and Development, and the Inter-American Development Bank, and a review of general literature on EIA practice.

performance and detect and correct environmental problems in a timely manner. These studies concluded that knowledge about actual environmental impacts and the performance of mitigation measures and management and monitoring plans is frequently incomplete.

1.4 However, **the Ex-post Evaluation of Dams (Wescoat, 1999 Op. Cit) found no comprehensive ex post evaluation of a major dam and related river basin project in Central and South America.**[4] Similarly, desk reviews and case studies carried out by the Inter-American Development Bank (IDB) relating to water impoundment projects highlight the need to report on actual project-related environmental impacts through the Bank's monitoring systems.[5] Other studies conducted in the countries of the region in 2001 (Rodríguez M. et al., 2001) highlighted the weaknesses of reports submitted to the environmental authorities, especially Environmental Management Plans providing for impact monitoring.

1.5 **This study presents an ex post evaluation exercise carried out by the Office of Evaluation and Oversight (OVE) on the impact of some mitigation measures related to the Porce II Hydroelectric Power Plant Project.** An innovative evaluation methodology was developed so as to deepen the EIA processes to measure the impact and effectiveness of mitigation measures with respect to the environmental quality objectives specified in the Environmental Management Plans for infrastructure megaprojects. The purpose is to strengthen both the Bank's and the borrowers' monitoring and evaluation systems, providing some methodological guidelines to prepare quantitative assessments of the environmental impact[6] of mitigation measures implemented under the project.

II. OVE's Environmental Evaluation

A. Scope and objective

2.1 The objective of this evaluation is to propose **methodological guidelines to review the outcomes of the impact of mitigation measures** implemented to prevent,

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[4] Only a few partial studies on social impacts carried out in the region are mentioned including: Lee, 1990, on project management performance in Argentina, Colombia, Peru and Chile; MacDonald, 1989, on the Uruguay River; Ribeiro, 1988, and Ferradas, 1990, on resettlement at Yacyretá; Goodland, 1974, Partridge, 1983, and Rose, 2005, on Chixoy in Guatemala and Arenal in Costa Rica; several authors with isolated studies on hydroelectric projects in the Brazilian Amazon; and some doctoral theses and NGO information posted on the Internet.

[5] Document GN-1724. Report on environmental planning and management for water impoundment projects funded by the Bank. IDB, 1991. All but one of the projects reviewed in this study are energy sector-related.

[6] For purposes of this study, the concept of environmental impact means the impact on the physico-biotic environment, using the nomenclature found in the relevant bibliography.

mitigate or offset environmental impacts and their actual consequences on the environmental quality of infrastructure megaprojects in the energy sector.[7]

2.2 Ecosystems have been altered in many and diverse manners by the construction of large dams.[8] Because of **complex intersystemic relations and the uncertainties surrounding the environmental impacts** of such infrastructure works, it is not easy to evaluate the overall environmental quality of the ecosystem in relation to the mitigation measures implemented under the project. However, a system simplification exercise is inevitable in order to prioritize the relevant impacts and make the necessary management decisions.

2.3 This **simplification is manifest in the selection of indicators** to evaluate certain environmental aspects (such as air, soil, water, aquatic plants). Although these indicators will not lead to general conclusions as to the impact of the mitigation measures on the ecosystem, they will serve to analyze the effectiveness of the measures as they impact these environmental aspects.

2.4 OVE performed a desk review to select projects with high quality environmental data in the EIA validation reports and the monitoring reports, as candidates for applying the evaluation methodology developed by OVE. Data availability would facilitate a comparison of baseline environmental data with monitoring data for the ex post evaluation. The Porce II hydroelectric power plant project complied broadly with these criteria.[9]

2.5 The contract between Empresas Públicas de Medellín E.S.P.[10] (EPM) and the Inter-American Development Bank for execution of the Porce II hydroelectric power plant project was approved in July 1994, in the amount of US$328 million, and

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7 According to the literature (Gómez Orea, 1999), preventive or protective measures are understood as those that avoid negative impacts by modifying the elements of the activity that causes the impacts; corrective or mitigation measures are those that cancel out, attenuate, correct or modify the actions and effects on productive processes and environmental factors; and offsetting or compensatory measures are those that only offset to some degree the alteration of the impacted environmental factor. For purposes to this evaluation, the term "mitigation measures" will be used to signify the three forms, and a distinction will be made only if relevant to the analysis.

8 The negative environmental impacts (physico-biotic) associated with dams include the impact on the quality and availability of fresh water resources, fragmentation of aquatic ecosystems, destruction of mangroves, loss of wetlands, the closing of river mouths, the loss of aquatic and terrestrial biodiversity, increased vulnerability to climate change, salt intrusion, greenhouse gas emissions, decrease in the natural absorption by rivers, and increased reproduction of disease vectors and parasites (WCD, 2000).

9 OVE prepared a list of items to review ex ante environmental data validated by the Bank, divided into five sections: Project description, Environmental and social baseline data, Environmental and social impacts, Alternatives and mitigation, and Monitoring and evaluation matters. Porce II scored good or excellent results in all the five sections. Thus, the project environmental and social viability data reviewed by the Bank was deemed to contain only minor omissions and, in general terms, to provide sufficient good quality data on environmental matters. The quantitative results for each section of the verification list scored 6% to 38% above the median for a sample of 22 energy projects disbursed in the 2000 to 2005 period (see OVE Report 2008).

10 E.S.P.: *Empresa de Servicios Públicos* [Public Utility Company].

completed in 2001 with the commissioning of the plant. Porce II, located in the department of Antioquia, Colombia, comprises a reservoir flooding an area of 890 hectares, and has an installed capacity of 392 MW. Colombian environmental authorities approved the project's environmental feasibility in June 1991 and granted the environmental license in December 1994. Additional permits for the use of natural resources were obtained in 1997.[11] These delays together with the lack of a consolidated environmental legal framework when the project was approved meant that infrastructure construction work began before an environmental management plan was put into place.[12] Subsequently, the EPM combined multiple baseline environmental studies into a single Environmental Management Plan (EMP, 1994).

2.6 In 2005, in compliance with a clause in the loan contract with the IDB, EPM conducted an ex post evaluation of the physico-biotic component to examine the relevance, efficiency and effectiveness of environmental management for this component during project construction and operation. The evaluation compared the pre- and post-construction situation, essentially based on administrative data in the EPM Monitoring and Control Program (MCP). Originally, the MCP was to monitor **14 environmental aspects**[13] in an attempt to simplify and select the most relevant matters in accordance with EPM environmental analyses validated by the national environmental agency. Five aspects recommended by the IDB were later added, addressing the risk of dam destruction, water quality of the Porce River upstream of the dam, quality of water exiting the turbine, public health, and occupational health and safety.

2.7 OVE's **evaluation of the impact of the mitigation measures** is independent and complements the ex post evaluation performed by EPM. Environmental variables were converted into environmental quality measures to calculate the mitigation effect of each environmental aspect given priority by OVE. To this end, evaluation of the impact of mitigation measures uses monitoring data collected by EPM in the past 10 years. In other words, instead of taking new ex post measurements as if it were a new EIA, environmental quality trends were analyzed based on monitoring data generated by EPM.[14]

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[11] Delays were caused by a lack of technical resources at the Autonomous Regional Corporation of Central Antioquia (CORANTIOQUIA), newly created when work on the Porce II project began.

[12] The IDB had an Environment Operational Policy (OP-703, approved in 1979) that provided very general guidelines on the Bank's areas of action in this sector, insufficient to effectively guide the project's environmental evaluation process.

[13] Climate, hydrology, flooding upriver of the dam, downriver navigation conditions, ravine flows in the pipeline area, sedimentation, erosion, land plants, aquatic plants, land fauna, fish, air quality, water quality in the reservoir, and landscape.

[14] This approximation is supported in literature on ex post environmental impact evaluation (Arts et al, 2001; Angus Morrison-Saunders, 2003; Marshall et al, 2005).

2.8 This evaluation also updates and recalculates **relevance, sustainability and efficiency** results, using broader criteria than those used in the EPM evaluation. Lastly, because this is an evaluation of the IDB's role in supporting projects, this evaluation also examines the **additionality of the Bank's involvement** in pursuit of better environmental outcomes.

2.9 **The monitoring data time series have certain limitations owing to the state of the art at the time and the lack of measurement standards for each environmental aspect.**[15] Accordingly, the results of the OVE exercise may not be considered conclusive with regard to the overall quality of the environment in the area of the Porce II hydroelectric project. What is more, it was not possible to obtain data for two of the environmental aspects originally deemed relevant (public health and erosion). Nevertheless, the evaluation of the impact of mitigation measures for the selected environmental aspects was conducted as an exercise to develop a methodological proposal for future ex post studies of the environmental impact and effectiveness of mitigation measures in infrastructure projects.

B. Methodology

2.10 The principal source of data used in the evaluation are the ex ante environmental studies (1992, 1993, 1994);[16] the requirements of the national environmental authorities and multilateral institutions;[17] the plans, programs and activities contemplated in the project's environmental management plan; and the administrative information generated by EPM's Environmental Monitoring and Control Program (progress reports, annual environmental management reports and environmental compliance reports). EPM officials involved in the project's environmental management were also requested to provide information, as were some representatives from national environmental authorities engaged in project-related environmental control and monitoring.

2.11 Given that the environmental impacts caused during the construction of the dam have ceased and that the principal environmental effect is now due to the presence and operation of the dam, this evaluation focuses on measures in effect during the operation phase. However, the analysis of environmental trends and quality of the environment also detects impacts attributable to the construction phase causing changes in the environmental indicators.

1. Definition of environmental aspects

2.12 In order to **define the environmental aspects** to be considered, this evaluation follows the recommendation of Arts et al (2001) on conducting a screening and

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[15] The monitoring limitations for each environmental aspect are described in detail in later sections.

[16] Environmental Impact Assessment (EIA, 1992), Environmental Impact Statement (EIS, 1993), Environmental Management Plan (EMP, 1994).

[17] Resolution 0618 of 1994, Records of the Ministry for the Environment, CORANTIOQUIA resolutions, and IDB Environmental Policies, 1979 and 2003.

scoping exercise.[18] In this case, the screening was based on the initial environmental classification[19] of a sample of Bank-financed electricity sector projects completed over four years ago. The objective of the evaluation is to develop an ex post environmental evaluation methodology. Accordingly, the selection focused on projects with ample ex ante environmental data to permit an in-depth study for this exercise. Following the screening, a review was made of existing bibliography[20] and of the information contained in numerous ex ante environmental analysis documents (EIA and the Bank's validation reports) and environmental monitoring. The purpose was to select the most relevant environmental aspects[21] to determine the ex post environmental impact of some of the project's mitigation measures for which there was sufficient data (scoping).

2.13 **Only seven out of 19 selected environmental aspects monitored by EPM were deemed relevant by the scoping exercise as the environmental impacts generated were significant for purposes of the ex post environmental evaluation.** Subsequently, two of the seven aspects were rejected for lack of sufficient quality data.[22] Therefore, the trends for five environmental aspects were considered:

a. **Water quality**, including water upstream, in the reservoir and exiting the turbine, the issue expected to yield the most significant impacts due to the creation of a eutrophic reservoir with water of moderate quality.

b. **Invasive aquatic plants**, given their potential to provide a habitat for tropical disease vectors, diminish the quality of the environment through decomposition, and silting of the reservoir.

c. **Land plants**, considering the forest coverage lost as a result of formation of the reservoir and other project-related works.

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18 The *EIA Follow-up* methodologies (including monitoring activities, audit, evaluation and environmental management systems) advocate first determining the need for an ex post environmental evaluation for a specific project (screening) and, if necessary, prioritizing the issues to be studied in detail (scoping). This preliminary analysis ensures that ex post evaluations are conducted for projects with significant adverse environmental issues.

19 The classification is prepared by the ministries for the environment as part of the Environmental Impact Assessment, and validated by the Bank's Committee on Environment and Social Impact (CESI) to ensure the environmental viability of loans to be approved. In this case, the projects with the highest environmental impact classification were considered.

20 Dee (1973), Conesa (1997), Ramírez and Viña (1998), CEPIS (2001), Thomaz et al (2004).

21 "Relevant" environmental aspects are those subject to significant environmental impacts. Internationally accepted EIA bibliography suggests that significant impacts include those that impact health and public safety, areas and ecosystems considered sensitive on the basis of their natural or cultural interest, or that generate an effect regulated by environmental legislation (IDB, 2001).

22 The two rejected aspects were Erosion (vulnerability to erosion of the basin and the shores of the reservoir, as principal contributors to sedimentation) and Public Health (increased incidence of tropical vector-transmitted diseases in the proximity of the dam). Annexes 2 and 3, respectively, present a summary of the data collected on these environmental aspects.

d. **Land fauna**, because of the change in faunistic population and diversity, especially wild mammals as a result of the loss of forest cover.

e. **Landscape**, which experienced a significant change from a lotic to a lentic system, i.e., from flowing to still waters.

2.14 The table below summarizes the five environmental aspects identified by the scoping and the indicators used for each.

Table 1. Environmental aspects and indicators

Environmental aspects		Environmental indicators
1. Water quality	Quality of the water upstream of the dam	BOD_5 Total coliform bacteria Total phosphorus Total suspended solids
	Water quality in the reservoir	
	Quality of the water exiting the turbine	
2. Aquatic plants		Macrophyte plant coverage
3. Land plants		Diversity (Shannon index)
		Number of species
4. Land fauna		Diversity (Shannon index)
		Number of species
5. Landscape		% area covered
		Area by weighted use

Source: OVE, based on the scoping exercise applied to data from the EPM Monitoring and Control Program.

2. Evaluation criteria

2.15 Each environmental aspect was rated according to the following **evaluation criteria: relevance, effectiveness of the mitigation measures and effect on environmental quality, efficiency, sustainability, compliance with environmental regulations, and the Bank's additionality** to achieve the best environmental quality results.

2.16 The **relevance and effectiveness evaluation criteria** were given a score of 1 to 4, adjusted to each environmental aspect. In general, they were: (1) Unsatisfactory; (2) Partially unsatisfactory; (3) Satisfactory; and (4) Very satisfactory. The other evaluation criteria were analyzed globally (for all environmental aspects) and, where possible, the monitoring data available for each aspect was taken into account to develop guidelines concerning the need for information to improve evaluation in future exercises. The table below explains each criterion.

Table 2. Evaluation criteria and their application

Evaluation criteria	Application
Relevance	The **relevance** of mitigation measures compares the identification of possible project impacts against those reported in literature for similar projects, as well as the measures or actions recommended in international publications to prevent, mitigate or offset such impacts.[23]
Effectiveness	The **effectiveness** of mitigation measures is gauged by comparing the trend values of environmental indicators measured from the baseline (V/bl) to the values in the most recent monitoring report (V/ex post) against regulatory benchmarks or the desired value (V/ref), giving prior consideration to the sampling methods to ensure comparability between measurement periods. The results of baseline environmental management measures are compared with the ex post situation by converting the values of the various monitored environmental indicators into **Environmental Quality Indexes** (EQI). This exercise also calculates the **Effect of Mitigation Measures** (EMM) by comparing the weighted environmental quality indexes for each environmental issue for a project with mitigation measures (actual ex post situation) against a scenario where such mitigation measures were not implemented (with project and without mitigation measures).
Efficiency	The **efficiency** in implementing mitigation measures is gauged by comparing the time and economic resources used for their implementation against those projected in the EIS.
Sustainability	The **sustainability** of mitigation measures is gauged by evaluating the institutional capacity of EPM in the many phases of environmental management (planning; execution; evaluation and control; and coordination and communication). Moreover, an analysis was made of the monitoring and control capacity of the environmental agencies: Ministry for the Environment and the Autonomous Regional Corporation (CORANTIOQUIA).
Additionality	The Bank's **additionality** in the achievement of better environmental outcomes both in the environmental conditions prefeasibility phase when the Porce II project was under consideration for a Bank loan, and during loan monitoring.

III. RESULTS OF THE ANALYSIS OF THE MITIGATION MEASURES

A. Relevance of the mitigation measures

3.1 **The relevance of the mitigation measures was considered in relation to those reported in the literature for projects with similar characteristics,**[24] without regard for their implementation or the quality of implementation. This evaluation criterion refers to EPM's knowledge about the potential impacts caused by the project, and the recommended actions to mitigate such impacts.

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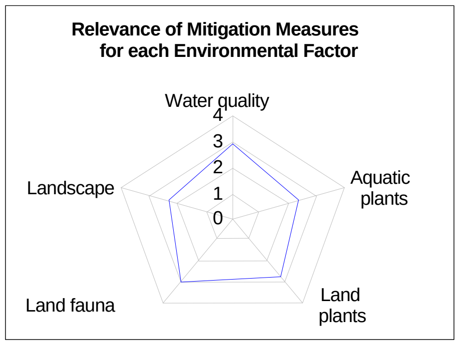
23 The relevance of mitigation measures is evaluated on the basis of declarations in the Environmental Impact Statement (EIS) (EPM, 1993), regardless of whether the mitigation plan or program was effective, a factor evaluated by the effectiveness criterion.

24 See analysis in Annex 1: Analysis of environmental criteria.

3.2 **In general, although the project was designed before Colombia developed a legal framework for environmental management of infrastructure projects, the measures proposed by EPM to mitigate environmental impacts were relevant for the five environmental aspects considered.**[25] Neither implementation nor monitoring of the measures was addressed in the evaluation of this environmental factor.

Figure 1. Relevance of Mitigation Measures



Source: Author's own creation

1. Water quality

3.3 The Porce River receives a significant amount of pollutants as it flows through the Aburra Valley and the city of Medellín before reaching the Porce II reservoir. The very first environmental studies predicted several environmental impacts including a serious deterioration of the quality of water in the reservoir as a negative impact of great ecological importance (EIS, 1993). They also predicted that the retention of pollutants owing to impounding the water would have a major positive effect on the quality of water downstream of the reservoir.

3.4 **The mitigation measures proposed to address the potential impacts related to this environmental aspect** were to construct two wastewater treatment plants upstream of the reservoir to avoid impounding highly polluted water, and to control erosion and sedimentation caused by the project or originating in other areas of the watershed. They also considered a comprehensive management plan for solid waste

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[25] Scale:

0-1: Unsatisfactory. Item not considered by EPM but deemed relevant in similar experiences, having caused deterioration to the quality of the environment.

1-2: Partially unsatisfactory. Item considered by EPM, but not deemed relevant in similar experiences or not relevant in this case in the opinion of the experts.

2-3: Satisfactory. Measure considered by EPM and recognized in similar experiences.

4: Highly satisfactory. Item considered and/or implemented by EPM, considered very important to assure the environmental quality of the area.

floating in the dam. Waste is removed, sorted and recovered where possible by workers hired through contracts with community associations in the area of influence of the Porce II reservoir.

3.5 The **relevance** of the mitigation measures proposed by EPM for the Porce II project was measured by weighting each impact identified and the associated mitigation action specified in the Environmental Impact Statement (EIS, 1993) against those reported in the literature for similar projects. Based on this weighting, using a scale of 1 to 4, the proposed mitigation measures were given a rating of **satisfactory relevance** (2.93) with respect to water quality (see Table 1 in Annex 1). This finding shows that at the time the EIS was drawn up, EPM had adequate and sufficient knowledge about potential impacts and the actions usually recommended to mitigate same.[26]

3.6 However, it should be noted that the **relevance of measures does not reflect their actual implementation.** In fact, in practice, only one of the two treatment plants proposed in the EIS studies (1993) was built and even then, construction was delayed.[27] Furthermore, the actions to be carried out by the regional and government authorities responsible for watershed management to reduce erosion and sedimentation were not implemented as specified in the EIS (1993).

2. Invasive aquatic plants

3.7 The first samples of the different bodies of water in the project area were taken in 1989 (ponds, marshes and banks of the Porce River), identifying 43 species of semiaquatic macrophyte species and two aquatic species. Based on the results of this study and the recommendations found in existing literature, none of the identified species was considered to be potentially invasive (EPM, 1993). The impact was therefore rated as of medium ecological importance for the quality of the reservoir. Taking into account these results and EPM's experience with other reservoirs free of invasion problems, the mitigation measure proposed was to manually extract the plant material. The Ministry for the Environment proposed, at the time, to conduct a study on the possible biological control of these species. Consideration was also given to monitoring and tracking the proliferation of highly invasive weeds, undetected in the study area, such as *Eichornia crassipes* and *Lemna sp*.

3.8 In 2001, the first post-damming sample was taken and the presence of two invasive species was detected, giving rise to the manual removal of the plant material. The

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[26] United Nations Environment Programme (UNEP), International Energy Agency (IEA), CEPIS, 2001; EPM, 1992, and other IDB hydroelectric projects.

[27] Clean-up of the Medellín River was to have begun with a first phase (1994-1998) to treat 20% of the city wastewaters at the San Fernando Plant. The plant did not come on line until 2000. The second planned plant, the Bello Plant, intended to treat the remaining 80%, was still under construction in 2008: designs were ready but EPM was still negotiating with the municipio to purchase the land where it was to be located.

present evaluation takes into account the baseline drawn up that year. In 2004, studies focused on the growth rates and curves for *Eicchornia crassipes*,[28] a highly invasive macrophyte plant, reporting a higher biomass in shallow waters and areas close to the tail of the reservoir (Environmental Compliance Report, EPM, 2005). Although macrophytes are considered an environmental impingement on the project (EIS, 1993), the location of the Porce II reservoir in a tropical area together with the low quality of water entering the reservoir (EMP, 1994 and EPM, 2002a) contribute to the development and proliferation of invasive water weeds. Early detection of this scenario may have helped predict the massive growth of macrophytes and recommend more stringent mitigation measures in the EIS and the EMP, measures that could potentially have made it possible to control the invasions recorded in 2002 and 2006-2008.

3.9 In general, the evaluation of the **relevance** of mitigation measures compared with those recommended in literature for invasive aquatic plants is **satisfactory** (2.34) (Table 2 of Annex 1). A closer look shows that identification of the impact from such species contained in the EIS (1993) was satisfactory with respect to most harmful effects described in the literature. However, the identification of proposed actions received a lower score because some actions recommended in the literature were not considered. For example, the necessary studies were not carried out with sufficient depth, nor was the advice from entities experienced in the matter sought until the proliferation of macrophytes spread in 2007.

3. Land plants

3.10 The principal impacts identified in the EIS (1993) include the loss of 160 ha of forest and shrubland and 2148 ha of grasslands. The document also predicted a floristic enrichment and an increase in forest cover thanks to the mitigation measures contemplated in the EIS (1993). These measures included establishment and management of protection areas, control and surveillance of natural resources, and education campaigns to prevent the deterioration of forests in the project area. Compensatory measures included forest development and conservation of forest areas, a reforestation program for the watershed, and conservation of existing forest areas in the vicinity of the project.

3.11 The **relevance** of the proposed mitigation measures to manage impacts on land plants was rated **satisfactory** (2.78) (see Table 3 in Annex 1). Although some of the impacts deemed relevant in the literature were not included in the EIS (i.e., fragmentation of wooded ecosystems, changes in flora composition, loss of riparian populations), EPM identified the impacts deemed most relevant according to most specialized sources.[29] The identification of specific actions to mitigate impacts related to this environmental aspect are described more fully in the EIS, with respect to the literature consulted.

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[28] Common name: water hyacinth.

[29] Mining and Energy Planning Unit of Colombia (UPME), International Energy Agency (IEA).

4. Land fauna

3.12 The first land fauna study (vertebrates) used as the baseline for the Environmental Impact Assessment (EIA, 1992) only provides data about species richness with no taxonomic discrimination. It was clearly preliminary because the list of species probably came from field observations and input from the inhabitants.[30] The 1994 EPM Monitoring and Control Plan (MCP) recognizes that deterioration and reduction of the forest cover may significantly diminish the fauna and its diversity in the region, especially wild mammals. However, formation of a new ecosystem and the planned mitigation measures are expected to create favorable conditions for fauna enrichment in the region. These measures included control and prevention activities to protect fauna from human activities (hunting and fishing), environmental education for the general population, programs to rescue fauna during filling, and creation of wooded protection areas around the reservoir to provide a habitat for displaced fauna.

3.13 The current evaluation gave a rating of very **satisfactory** (3.07) to the **relevance** of proposed mitigation measures with respect to those recommended in the literature[31] since the majority of the actions aimed at assuring the maintenance, repopulation and recolonization of the affected fauna (see Table 4 in Annex 1). However, it should be noted that some of the actions planned to mitigate these impacts were neither properly implemented nor subsequently monitored. For example, actions to monitor relocated fauna did not measure the effectiveness of signaling nor provide passage under the roads to avoid running over animals, nor were the possible impacts on endangered or endemic species studied.

3.14 Thus, although the proposed mitigation measures were relevant, their implementation and monitoring were not consistent over time. Land fauna (vertebrates) studies and monitoring performed in 1996 and 1999 took into account some of the monitoring guidelines specified in the MCP (sampling areas and coverage, environmental indicators), but not as a standard procedure. The 2001 and 2004 monitoring changed locations and classification (type of coverage) for some lots owing to difficulty in accessing certain sites. Lastly, the 2006 monitoring was consistent with the coverage denomination used in 2004, although it evaluated fewer lots.[32] In summary, there was a lack of continuity in the methods used to

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[30] Only 23 families and 14 species were identified, with very few species of small flying and non-flying mammals, indicating that the trapping methods (traps and nets) were not implemented. Neither was there any indication as to sample sites, nor sampling methods or efforts.

[31] References to institutions such as UPME, EPM, IEA, WB, WCD.

[32] See Table 5 and Figures 1, 2 and 3, with maps of the monitoring sites in Annex 1.

monitor land fauna,[33] an essential condition to ensure validity and comparability of results.

5. Landscape

3.15 The EIS (1993) identified landscape degradation in the vicinity of the reservoir and work sites as the principal expected impact. The principal mitigation measures mentioned were landscape beautification work (grassy areas, reservoir sediment traps, planting of trees and bushes) and treatment of deposit areas.

3.16 The current evaluation found that the relevance of measures to mitigate project impact on the landscape was, in general terms, **satisfactory** (2.3).[34] However, the mitigation measures to reduce sediment inflow to the reservoir and regulate water received a more satisfactory rating (2.30) than those associated with improving landscape visual quality (1.9). In fact, had the analysis focused on the importance of the landscape, the relevance rating would have been only partially satisfactory from the perspective of integration with strategic ecosystems in the regional context, social and economic function (productive landscape), and the entirety of ecologic functions (see Table 6 in Annex 1).

B. Analysis of the effectiveness of mitigation measures and outcomes on environmental quality

3.17 As discussed in the section on scope and objectives of the study, it was not possible to make a determination on the effectiveness of the mitigation measures implemented under the project and their outcomes on the overall environmental quality of the project given the quality limitations of some monitoring data.[35] Nonetheless, an effectiveness analysis exercise was conducted for each environmental aspect given priority by OVE with a view to suggesting guidelines for future application of this methodology, data permitting.

3.18 The methodology developed by OVE proposes to measure the **effectiveness of the mitigation measures** implemented by comparing the indicator values in the monitoring reports against benchmark values for each selected environmental aspect. To this end, a variance range of possible values for each indicator is

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[33] The sampling methods used were direct capture (Sherman and Tomahawk traps, mist nests), visual field sightings and indirect methods (tracks, prints, hunter surveys). However, records provide no details or comparable data about the effort deployed in each monitoring (number of sampling days, number of traps or nets/day, hydrological moment).

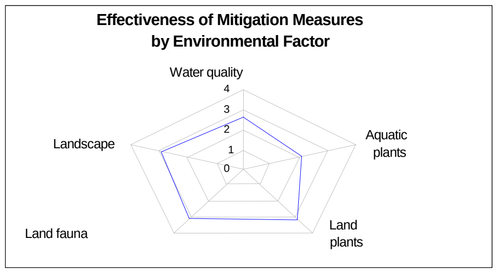
[34] This evaluation did not focus on all actions and impacts to assess the relevance of the proposed mitigation measures to manage landscape impacts. Instead, it focused on an analysis of the general categories for each mitigation measure and action mentioned in the literature.

[35] The analysis of the project's overall environmental quality called for weighting the analyzed environmental indicators for each environmental aspect. The sum of the weighted values is then used to indicate 100% so as to calculate the relative value of each indicator, referred to in the literature as Parameter Importance Units (PIUs).

identified and plotted in a series of Battelle theoretical curves[36] to convert the monitoring values into environmental quality terms. The curves generate an EQI, standardized in a 0 to 1 scale (0 for the worst quality, 1 for the best).[37]

3.19 Given the analysis limitations and available data, the **effectiveness of mitigation measures** was rated as **satisfactory** for land plants and land fauna, and **partially unsatisfactory** for all other aspects.[38]

Figure 2. Effectiveness of Mitigation Measures



Source: Author's creation.

3.20 This effectiveness analysis was complemented by an estimation of the **Effect of Mitigation Measures (EMM)** computed by means of an innovative method to evaluate environmental quality.[39] To this end, Environmental Impact Units (EIUs) were calculated for each environmental indicator, based on the EQIs weighted according to PIUs for each environmental indicator.[40]

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36 CONESA FDEZ-VITORA V. 1997. *Guía metodológica para la evaluación del impacto ambiental.* 3rd ed. Mundi-Prensa. Madrid. Dee, N. et al. 1973. An environmental evaluation system for water resource planning. Water Resources Research, vol. 9, No. 3, pages 523–535.

37 The variance range was identified for each indicator, and Battelle environmental quality curves were plotted, extracted or adjusted per Conesa (1997), Ramirez and Viña (1998), and/or reference values cited in CEPIS (2001), Ramírez and Viña (1998), and Thomaz et al (2004). The EQI can be derived from these curves, using a scale of 0 to 1 (where 0 is worst quality, 1 best quality). For the species diversity and species richness variables (land fauna and flora), an accrued beta sigmoid growth function was adapted (logistic curve). These curves are used for populations whose growth may be limited by the availability of resources. For the other variables, the environmental quality functions were calculated using three functions: 1. Logarithmic in the form K(x')=a+b*ln(x') (BOD, total coliform and aquatic plants), 2. Linear (total phosphorus and total suspended solids), and 3. Quadratic (landscape).

38 Only a preliminary analysis of the effectiveness of the Erosion and Public Health mitigation measures was carried out due to the insufficient quality of the monitoring data. The results are shown in Annexes 2 and 3, respectively.

39 Given the state of the art for environmental monitoring practices at the start of project and the methodological limitations in EPM monitoring data (including the impossibility of making comparisons over time because of the disparity in methods), conclusions could not be drawn from this analysis of the mitigation effect on each environmental aspect.

40 EIU = EQI * PIU

Table 3. Parameter Importance Units (PIUs)

Environmental aspect	Environmental indicator	PIU
Water quality	BOD_5	0.061
	Total coliform bacteria	0.037
	Total phosphorus	0.085
	Total suspended solids	0.061
Aquatic plants	Macrophyte plant coverage	0.146
Land plants	Diversity (Shannon index)	0.073
	Number of species	0.110
Land fauna	Diversity (Shannon index)	0.073
	Number of species	0.110
Landscape	% area covered	0.098
	Weighted area by use	0.146
Total		1.000

Source: Author's own calculations.

3.21 In addition, three scenarios were constructed to compare the environmental quality values using the conditions *with and without project*, and *with and without mitigation measures*.

a. ***Scenario "without project."*** This is the initial situation calculated with the average EIU values for each indicator before construction began (1989-1994).[41]

b. ***Scenario "with project with mitigation measures."*** This is the actual ex post situation calculated with the average EIU values for each indicator recorded during the construction and/or operation phases (1995-2007).[42]

c. ***Scenario "with project without mitigation measures."*** This is a hypothetical situation showing what would have happened had the mitigation measures not been implemented, calculated through the semi quantitative extrapolation of the scenario without project (1989-1994) to 2007.[43]

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[41] The following monitoring data were used: water quality, 1989 to 1994; landscape, baseline studies (1996); land plants (1996, 1998); land fauna (1994, 1996, 1998); and aquatic plants (1998).

[42] The following averages were used: for water, the construction and operation averages for all indicators (1995-2007); for aquatic plants, annual data (2001-2007); for land fauna, monitoring data (2001, 2004, 2006); for land plants, monitoring data (2004, 2006); and for landscape, monitoring data (2001, 2005 and 2006).

[43] Based on the trend graph plotted with the baseline data for each environmental indicator, EPM prospective data (EIS, 1993) were adjusted for the area of influence trends without mitigation measures, as a counterfactual simulation.

3.22 Comparing the EIU values under each scenario makes it possible to calculate the **net change** and the **effect of the mitigation measures**, defined as:

a. **NET CHANGE:** difference between the EIU values for the scenario *with project with mitigation measures* and the EIU values for the scenario *without project*.

b. **EFFECT OF THE MITIGATION MEASURES (EMM):** difference between the EIU values for the scenario *with project without mitigation measures* and the EIU values for the scenario *with project with mitigation measures*.

3.23 The next section provides a detailed evaluation of each environmental aspect and of the methodological limitations of the monitoring data.

1. Water quality

3.24 **Six quality indicators for different sampling sites** were selected at the outset for the water quality study.[44] These were: **dissolved oxygen (DO), biological oxygen demand (BOD), total coliform (TC), total suspended solids (TSS), total phosphorus (TP), and trophic state.**[45] The values obtained during the 1989 to 2006 monitoring were computed for each indicator (Table 7 in Annex 1). To determine the effectiveness of the mitigation measures on water quality, the values for these indicators at the baseline and during operation were compared to the benchmark values[46] (Table 4).

3.25 The results of this exercise show that the water quality indicator values are **better downstream of the reservoir** compared to pre-project, thus the effectiveness of the mitigation measures was rated as **highly satisfactory** (3.4) for this portion of the river. The indicator values **upstream of the dam and in the reservoir** were partially acceptable, therefore the effectiveness of the mitigation measures was rated only **satisfactory** (2.2). This outcome ratifies the EIS prediction that the dam would behave as a trap for organic material, coliform bacteria, suspended solids and phosphorus, thereby reducing the pollutant load in the downstream waters. Despite the methodological problems encountered when the trophic state of the reservoir was monitored, these data appear to confirm the environmental study forecast (1992) that the reservoir would be eutrophic.[47]

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[44] See Figure 4 in Annex 1 for details about the different sampling sites.

[45] OVE's evaluation identified inconsistencies in the monitoring data for some water quality indicators. Thus, only four of the six indicators originally considered were used to evaluate the environmental quality of this environmental factor: BOD_5, TC, TSS, and TP.

[46] Refers to the desirable values prior to dam construction and in the reservoir after stratup of the treatment plants referred to in the Environmental Management Plan.

[47] Comparison was hampered by the use of different indicators to evaluate the trophic state of the reservoir in successive monitoring reports. In 2001 and 2002, phosphorus values were used; in 2003 and 2004, chlorophyll a; in 2005 and 2006, the LACAT and Toledo modified trophic state index methods were used.

Table 4. Effectiveness of the mitigation measure to improve Porce River water quality

Mitigation measure	Monitoring indicator	Baseline value			Reference value			Value during operation			Effectiveness rating[48]		
		W/up	Res	W/dn	W/up	Res	W/dn	W/up	Res	W/dn	W/up	Res	W/dn
1. Promote the Aburra Valley wastewater treatment program	BOD_5 (mg/l)	5-108	2-15	2-7	**<11**	**<11**	**< W/up**	5-90	2-26	2-10	**2**	**2**	**4**
	DO (mg/l)	3.3-8.5	0-12	1-2.1	**>7.5**	**>4.0**	**>2**	4.2-7	0-15	0.8-6.4	**2**	**2**	**1**
	Total coliform (NMP/100ml) *104	≤240	≤1.2	≤0.5	**≤240**	**≤1.2**	**< W/up**	≤240	≤2	≤160	**3**	**2**	**4**
2. Control erosion and sedimentation caused by the project (EPM, 1994)	TSS (mg/l)	≤1608	≤125	≤38	**<150**	**≤125**	**< W/up**	≤1250	1-488	≤65	**2**	**2.5**	**4**
	Total phosphorus (mg/l)	≤2.1	≤0.7	≤0.6	**<0.1**	**<0.005**	**< W/up**	≤1.49	≤1.73	≤0.7	**2**	**2**	**4**
	Trophic state (algal biomass, chlorophyll a) (mg/m^3)		41-239 (2003)			**<31**			6-239			**2.5**	
Average score											**2.2**	**2.2**	**3.4**

Note: W/up: water upstream of reservoir; Res: reservoir; W/dn: water downstream of discharge. Mitigation effect, through comparison of values (operation, trend and desired or benchmark).

Source: Author's own calculations.

3.26 Although the mitigation measures to improve Porce River water quality were effective in general, the EQI calculation for the water[49] shows that the environmental quality of the proposed indicators cannot be considered acceptable under any circumstances, despite the better water quality downstream of the reservoir (EQI: 0.42) (Table 5).

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48 Scale:

0-1: Unsatisfactory. Negative environmental quality trend, indicator values worse than baseline due to project.

1.1-2: Partially unsatisfactory. Negative environmental quality trend, indicator values worse than baseline, not directly due to project activities.

2.1-3: Satisfactory. Values equal to baseline.

3.1-4: Highly satisfactory. Values better than baseline or in line with benchmarks.

49 Similarly, the results of the *environmental quality* evaluation, calculated by analyzing the selected environmental indicators over time (BOD_5, suspended solids, coliforms in the Porce River upstream of the dam and downstream of the water exiting the turbine), show significant peaks over time after the entry into operation of the project in 2001 (Figure 5, Annex 1). To calculate the EQI for each indicator, the OVE evaluation used logarithmic functions [K(x')=a+b*ln(x') for BOD_5 and total coliform; linear functions for total phosphorus and total suspended solids], to correlate these indicators with environmental quality values ranging from 0 to 1, in accordance with the respective literature (Ramírez and Viña, 1998 and CEPIS, 2001). The ratio of the resulting values and the graphic representation of the functions are shown in Table 7 and Figures 6 through 9 in Annex 1. Subsequently, the monitoring values for each indicator were evaluated against the EQI values, obtaining results on the change in environmental quality from the baseline to river water values before impounding in 2000; water upstream, in the reservoir and downstream of the discharge up to the latest monitoring in 2006.

Table 5. Environmental quality index for Porce River water

Mitigation measure	Monitoring indicator	Environmental quality* [0.0 - 1.0]		
		W/up	Res	W/dn
1. Promote the Aburra Valley wastewater treatment program. 2. Control erosion and sedimentation caused by the project (MCP, 1994).	**BOD_5** (mg/1)	0.3	0.45	0.65
	DO (mg/l)	0.76	0.5	0.63
	Total coliforms (NMP/100ml)	0	0.03	0
	TSS (mg/l)	0	0.5	0.84
	Total phosphorus (mg/l)	0	0	0
	Algal biomass (clorophyll a) mg/m^3)		0.4	
Environmental quality (average)		0.21	0.31	0.42

Note: W/up: water upstream of reservoir; Res: reservoir; W/dn: water downstream of discharge.

* Aggregation of environmental quality indicators through standardization of environmental indicator values to value functions (0 worst environmental quality, 1 best environmental quality).

Source: Author's own calculations.

3.27 The three scenarios were analyzed to determine the **Effect of the Mitigation Measures (EMM)** implemented under the project ("without project" – "with project with mitigation measures" – "with project without mitigation measures") resulting in the following:

Table 6. Effect of the mitigation measures on water quality

Environmental issue	**Environmental indicator**	**(1) EIU w/o project**	**(2) EIU with project with MM**	**Net change (2)-(1)**	**(3) EIU with project w/o MM**	**EMM (3)-(2)**
Water quality	BOD_5	0.0162	0.0237	**0.0075**	0.0091	**-0.0146**
	Phosphorus	0.0033	0.0060	**0.0027**	0.0000	**-0.0060**
	Total suspended solids	0.0166	0.0338	**0.0172**	0.0122	**-0.0216**
	Total coliforms	0.0000	0.0080	**0.0080**	0.0000	**-0.0080**

Notes: EIU: Environmental Impact Units
Net change: difference between values with project (1994-2007) and without (w/o) project (1989-1994).
EMM: Effect of the Mitigation Measures, difference between project values with and without (w/o) mitigation measures (MM).

Source: Author's own calculations.

3.28 According to the EIS (1993), the expected "without project" situation indicated that the initiatives to address environmental problems associated with the Medellín River showed some improvement in waste and trash treatment, whereas other aspects pointed to a continuation of environmental deterioration observed, such as lower water quality associated with increased mining activity, the introduction of heavy machinery to move alluvial material, and population growth.

3.29 Although the values in Table 6 are indicative of a positive effect of the mitigation measures, the fact remains that not all planned mitigation measures were implemented[50] and that there were monitoring problems. Consequently, the slight improvement in water quality indicators cannot be attributed to the project mitigation measures but rather to the natural effect of impounding waters with a high pollutant load. What is more, no significant changes from the baseline to the present support the idea that in eight years of operation the project has had a positive impact on water quality.

2. Aquatic plants

3.30 **The effectiveness of mitigation measures relating to invasive aquatic plants was measured against two indicators: percentage of reservoir area covered by macrophytes and tons of material extracted from the reservoir.**[51] The *reference value* considered, extracted from data developed under the Porce II studies, was the equilibrium point between the surface covered by plant matter and the capacity to manually extract such material. The value used was 11 ha of reservoir coverage and 6500 tons of macrophytes extracted per year. Thus, for levels above the reference value, the proposed mitigation measure "manual removal of plant matter" ceases to be effective and must be replaced by mechanical removal, an option not originally considered as a mitigation measure.

3.31 Comparing values of these indicators in the baseline and during operation to the reference value (Table 7) shows that the **effectiveness** of the mitigation measures was only **partially satisfactory** (2.0) because it became necessary to switch from manual to mechanical removal, and to develop a comprehensive removal plan with a "technically managed deposit" to dispose of the macrophytes extracted from the reservoir (EPM, 2002a and Rodriguez, 2007). The magnitude of the impact was greater than anticipated and therefore the mitigation measure was insufficient to prevent degradation of the environmental quality. However, it is important to note EPM's willingness to monitor and attempt to manage this impact, by mobilizing additional funds to increase the investment on this environmental aspect.

Table 7. Effectiveness of the mitigation measure to control aquatic weeds in the Porce II reservoir

Mitigation measure	Monitoring indicator	Baseline value	Reference value	Monitoring value	Rating
Prevention and control of growth	Covered area (ha)	65.6	<11	20 -190	2.0

[50] For example, only one of the two projected wastewater treatment plants was built, and there was a lack of cooperation on the part of the authorities responsible for watershed management in the implementation of actions to reduce erosion and sedimentation.

[51] Monitoring this indicator was supposed to establish a correlation between the weight of plants extracted and the area invaded to determine the manual removal capacity (EPM, 2002). The studies determined that ideally macrophytes should be removed in the first phase of their development because mature plants tend to accumulate sediment in the roots, becoming heavier and slowing down the removal process (see data series for invasive aquatic plant indicators in Table 8 of Annex 1).

and proliferation of aquatic weeds	Volume extracted (Tn/year)	38,580.2	<6500	11,719 - 111,892	2.0

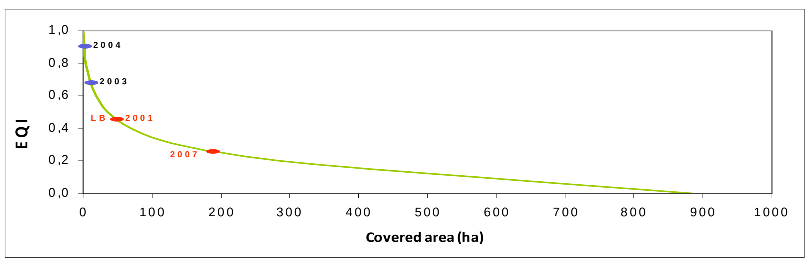
Source: Author's own calculations.

3.32 The **environmental quality index (EQI)** was calculated by graphing value functions in accordance with existing literature, on the assumption that "the denser the macrophyte cover in the reservoir, the lower the environmental quality" (Table 8 and Figure 3).[52] Monitoring data for these two indicators from construction of the dam in 2001 to 2007 show that the associated quality trend improved from the baseline (EQI: 0.43) until 2004 and 2005 (0.87 and 0.82) and began to decline in the following two years, falling to an EQI of 0.26, i.e., lower than the baseline (see figures 10 and 11 in Annex 1). In early 2008, the macrophyte invasion was still a problem for the Porce II reservoir.[53] Despite mechanical extraction and the booms in the reservoir tails, more effective actions are needed to prevent arrival of organic matter in the reservoir and rigorous control of the macrophytes in the reservoir. Such actions would include chemical control of macrophytes and interagency actions by EPM and the environmental authorities responsible for conservation and protection of the Porce River watershed.

Table 8. EQI coverage relative to water surface (%) and macrophyte-covered area (ha)

EQI	Coverage (%)	Covered area (ha)
0.0	100	890
0.1	64	570
0.2	32	285
0.3	16	142
0.4	8	71
0.5	4	36
0.6	2	18
0.7	1	9
0.8	0.5	4
0.9	0.25	2
1.0	0	0

Figure 3. Value function of the EQI for the *Eichhornia crassipes* macrophyte at Porce II, baseline value (BL) and years of extreme behavior



Source: Developed by OVE based on Thomaz et al. (2004).

Note: In this case, zero is presumed to be the best environmental quality level only in theory, pending results of the Porce II dam hydrologic studies.

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52 Thomaz et al., 2004, modified for *Eichhornia crassipes*. However, studies carried out by EPM officials indicate that the desirable environmental quality would not actually be the complete removal of the macrophytes owing to the ability of these floating plants to act as biological filter in the reservoir (INGETEC studies in 2007 determined that the plants capture and purify over 80% of the phosphorus, nitrogen, organic load and suspended solids entering the reservoir). Furthermore, complete removal of the plants could result in algal colonization that would negatively impact oxygen availability in the water column at night. Thus, the higher EQI is not equivalent to a 0 ha coverage but some equilibrium point to enhance the benefits from this aquatic plant, currently under study at EPM.

53 See photos 1-4 in Annex 1.

3.33 The results of the three-scenario analysis ("without project", "with project with mitigation measures" and "with project without mitigation measures") to measure the **Effect of Mitigation Measures (EMM)** with respect to Aquatic Plants are summarized in Table 9:

Table 9. Effect of the mitigation measures for invasive aquatic plants aspect

Environmental issue	Environmental indicator	(1) EIU w/o project	(2) EIU with project with MM	Net change (2)-(1)	(3) EIU with project w/o MM	EMM (3)-(2)
Invasive aquatic plants	Covered area	0.1470	0.0866	-0.0604	0.0050	-0.0816

Notes: EIU: Environmental Impact Units
Net change: difference between values with project (1994-2007) and without (w/o) project (1989-1994).
EMM: Effect of the Mitigation Measures, difference between the project values with and without mitigation measures (MM).

Source: Author's own calculations.

3.34 Although the net change in EIUs is negative, the effect of the mitigation measures shows a positive value because the quality deterioration in the area for this environmental aspect would have been greater (8.16%) in the absence of the mitigation measures. Although not a conclusive numeric value because of sampling method problems, it does reflect a situation addressed in the EIS (2003) prepared by EPM and in other projects with similar characteristics.

3. Land plants

3.35 According to the EIA, construction and filling of the reservoir resulted in the loss of 160 ha of forest and shrubland and 2148 ha of grasslands. The mitigation measures identified in the EIS (1993) to address this aspect were the establishment of forest protection and development areas, and conservation of forest areas together with a reforestation program for the watershed. To evaluate the changes in plant cover in the direct area of influence of the Porce II hydroelectric project, EPM's environmental management plan provided for monitoring, every two years, the different sequential stages of plant species in permanent sampling lots, considering the following five indicators: Shannon Diversity Index (H') for tree species; Simpson's Dominance Index (D); Jaccard Index of Similarity (Cj); the Importance Value Index (IVI), and Species richness (taxonomic composition).

3.36 Based on monitoring data gathered by EPM, the effectiveness of mitigation measures was measured by comparing the baseline value for these indicators with monitoring data gathered from 1998 to 2006. However, considering the state of the art measurement methods used for these indicators when the baseline was established and later evolutions in such methods,[54] plus some technical issues,[55] the data from different monitoring dates are not comparable for purposes of this evaluation, which means the indicator does not help measure a real change in environmental quality. Thus, the data, resulting in a very satisfactory rating (3.14) for the effectiveness of mitigation measures relating to the land plant aspect, are not significant (Table 10).

Table 10. Effectiveness of the mitigation measure for Land Plants

Mitigation measure	Monitoring indicator	Monit. sites	Baseline value	Monitoring value (1998-2006)	Rating (1.0 - 4.0)
Establishment of protection areas Forest development and conservation	**Shannon Index (H')** tree species 1994	S4	2.54	1.13 - 3.34	1.0 - 3.1
		S5	2.65	3.28 - 3.99	3.1
		S6	2.73	3.97 - 4.38	3.5
		S7	3.83	4.24 - 4.30	3.1
	Simpson's Index (D) 1994	S4	0.87	0.41 - 0.95	1.0 - 3.1
		S5	0.76	0.92 - 0.97	3.1
		S6	0.90	0.96 - 0.98	3.1
		S7	0.97	0.97 - 0.98	3.0
	Jaccard Index (Cj) 1994	S7-S6	0.03	0.12 - 0.22	3.1
		S7-S5	0.02	0.05 - 0.10	3.1
		S7-S4	0.00	0.01 - 0.03	3.1
		S6-S5	0.20	0.19 - 0.29	3.1
		S6-S4	0.08	0.09 - 0.16	3.1
		S5-S4	0.10	0.14 - 0.23	3.1
	Species richness 1994	S4	33	32 -67	3.5
		S5	32	85 - 151	4.0
		S6	34	123 - 204	4.0
		S7	109	184 - 192	3.6
		3.14[56]			

Source: Author's own calculations based on sampling data.

3.37 Because of the above-mentioned methodological differences, three of the proposed indicators could not be used for a comparison over time or to calculate a value for

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[54] For example, the indicators have a strong bias associated with the number of individuals recorded in the baseline, clear sampling site guidelines were not used, or standardized monitoring methods and efforts were not standardized, and some methods to assess population structures and configurations at different stages were very subjective.

[55] Problems include the impossibility of keeping ruminants out of monitoring lots, or the abandonment of some land plant monitoring lots for several years due to security concerns in the area.

[56] This value is the average of single values and extreme values for each cell in the column, for all indicators available for each rated site.

the *environmental quality* of the land plant aspect.[57] Thus, only a partial environmental quality valuation exercise could be carried out by correlating the Shannon diversity index and species richness.[58] To convert data on the number of plant species and the diversity of species monitored into terms of environmental quality, adjustments were made to value functions to include indicator values from EPM monitoring reports (Figures 4 and 5). Although EQI shows an improvement in number of tree species and in species diversity, this exercise could not reach a conclusive affirmation about the improvement of the environmental quality with respect to land plants in the project area of influence due to methodological limitations and the impossibility of comparing data. Consequently, these data, although used for methodological purposes in this evaluation, cannot be considered final results.

Figure 4. EQI value function curve for number of tree species

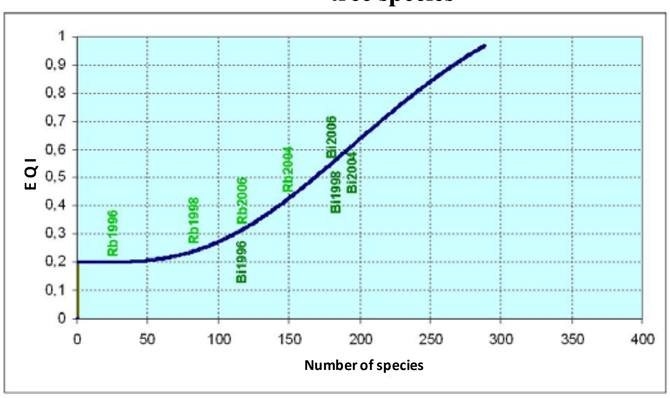
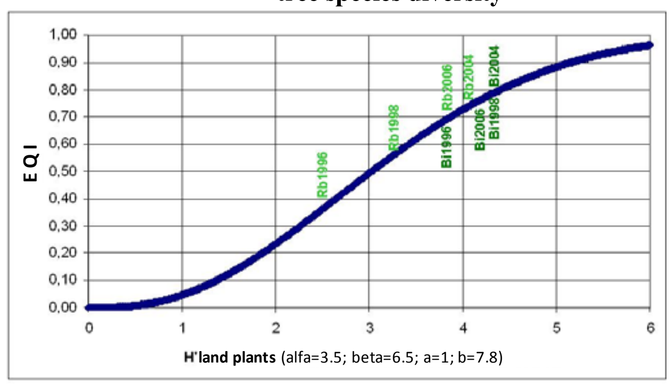


Figure 5. EQI value function curve for tree species diversity



Note: Rb: low stubble lots; Bi: disturbed forest lots

3.38 With regard to mitigation measures for Invasive Land Plants, although inconclusive because of methodological limitations, the results are indicative of a positive effect of the mitigation measures. Had the project not provided for mitigation of invasive land plants, the environmental deterioration that would eventually occur could affect the normal operation of the plant.

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[57] Because of inconsistencies in the methods used, these environmental indicators do not express ecosystemic conditions in the strict sense, but statistical attributes for data sets (natural elements, in this case) that cannot be expressed in value terms for the environmental quality of the area.

[58] This evaluation recommends using other types of indicator, such as "structural complexity time" (specific aspect for each plant formation considering population variables such as distribution of diametric classes, growth habits, number of strata, species richness and diversity, and succession time) so as to translate monitoring data into environmental quality, and calculate baselines for future applications. See Table 9 and Figure 12 in Annex 1.

Table 11. Effect of mitigation measures for the Land Plants aspect

Environmental aspect	Environmental indicator	(1) EIU w/o project	(2) EIU with project with MM	Net change (2)-(1)	(3) EIU with project w/o MM	EMM (3)-(2)
Land Plants	H' Land plants	0.0353	0.0521	**0.0168**	0.0200	**-0.0321**
	Number of species	0.0244	0.0410	**0.0166**	0.0150	**-0.0260**

Notes: EIU: Environmental Impact Units

Net change: difference between values with project (1994-2007) and without (w/o) project (1989-1994).

EMM: Effect of the Mitigation Measures, difference between the project values with and without mitigation measures (MM).

Source: Author's own calculations.

4. Land fauna

3.39 The project identified some impacts it would have on land fauna, such as reduction of the faunistic population and diversity due to loss of habitat. To mitigate these effects, the management plan proposed to implement **land fauna management programs, rescue programs and programs to protect endangered species**.

3.40 Here again, the evaluation could not easily compare monitoring data, essentially due to the state of the art of the methodologies used to establish the baseline. It was not possible to evaluate the effectiveness of mitigation measures associated with the land fauna environmental aspect and the calculation of the EQI against the indicators proposed in the EMP: diversity indexes (alpha or Margalef's richness index; Shannon diversity index; beta or Jaccard similarity index); number of species (S); endemic, rare and endangered species;[59] and comparison of dietary guilds in birds.[60] In general terms, the indexes used in monitoring help summarize the data collected in a single value so as to facilitate comparisons between different habitats or sites. However, access to the underlying assumptions is required in order to use the data generated to correctly interpret the behavior of the biodiversity (Villareal et al., 2006).

3.41 On the other hand, given the variety of behaviors among mammal species, monitoring requires implementing a broad range of methodologies (direct capture, observation, tracking) to obtain a good estimate of the richness in a particular area.

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[59] OVE's evaluation considers that the number of endemic and endangered species may reflect the biotic importance of a particular area and serve as a guide to design management and conservation plans, but is not an indicator of faunistic enrichment for an area over time.

[60] OVE is of the view that the analyses of dietary guilds as enrichment indicators would be more relevant if analyzed together with data on structure and phenology of the plant cover. Otherwise, it is purely descriptive, of limited worth as an indicator.

The diversity indexes proposed in the EIS and those implemented in the course of subsequent monitoring exercises are highly susceptible to differences in the number of individuals recorded for each sampling unit, a factor directly dependent upon the methods and effort deployed. For example, this evaluation found that monitoring in 1996, 1999 and 2001 did not estimate the abundance of species[61] (essential for most index calculations). Technical errors were also found in the 2004 and 2006 monitoring of fauna, owing to the use of different methodologies specific to each group of mammals that are highly differentiated by habits, e.g., gregarious, nocturnal, etc. Lastly, baseline value data were insufficient, no trends were identified, nor were reference values established for all the indicators identified in the management plan (see Table 10 in Annex 1).

3.42 Although inconclusive, as a result of the methodological computation exercise, the information available based on data from the 1989, 1996, 1999, 2001 and 2006 monitoring shows enrichment in the number of species (Figure 6), yielding a rating of highly satisfactory (3.07) for the effectiveness of the mitigation measures.[62] Similarly, the calculation for the environmental quality index relating to the land fauna environmental aspect,[63] using only the species richness indicator (S) for land mammals, would also be rated satisfactory as the achieved values were higher than the baseline. These results would only be acceptable if the sampling errors were not known, especially the non-comparability of lots and changes in methodology, which make it difficult to compare monitoring results. As a matter of fact, an increase of this magnitude could not be attributed to habitat enrichment in the sampling sites.[64] With reliable data to calculate diversity, a beta function could be adapted (Rueda, 2007, based on Conesa, 1997) for the conversion to EQI values (Figure 7).

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[61] Number of individuals per species.

[62] This evaluation also warns about the danger of using indicators such as the number of endemic or endangered species (Figure 4) that apparently increased slightly according to monitoring data, but masked method comparability and sampling effort problems. Also, as previously mentioned, these measures only reflect the biotic importance of a specific area, serving as a guide to design management and conservation plans, but not as indicators of faunistic enrichment in an area. It should be used for monitoring in the future to support the importance of the project's direct area of influence, but not be taken as an environmental indicator of enrichment.

[63] According to the value function, the Porce II area could have a maximum of some 90 species of mammals given the bio-geographic context. Another possible approach to plot a value function for land fauna environmental quality would be to extrapolate the number of carnivorous mammals in the Porce II project area to the context of other similar geographic areas (control areas such as Alto San Miguel and some natural reserves). However, the EPM monitoring data collected thus far for the Porce II area of influence are not useful to evaluate enrichment in habitats with cover.

[64] One explanation could be implementation of methods to capture small flying (bats) and non-flying mammals (didelphid marsupials and rodents) for monitoring purposes in 2004 and 2006, because of their high growth rates. Also, the richness of some mammals may be overestimated as some species cannot be identified by their morphologic characteristics due to the inexistence of specimen collection methods to check their craniodental morphology (Zurc, 2006).

Figure 6. Species richness, number of endemic and endangered species in monitoring and programs in the direct area of influence of the Porce II project

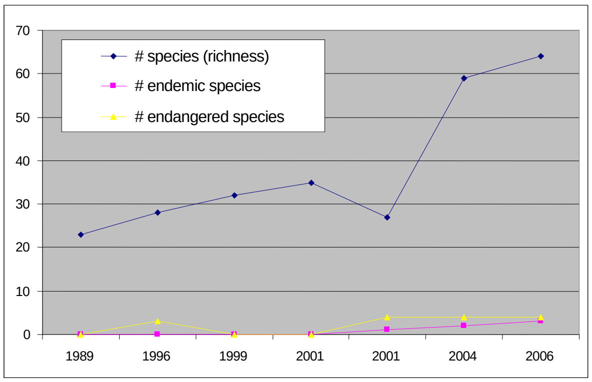
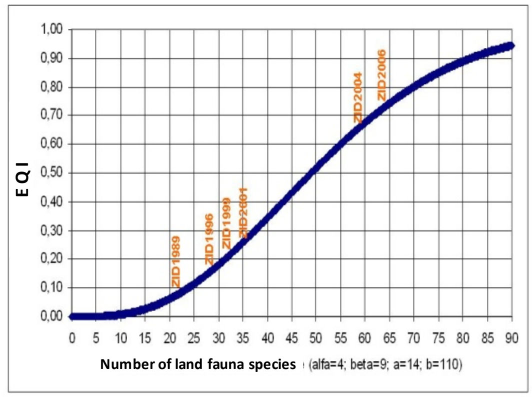


Figure 7. Proposed EQI value function plotted with the number of land mammals for Porce II area fauna



3.43 In summary, although the **use of diversity indexes** as environmental indicators is generally acceptable for projects of this nature, standardized sampling methods are required so as to avoid erroneous interpretations. Indeed, the evaluation of faunistic enrichment in an area—understood as the increase in population diversity owing to a change in the use of plant cover—requires a highly standardized strategy, in both methodological and temporal terms, with implementation over a very large time scale for an assemblage of mammal populations.[65]

3.44 Environmental Impact Units and Net Change and Effects of Mitigation Measures were also calculated for the **effects of the mitigation measures** for this environmental aspect. Although the numeric results were not assigned values due to the methodological limitations explained above, it is logical to presume that the effects of the mitigation measures were positive in comparison to executing the project without implementing any mitigation measure.

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[65] When these conditions do not prevail, it is best to use indicators such as species richness, sampling efforts and accumulation curves as suggested by Villareal et al., 2006. These indicators make it possible to estimate the expected number of species or the potential number of captures for a determined sample size. EPM used these curves for monitoring in 2004 and 2006 as they provide a general vision of the sampling behavior in relation to the effort. However, the curves should be interpreted with caution because differences in sampling, community dynamics and temporal factors may alter the behavior.

Table 12. Effect of mitigation measures for Land Fauna

Environmental aspect	Environmental indicator	(1) EIU w/o project	(2) EIU with project with MM	Net change (2)-(1)	(3) EIU with project w/o MM	EMM (3)-(2)
Land fauna	H' Land fauna	NA	0.0412	**NA**	0.0200	**-0.0212**
	# of species	0.0134	0.0478	**0.0344**	0.0080	**-0.0398**

Notes: EIU: Environmental Impact Units; NA: not available
Net change: difference between values with project (1994-2007) and without (w/o) project (1989-1994).
EMM: Effect of the Mitigation Measures, difference between the project values with and without mitigation measures (MM).
Source: Author's own calculations.

5. Landscape

3.45 **The principal impacts identified were landscape degradation in the reservoir area and work sites. To mitigate these effects, landscape beautification work and treatment of deposit sites were proposed, among other reservoir cleanup actions.** The studies to determine the baseline in 1996 established a broad objective for monitoring landscape evolution, requiring both a study of landscape visual or aesthetic attributes and a study of intrinsic attributes, such as ecological processes and functions.[66] However, the methodology proposed only evaluates the visual quality associated with landscape aesthetics, using an indirect valuation method for the different landscape components (topography, water and vegetation). In the case of topography and water, the scale of satellite images strongly influences valuation.[67] In addition, these components present very low variation in the time frame covered by the evaluation (11 years, 1996-2007). Consequently, the third component—vegetation—gains importance as changes are more likely in the timeframe considered by the study.

3.46 The University of Medellín (2001) and the National University (2006) collected monitoring data for the vegetation component, applying different techniques for visual classification of satellite images used to monitor the landscape, making it impossible to compare the results so as to evaluate landscape evolution (see Table 11 in Annex 1). Moreover, the comparison of visual quality values obtained

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66 "The fundamental objective is to monitor landscape evolution [...] and identify units with a view to planning land management based on plant cover distribution patterns so as to guarantee stability in the ecological processes that will occur with the introduction of an artificial element in the region." Integral, 1996.

67 In this instance, the 2001 monitoring recognized that apparent changes were due to the use of more complete mapping data than those used for the baseline, and did not represent real change. Therefore, for comparison purposes, the technical approach to attribute valuation should have been modified to incorporate the additional detail from subsequent monitoring maps.

by these different monitoring methods had other methodological inconsistencies, such as assigning a positive value to erosion for soil combinations, despite the visual impact.[68]

3.47 The **effectiveness** of mitigation measures on landscape quality was measured using vegetation cover as a monitoring indicator (Table 13). In this case, the rating for the effectiveness of forest cover recovery measures was unsatisfactory (0.8), and Highly Satisfactory (3.5) for the effectiveness of early and medium-term successional cover recovery (low and tall stubble)[69] and local erosion control (3.1). However, there is a caveat: natural plant succession with or without the project (grasslands, shrubland and young forest) could mask the effects on the quality of the landscape in the short and medium term. Thus, the mitigation measures to establish forests could help speed up the process, although the pattern would be the same so it is difficult to attribute improvements to the project mitigation measures. Alternative government-sponsored actions, such as incentives to the local primary sector, may be far more effective in preventing, mitigating and offseting the impact on the landscape through changes to the forest cover.

Table 13. Effectiveness of the mitigation measure on the Landscape aspect

Mitigation measure	Monitoring indicator	Baseline value	Reference value[70]	Monitoring value	Effect.
Establish protection areas (3.4 Table 21, EIS-1993) Promote forest development and conservation (3.6 Table 21, EIS-1993)	Cover (EMP, 1994)	12.6 %Sf 7.5 %Ts 5.9 %Ls 69.9 %Gs 0.3 % erosion	36 %Sf NA %Ts NA %Ls NA %Gs NA % erosion	10.8 %Sf 34.1 %Ts 19.7 %Ls 21.3 %Gs 0.1 % erosion	0.8 3.5 3.5 3.5 3.1
	Matrix (km^2) (EPM, 1994)	NE	NE	NE	
	Fragments (shape, area, isolation) (EPM, 1994)	NE	NE	NE	
	Corridors (length, shape) (EPM, 1994)	NE	NE	NE	

Note: NE: Not evaluated by EPM; NA: Not available
(Sf) Secondary forest; (Ts) Tall stubble; (Ls) Low stubble; (Gs) Grasses; Erosion: Areas exposed to erosion
Source: Author's own calculations.

68 What is more, the dominant cover attributes and land use combination are contradictory when applied to intrinsic landscape characteristics such as soil protection and hydrologic regulation in a satellite image grid. Although forest cover must be increased to achieve these environmental services, i.e., increase cover homogeneity in the grid, this method attaches a positive value to land use heterogeneity per grid (soil combination). Likewise, a greater soil combination may affect connectivity and therefore landscape sustainability and resilience over time.

69 Environmental quality trends for forests have fluctuated within the low quality range (0.05 - 0.18), whereas low and tall stubble values range from low to medium (0.03 - 0.52).

70 Premised by Marquez (2000) with the Remaining Vegetation Index.

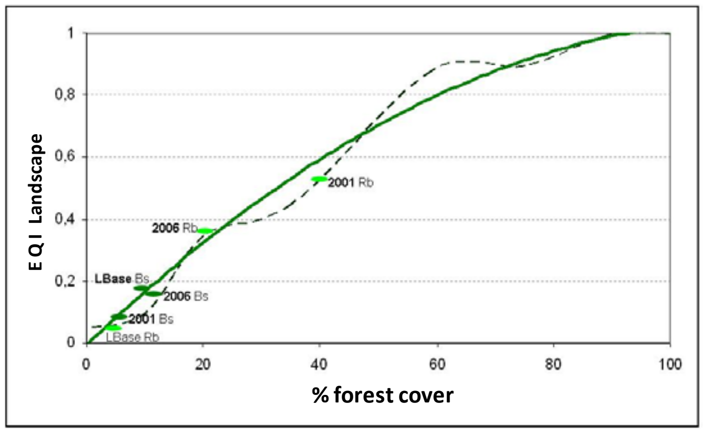
3.48 The **environmental quality index (EQI)** uses the forest cover indicator based on the remaining vegetation (forest and stubble) for a watershed in a tropical rain forest. The benchmark is a contribution by Marquez (2000) considering that a basin needs a forest cover of 36% in order to perform its functions. However, no conclusions could be drawn from the EPM landscape data, nor was it possible to ascertain with scientific certainty that this is the desirable level of coverage for this watershed (see Table 14, Figure 8).[71]

Table 14. EQI landscape forest cover based on remaining vegetation index

% Cover (Bn-Bs)	EQI[72]
90-100	1.0
75-89	0.9
59-74	0.8
35-58	0.45
20-34	0.35
10-19	0.10
<10	0.05

Bn: Disturbed natural forest
Bs: Secondary forest

Figure 8. EQI value function for the watershed forest cover, from baseline (BL) to 2006



Rb: Low stubble
Bs: Secondary forest

3.49 Considering the already mentioned methodological limitations and inaccuracies, this evaluation calculated, on an experimental basis, the Landscape Visual Quality Index (LVQI) using data from the three monitoring reports (Integral, 1996; National University 2001 and 2006), analyzing data as an experiment not intended to generate conclusive values for the real status of the project (see Tables 12 and 13, and Figure 13 in Annex 1). Figure 9 shows a decrease in visual quality for the project's direct area of influence from the baseline to the 2001 monitoring report, although an improvement was noted from start of operation in 2001 to the last monitoring in 2006. Should this trend continue, the visual landscape quality could reach the pre-intervention state in 3.5 years (see Figure 14 in Annex 1). On the other hand, although VQI and monitoring methods used are widely accepted, the data generated when monitoring the Porce II landscape visual quality appear to be deficient for value calculations because of methodological inconsistencies (changes

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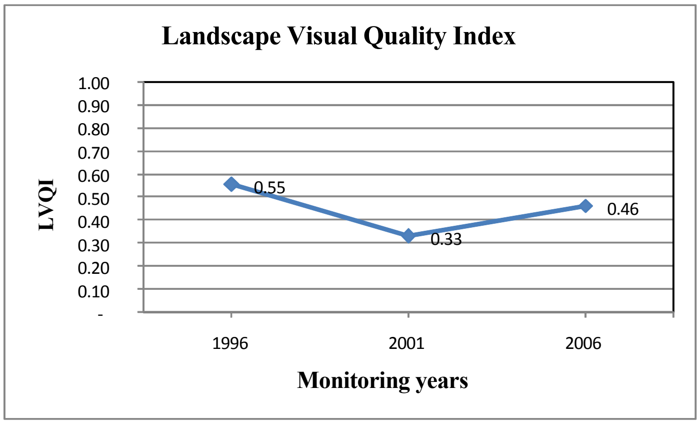
[71] Márquez, G. 2000. *Vegetación, Población y Huella Ecológica como indicadores de sostenibilidad en Colombia. Gestión y Ambiente (5):33-49*. National University of Colombia, Medellín.

[72] 1.0 desirable situation for a watershed in a tropical rain forest (T/rf), corresponding to the maximum forest cover (Bn-Bs: disturbed natural forest or secondary forest).

in the valuation criteria for each attribute, different data scales, etc.), in addition to the number of samples collected.

Figure 9. LandscapeVisual Quality Index (LVQI) value function



Source: Author's own creation.

3.50 Two environmental indicators were analyzed to determine the **effect of the mitigation measures**: % of forest cover and natural use of land, under the above-described methodological assumptions and limitations. The results of this exercise are summarized in the table below.

Table 15. Effect of mitigation measures on the Landscape aspect

Environmental aspect	Environmental indicator	(1) EIU w/o project	(2) EIU with project with MM	Net change (2)-(1)	(3) EIU with project w/o MM	EMM (3)-(2)
Landscape	% forest cover	0.0513	0.0615	0.0102	0.0150	-0.0465
	Natural use of land	0.0665	0.0762	0.0097	0.0350	-0.0412

Notes: EIU: Environmental Impact Units

Net change: difference between values with project (1994-2007) and without (w/o) project (1989-1994).

EMM: Effect of the Mitigation Measures, difference between the project values with and without mitigation measures (MM).

Source: Author's own calculations.

3.51 The expanding agricultural frontier and the resulting loss of protective cover to grasslands, together with the associated erosion, are some of the factors that further exacerbate the deterioration observed prior to construction of the dam (positive net change). However, this does not necessarily mean that this improvement in environmental quality with respect to this aspect is specifically due to the project.

The data concerning the effect of the mitigation measures are negative, although inconclusive owing to the absence of comparable data.

C. Efficiency of the mitigation measures

3.52 Initially, the objective of this section was to **compare the efficiency in the use of economic resources and the time needed to implement the mitigation measures with respect to EIS projections** (EPM, 1993) against the percentage of progress achieved for each measure. However, EPM did not keep data broken down by expected and executed timeline for each of the project's environmental mitigation measure. Also, although the EIS provides projected costs to be executed annually, year-on-year investments executed during construction and operation were not broken down, nor were the costs for each environmental mitigation measure in the civil works contracts.

3.53 In fact, execution of mitigation measures during the operation was included under the heading "physico-biotic-social impacts management" without further discrimination by measure. This explains why this evaluation suggested using civil works progress report data as a proxy for mitigation measures. The evaluation identified serious delays in surface works and underground works (57 and 78 months, respectively, between scheduled and actual dates due to technical and administrative problems). However, this approximation does not answer the question of whether the mitigation measures were applied in an optimal and timely manner to mitigate environmental impacts despite delays in the civil works.

3.54 The proxy used to measure economic efficiency was a comparison of projected and actual budgets for the principal works of the Porce II construction phase. The results obtained by this method show **low economic efficiency** for underground works and for compensation, relocation and environment, and high for dam construction.[73]

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[73] An IDB report prepared as input for the EPM ex post evaluation (Lecaros, 2005) indicates that although EPM faced problems during project execution requiring a change of contractor, the power plant works were nonetheless completed at less than originally budgeted. This coincided with low market prices, which offset the financial consequences.

Table 16. Economic efficiency in the execution of the principal works for the construction phase

	Original cost Bpp (US$)	Actual cost Be (US$)	Eei	Rating
Dam works	76,110	63,732	119.42	High
Underground works	127,980	165,589	77.29	Low
Compensation, relocation and environment	20,470	23,904	85.63	Low

Note: Eei: economic efficiency index for project execution; Eei = (Bpp / Be) x 100, where: Be: Budget executed; Bpp: Budget projected or programmed.

Source: Porce II ex post evaluation report, 2005.

3.55 The aggregate data were complemented with an analysis of available information on the efficiency in the use of resources for the five environmental aspects selected through the scoping. In general terms, on the one hand, there was significant variability in economic efficiency for different years for each aspect[74] and, on the other, resources needed for implementation were regularly underestimated. For example, efficiency in the financial execution of the landscape aspect was very low every year for which data are available. In the case of aquatic plants, ex ante studies only contemplated an allocation of 18 million Colombian pesos to study the biological control of invasive macrophytes. The study was never conducted and ultimately, as explained above, far more resources than planned had to be invested given the magnitude of the impact—well above EIS projections.[75] The same occurred with land plants: actual investments were approximately four times greater than initially projected (from 243.2 million Colombian pesos in 1992 prices to 1,626,240,000 Colombian pesos in 2006). This would seem indicative of a faulty projection of needed mitigation activities and their cost. In the case of erosion, the economic efficiency is satisfactory, with only 4,628,900,000 of the projected 8.93 billion Colombian pesos invested, according to unpublished information provided by EPM officials.

3.56 In summary, the information gathered in compliance with the EIS provisions (EPM, 1993)[76] was not systematized during project construction and operation, thereby hindering the efficiency analysis relating to implementation of the mitigation measures. In addition, without data, it is difficult to correlate the level of physical and financial implementation of each mitigation measure with its effectiveness to

[74] A methodological exercise produced the same results for other aspects omitted by the scoping: flooding upriver and downriver of the dam, air quality and fish.

[75] According to EPM officials, investments for the period 2007-2009 alone were estimated at 770.7 million pesos. Details on actual amount executed could not be obtained as this was part of monitoring and actions for other mitigation measures.

[76] Data on the projection of time and annual and total costs for each proposed mitigation measure.

mitigate environmental impacts.[77] Given these limitations, partial analyses of the efficiency criterion put forward in this evaluation are intended as a contribution to improve the project evaluation and monitoring system, and the environmental management system of EPM.

D. Sustainability of the mitigation measures

3.57 This section reviews the **sustainability of the mitigation measures from the perspective of the results of the environmental management evaluation** by Empresas Públicas de Medellín (EPM). It also reviews the **institutional capacity of the environmental authorities** responsible for monitoring and controlling the project's environmental requirements. The present evaluation assumes that proper environmental management by the company and the institutional capacity of the lead agency guarantee the sustainability of mitigation measures and environmental protection. The analysis primarily relied on secondary information such as EPM management reports for 2004, 2005 and 2006, as well as interviews with EPM officials.

1. Evaluation of EPM's environmental management

3.58 EPM defines **environmental management** as **the series of actions needed to ensure that projects, works or activities are effectively integrated into the natural and social environment of their areas of influence, and to guarantee their operation and compliance with national environmental regulations and EPM policies**, all within a framework that preserves the company's competitiveness.

3.59 The Porce II environmental studies were presented in 1989, at a time when there was a legislative and technical void in Colombia in the field of environmental issues associated with infrastructure projects. The environmental impact evaluation process was therefore conceived by EPM as a learning process (EPM, 2005). During the Porce II construction process (1994-2001), various guidelines and procedures were developed and gradually integrated into an environmental management business model.[78] In 1997, EPM undertook an internal restructuring process aiming, among other things, to address the lack of coordination and the segmentation of environmental management. One of the strategies was to create five Strategic Business Units (SBUs): energy generation, energy distribution, telecommunications, water and commercial. Subsequently, EPM issued its Corporate Environmental Policy and created the Environmental Committee with the chief purpose of drawing up environmental management guidelines for use in business. In parallel, the Energy Generation SBU strengthened its structure to focus on environmental management at each step of energy generation projects (planning,

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77 This information is important because high financial or temporal efficiency may mask deficient implementation in relation to the environmental protection objectives specified in the Environmental Management Plan for projects of this nature.

78 Lecaros, Fernando. *Evaluación ex post de Porce II*. February 2005.

design and construction, operation, marketing). EPM's institutional management is carried out through principal and support processes that make up the so-called value chain. In this chain, environmental management—known as Administration of Environmental Matters—is one of the support processes for all SBUs, including the Energy Generation SBU. Its duties include management, policy decision-making, compliance oversight, and management of project environmental impacts[79] (see Table 19 in Annex 4).

3.60 Since 2000, as a result of the evolution in environmental legal requirements imposed both by the Colombian government and multilateral banks (including the IDB), in addition to international trends concerning corporate social responsibility, EPM adopted a **systemic environmental management** approach. Systemic management consists in a cyclical process of continuing improvement, to gradually attain better environmental quality moving through the phases of **planning, execution, evaluation and control** (DNP [National Planning Department, Colombia] 1998). OVE's criteria to evaluate EPM's management follow these phases, and the company's capacity to coordinate and communicate environmental matters was also reviewed.

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79 EPM, *Informe ambiental 2006*, and EPM, *Informe de gestión 2007*.

Table 17. Summary of the evaluation of the sustainability criterion

<table>
<tr><th colspan="2"></th><th>Qualitative Evaluation</th></tr>
<tr><td rowspan="4">Sustainability of EPM's environmental management</td><td>Planning capacity</td><td>Inclusion of environmental management as part of the company's institutional management, together with its environmental policy, promote cross-cutting and sustainable environmental management for all projects in the long term. The environmental management plan becomes a long-term environmental management tool, adapted to circumstances during project implementation based on the operational functions of the environmental division. In addition to the three-year strategic planning, the environmental division prepares a short-term (annual) plan to be complemented by a long-term plan to achieve this goal.</td></tr>
<tr><td>Execution capacity</td><td>The secondary information reviewed indicates good execution levels in accordance with the legal compliance process. There is also evidence of sufficient technical capacity based on the number of staff assigned to environmental management, and their levels of training. Nonetheless, more needs to be done to develop and implement instruments to systematically monitor environmental impacts during project operation for all environmental aspects. Likewise, there is a disconnect between the construction and operation departments that may have caused some gaps in the gathering of monitoring data and the centralization and strategic use of environmental data.</td></tr>
<tr><td>Evaluation and control capacity</td><td>Methodologies for identifying and evaluating environmental impacts are in place for the different phases of EPM projects. The company's participation in regional environmental projects, at national discussion panels and international conventions on the environment is satisfactory based on the information reviewed and the national and international awards received by EPM (hemispheric consultant on good environmental practices). The monitoring methods became more consistent and comparable beginning in 2004.
Environmental management for the operating phase of energy generation projects relies on an annual environmental management plan, a management tracking and control regime and a balanced scorecard. The balanced scorecard includes a number of environmental management indicators for the project, with red flag areas in case the environmental indicator scores are outside the expected range. This contributes to continuing improvement of management.</td></tr>
<tr><td>Coordination and communication capacity</td><td>The company has been able to establish coordination and communication channels with the local population and institutions in project areas. This is done through community participation mechanisms (information, consultation, consensus building, shared- and self-management) supported by the process "Participation in institutional and community development."
Based on the information reviewed, EPM's performance with respect to its coordination and communication capacities is positive, which supports the sustainability of the company's environmental management.</td></tr>
<tr><td>Capacity of the environmental agencies</td><td colspan="2">Several studies indicate that monitoring and following up on environmental licenses is one of the weaknesses of the Colombian environmental system. The principal environmental agencies responsible for licensing and monitoring the Porce II environmental management, the Ministry for the Environment, Housing and Territorial Development (MAVDT) and CORANTIOQUIA, face budget and technical limitations that hamper achievement of the environmental licensing and monitoring objectives other than an administrative review of permits and procedures.</td></tr>
</table>

Source: compiled by author.

3.61 Despite these limitations, continued environmental management of Porce II appears to be assured, both from a budget and technical standpoint, upon completion of the Bank project. The following factors support sustainability:[80]

[80] See Table 19 in Annex 4.

a. **Inclusion of environmental management** and, in particular, compliance with the requirements specified in the Porce II Environmental Management Plan and the Monitoring and Control Plan, in the business management model.

b. The company's **environmental policy** and related processes, which assure future allocations of technical and budget resources.

c. The **environmental management design** that goes beyond compliance with legal environmental requirements, including several discretionary procedures, is evidence of the company's desire for continued improvement.

d. **The company's environmental management is process-driven instead of project-driven**, although there is room for improving the evaluation and control instruments for some environmental management processes.

e. The **company's coordination and communication capacity**.

2. Evaluation of the capacity of the environmental agencies responsible for monitoring and oversight of legal requirements at Porce II.

3.62 **The Ministry for the Environment, Housing and Territorial Development (MAVDT) is responsible for approval, monitoring and oversight of Environmental Licenses** for hydroelectric projects with installed capacity greater than 100,000 KW, as in the case of Porce II. The Autonomous Regional Corporation of Central Antioquia (CORANTIOQUIA) issues permits to use the natural resources needed for the construction and operation of projects in the region, such as water concessions and dumping and waste management permits.[81] The following is a qualitative assessment based on secondary information relating to the two main environmental agencies responsible for licensing and monitoring environmental management at Porce II: MAVDT and CORANTIOQUIA.[82]

3.63 As to the **technical capacity of the MAVDT**, created by Law 99 of 1993, it has a clear structure, with a roadmap for processes including an environmental monitoring manual for projects, a quality control system and a team of specialists to assure the institution's strength to discharge its functions. The responsibility for monitoring obligations stemming from licenses issued by the institution is held by an official who coordinates a group of professionals that every year covers a sample

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[81] Other environmental agencies involved in EPM's environmental management, and more specifically Porce II, include the Environmental Department of Municipio of Medellín, currently in charge of recovery and conservation of the Medellín River as it flows through the city, and the Office of the Comptroller General of Medellín that conducts annual audits of the company's overall management.

[82] No quantitative information was available on the technical capacity and efficiency of the environmental licensing and permit processes, such as number of people working for the entity to issue, monitor and control licenses and their formal education levels; number of requests processed versus number received; processing time by type and size of project, etc.

of all projects to be monitored according to a prioritization schedule.[83] In the case of CORANTIOQUIA, the professional team at the Zenufana local office is assigned to monitor Porce II because it does not have a specific division in charge of environmental matters. This government agency was created in 1995, hence the delay in issuing some of the environmental permits. As a result, construction of the infrastructure works began without having a proper environmental management plan, requiring the implementation of mitigation measures a posteriori to ensure comprehensive environmental management throughout the project.

3.64 In terms of **licensing efficiency**, a study (Torres, 1998)[84] has shown that license monitoring and follow-up is a weakness in the Colombian environmental system. This diagnosis matches the findings in the 2006 report of the Office of the Comptroller General of the Republic.[85] The causes include failure to define monitoring criteria and guidelines; time constraints imposed on part-time staff assigned to evaluate records, limiting their ability to improve the quality of work and provide continuity within the environmental monitoring agencies; and budget constraints limiting the agencies' ability to evaluate and monitor records. As a result, despite requirements for exhaustive ex ante EIAs and EMPs, the capacity and thoroughness of the monitoring process is very limited.

3.65 Similarly, **deficiencies in the monitoring and follow-up processes at state and regional environmental licensing agencies** curtail their ability to assure effective environmental management at Porce II, due to their inadequate oversight capacity and limited capacity to evaluate the effectiveness of mitigation measures specified in the EMP. Indeed, although Ministry and CORANTIOQUIA decisions, resolutions and communications report on annual visits by officials to monitor and control legal requirements, it is more of an administrative process instead of a process intended to add technical value or evaluate the effectiveness of mitigation measures on the environment of the Porce II hydroelectric project. OVE reviewed compliance with Colombian environmental legislation requirements at Porce II, finding no evidence in the authorities' monitoring reports about violations that could have caused significant environmental harm. What is more, management of Porce II by EPM was evaluated against the IDB's safeguard requirements, finding full compliance as planned and executed under the Environmental Management Plan and General Monitoring Plan (see Table 21 in Annex 6). In particular, OVE found there was compliance with the EIS and the EMP, the Resettlement and Public Health Plan, and the preparation of environmental evaluations.

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[83] Office of the Comptroller General of the Republic. *Estado de los Recursos Naturales y el Ambiente. Bogotá (Colombia), 2006.*

[84] Guio Torres, D.M., 1998. *El Sector Energético y la Banca Multilateral de Desarrollo: El caso colombiano.*

[85] Office of the Comptroller General of the Republic, Ibid., pages 155–188.

E. The IDB's additionality

3.66 **In this study, the concept of additionality evaluates the Bank's participation in the project, under the assumption that it contributes to achieving better environmental results than those possible with only a public or private capital investment, that is to say without the Bank's participation.** For Porce II, the idea was to examine which mitigation measures or other environmental management activities were directly proposed by the Bank, and how relevant they were to improving the project's environmental quality outcomes.[86] The IDB's environmental policy and guidelines were very useful to direct the environmental evaluation work when designing the Porce II environmental studies. However, the IDB Environmental Policy (OP-703) in effect at the time, approved in 1979, cannot be considered an essential reference document as it is only four pages long, providing some basic environmental lines of action for the Bank, and some very general principles to guide those actions. On the other hand, the EPM evaluation recognizes that the environmental commitments entered into with the IDB and with environmental authorities, together with the diverse issues encompassed by environmental management, gave rise to creating a work team to implement environmental management in the Porce II hydroelectric project. This is how a new line of work, devoted exclusively to environmental inspection, became part of civil works inspection. The loan operation also provided for an institutional capacity-building program that included environmental training.

3.67 The ex post evaluation (EPM, 2005) recognizes that five aspects added to the Monitoring and Control Program upon the recommendation of the IDB.[87] The following were added to the list of environmental aspects monitored during construction and operation: the risk of dam destruction, water quality of the Porce River upstream of the reservoir, quality of water exiting the turbine, public health, and occupational health and safety.

3.68 A qualitative comparison of the obligations specified in the MAVDT environmental license and those listed in the Bank's environmental validation reports (Environmental Brief, June 1993, and environmental sections of the loan document dated November 1993) shows that during project design the IDB's recommendations on additional studies and mitigation measures were relevant in all cases, although not always effective (Table 22 in Annex 6). In the case of watershed protection, the study conducted at the IDB's recommendation was considered meaningful to provide a context for environmental problems associated

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[86] This chapter presents an evaluation of the Bank's additionality for the Porce II Hydroelectric Power Plant project, focusing in particular on the prefeasibility phase of the environmental conditions when the Porce II project was being considered for a Bank loan. The review also includes data available for the environmental monitoring of the project by the Bank, and the Bank's support for EPM to prepare the ex post evaluation in 2005.

[87] And also indirectly as a result of Ministry requirements and recommendations made in some environmental studies.

with megaprojects such as Porce II, and to evaluate cumulative and synergistic impacts of a chain of dams under construction. According to CORANTIOQUIA officials, this Bank recommendation brought about the creation of Instituto Mi Río, an institute that, inter alia, improved environmental management in the Aburra Valley. On the other hand, the study on water quality in the watershed, although relevant, should have been complemented with institutional and technical strengthening activities for the environmental authorities with jurisdiction over watershed management to ensure effective implementation, and with discussion panels to involve third parties in the monitoring effort. Data on the Epidemiological Surveillance System was very limited.

3.69 **Information on the Bank's additionality during project execution** is more difficult to establish because the IDB's monitoring system reports (PPMR and PCR)[88] are too general and do not provide specific information on environmental issues. Of the four Porce II monitoring reports,[89] only the last three refer in very general terms to progress made in some of the environmental control activities that were implemented. The completion report only refers in passing to the excellent performance of the project's environmental component, recommending the experience be compiled and reviewed as an example of good practice. Information on the IDB's role in planning the ex post evaluation was also insufficient.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

4.1 This study helps fill a void in the literature on Environmental Impact Assessment (EIA) during monitoring of operations and ex post evaluations, helping to **develop innovative methodologies for ex post environmental assessments** both for the Bank and for borrowers. It also sets out to deepen the EIA processes to measure the effectiveness of mitigation measures with regard to the environmental quality objectives specified in environmental management plans.

4.2 **The study makes it possible to make use of environmental monitoring data for infrastructure projects through an analysis of indicators and their long-term trends.** It therefore transcends the dimension of mere compliance of environmental monitoring reports required by authorities and by the Bank. In EPM, as in many other public and private enterprises, different divisions within the company are involved in the construction and operation of such infrastructure megaprojects. This often thwarts efforts to analyze and take into account data collected over time by different departments in the environmental management of the projects. Thus, ex post evaluations of this type make it possible to retrieve recommendations from

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88 Project Performance Monitoring Report and Project Completion Report.

89 December 1997, June 1998, June 2000, June 2001.

earlier studies and monitoring reports, collect disperse data over the years, and even promote the improvement of data management systems.

4.3 This environmental evaluation (OVE, 2007-2008) considers several **evaluation criteria for the proposed mitigation measures**[90] and develops **innovative methodologies to assess project effectiveness in terms of environmental quality and the mitigation effect of the measures.** Although the Porce II Hydroelectric project was selected because of the quality of available data, the quality was not sufficient (limited consistency in sampling methods, limitations as to the relevance of indicators) to draw any conclusions about the overall impact of the mitigation measures and their effect on the quality of the ecosystem.

4.4 In general, the evaluation results indicated that the Porce II Hydroelectric project's mitigation measures were **relevant** for four of the environmental aspects considered (the exception was landscape)[91] despite the failure to implement some of the proposed measures and the inadequate implementation of others.

4.5 The proposed mitigation measures were **effective** to mitigate the environmental aspects reviewed by OVE, on the presumption that the environmental quality of the surrounding area would have deteriorated had the project been executed without implementing any mitigation measure. However, this conclusion does not help determine whether the net change to the quality of the environment in the area when the project went online was positive or negative, or which variables were most significant.

4.6 The **economic efficiency** for each environmental aspect was varied. One of the most significant problems were budget overruns to address certain impacts, such as those relating to aquatic and land vegetation. EPM has no cost breakdown so as to calculate the cost-effectiveness of each mitigation measure. The **capacity to implement and keep environmental management measures up to date is considered sustainable** over time thanks to the institutionalization of environmental matters and technical capacity-building by the company.

4.7 Lastly, the Bank **added value** to the design of some environmental aspects by requiring specific studies, such as watershed management, water quality and the epidemiological surveillance system. However, implementation of several measures proposed by the Bank exceeded the EPM's jurisdiction, and no provisions were made to coordinate with the agents responsible for their implementation. Most technical consultancies focused on the pre-loan approval phase (socioenvironmental viability analysis). The IDB systematically monitored the proposed measures, and none of these issues are reflected in the Bank's monitoring instruments.

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[90] Evaluation criteria: relevance, effectiveness, efficiency, sustainability and additionality.

[91] Water Quality, Invasive Aquatic Plants, Land Plants, Land Fauna.

B. Recommendations

4.8 This evaluation applied pilot methodology to assess the relevance, effectiveness, efficiency and sustainability of the Porce II project mitigation measures for the environmental aspects considered most relevant in terms of their ex post impact. When monitoring data are robust and comparable over time, the interpretation of aggregate evaluation criteria results for the environmental aspects given priority could be used to generate an **ex post environmental impact assessment** for the project, as recommended in relevant bibliography. Accordingly, to improve future application of this methodology, the following is recommended:

a. Enforce a strict methodological approach to monitoring (sampling methods and effort, data analysis, etc.) so as to identify environmental quality trends for each aspect and enable a multi-temporal analysis. This does not preclude the possibility of perfecting methodologies. Rather, the idea is to pursue options that seek to reconcile multiple monitoring results to ensure their consistency, or at least keep separate records for the varioous methodologies used until a sufficient time series is established. At the same time, the systematization of results for each core environmental aspect and performance evaluation should be improved.

b. Ensure that the indicators selected to verify the effectiveness of mitigation measures reflect achievement of the environmental quality objectives for each aspect. Otherwise, the effectiveness analysis will not make is possible to attribute results to the actual mitigation measures, serving only to review compliance with the implementation of the measures without considering actual results.

4.9 Similarly, it should be possible to jointly apply **the relevance, effectiveness and efficiency criteria of the mitigation measures** so as to estimate if the mitigation measures that were considered relevant ex ante achieved the expected outcomes, and determine their cost-effectiveness to improve budget compliance and avoid underestimating resources. The Bank should promote the conduct of specific studies to estimate the cost of mitigation measures and their relation to impact prevention and future need for remedial interventions. For example, studies could estimate the actual cost of reforestation programs with respect to their value in preventing erosion around reservoirs and avoiding future dredging costs to keep the hydroelectric project in operation.

4.10 The initial environmental studies should clearly spell out which of the planned mitigation measures are under the direct jurisdiction of the borrower or project proponent, and which require cooperation with other enterprises or public institutions since their scope goes beyond the project. It may be necessary to strengthen the work with these entities and institutions, exploring what actions will help the company create synergies with the other players.

4.11 Environmental studies covering a wider area than the project's direct area of influence are valuable to contextualize the environmental problems in megaprojects and evaluate cumulative and synergistic impacts of a chain of projects. In these cases, it is worth exploring the possibility of providing technical cooperation resources instead of adding environmental requirements as part of the environmental management of a specific project. What is more, these instruments could help build institutional capacity so as to implement more wide-ranging mitigation measures, and boost the effectiveness of the monitoring and follow-up by environmental authorities in terms of environmental quality and future sustainability of environmental management actions. The same limitations for management of the environment in the area are being replicated in a new loan for the Porce III hydroelectric plant, also operated by EPM. Evaluations of the project's cumulative, synergistic and indirect impacts requested by the Bank for this new loan also consider what actions ought to be performed by CORANTIOQUIA and the local municipios for basin recovery and conservancy. Despite some coordination between EPM and these institutions, the Bank has not provided for mechanisms to build their technical and logistical capacity to ensure effective compliance with the recommendations made in the studies requested.

4.12 In considering the efficiency of mitigation measures, the budgets must be better dimensioned on the basis of expected outcomes, admitting it is difficult to gauge the magnitude of impacts and the uncertainties surrounding EIS forecasts for infrastructure megaprojects. The specialized literature on environmental monitoring systems suggests the use of adaptative environmental management (Morrison-Saunders and Bailey, 2000). This concept proposes a flexible approach promoting an adaptative and continuous management focused on achievement of the environmental objectives rather than on prescriptive requirements.

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