Rapid Socio-Economic and Hydrological Assessment of Prey Lang Forest Summary of Baseline Conditions

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1. INTRODUCTION

This report summarizes the Rapid Socio-Economic and Hydrological Assessment of Prey Lang Forest report dated July 2011 (referred as Primary Assessment Report herein-PAR). Its purpose is not to replace the Primary Assessment, which contains the study assumptions, basic information and details regarding the methods, but rather to provide a general overview of the key elements of the Assessment. The Primary Assessment should be referred for more in depth clarification. In addition, an informal and cursory follow-up review of the reported development activities that have occurred in the PAR study area since it was submitted, was conducted as a supplement to this Summary, and is located in the Appendix.

The objective of Primary Assessment was to conduct a preliminary socio-economic hydrological analysis of the internal and external natural and social aspects of the Prey Lang Forest, and to assess net negative and positive impacts on the forest and downstream ecosystems (economic as well as ecological). The study focused specifically on the hydrological aspects of the forest, as a whole, on which to build an optimum strategic decision model to maximize prudent sustainable forest utilization without devaluating the natural capital and services provided by the forest. The study was conducted in collaboration with the Royal Government of Cambodia (RGC) Forest Administration and USAIDs Micro, Small and Medium Enterprises (MSME) initiative. It assessed three forest management strategies taking into account the inherent natural services provided by the Prey Lang Forest, considering the downstream economics, health and social impacts of the different land uses relative to the hydrology cycle and environmental effects.

The three forest management strategies (Scenario 1, 2, and 3, respectively) considered were:

1. **Conversion** is the full exploitation and conversion of the existing forest to other land uses in order to reap the maximum economic value of the timber in the shortest possible time frame.

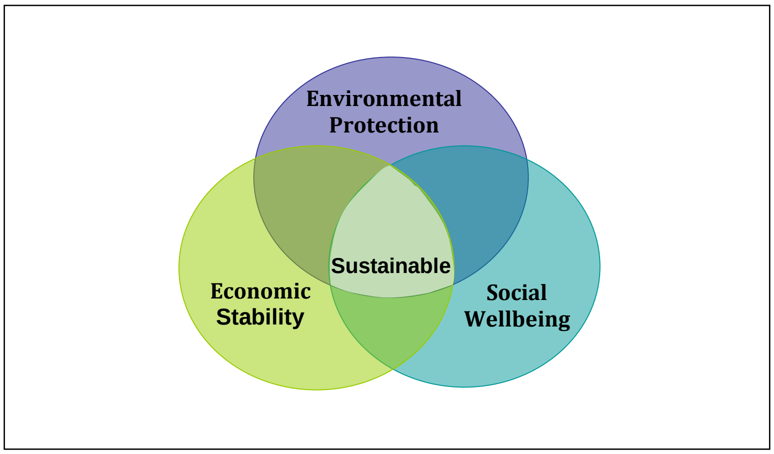
2. **Preservation** is to provide sufficient funding, policy, regulation and enforcement to protect the forest from exploitation, environmental disruption and social-economic intrusion, to preserve the remaining forest as is or better in perpetuity.

3. **Conservation** is the optimization of forest development and environmental conservation by developing, implementing and maintaining a balanced sustainable land use management approach involving local communities, advocacy groups, and economic

enterprises in partnership with the national government to maximize optimum economic returns, while minimizing disruptive environmental and social impacts.

Each scenario seeks to maximize the objective of the specific goals. For conversion, the objective is to maximize revenues for economic benefits. For preservation, the objective is to maximize forest protection to mitigate environmental concerns relative to social welfare. And for conservation, the goal is to maximize the optimum balance between the two extremes. The scenarios were assessed in term of the three main pillars of sustainability: environmental protection, economic stability, and social wellbeing (Figure 1.1).

Figure 1.1 Primary Themes of Sustainability



Adapted from Conference Board, NYC 6/04

1.1. Project Background

The study area was the Prey Lang forest landscape, an evergreen dry forest located within Kampong Thom, Preah Vihear, Stung Treng and Kratie Provinces in central Cambodia.

CARBON CREDIT PROGRAM

In 2007 the Intergovernmental Panel on Climate Change (IPCC) recognized that prevention of both deforestation and degradation of tropical forest was the most practical immediate short-term measure to curb the release of CO_2 into the atmosphere. Consequently, Sustainable Forest Management (SFM) practices encourage reduction of emissions from deforestation and degradation policies (REDD) to increase carbon stocks by maintaining sinks. Collectively REDD and SFM are referred to as REDD+. The UN pledged “fast-start” funds between 2010-2012 to develop SFM in tropics to include production and ecosystem services.

The objectives of the emission reduction initiatives are to increase carbon stock by regulating timber production and to provide a short term funding source to pay the carbon credit with the idea that over time a self-sustaining carbon market will develop. The Study assumed that a successful carbon credit market does develop. If such an effective carbon credit program does not materialize, it is assumed that maximizing forest production and reforestation efficiencies, enhancing yield of viable cash crops, and developing a robust ecotourism trade can achieve equivalent value to that of a successful REDD+ program. In the case of Scenario 3, the carbon storage capacity retains its value as Indirect Use (IUV as discussed in Section 2), and in the cases of Scenario 1 and 2 it is a direct use value (DUV); therefore, in either case, carbon storage is taken into account in the Benefit Cost Analysis (BCA). See Section 2.6.2.

This study relies on secondary information and makes a fair number of assumptions; however, does try to introduce a level of replicable quantification by interpolating and extrapolating between established low and high, best and worst case ranges. For the most part, this report relies on either the mean or median of the ranges. This makes it relatively easy to conduct sensitive analysis using different factors within the ranges, which is beyond the scope of this study, but could be a very helpful follow-up.

1.2. Rapid Assessment Limitations

The study was a rapid assessment based on existing secondary data and information compiled during the project. Consequently, without sufficient quantitative information, a comprehensive quantitative study cannot be conducted, but taking into account these limitations, this study does provide a starting point and preliminary guidance, and highlights the data gaps that need to be filled before a more quantitative study can be completed. In the meantime development is occurring, and the use of the Sustainability Matrix tools discussed in Section 2.7, in combination with TEV and BCA, as discussed below, provides a basis for determining which scenario most likely presents an optimum strategy.

2. METHODOLOGY

Methodologies used in this Assessment relied on standard methods and procedures to assess watershed hydrology and river hydraulics, forestry management, soil classification and environmental assessments (EA), total economic value (TEV), benefit cost analysis (BCA), geographic information system (GIS), watershed analysis, etc. Preliminary community participation assessment surveys were incorporated into the study

2.1. Study Area Delineation

The first step was to identify the regional characteristics within their known spatial boundaries using available maps. Political and watershed boundaries were used for the initial assessment, with Prey Lang Forest as the focal point.

Watershed boundaries were the defining factor for the hydrological study area because of the dynamics of the hydrological cycle in relation to the forest, underlying aquifers, and surface water hydrology and river hydraulics. All of these were then considered with respect to internal and downgradient stakeholders, environmental impacts, and socio-economic conditions.

2.2. Data Collection

A data and literature review was conducted of available records with respect to the study area to assess bio-physical conditions including: topography and meteorology, land use and surface cover, forested area, slopes, soil properties, and rainfall; and surface water flow characterization such as: surface runoff patterns and infiltration, stream and flow rates, gradients and water quality; and *demographics:* current and projected population estimates, public works infrastructure update, changes in land use, economic sectors, and government policies.

2.3. Hydrology Analysis

WATER BALANCE

A generalized study area water balance was prepared using the information discovered. In general, water balance is the sum of the volume of water flowing into the study area from all sources versus the sum of water flowing out of study area. It provides a reference framework on which to base watershed qualitative interpolation and extrapolations. Figure 2.1 shows the inputs and outputs.

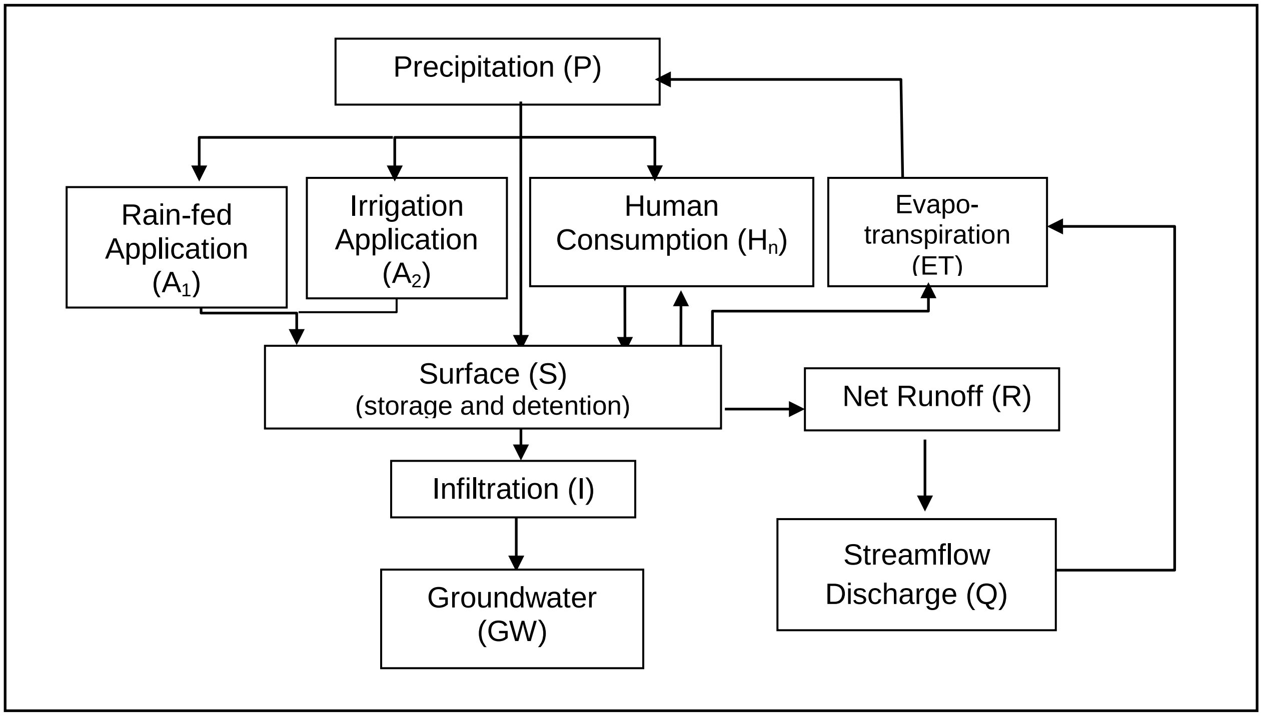
HYDROLOGIC AND HYDRAULIC CHARACTERISTICS

The historical data from available records was used to determine the Baseline Conditions. Subsequently, a range of hydrological changes associated with each scenario was estimated. While the data gaps and inconsistencies were many, the quantity of data over an extended period of time did allow for a conceptual characterization of the study area.

WATERSHED

The watershed ecosystem contains a large set of subsystems each providing a list of unique and complementary services. The value of the watershed services is the aggregate value of all the ecosystem services provided within it.

Figure 2.1 Generalize Study Area Water Balance



FOREST

The forest services include erosion control, buffering water velocity, rain fall distribution and impact, water quality, temperature control, soil quality as well as carbon sequestering, photosynthesis, etc., plus the economic value of the wood used as lumber, paper, and NTFP, as well as heat from the wood used as fuel. The forest also provides habitat for flora and fauna, and protects biodiversity (which is not covered by value of biodiversity), as well as a host of sub and micro ecosystems, which provide their own unique contribution. There are also the values of the very presence or existence of the forest, such aesthetic, cultural, and social context.

BIODIVERSITY

Biodiversity contributes to ecological balance through species interactions, which reinforce sustainability of the ecosystem. In addition, there are cultural, educational, and traditional values. Biodiversity of the study area assessed in this report is quite high, and in the context of this report, biodiversity is best presented by the fish species.

2.4. Placing a Value on Ecosystems

To place a value on the services within the ecosystem from a human perspective typically means a monetary value, such as TEV as discussed below. The monetary value of an ecosystem is the accumulated worth of the multi-micro/macro services provided within the system as a whole.

There are non-empirical methods being used to interpolate and extrapolate ecosystem value and determine the monetary system of an ecosystem. The methods commonly attempt to base service values on estimates of the replacement costs that humans would have to pay if the service was no longer available. The measurable direct economic market value of a forest could be the financial revenues obtained through logging the trees for lumber, harvesting non-timber products such as honey and resin, and in some cases ecotourism based to the attraction of the forest. The ecosystem value would be the environmental services it provides in stabilizing soils, providing nutrients and pollination, temperature control, provide habitat for biodiversity, photosynthesis, and sequestering carbon to name but a few. There are three methods commonly used to assign a monetary value to ecosystems:

- *Mitigation costs* - placing a price based on the cost of offsetting damages as a result of activity impacting the ecosystem (e.g. pollution, or clearing land).
- *Willingness to pay (WTP)* - WTP is based on surveys of different groups to determine the amount of money they are willing to pay to preserve or conserve the various services of an ecosystem.
- An alternative to WTP is willingness to accept (WTA) in compensation to give up a good, or put up with a bad (e.g. pollution).
- *Maintenance and protection costs* - These costs are the estimated expenses it would take to maintain and protect the system. Carbon sequestering could come under this method.

All these methods are susceptible to the biases of the evaluator, and the situation of the interviewee. The price a person says they are willing to pay is affected by their ability to pay. Currently, there is no generally accepted standard for creating a monetary value for ecosystem services in terms of dollars, although the UN TEEB method is an attempt at standardizing this valuation. However, in most cases, including TEEB, no two estimates agree, hence the immense disparity found in the references. Therefore, the use of any method must be done cautiously and skeptically. This study integrates the methods with economic analysis discussed in the following section and incorporated into a Sustainability Matrix (see Section 2.7).

The basic ecosystems addressed in this report are the forest and biodiversity as they affect or are affected by the hydrology of the watershed, each including a list of services with some overlap.

2.5. Dealing with Uncertainty, Incomplete and Imperfect Information

In the context of this study, there are a lot of information gaps, resulting in a low confidence level. Consequently the decision alternatives are:

- Wait and see – to do nothing until physical evidence occurs to confirm there is a concern.
- Conduct proactive scientific studies – confirm whether or not there is a valid concern, and in the interim:
    - Assume the worst case concerns are valid taking aggressive corrective action to mitigate what might be a non-problem, or
    - Assume less than the worst case most likely taking precautionary preemptive measures to mitigate concerns, adjusting actions as more relevant information becomes available.

An interpolation alternative is to determine a reasonable likely case within best case and worse case scenarios based on confidence level in the date available as discussed in the Section 2.7.

2.6. Economic Analysis

Total Economic Value (TEV), in conjunction with Benefit Cost Analysis (BCA), determined the Net Present Value (NPV) of the Study Area in an attempt to consider the negative and positive impacts of developing the forest.

TEV addresses direct use values, such as timber, NTFP and potentially effected economic sectors, such as: tourism, fishing, and agriculture, and indirect or inherent services provided by the forest, which could be valued in monetary terms, such as: carbon sequestering, biodiversity and watershed stabilization.

BCA weighs the net result value of the benefits less the costs of taking a specific action, policy for each of the respective scenarios.

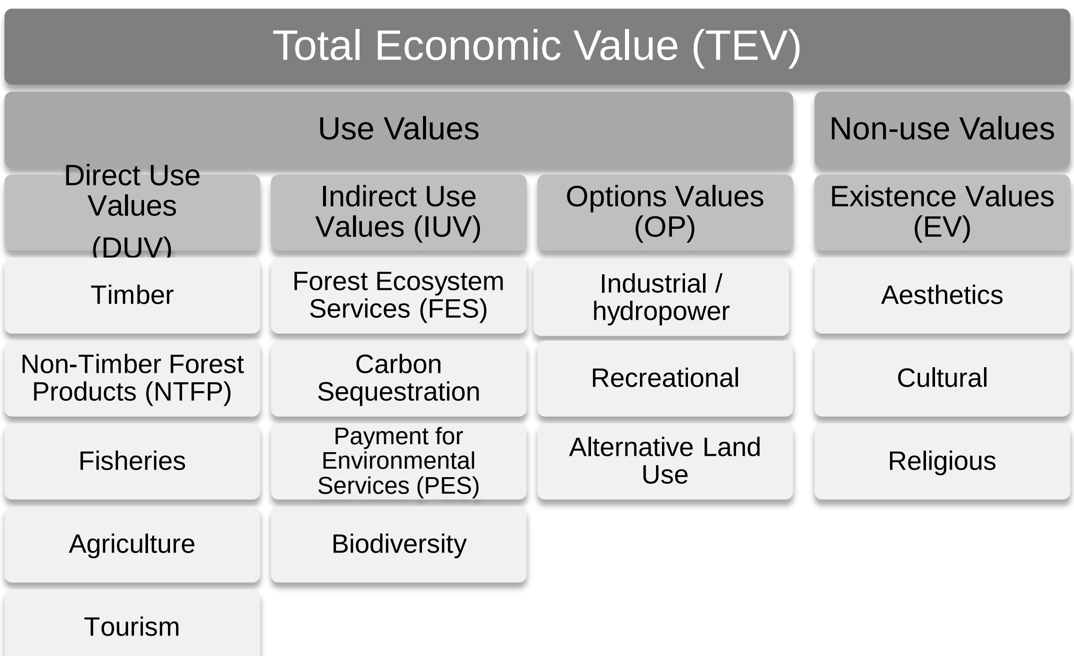
While TEV and BCA both use monetary units, the services provided by the various ecosystems within the study area cannot always be measured in purely financial terms. Consequently, a “Sustainability Matrix” was established to normalize the measurement units of the different parameters in order that they could be considered on a common basis. The matrix provides a platform on which to assess sustainability as a function of its three primary aspects (social, environmental and economic).

Collectively, the TEV, BCA and the Sustainability Matrix can be used by policy makers as a tool to determine an optimum strategy to achieve a sustainable economic, social, and environmental policy that will maximize the benefits, and minimize the losses for the greatest good of all aspects.

2.6.1 Total Economic Value (TEV)

The TEV is an economic evaluation method, which integrates the various economic values of the forest, from direct benefits, like timber, to indirect intangible benefits such as forest ecosystem services. The indirect ecosystem valuation takes into account the various complex dynamics between the forest, the environment and socio-economic concerns and establishes a monetary value for its intrinsic services (see Figure 2.2).

Figure 2.2 Total Economic Value (TEV) Framework



(Adapted from Hansen & Neth 2006; OECD, 2000)

The TEV is the sum of all use and non-use values for the given resource or service being measured. The TEV framework incorporated data from the Cambodia Development Resource Institute (CDRI), and referenced in "Natural Forest Benefits and Economic Analysis of Natural Forests Conversion in Cambodia, Working Paper 33" (Hansen and Neth, 2006).

The formula for Total Economic Valuation (TEV) is (Refer to Figure 2.2).

$$TEV = UV + NUV = (DUV + IUV + OV) + EV$$

For the purposes of this assessment, TEV focused on DUV, IUV, and OV, although the ten-year study time frame is relatively short in assessing future options of the study area. The TEV does not include EV, because it is difficult to establish a consensus value to the inputs included in this parameter. Therefore, this study utilizes the following equation adapted from above:

$$TEV = DUV + IUV$$

The economic value calculated for the baseline year (2010) and the NPV value is projected over the ten-year study period.

2.6.2 Benefit Cost Analysis (BCA)

Benefit Cost Analysis (BCA) is a decision tool, which evaluates projects according to positive direct and indirect outcomes of a decision and compares them to their negative effects, that is, the net gain or loss as a result of the implementing the decision. “Direct” refers to conditions for which a monetary value can be assigned and measured in a national currency, such as the economic value of harvesting the lumber from a forest, typically in US Dollars (USD). Indirect benefits are those conditions for which there are no markets to define a monetary value and includes most of the intangible services provided by environmental systems, such the value of trees to sequester greenhouse gases, or the unrecovered costs of pollution.

The BCA takes into account direct benefits and costs by calculating TEV, and indirect benefits and costs using estimated values of ecosystem serves, such as forest watershed services and biodiversity (TEEB, The Economics of Ecosystems & Biodiversity.)

A weighted matrix allows for scoring of the common major themes (economics, social, and environmental) of each scenario, using theme specific indicator parameters. Because of the subjectiveness of the analysis, the longer the list of common indicator parameters the better the score reflects the position of the stakeholders, and the higher degree of assurance that common ground will be identified upon which an accord can be reached. Each score provides a qualitative measure of the respective theme, and collectively, the total score provides the foundation on which to base a decision with a reasonable level of confidence. The higher the score the greater the potential net advantages to be gained, the closer the scores are indicates level of consensus and disparity.

NET PRESENT VALUE (NPV)

The first step of the BCA analysis requires determining the present value of a particular forest service and then converting the net value of benefits and costs to NPV over 10 years. Any positive NPV is considered beneficial and the higher the NPV, the more economically viable a project will be compared those with lower values. A discount rate converts the future value (FV) of benefits and cost into present day value (PV). While it is not arbitrary, it is discretionary and subject to debate generally ranging from 6-12% depending on circumstances. It is not the prime interest rate, but rather a projection of future economic indices, including interest rate, inflation or recession, and growth rates and therefore referred to as discounted cash flow (DCF, or ‘r’). For this study, a discount rate of 8% was used due to the shorter time frame of 10 years. It is used within this study for illustrative purposes only and a project specific DCF should be determined on a application conditions.

The NPV is calculated as follows (Chheng, 2007):

Net Present Value (NPV):

$$NPV = \sum_{r=0}^{n} PV_{benefits} + \sum_{r=0}^{n} PVc_{cost}$$

$$NPV = \sum_{t=0}^{n} B_n /(1+r)^n - \sum_{t=0}^{n} C_n /(1+r)^n = \sum_{t=0}^{n} \frac{B_n - C_n}{(1+r)^n}$$

{Note: Σindicates sum of formula iteration.}

Where:

B_n = value of benefit in year n

C_n = value of cost (loss) in year n

n = year of B and C (0,1,2…………n when is final year of study)

t = starting year of study, 0= current year

r = discounted rate

Benefits include total direct, indirect and option use (including economic, environmental, and social aspects). Direct use value (DUV) is calculated using market price and produce quantities (Chheng, 2007):

$$DUV = \sum_i (P_i Q_i - C_i)$$

Where,

P = price per unit of product *i*,
Q_i = quantities/ amounts of products *i* being collected,
C_i= cost involved in the collection of product

BENEFIT COST RATIO

The benefit cost ratio (BCR or B/C ratio) is the ratio of the NPV of the benefits to the NPV of the costs as determined above. The difference between the benefits and the costs is the net benefit or cost. If the benefits are greater than costs then the scenario is a viable economic option. However, since the value of the NPV benefits is based on estimated effects, the net difference is not the “real” value. Therefore, the ratio of the benefits to costs (BCR) provides a less ambiguous determinant. If the ratio is greater than 1, the scenario is a viable economic option. If it is less than one, it is not.

The benefit cost ratio (BCR) is:

$$BCR = \frac{PV_{Benefits}}{PV_{Costs}} = \frac{B_n}{C_n}$$

INTERNAL RATE OF RETURN (IRR)

When several options have BCR greater than one, it is difficult to determine which is the better choice. The amount of difference does not help since a small change in any of the parameters could sway the balance and using a different discounted rate (r) result in significant shifts. Consequently, economists generally use internal rate of return (IRR), rather than BCR for ranking ((Martin, 1997, TEEB 2010, Turner, 2008).).

IRR determines the *interest* rate at which the net present value is equal to zero or the BCR=1, and is determined by trial and error. It determines the order of NPV results and indicates which option offers the optimum outcome.

$$IRR = interest\ rate\ when\ NPV = 0$$

$$r'\,when\ \ NPV = \sum_{i=0}^{n} \frac{(B_n - C_n)}{(1+r)_n} = 0$$

All these methods provide a metric to help reach a decision with a qualitative level of confidence when there is not enough information to be able make a quantitative assessment. One decision could be to fill the data gaps needed to identify a better-defined course of action. In addition, the matrix provides a good general portrait of different options, themes and indicator parameters, which provide grounds for understanding and cooperation.

2.7. Sustainability Matrix

The Sustainability Matrix is a chart that provides a quasi-quantitative method to systematically score sets of central themes and indicator parameters to identify, and evaluate areas of conflict and basis for resolution, and consensus on aspects that can be implemented collaboratively to solve common problems.

The Sustainable Matrix is used here to weigh and compare the 3 scenarios as presented in Section 1.0. To be of real value it must be evaluated by all the individual stakeholders independently and then compiled by process of elimination into a consensus to be used to establish a plan of action to implement the optimum strategy, a Sustainable Development Extension Plan, to set goals and identify performance and accountability measures to ensure continuous improvement is made toward reaching the goals.

2.7.1 Matrix Methodology

The Sustainability Matrix is unique in that it integrates economic, social and environmental themes into one score, which can also be considered either as broad themes or individual indicator parameters. It is three-dimensional in that it considers the three pillars of Sustainability (Environmental Protection, Economic Stability and Social Wellbeing) as one system.

INDICATOR PARAMETERS (IP)

Like pixels in a photograph the greater the number, the greater the clarity of the image, so too the greater the number of data points, the better a representation and understanding of the scenarios is achieved. The lower confidence level in the available data, the greater the number of parameters needed to offset the weaknesses.

The composite list of IP used for this assessment was derived from *Sudex* (Forbes, 2009), *Indicators of Sustainable Development* (UN), and *The Wellbeing of Nations* (Prescott-Allen, 2001) and is comprised of nearly 300 parameters, divided into three aspects of sustainability. The composite list was reduced to items that were directly or indirectly affected by the forest logging, and surface water affects. The revised list includes 112 parameters. Figure 2.3 provides a condensed list of indicator parameters used for the matrix.

Figure 2.3 Condensed lists of indicator parameters for the matrix

Economics	Social	Environment
• GDP Annual Growth	• Poverty	• Landuse
• GDP per Capita	• Income Ratio	• Water quality
• Agriculture	• Shelter	• Water treatment
• Tourism	• Water resource	• Forest cover
• Fisheries	• Health	• Carbon
• Employment	• Education	• Biodiversity
• Timber	• Governance	• Air quality
• Water use	• Sanitation	• Climate
• Production	• Food Security	• Erosion
		• Soil quality

CONFIDENCE LEVEL (CL)

Ideally, at least three confirming references would be available for each datum, without which the confidence level (CL) in the information would be lowered. With each data compromise, the CL decreases. Figure 2.4 presents the CL ranges.

Figure 2.4 Matrix scoring ranges (Score = I x V x CL)

Importance (I)	Value (V)	Confidence Level (CL)
• 1 = least important • 2 = moderately important • 3 = most important	• 1 = substantial negative impact • 2 = moderate negative impact • 3 = no significant change • 4 = moderate positive impact • 5 = significant positive impact	• < 0.5 not enough information • 0.5 - 0.6 subjective but based on sufficient research • 0.6 - 0.7 sufficient quantifiable data available • 0.8 rigorous confirmed quantitative data or strong consensus

The CL can range from subjective personal biases to objective professional experience and judgments. The total score and overall CL reflect the range of perspectives. The lower the confidence level, the higher the number of indicator parameters necessary to create a satisfactory image. The best that a rapid assessment (RA) can attain is a CL of between 0.5-0.7, because it relies on secondary information. A CL of greater than 0.5 should provide an indication that consensus can be reached and there is confidence that there at least a 50-50 chance that the same decision would be reached, even though the relative scores conducted by different individuals of the same cohort are different.

Cambodia has been diligently and proactively generating essential information over an extended period of years, but there remain many data gaps. Consequently, the assessment CL ranged from 0.5-0.7 in each of the three sustainability aspects evaluated for each scenario.

Whether to include CL in the score is dependent upon the objectives of the specific study and the available data. In this case CL was included to take account of the data gaps, and inconsistencies in the data. Discretely, the CL and importance (I) can be used to determine which IP have the most important data gaps that need to be filled.

IMPORTANCE (I)

The list of indicator parameters for potential forest impacts was subdivided into the three sustainability themes and the scale of relative importance was established from 1-3 to prioritize their importance. ‘I’ provides a measurable relationship between the individual parameters and the themes, and helps in strategic planning to rank the different objectives, and along with CL can help to identify where funds should budgeted for additional investigation.

VALUE (V)

A value (V) was assigned for each parameter relative to its potential impact within each of the scenario strategies as it affects the sustainability themes. The value is determined for each parameter for each scenario by asking the question: "*Given the objective of the scenario, how will the parameter impact each of the themes based on the scale of 1-5?"*

ASSSUMED BEST CASE AND WORST CASE

Reasonable worse case/best case scenarios are common methods used in risk and financial analysis to reach a decision when there is insufficient information to establish a quantifiable level of confidence. The specific guidelines used for the Study are provided in the Primary Assessment Report. The following offers a general outline based on the assumed level of confidence (CL) in the data and/or default conditions assumed represent the reasonable worst and best cases, where a CL less than 0.5 insufficient, .5 -0.7 low but sufficient and above 0.7 to 0.9 as fair to good.

Since a low CL is typical for the information discovered during the Study, quantifiable reasonable likelihood of occurrence could not be established, and an assumed worst and best case (AWC/ABC) was hypothesized for each variable using professional judgment and experience, and stakeholder group consensus. Assumed likely case (ALC) was derived from the mean. Small percentage differences can make a large difference in the baseline values over the ten-year study period. Relatively low percentages were used for this study to be ultra conservative. The values are used as default estimates on which to determine the ultimate score tabulated from the Sustainability Matrix, used to choice between the options under consideration. Furthermore the CL identifies and prioritizes the data gaps which would need to be filled first, while concurrently strategic planning and policies can be established implementing the scenario which has the highest potential for improving the social, economic and environmental aspects, without having to wait until all the information is complete and adequate, much less perfect. Basis for the AWC/ABC are summarized in Tables 2.1a and b of the Primary Assessment.

SCORING

The subtotal score (*S*) is determined by multiplying I x V x CL for each indicator parameter relative to the respective sustainability theme under each scenario. The total score (**S**) for the respective scenario is then determined summing the subtotal S. The subtotals are added for each parameter theme and the Grand Total Score is the total for each scenario and the CL is averaged to determine the overall CL of the evaluation. Figure 2.5 is a simplified matrix used for this assessment.

Figure 2.5 Simplified Sustainability Matrix

Indicator Parameters	Scenario X												
	Economics				Social				Environmental				Total Score
	I_x	V_x	CL_x	S_{eco}	I_x	V_x	CL_x	S_{soc}	I_x	V_x	CL_x	S_{env}	$S=\sum S$
GDP													
NTFP													
Forest													
Carbon credit													
Fisheries													
Water Quality													
Irrigation													
Average CL													
Total Score for Scenario X	(S = I x V x CL)												$\sum S$

Adapted from Forbes 2009 I = Importance, V = Value, CL = Confidence Level, S = Score

MATRIX LIMITATIONS

One matrix completed by one evaluator is not sufficient to rely upon. One user's qualitative score is a subjective assessment of the importance and value of different parameters with regard to a specified scenario and when CL is included, the user's confidence in their own ability to make this assessment. However, taken collectively accounting for all the stakeholders, the matrix approach does have significant cost effective utility, which can be expanded and improved as funding allows and data improved.

Collectively all stakeholders decide upon a list of indicator parameters they feel best addresses their perspective and concerns. A representative group of each special interest then fills out the matrix from their own perspective, either individually or in brainstorming sessions to reach a consensus. Then the individual stakeholder matrices are compared with the others, and the same process is conducted in a plenary session until there is one master consensus. Not all parameters will be seen as important to each group, but those that are common to all can provide a starting place on which to focus.

STRATEGIC PLANNING

The primary purpose of the Sustainability Matrix within the context of this assessment is to provide a holistic qualitative measurement for each of the individual themes and then a comparative score for each of the scenarios. The matrix serves as a screening tool providing a way and means to establish priorities, evaluate thematic interrelations, and identify the most helpful information gaps that need to be closed in order to conduct a more quantitative assessment. In addition, once the appropriate data gaps filled, it provides a good foundation for systems analysis to assess quantitative alternatives and reach optimum decisions.

While beyond the scope of this assessment, the matrix provides a strategic planning tool to prepare holistic long term Sustainable Development Extension Plan (SuDeX Plan). Using the matrix, a baseline score can be established for conditions as they are now, and a target score can be established for where the participating parties would like to be it the future that becomes the goal to strive for.

It is important to recall that the scores presented in this report, while representative of the findings of this assessment, are for illustrative purposes only, since it represents only the perspective of the investigators, which is of value for its objectivity, but is lacking in cultural perspectives of the stakeholders **who are directly affected by the outcome and** ***are essential for the score to have any substantive value.***

Taking all these factors into consideration a potential course of action to reach a modified target will become apparent. Using this course of action as a guide, the SuDeX plan can be prepared using a phased approach incorporating additional measurements (e.g. funding, political will, best available appropriate technology, probabilities and feasibility) to establish reasonable attainable targets as data gaps are filled.

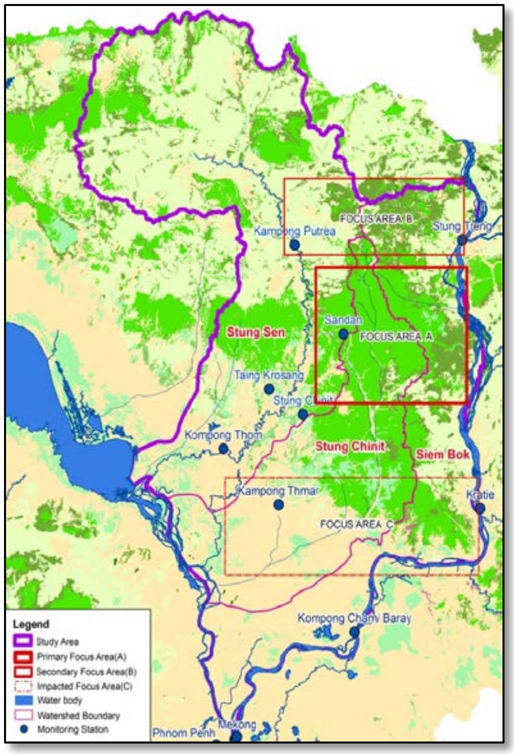
Scores are determined for current conditions (CS_1) and target scores (TS) are set for short and long term goals. As progress is made toward reaching TS, interim baseline score (CS_i) is reassessed at critical milestones, providing a measure performance over time. The ratio of the CS_1 to CS_i indicates the degree of improvement from the start and the ratio of the different CS to the TS provides relative measures of what progress has been made toward achieving goals and how much more needs to be accomplished. These monitoring and evaluation indices encourage follow-up and follow-through, and assess progress highlighting where the Plan needs to be revised and improved. In addition, the indices provide a benchmark to which the responsible parties can be held accountable to assure the desired optimum level of sustainable economic stability, social wellbeing, and environmental protection can be attained.

3. STUDY AREA

There is no official legal boundary that identifying the limits the Prey Lang Forest, and since the focus of the study is to assess impacts of forest activities on hydrology to evaluate optimum forest management strategies, to look only to the forest fringe zone would be insufficient. Therefore the Study Area was defined by the three watershed boundaries that encompass the forest landscape and those indicator parameters that could be most affected by the impacts. Stung Sen, Stung Chinit, and Siem Bok are the primary watershed. Within the Study Area are three focus areas identified as representative of the different perspectives considered in the study affected by the forest and hydrology. Focus Area A is the Prey Lang Forest itself. Area B is the upgradient area and potentially important aquifer resources that could affect and be affected by forestry development. The current conditions within Focus Area C serves as the basis for socio economic conditions used to assess downgradient changes as a result of the hydrological affects of forestry development over the ten year study time period. Figure 3.1 shows the Study Area Boundaries of the general outline of the Focus Areas.

The primary forest activity considered as part of this study was the harvesting of the trees for logging value, since this would have the most significant economic, social, and environmental impact on the surface water. The primary social economic impacts focus on the positive and negative effects of resource development on local populations living in and around the forest and the urban economic centers downgradient of the forest with in Focus Area C. However what happens outside the Study Area cannot be excluded because upstream activities along the Mekong River and within its primary and secondary watersheds to the east of the River have a major impact on the reach of the river affected by the Forest, and watersheds to the west draining into the Tonle Sap Lake are significantly affected by changes within the Study Area

Figure 3.1 Study & Focus Areas

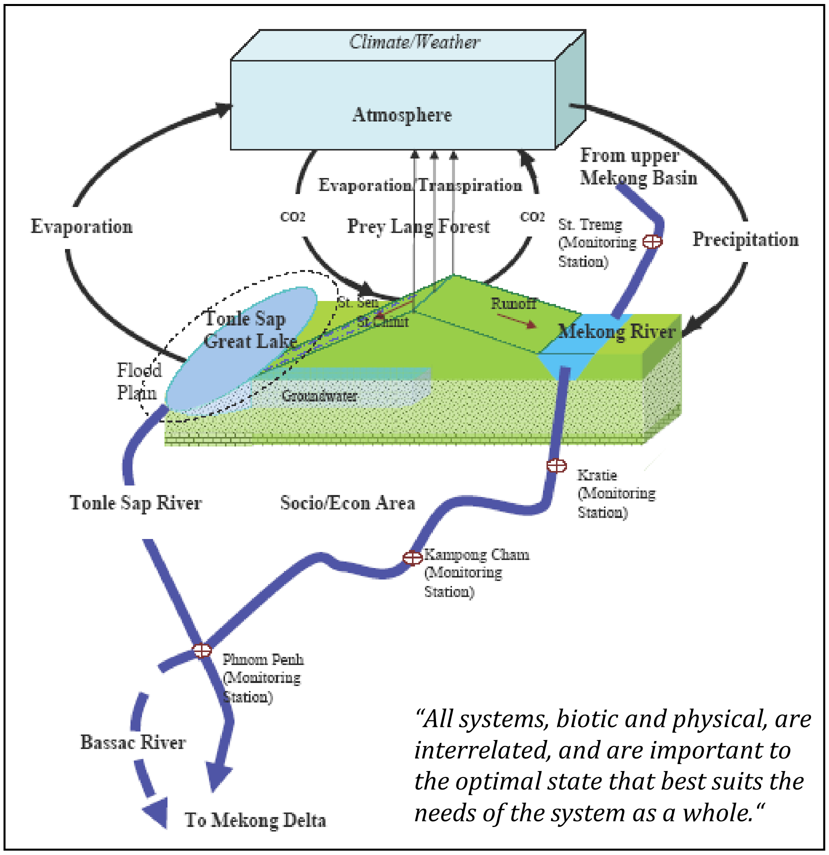


4. BASELINE CONDITIONS

Baseline Conditions are the existing conditions of the Study Area relevant to the assessment and provide a benchmark with which to measure results of changing conditions, in this case changes in the forest and hydrology. The Figure 4.1 presents a conceptual model of the Prey Lang Forest Study Area.

Baseline components include the forest itself, the hydrology of the watershed and how changes to these might impact the river and lake hydraulics. Those aspects, which can be assessed based on monetary value, either directly or indirectly, are addressed in the TEV and BCA calculations (Sections 2.6.1 and 2.6.2), which provide the foundation of the Baseline model. In addition, a myriad of unquantifiable parameters are evaluated in the Sustainability Matrix (Section 2.7) with which to assess the potential sustainability of each of the scenarios.

Figure 4.1 Conceptual Model of Prey Lang Forest Area



4.1. Prey Lang Forest Baseline

A variety of factors contribute to forest loss including: logging (both commercial and illegal), agriculture, fuel wood, new settlements, roads (logging and development), as well as forest fires and infrastructure development (MRC, 2003). Using maps showing the area of forest cover at different stages of development, the rate of area forest decay could be estimated over time.

The Study Area is as defined by the boundaries of the three watersheds is approximately 33,448 square kilometers (3,344,800 ha) in total as shown in Table 4.1.

Table 4.1 Spatial Extent of Study Area

Watershed	Area (Sq. Km)
Stung Sen	16,360
Stung Chinit	8,237
Siem Bok	8,851
Study Area Total	**33,448**

4.1.1 Area and Physical Characteristics

Since the Forest boundary limits have not been officially defined, different limits have been used to estimate the total landscape, as discussed in the Assessment. Using historical forest cover maps, the Prey Lang Forest was estimated to be 834,000 hectares (ha) for this study with the following physical characteristics.

FOREST TYPE DISTRIBUTION

The evergreen, semi evergreen and dry deciduous forests cover an area of 760,000 ha. The rest of the area is designated as non-forest and includes: degraded/other forest, grass, agriculture, plantations and shrub lands.

Wood density for evergreen forest is 128 m^3/ha with a cover ranging between 70-90% depending on density. For deciduous forest the density is 95 m^3/ha with cover significantly lower and seasonal. Mixed forests fall somewhere in between.

SOILS

The predominant soils of the forest are shallow hydromorphic soils and deep podzols. These soils tend to have poor fertility, and consequently low potential for agricultural use. However, there are small areas of alluvial organic sediments within dry evergreen forests, which provide rich soil more favorable to farming.

The poor drainage soils are in the low land areas with little infiltration and low velocities. The storage capacity characteristics of the podzols would indicate a low infiltration with higher drainage potential, but with slow velocities due to the generally low gradients of the topography.

TOPOGRAPHY

Slopes within the Assessment study area are generally flat, with slopes ranging from 0.15% to 1.8%. Siem Bok has steeper slopes ranging from 0.4%-1.8%.

4.1.2 Carbon Cycle

Of all the services provided by the forest, photosynthesis and carbon sequestering may have a more urgent value today because of the growing awareness of the effects of excess concentrations of carbon dioxide (CO_2) building up in the atmosphere— a likely cause of climate change.

Some of the carbon is stored in the biomass (sequestered) and the remainder is converted back into CO_2 and respired back into the atmosphere. All plants go through this process, but the large mass of a tree's biomass makes them especially effective in removing large volumes of CO_2 from the atmosphere. The effectiveness is increased with size of the tree. Tropical and swamp trees (wetlands or ramsar) are considered among the most effective. The Prey Lang Forest provides an excellent bank in which to sequester CO_2.

4.1.3 Prey Lang Forest Clearing Rates

The estimates of forest clearing rates are based on comparing forest cover over the years as interpreted by the various sources. It is estimated that the Prey Lang cover has decreased by approximately 6% since 1973 with most of it occurring in the northern most reaches of the forest. An eight-fold increase since 1998 indicates that significant Prey Lang Forest exploitation has occurred since then, with a slight decrease after 2004, when a government moratorium was placed on logging concessions within the forest.

Prior to 2004 the cover loss to date is assumed to be have been primarily through legal logging and clearing of deciduous forest for settlements, subsistence farming and firewood, with some illegal. Since that time illegal logging and the encroachment for agriculture is the most likely cause.

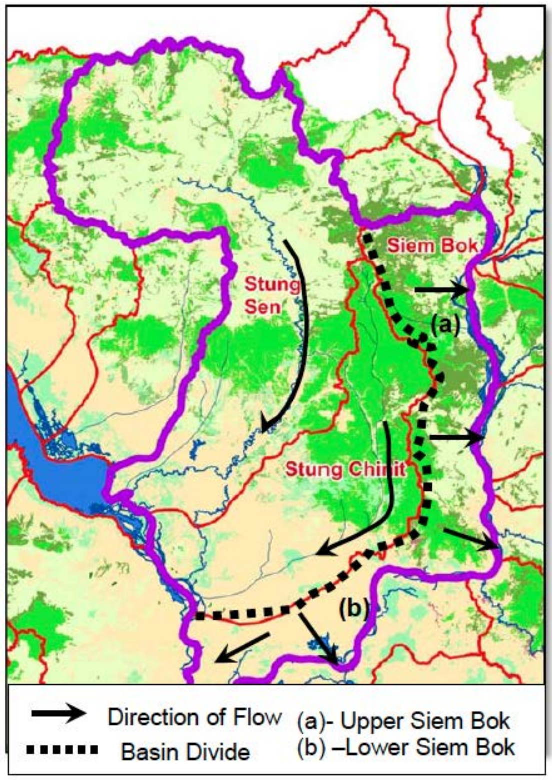
4.1.4 Economic Land Concessions

Approximately 288,525 ha have been let as Economic Land Concessions (ELCs) within the provinces of the study areas, for teak, rubber, Fang lean, acacia, and agro industry. Prey Lang is governed by the Forest Law, and classified as state private land. ELCs can apply to a forest or any tract of land; however, the 2004 moratorium on logging forest limited the economic viability of forestry in many concessions.

4.2. Hydrology Baseline

Figure 4.2 shows the layout of the three watersheds that make up the Study Area. The heavy blue is the boundary to the Study Area and outer limits of the Stung Sen to west ultimately discharging into the Tonle Sap Lake and River, and the Siem Bok, which for the most part drains into the West Bank of the Mekong River, except the small area in the southwest end flowing into the Tonle Sap River A major topographical divide separates the drainage from the Tonle Sap Basin and the Mekong, with the Stung Chinit and Stung Sen draining to the west into Tonle Sap River, and the Siem Bok predominantly flowing to the east and south east .

Figure 4.2 Watershed Boundaries



4.2.1 Watersheds

The primary water sources to the Tonle Sap Lake are the Mekong River (57%), watershed tributary discharge (30%) and precipitation (13%). The study area is comprised of the three watersheds, Stung Sen, Stung Chinit, and Siam Bok, mentioned earlier. These three watersheds make up about 22% of the entire Cambodian Mekong River Basin catchment area and are briefly described below.

STUNG SEN WATERSHED

The Stung Sen Watershed includes most of the Preah Vihear Province to the north and most of the northern half of the Kampong Thom Province to the south. This watershed is sparsely populated, although the river is a major tributary to Tonle Sap.

Hydrological and Meteorological data reported an average precipitation of 1460 mm per year and evaporation rates of 1550 mm per year. The average runoff is estimated at 11,685 m^3/s (WEPA, 2010).

Changes in Stung Sen River flow have been reported since 2000. These changes are reportedly due to forest concessions in the Prey Lang Forest resulting in an apparent corresponding increase in flooding (Mak, 2005). However, the relative scale would indicate that there is insufficient information to draw any definitive correlation one way or the other.

Stung Sen Irrigation

There are currently no irrigation systems in this watershed and the river floodwaters provide water for farmland. Feasibility and environmental studies are being conducted to assess building a large irrigation/hydropower system on the Stung Sen River to increase irrigated land as much as 130,000 ha; potentially tripling current paddy rice production. In addition, the system would provide estimates of 40MW of hydropower (Sithi.org, 2009).

Stung Sen River Fisheries

The Stung Sen River is a tributary of the Tonle Sap providing an important migratory path for fish. Currently, the Stung Sen watershed provinces are generally undeveloped, and the portion of the Prey Lang forest in the area is relatively small. However if the proposed irrigation/hydropower plant is constructed and the forest developed, it seems likely that this area will experience significant growth.

Changes along the river hydraulics as a result of forestry and dam construction, would have a noticeable effect on local fishing, as well as Tonle Sap fisheries, this includes the irrigation dams and reservoirs, with the outflow through spills replenishing oxygen concentrations, reduced within the reservoir due to decay of organic material. The oxygen increase in outflow can be as much as 20% of the inflow into the reservoir (Baran, 2007).

STUNG CHINIT WATERSHED

The Stung Chinit flows into the Tonle Sap Great Lake River. The Stung Chinit watershed includes the southern portion of the Kampong Thom Province and the northern portion of the Kampong Cham Province, which lie north of the Mekong River.

The area receives an average of 1400mm of rain per year and evaporates 1,530mm per year based on data covering the period from 1960-1990. The average discharge (total cumulative runoff) from the Stung Chinit watershed is estimated to be 6,711 m^3/s (WEPA, 2010).

Stung Chinit Irrigation

The Stung Chinit Irrigation System and Rural Infrastructure Project is currently the largest in Cambodia and has been in operation since 2006, as part of the Second Socio-Economic Plan of Cambodia, to reduce poverty by improving agricultural production by increasing irrigation coverage. Therefore, it is anticipated that irrigation capacity will increase substantially over time, within the study area and throughout the country (Baran, 2007).

The Stung Chinit reservoir is approximately 12 km long with a total storage area of 25 km². Up to 60 million m^3 (mcm) of water can be stored. The spillway is built across the Stung Chinit River to irrigate surrounding agricultural land in Santuk and Baray districts of Kampong Thom.

There are two Tonle Sap tributaries in the area: Stung Chinit and Tang Krasang. The project is intended to benefit 2,400 households within 3 communes and 25 villages, mainly in Kampong Thmor commune. The irrigated area is projected to be 3,000 ha in the wet season (supplemental irrigation) and 1,800 ha in the dry season (full irrigation). The project was designed to deliver economic benefits primarily through increased agricultural income and productivity.

It is too early to assess direct impacts of the irrigation system on socio-economic status of communities and downstream beneficiaries. Reportedly, there are conflicts with upstream forestry development, and mining activity. There are engineering controls that could mitigate the issues, but much more detail would be necessary.

Stung Chinit River Fisheries

The Stung Chinit River system has one of the richest natural fish populations migrating upstream and downstream (Try, 2008). Seventy-nine species were found in 2003-2004 (Puy, 2004 IN Try, 2009). Prior to the construction of Stung Chinit reservoir, fish catch was 7,000 tons/year from five commercial fishing lots downstream in Tonle Sap Lake, and 1406 tons/year from families and professional catches (Try, 2008). It is not known at this time what impact the reservoir may have had on the production.

The northern portion of the Chinit Watershed is heavily forested. Heavy logging of this area could affect the richness of the fish populations, and biodiversity along the Chinit River, as well as reduce fish catch yield without engineering controls to reduce sedimentation and manage flow.

SIEM BOK WATERSHED

The Siem Bok is a long narrow watershed along the west bank of the Mekong, discharging into the vulnerable biodiverse “Central Section” of the river. Below Kratie, the watershed lies along the north bank of the southwest trending river, terminating at the Tonle Sap River and Phnom Penh. The watershed has two directional axes, one running north-south, referred to in this report as Siem Bok (a); the other running to the south west and referred to as Siem Bok (b). The upper third of Siem Bok (a) lies in the west portion of the Stung Treng Province, and lower two-thirds lies in the west portion of the Kratie Province. All of Siem Bok (b) lies in northern portion of Kampong Cham Province. See Figure 4.2.

Essentially all of the Prey Lang Forest focus area is within Siem Bok (a) along the Central Section of the Mekong, which is the river reach between Stung Treng and Kratie monitoring stations. The area is rural with a low population density.

There is no hydrological and meteorological data collected directly from the Siem Bok Watershed. Therefore, the data was interpolated from six monitoring stations in the general vicinity. Between the years 1960-2004, the average annual rainfall for the area was 1420mm, with average evaporation rates of 1700mm per year.

The farming activity in the Siem Bok (a) area is relatively minor, hence, little controlled irrigation. The most vulnerable area to forestry logging operations, would be the Mekong River between the Stung Treng and Kratie monitoring stations and more specifically the biodiversity rich Central Section. However, large hydroelectric projects are being considered on both the Stung Treng and Sambor, Kratie (ICEM, 2010). The impact of forest logging in Siem Bok, would be overwhelmed by those associated with the impact of these projects. Because of the low topography and nature of the river channel, the area of inundation would be quite large and could encroach on the forest.

4.2.2 Floodplain

The natural flood cycle as a result of the wet season during the months of July and October is the basis for the high ecosystem productivity in the Lower Mekong floodplains. Changes in the frequency and amplitude of seasonal flooding due to increased runoff discharge into the Mekong River and the Great Lake as result of deforestation could significantly affect the flood cycle system, which would impact the ecosystem yield. In addition, flood delays can have dire effects of sensitive fish juveniles bred in the floodplains, due to slow arrival of oxygen rich waters.

4.2.3 River Systems

The predominant hydrologic system of Cambodia is the phenomenal water basin created by the drainage system into the Tonle Sap Great Lake within the Mekong River Basin. The vast majority of the surface area of Cambodia is within the Cambodian Sector of the Mekong River Basin, of which the Tonle Sap Basin is the centerpiece and the entire system ultimately flows into Mekong Delta. All activities within Cambodia and many to the north have a direct effect on the hydrology and hydraulics of the system. The subject of this study, the affects of Prey Lang Forest on hydrology, is a relatively small but significant part of the system as a whole, neither can be fully assessed without considering the other.

MEKONG RIVER

The length of the Mekong River within Cambodia is about 480 km reaching from the Lao PDR border to the north to Vietnam border to the south. The flow rate along this reach is 2,860m^3/s (MRC, 2003; WEPA, 2010). The FAO estimated the total annual total discharge of the Mekong River into Cambodia to be approximately 300 billion m^3, and the annual discharge as it flowed into the South China Sea was estimated to be 500 billion m^3. A significant portion of this increase would be due to the contribution of the Tonle Sap Basin and the Mekong River within Cambodia.

The Mekong River conditions are affected by projects already in existence upstream, creating a highly complex array of variables that must be considered when considering the impacts from any new development. The relationship between rainfall, runoff, and pollutant concentration/load is complex as well, and depends on the size of the river system – the larger the river, the more difficult it is to assess. And the Mekong is one the world's largest river systems (MRC, 2008).

TONLE SAP RIVER AND LAKE

The directional flow in the Tonle Sap River is determined by the wet and dry seasonal flow of the Mekong River. During the monsoon rains of September to October the volume and height of the Mekong increases to a level where the flow into the Mekong Delta backs up into the Tonle Sap River which then reverses flow into the Great Lake raising the water elevations from a couple of meters to as much as 15 meters in elevation, an estimated 8-fold increase in elevation. This increases the size of the lake from approximately 2,500 square kilometers to about 25,000 square kilometers at the peak flow, approximately a 10-fold increase in area.

TONLE SAP LAKE

During this unique dynamic stage, the Tonle Sap serves as a huge settling pond for sediments and each cycle and fresh layer of sediments is deposited in the lake and due to poor drainage along exposed lowlands returns to marshland, unsuitable for agriculture. Overtime, there is a natural net gain in the sediments retained in the lake versus those that are transported out, due to the physical properties and dynamics of the lake. This is a natural lake succession, which over geologic time would normally lead to the ultimate transition of the lake to a terrestrial biome. However, in the case of the Tonle Sap / Mekong River system the succession is muted, and if left undisturbed may well continue indefinitely. Any change within the system, be it due to natural or anthropogenic occurrences, could affect the balance.

As the monsoon rains decrease, the flow in the Mekong recedes and the Tonle Sap River reverses flow as the Lake recedes and returns to pre-monsoon levels, and the lake volume bleed into the Bassac River loaded with an immense bounty of fish.

BASSAC RIVER

The Mekong and Tonle Sap Rivers converge at a point called the Chattomukh (Four Faces), where they diverge into the Mekong and Bassac Rivers. From this point, the two rivers become independent headwaters of the Mekong Delta.

The Bassac River serves a vital and often overlooked role in the hydraulic system dynamics. In a sense, the Bassac River serves as a spillway during the wet season, ensuring that a relatively constant flow reaches the Mekong Delta as the Tonle Sap rises. This sustains the Delta during the large seasonal water availability fluctuations.

MEKONG DELTA

The Mekong Delta spans from Bassac River south of Phnom Penh to the south shores of Viet Nam where it discharges into the South China Sea. It is one of the major Deltas of the world covering and considered a “biological treasure trove” with reported estimates of over 10,000 species including newly discovered and endangered species.

Like all Deltas, the Mekong Delta is extremely sensitive and vulnerable to seemingly minor disturbances as a result of either or both natural or human related events, including what happens in the Prey Lang Forest and how it impacts the system as a whole, altering the hydrology, hydraulics and loading of the Tonle Sap/Mekong Water Basin, including the Delta.

The information is not sufficient to quantify the effect of deforestation on the system, but based on its unique dynamics and sensitivity and vulnerability any changes, the potential for irreparable damage is a real risk. The Assessment attempts to provide some preliminary tools to decide how to manage the forest in order to minimize the negative and maximize the positive effects, when there is insufficient information.

4.2.4 Groundwater

Cambodia has very limited identified information regarding groundwater aquifer resources, yield and quality. Estimations by the Ministry of Water Resources and Meteorology (MOWRAM) report the potential groundwater resources to be 17.6 billion m^3. While it is not a primary water source at this time, groundwater is being used at an increasing rate as domestic water supply and for irrigation. There are at least 25,000 community water supply tube wells and large diameter motorized tube wells for irrigation in place, and about 2,000 manually operated shallow wells installed annually (Atlas, 2006). There are reports of industrial use of groundwater, but information on quantities was not available.

One of the main sources of recharging the groundwater is surface water through infiltration and direct recharge pathways. As the use of groundwater increases, its sensitivity to surface water quantity and quality becomes increasingly important, and changes in surface water dynamics, such as runoff velocity and retention times, due to increased open surface area as a result of deforestation can have significant groundwater consequences.

Due to apparent lack of faulting or karst-like geologic features, direct surface recharge is suspected to be limited within the Study Area of the three watersheds. In addition, the highly responsive increases and withdrawal of the Tonle Sap flood zone to seasonal rainfalls would indicate that there is not a significant recharge system. However, the alluvial deposits of the Tonle Sap floodplain do present a likely host for extensive shallow water table aquifers. Such aquifers are relatively easy and inexpensive to tap as a water supply, but also very vulnerable to natural, agricultural, industrial and domestic waste pollutants.

4.2.5 River Hydraulics

Whereas hydrology, as referred to in this Assessment, addresses the characteristics of water flow over the land surface, hydraulics addresses the characteristics of water flow through open channels, or in this case rivers.

River Hydraulics data is collected by MRC at monitoring stations along the river reaches. For the purposes of this Study the two main monitoring stations on the Mekong River are located at Stung Treng and Kratie, and the downstream stations located around Phnom Penh, and Tonle Sap as well was the stations located within the study watersheds important to assessing Tonle Sap.

Data collected from monitoring stations include: annual rainfall, evaporation, weather parameters, discharge rates, Gauge Height and flood levels, and water quality. Data has been reported for the last 50 years, from 1961-2010, using MRC Hydrological Yearbooks, PDOWRAM records, and the IWMI World Water & Climate Atlas. However, there are large data gaps that make quantitative assessment difficult.

Collectively, this data has provided the baseline for the hydrology and hydraulics of the study area, and have been used to qualitatively estimate the runoff volumes as a result to clearing caused by forestry operations. These have been used as a baseline to compare the potential magnitude of relative affects based on the three scenarios.

4.2.6 Climate & Meteorology

Cambodia's climate is classified as a tropical with two distinct seasons associated with tropical monsoons: Dry Season from November to April, Northeast Monsoon and Rainy Season from May to October, Southwest Monsoon.

The country has three climatic zones: coastal and mountainous area of the southwest, central plains which include the Mekong River and Tonle Sap Lake, and the North/Northeastern Region.

Annual rainfall estimates vary by region. The lowland area around the Tonle Sap Lake receives about 1,200mm to 1,900mm of rain annually. The coastal zones receive the heaviest rainfall, about 3,000mm per year.

4.2.7 Water Quality

The MRC *Lower Mekong Water Quality Assessment (2008)* has established a method of determining the relative quality of the water using a Water Quality Index (WQI) at the different monitoring stations along the Mekong River from China to Viet Nam. The generalized MRC method is to assign a relative score (e.g. 2, 1, 0) if a specific water parameter meets or exceeds guidelines. The scores are weighted to reflect relative risk and probabilities. The relative importance is based on three general classifications: aquatic life (al), human impact (hi), and agriculture (ag). Agriculture is included because it is such a prevalent activity in the Mekong Basin, and is subdivided into three broad categories: 1) general, 2) paddy rice, and 3) livestock. Each classification is scored differently based on unique conditions and considerations. All the parameters are evaluated and the weighted scores are determined.

The MRC established median WQI values over the period of 2000-2005 for three monitoring stations on the Mekong, which receives runoff from the Study Area, primarily Siem Bok. While not sufficient to serve as representative for the area as a whole, it does provide general baseline indication of water quality. The MRC WQI for the study area monitoring station is indicated in Table 4.2.

Table 4.2 MRC Baseline Water Quality Index (WQI) for Prey Lang Study Area

	WQI(al)	WQI(hi)	WQI(ag1)	WQI(ag2)	WQI(ag3)
Stung Treng	9.8	7.6	10	10	10
Kratie	10	9.5	10	10	10
Kampong Cham	9.8	8.2	10	10	10

The MRC indicator parameters and respective water quality base guidelines are shown in Table 4.3. The table has been expanded by additional parameters for which there is some data, which could be included if more data is acquired.

For the purposes of this study, the guidelines should not be considered binding standards. They are benchmarks of the baseline water quality characteristics of river water at the present time. Ideally, water quality parameters should be measured on regular intervals over a sufficiently long period to include seasonal changes to establish baseline conditions. Heavy metals, in particular arsenic, need to be considered to establish potential significant health risks.

Table 4.3 MRC Water Quality Indicator Parameters

Water Quality Indicator Parameters	MRC Guidelines	Monitoring Stations		
		St. Treng	Kratie	Kpg. Cham
Dissolved Oxygen (DO)	>5.0 mg/L	ND	7.4	7
pH	6.5-8.5 SU	ND	7.26	7.33
Conductivity	< 70 mS/m	ND	TBD	TBD
Total Phosphorous (P)	0.13 mg/L	ND	0.03	0.03
Ammonia-Nitrate (NH_3-N)	< 0.10 mg/L	ND	ND	ND
Nitrite (NO_2-N)	< 0.7 mg/L	ND	0.15	0.15
Nitrate (NO_3-N)	< 0.7 mg/L	ND	0.15	0.15
Ammonia (NH_4-N)	< 0.05 mg/L	ND	ND	ND
Chemical Oxygen Demand (COD_{Mn})	< 4 mg/L	ND	ND	ND
Additional Parameters to be considered				
Total suspended solids (TSS)	NE mg/L	ND	120	120
Turbidity	NE NU	ND	ND	ND
Heavy Metals	NE mg/L	ND	ND	ND
Biological Oxygen Demand (BOD)	NE mg/L	ND	ND	ND
he transported loads in ton are determined by flow rate (Q) x concentration. ND = no data; NE= Not established by MRC				

Stung Treng and Kratie are the primary data points, since they are relatively undisturbed compared to the stations in the vicinity of Phnom Penh, which has too many point sources to be able to differentiate the upgradient sources. This logic is also true for Kampong Cham, but it is included as a “key station” to provide an outer limit comparison point.

In Stung Treng, 25% of the population has access to safe water, which may explain the relatively low WQI (hi). In Kratie province, the WQI is much higher and reportedly 40% of the population has access to safe water. The overall number of households that have access to safe water declines in both urban and rural areas during the dry season (JICA, 1997).

SEDIMENTATION

Sediments play a key role in providing nutrients to the Tonle Sap and Delta landscapes and are critical to maintaining their high productivity and stability. About 70% of the sediment influx to the Tonle Sap originates from the Mekong. Thus changes in the amount and composition of sediment caused by upstream development or land use changes can have a major impact on the sediment flow and Tonle Sap productivity. Analyses detailed in Plinston and He Daming (2000) showed that about half the sediment reaching the Mekong Delta originates in the Upper Mekong in China (Carling, 2009).

While sediments are of immense importance to the Lake and Delta ecosystems, it is also the largest “pollutant” transported by rivers, streams and runoff. As land is cleared for development, soil transport increases and its impacts are proportional to the area exposed, and the types of preventive and control measures implemented. Deforestation, and dams presents high potential high risks to the Lake, Rivers and Delta.

Top soil loss and land degradation by gullying and sheet erosion can lead to excessive levels of turbidity in receiving waters, and off-site ecological and physical impacts from deposition in river and lake beds, disrupting natural balances. Agriculture is a primary cause of erosion and sedimentation and water quality issues, and mining and industrial activity can compound the effects.

The effects of increased sedimentation into this system as result of the Prey Lang forest are bi-directional. One direction is runoff flowing to the east from the Siem Bok watershed into the Mekong River; the other to the west flowing from the Stung Sen and Chinit watersheds into the Tonle Sap Basin (There is a minor third vector from the lower portion of Siem Bok into the Mekong and Tonle Sap Rivers, but it is not directly affected by the Prey Lang Forest).

The magnitude of the effect of the deforestation on sedimentation in the river and lake environs is relative to incoming sediment concentration above the Stung Treng monitoring stations, current development within the watersheds on both sides of the Mekong River, and the increases to the sediment concentrations due to construction and development along the Mekong River, Tonle Sap, and their tributaries.

The existing sediment data exhibits the same variances and quality issues as most of data available and used in this report. Sediment concentrations are generally determined using two different measuring methods, suspended-sediment concentration (SSC), and total suspended solids (TSS), which produce widely divergent estimates (ICEM 2010). It is difficult to correlate the two, and according to ICEM the margin of error can be as high as 30%.

The information is insufficient to quantify the effect of the increase in sedimentation as a result of deforestation on the river and flood plain, especially in light of the proposed large-scale irrigation and hydroelectric plants in the area. Therefore it is addresses qualitatively in the Sustainability Matrix.

4.2.8 Water Uses

It is estimated that about 25 million people within the lower Mekong basin live within the 15km corridor along both sides of the Mekong mainstream. Approximately 70% of Cambodia's total population (13,395,682) or 9,376,977 Cambodians reside in this corridor.

Within the Phnom Penh urban area the primary water uses are: drinking, domestic, and commercial, with relatively minor industrial use. In the rural provinces outside of Phnom Penh the primary water uses are: drinking, domestic, agriculture and livestock feeding.

According to a study by Water Utilization Program (WUP-JICA), the estimated urban water usage is approximately 68 mcm per year. At the Phnom Penh Port, water extraction is about 100,000 m^3 per day, which is higher than most provincial towns (JICA, 1997).

In Cambodia an estimated 500 mcm is used for industrial purposes, which is about 1% of all uses. Very little industrial activity takes place within the Study Area. Commercial use is primarily in the urban areas and not included in the Study area.

DOMESTIC

The MRC has determined Cambodia Domestic Water Use as shown in Table 4.4.

Table 4.4 Cambodia Domestic Water Use

Average per Capita Use (liters / day)				
	2000	**2007 (2008)**	**2030**	**2060**
Rural	32	90	100	100
Urban	No Data	130	150	170

Source: MRC, 2010

Based on this data, it is assumed that the total daily domestic consumption has not significantly changed from 2007 to 2008. The estimated increase in domestic water consumption over the ten-year period of this study is calculated from projected population growth rates and consumption rates.

The population of the study area is estimated to be 630,000, of which approximately two-thirds live in rural communities and one-third may be considered peri-urbanites located south west of Kratie. Applying the 2007 domestic uses (Table 4.4), the total annual domestic water use for the study area is approximately 37 mcm. This is considered to be conservative since many living in peri-urban areas do not have any better access to water than those living in rural settings.

IRRIGATION

In most agricultural societies, irrigation is typically the largest water user. In the Lower Mekong Basin irrigation uses an estimated 41.8 bcm of freshwater resources (MRC, 2005). In Cambodia 2.7 bcm collected and stored during wet season is used to fully irrigate multi-crops. This implies significant storage areas, which would affect water balance and watershed discharge.

The total irrigable area in Cambodia for the Study is 504,245 ha. Rice is the primary crop accounting for 98% of the irrigated land. The remaining 2% is used for other crops such as maize (MRC, 2003e).

Reportedly, 2% of the precipitation within the Stung Sen and Chinit watershed is used for irrigation, most is believed to be within the Stung Chinit watershed, which would be equivalent to 460 mcm.

INDUSTRY

At the present time there is relatively little heavy industrial activity in Cambodia. Mining is the one with the most immediate importance to the study area. In terms of water usage mining is generally a high consumer, but the entire annual industrial water use for Cambodia is reported to be 500 mcm, which is about 1% of all use. It is presumed that a relatively large portion of this use is for mining, but the actual percent is not known. Nearly all of the mining activity is outside of the primary Prey Lang Forest area. If mining made up for all the industrial use of water, the mines in the study area would use an estimated 90 mcm, which is about 13% of all human water use (excluding direct rainfall irrigation). Since, in fact mining does not make all industrial use the actual percentage would be a lot less. Therefore, without more focused study and information about mining, it was not included directly in the water inventory.

4.2.9 **Water Inventory Baseline**

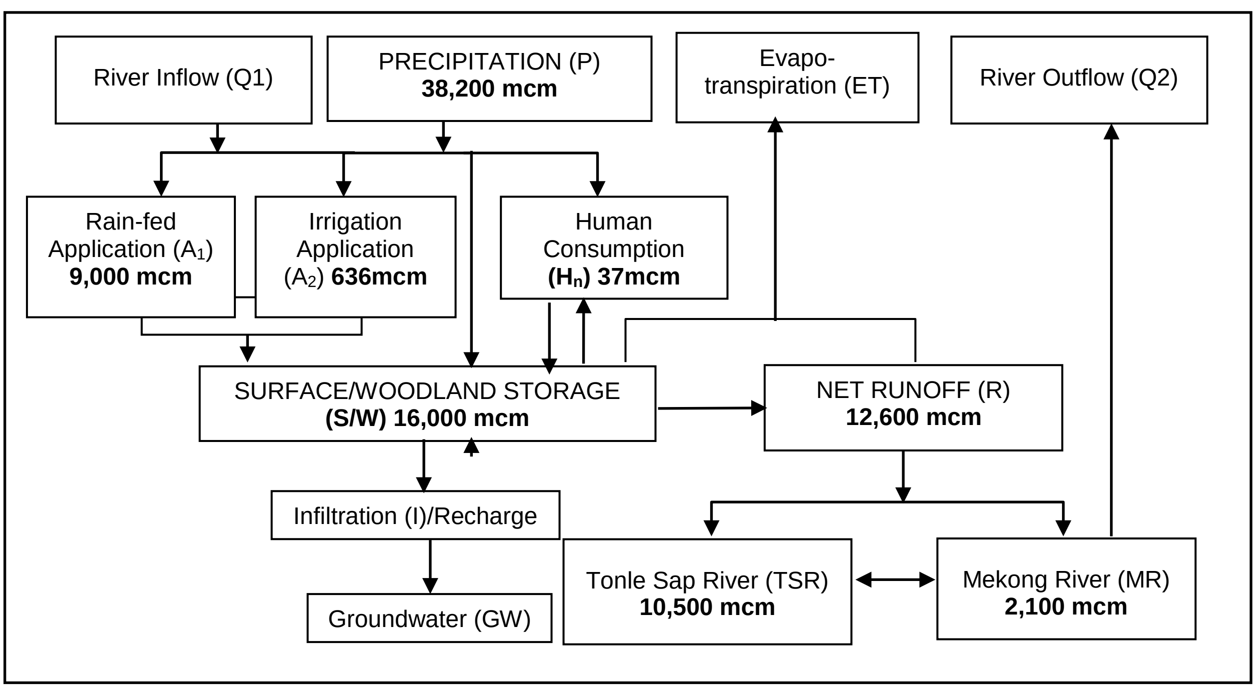
There is insufficient data to conduct a complete water balance for the study area, but using the meteorological, hydrological and hydraulic databases available, key parameters were interpolated to estimate a preliminary inventory of the study area water inflow and outflow.

In terms of water inventory within the study area, inputs are: rainfall and upgradient river flow as measured at the Stung Treng monitoring station. Water balance study area outputs are primarily natural forest and vegetation uptake and direct rain fed agricultural irrigation, and secondarily mechanical irrigation and human consumptions as discussed above.

Using percentage estimates, in lieu of more sophisticated hydrologic models provides a reasonable qualitative rapid assessment within the objectives of this study. Using these estimates, a preliminary water inventory was prepared for the study areas as a whole, averaging the inputs of the three watersheds, but separating out the discharges of Stung Sen and Chinit from Siem Bok(a), since both discharge into the Tonle Sap, while Siem Bok(a) discharges into the Mekong River. Siem Bok (b) was not included since it is a peri-urban area outside the forest hydrology influence.

Along with the Mekong River, the Tonle Sap Great Lake is the primary receptor of the Mekong Basin with in Cambodia. It serves as a critical component of the unique pulsating dynamics of the river hydraulics and provides extremely important ecological services for the region from both an environmental and economic perspective, and the basis for an entire Khmer culture. The primary Assessment report should be referred to for the details. Figure 4.3 provides a summary of the available water volumes. The boxes without data indicate respective volumes were not discovered.

Figure 4.3 Study Area Water Inventory



HYDROLOGICAL EFFECTS OF FOREST CLEARING

The forest serves as a hydrology buffer reducing runoff velocity and absorbing a portion of the precipitation. Clearing the forest removes these natural services (among others) and increases the amount of net runoff reaching their respective sinks (Tonle Sap or Mekong River) and rates of and locations of sediment deposits. Due to the size of the area involved and the complexity and importance of the relationship between the Tonle Sap and Mekong River it would take a sophisticated quantitative model to determine how much the actual net runoff would be affected, which is beyond the scope of this study. However, the qualitative assessment conducted provides a relative objective indication of the potential outcomes.

The effect of forest removal on the hydrology of the region is a function of the characteristics of area of forest removed, such as slopes, soil drainage characteristics, vegetation, and change in land use. Therefore, if in the extreme worse case, the entire forests in all three watersheds were removed, the total net runoff contributed to the Mekong River could significantly increase the river discharge and sediments from Cambodia into the Mekong Delta, with potentially devastating effects.

4.3. Ecosystem Services

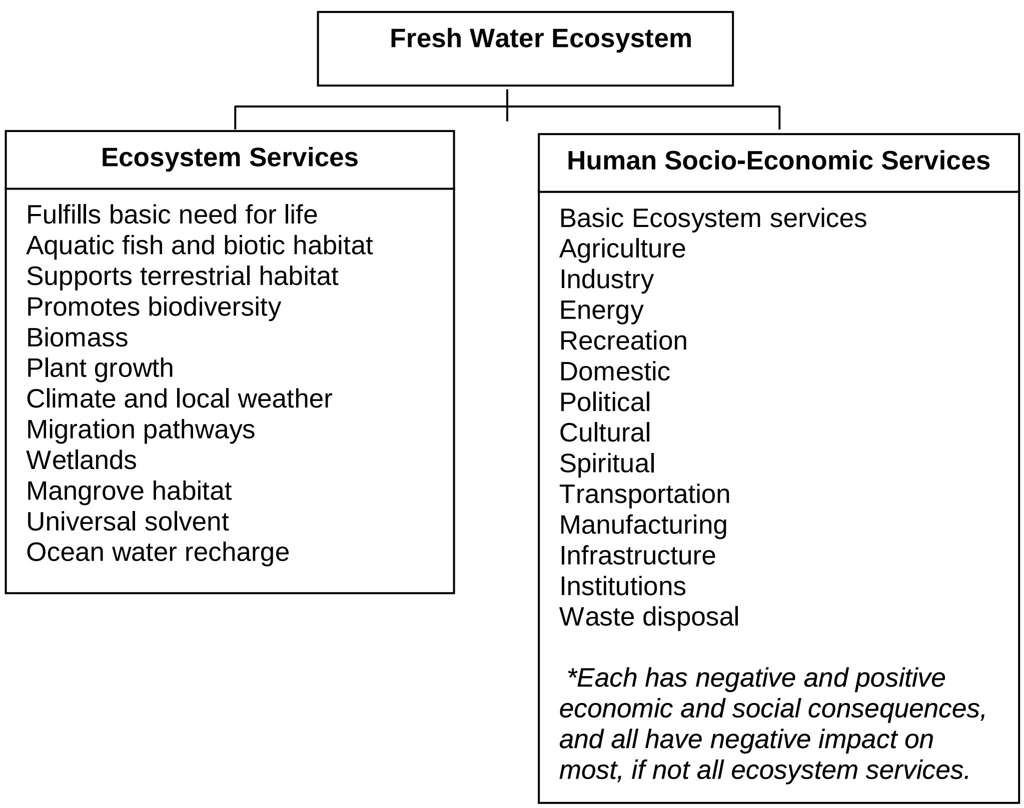
The natural services provided by any ecosystem, such as the forest, are referred to as "*ecosystem services*" as defined by the Millennium Ecosystem Assessment (MA) which divided the services into four broad categories: Supporting, Provisional, Regulating, and Cultural. It determines services as those activities that affect human wellbeing, so that it may be viable to exploit a resource and account for ecosystem services, with addressing those disruptions that do not affect humans. The focus of this Assessment concentrates on how the "*natural services*" of the fresh water cycle are affected by the replacement of forest's services by clearing the land. The *natural services* include all services that benefits and sustains an ecosystem, regardless of the human considerations. And then, with this in mind, the effects of human socio-econ conditions are considered.

FRESH WATER ECOSYSTEM SERVICES

The list of water ecosystem services can include just about every aspect of life on earth, and is affected by every aspect of it. While a list of services for a discrete ecosystem, such as a forest, would apply to the forest itself regardless of whether or not humans involved, those same services have direct and indirect effects on human wellbeing. Water however, is ubiquitous and any and all changes in the hydrologic cycle, regardless of where these changes take place, have certain direct and indirect effects on humanity's wellbeing, as well as other species.

By clearing a forest, all the natural services provided by the forest are lost until (and if) renewed. By depleting a naturally occurring water source (e.g. over pumping groundwater), the local water balance is altered, and ecosystem services adjust accordingly, but the water cycle and its essential service is maintained. Humans can and do effect water quality, quantity and location, all of which have significant effects on ecosystems, but perhaps its most damaging impact is on water quality, since by rendering it unfit for consumption, humans in effect reduce their own usable water supply, potentially threatening its own existence. Figure 4.4 provides a partial general list of fresh water services ecosystem and socio-economic services.

Figure 4.4 Fresh Water Services



PREY LANG WATER ECOSYSTEM SERVICES

As an ecosystem in its own right, the Prey Lang forest provides services and is dependent upon the services provided by the water present within its system as defined by the surface hydrology.

The Prey Lang Forest potentially stores more carbon than other forests since its undisturbed timber volume and biomass are relatively high. In addition, the swamp areas are reported to have significant carbon storage potential.

Figure 4.5 lists the potential Prey Lang Forest Ecosystem Services. It contains most of the services provided by any forest. Figure 4.6 shows how those services might be affected by clearing the forest.

Figure 4.5 Potential Prey Lang Forest Ecosystem Services

Prey Lang Forest

Ecosystem Services

Photosynthesis
Carbon Sequestering
Watershed management
- Flood retention
- Torrent control (buffering)
- Erosion Control,
- Water quality
- Sediment reduction
- Stream Flow
- Wetlands (swamps)

Transpiration
Biomass
Nutrient cycle
Stream bank management
River bank management
Biodiversity
Endangered species
Pollination
Seed dispersal
Terrestrial Habitat
Natural pest control
Land use barrier
Protected wildlife migration pathways
Flood control
Drought mitigation
Food
Primary production
Shading

Human Socio-Economic Services

Timber
Fuel wood and biomass
Non-wood forest products
Tourism
Cultural value
Spiritual value
Recreational
Aesthetics
Food
Pharmaceuticals
Land use
- Residential
- Industrial
- Agriculture

Employment
Energy

Figure 4.5 Potential Effects of Deforestation on Ecosystem Services

Potential Prey Lang Effects of Deforestation

Ecosystem Services

Decreased
Photosynthesis
Recreational
Food
Tourism
Carbon Sequestering
Watershed management
- Torrent control
- Erosion Control
- Water quality
- Sediment reduction

Biomass
Nutrient cycle
Stream bank management
River bank management
Biodiversity
Pollination
Seed dispersal
Terrestrial Habitat
Transpiration
Land use barrier
Drought mitigation
Food
Primary production
Shading

Increased
Stream Flow
Flood potential
Sediment load
Wetlands vulnerability

Altered
Endangered species
Natural pest control
Wildlife migration pathways

Socio-Economic Services

Increase
Timber
Non-wood forest products
Pharmaceuticals
Land use
- Residential
- Industrial
- Agriculture
- Transportation

Employment
Economics
Energy

Decrease
Aesthetics
Fuel wood and biomass
Fisheries

Unknown
Cultural value
Spiritual value

Downstream
Socio-Economic Services

Increase
Recreational
Migration to Forest Area
River flow
River height
Flood intensity
Sedimentation
Economics

Decrease
Aesthetics
Fisheries

Altered
Cultural value
Spiritual value
Social value

Placing a dollar value on ecosystem services is complex and difficult, if not impossible to accomplish quantitatively and certainly limited. Identifying interrelations between service and value can be subjective and contentious. Extrapolations and interpolations between incomplete or inconsistent data sets tend address a large range to cover a host of inadequacies. The valuing of the ecosystem is only sustainable as long as funding provider is willing to pay, which is dependent on social and political will, and economic conditions. Those ecosystem services, to which some value that can be measured in terms of money are included within the economic model (TEV); otherwise, they are considered as part of the sustainability matrix scorecard.

4.3.1 Non-Timber Forest Products (NTFP)

NTFPs are of particular importance to the Prey Lang area. Typical NTFPs used in and around the Prey Lang area include types of leaves, bark, frogs, toads, eels, orchids, ginseng, resin, rattan, honey, firewood, fencing, vegetable, mushrooms, and fish. Local villagers are highly dependent on NTFP as source of food. Resin is one of the most important NTFPs Cambodia-wide, and shows significant potential for market development (Prom, 2009). The estimated total value of resin is about $10 million.

4.3.2 Fisheries Important to Prey Lang Forest

Inland fisheries in Cambodia are part of the two interrelated systems made up of the Tonle Sap and Mekong River. The flow reversal discussed earlier is a critical dynamic of fish productions and migration. Fish migrations of economically important species are triggered by seasonal hydrological changes.

The total annual income per year of fisheries in the Prey Lang watershed Provinces is roughly $7 million for small-scale fishermen. Commercially the annual total fish catch is about $36 million (Mak, 2010; MRC Fisheries, 2010).

Roughly 4,032 households depend on fishing as a primary source of income, and 16,080 households as a secondary source. Households earn roughly $2,200,000 USD and $4,500,000 USD annually, respectively (Mak, 2010; MRC Fisheries, 2010).

MEKONG RIVER FISHERIES

The total 2007 commercial and industrial fish catch for Cambodia was 125,000 tons. In Stung Treng and Kratie Provinces, the individual catch was 2,000 tons, or together 3.2 % of national catch. In 2009, these increased to 6,373 tons in Stung Treng, while decreased to 1,885 tons in Kratie (Mak, 2010; MRC Fisheries, 2010). While portions of these provinces lie within the study area, they also extend across the Mekong and outside the assessment boundaries, so it is assumed that most of the commercial fishing takes place on either side of the river and is essentially equally distributed.

COMMUNITY FISHERIES

The community fisheries were established in 2001 with the objective to promote sustainable fishing practices to help improve community socio-economic conditions and alleviate poverty. In 2006, 388 community fisheries existed. As would be expected nearly all lie along the Mekong and within the Tonle Sap flood plain along its tributaries. Within the study area, 17 existed in Kampong Thom mostly along Stung Sen. Oddly, very few existed in the Stung Chinit watershed. Fifty-one were present in Stung Treng and Kratie Provinces each and again roughly estimated to lie equally along the Mekong. Therefore, approximately 51 are located within Siem Bok (a) watershed. Sixteen were located in Kampong Cham province, most of which within Siem Bok (b) (Atlas of Cambodia, 2006).

4.4. Socioeconomic Baseline

While many socioeconomic studies have been conducted in Cambodia, very limited information is available on the socioeconomics of the study area forests and hydrology. The economic value of the study area is based on direct use values, for timber, fisheries, NTFP and tourism. Agriculture is the largest sector of the GDP and it is primarily subsistence farming within the study area. Tables 4.5 through 4.13 summarize the TEV and NPV for each parameter over the 10-year period. ***It is important to note and keep in mind that the data provided in these tables are for illustrative purposes only, and should not to be used for planning or budgeting purposes without further study and confirmation.***

Several valuation techniques were used for the main direct use and indirect use values (DUV and IUV) as described previously. The baseline analysis is dependent on a number of parameters, such as average forest density, NTFP collection per hectare values, and market costs for fish and tourism statistics. The values for these DUV are based on previous studies and/or statistical reports within Cambodia, if not within the study area provinces. Information regarding indirect values of forest resources in Cambodia was not found during the timeframe of data collection. Values for IUV were based on research done outside of Cambodia.

4.4.1 Timber Baseline

This study focuses on potential values from evergreen, semi-evergreen, and deciduous based on current loss rates of 1% as advised by the RGC Forestry Administration (FA). The loss rates for the different forest types range from 0.8% to 2.8%. The deciduous forests have the highest loss, even though not valued as highly as the other types. The analysis of timber TEV is based on the following assumptions:

- Forest area is based total forest cover, which is estimated to be 760,000 Ha.
- Timber volume varies within the three types of forest and an average of 115 m^3/ha density
- Logged wood prices and production/manufacturing costs were based on market rates from various 2008 studies within Cambodia, using average commercial wood value of $130/$m^3$
- Studies done on forest growth rates vary widely and forest annual growths make up a relatively small amount of forest volume lost.

Based on these assumptions, the TEV for timber logged at 1% annually is approximately $68 million and contributes about 0.6% to the GDP of Cambodia. See Table 4.5.

The 8% DCR was applied as conservative representation of stable economic development in developing countries (Sasaki, 2010) and reflective of Cambodia's potential.

Table 4.5 Logged Timber TEV and NPV over 10 Years

Timber	
Timber volume (m^3)	**87,400,000**
Production rate (1% of available baseline forest per FA) remains constant (assumes no improved harvesting efficiency)	1%
vailable for market after 40% wastage (assume no improvement)	60%
Stumpage Value ($/$m^3$)	$130
Baseline TEV (2010) (million USD)	**$68**
Baseline NPV 10 yrs @ 8% (million USD)	**$487**

4.4.2 Non-Timber Forest Products (NTFP) Baseline

NTFP are considered a DUV of forest, and have considerable economic value to Cambodia. For valuation purposes, the cash and subsistence values are determined by examining collection, trading, and consumption to determine consumption/use per ha per year (Heov et. al., 2006).

Direct values for NTFP are based on studies reported by Hansen and Neth (2006) in Mondulkiri, Kratie, Kampong Thom and Pursat districts. Average reported values of NTFPs for different types of Prey Lang tree types are: $32/ha for deciduous, $23/ha for semi-evergreen and $13/ha for evergreen. An average of $22/ha for all forest is applied for NTFP TEV valuation.

The NTFP baseline TEV is based on standing volume of forest multiplied by the average per hectare value of NTFP collection. Because NTFP collection is the main source of income and subsistence for forest dependent households, harvesting costs (i.e. labor) are very low, and were not included for this NTFP valuation. TEV and NPV of NTFP collection for Prey Lang forest estimates are presented in Table 4.6.

Table 4.6 NTFP TEV and NPV over 10 years

NTFP	
Forest area (ha)	**760,000**
Available forest for NTFP based on constant 1% annual loss of forest due of logging production rate	1%
FV assumed to be constant over study period	$22
Baseline TEV (2010) (million USD)	**$17**
Baseline NPV 10 yrs @ 8% (million USD)	**$114**

4.4.3 Fisheries Baseline

Fisheries are included as direct forest use because the forest is a major contributing factor to both commercial and subsistence production. The fish catch estimate of 21,000 tons is based on NCDD and MAFF data from 2008 for the four provinces. Fish market values are taken from IUCN data for the same year and valued at $2350/ton. Various studies show a decreasing fish catch over the years, while also reporting significant fish cash underestimates (MAFF and ICEM). Therefore, compounding the uncertainty and difficulty of estimating fish catch and making accurate projections. TEV and NPV of fisheries estimates are presented in Table 4.7.

Table 4.7 Fisheries TEV and NPV over 10 years

Fisheries	
Fish catch for study area (tons per year)	21000
FV of fish catch based on $ per ton assumed to remain constant over study period.	$2,350
Baseline TEV (2010) (million USD)	**$49**
Baseline NPV 10 yrs @ 8% (million USD)	**$352**

4.4.4 Tourism Baseline

The Mekong River and Tonle Sap areas are assumed to have significant potential tourist attraction that will be directly affected by the different forest development strategies considered in this assessment and are considered as direct use value (DUV) for economic valuation (MOT Statistics, 2008).

It is assumed that the majority of tourists visiting Northeast Cambodia visit the Mekong River and dolphin pools. While Stung Treng province has an estimated budget for ecotourism of $414,575 for 2010 (MRC, 2010), very limited information on ecotourism statistics outside of dolphins was available. However, the need for alternative costs to replace logging activity for Scenario 2 and the potential decrease in tourism as a result of Scenario 1 cannot be ignored.

Table 4.8 shows the number of foreign and local tourist as well as the average amount they spend per day. The annual TEV and NPV estimates are also presented in the table below.

Table 4.8 Tourism TEV and NPV over 10 years

Tourism	
International visitors/year	13,356
Average expenses per international visitor/year (2 days at $118/day including transportation)	$236
FV at 5% growth rate	5%
National visitors per year	117,187
Average expenses per national visitor/year (1 days at $22/day including transportation)	$22
FV at 3% growth rate	3%
Baseline TEV (2010) (millions USD)	**$6**
Baseline NPV 10 yrs @ 8% (millions USD)	**$49**

4.4.5 Agriculture Baseline – Rice

The study used rice as the agriculture benchmark, since it is such a significant part of the agricultural economy and Cambodia's GDP, as well as its cultural importance, and main food source. Conversion to other land use, e.g. plantations, etc. would have lower net economic and social (health and cultural) values. However, much of the soils within the study area are not conducive to rice and therefore, its value in considering Scenario 3 on applying improved agriculture practices to increase soil quality and improve yield, as well as, improved water management. The TEV is based on map imagery metadata and current market values for rice. TEV and NPV estimates are presented in Table 4.9.

Table 4.9 Agriculture Baseline - Rice TEV and NPV over 10 years

Agriculture	
Study areas under cultivation (ha) assumed to remain constant over study period	39,000
Yield tons based on ton/ha (assumed to be constant).	2
FV of crop value based on $/ton)	$625
Sliding scale assumed to be constant over study period.	0%
Baseline TEV (2010) (millions USD)	**$49**
Baseline NPV 10 yrs @ 8% (millions USD)	**$384**

4.4.6 Carbon Sequestration Baseline

Like tourism, carbon credit can significantly alter the benefic cost analysis. Currently there is no system in place to pay for the carbon storage service, and very little data is available for setup, monitoring, and management. However, the apparent willingness to pay appears to be sincere and the potential offsetting benefits and costs for the different scenarios are too great not to be included as a separate TEV line item. This study limits carbon valuation to above ground biomass estimates for evergreen, semi-evergreen and deciduous forests only. Evergreen and semi evergreen forest regrowth rate is 0.33 m^3/ha/year (Ashwell, 2008). It would take considerably longer than 10 years for forest regrowth to contribute to carbon sequestering (FAO FRA Report, 2005). This would be a significant BCA consideration for Scenario 1 and relatively less of one for Scenario 3 within the 10 year time frame but very important in the long term. Regrowth would not be a significant factor for Scenario 2, but still a contributing factor restoring existing uncovered land. Therefore, evergreen and semi-evergreen regrowth were considered in BCA for each scenario.

The price of carbon can range between $3.50/ton to over $20/ton. This study used $3.50/ton as a reasonable conservative estimate. Based on the 760,000 ha estimate and conservative carbon value of $3.50/ton, the TEV of standing forest is about $150 million. Considering the annual loss rate of 1%, the NPV at 8% is projected just over $1 billion.

Using a range between RWC and RWB would make a significant difference for all scenarios. Again, limited information is available for set-up, monitoring and management costs, but a recent REDD+ roadmap has been prepared and estimates that a program could begin mid-2014. Therefore, the current valuation for 2010 is $0, and assuming a program will take place mid-2014, the estimated NPV is around $671 million. Refer to Table 4.10.

Table 4.10 Carbon TEV and NPV over 10 years

Carbon Storage (sequestering)	
Forest study area (ha)	760,000
Density (tree volume in m^3/ha)	115
Forest study volume(m^3)	87,400,000
Standing Stem Volume (SV) is the remaining forest volume after assumed baseline production rate of 1%.{Note: volume loss assumed to an annual rate to account for natural decay and forest degradation due to roads, etc.)	-1%
Wood density (WD) is the average wood density for natural forest in SE Asia	0.57
Biomass expansion factor (BEF) converts SV to AGB	1.74
Carbon factor (Cf) is the carbon stored in mt based on 0.5 C ton/SVm^3 (based on dry volume and weight)	0.5
Above Ground Biomass (AGB= SV*WD*BEF)*Cf in (mt) = .5*SV {Note:1.74*0.57=0.99}	0.5
FV at Carbon value in $/ton	$3.50
Baseline TEV (2010) (millions USD)	**-**
Baseline NPV 10 yrs @ 8% (millions USD)	**$671**

4.4.7 Payment for Environmental Services & Biodiversity

Very limited studies were available covering biodiversity and Payment for Environmental Services values in Cambodia. Bann conducted a biodiversity study in the Kampot Province (1997), which placed a total “captural” value $30/ha on forest biodiversity based on Ruitenbeek’s *“Rainforest Supply Price*” (1990).

PES values are based on planned community forest (CF) management schemes. In Prey Lang, there are currently 100,000 ha of CFs with a management value of $2/ha. See Table 4.11.

Table 4.11 PES TEV and NPV

Payment for environmental services (PES)	
Community forests (CF=26) area within study area (ha) (assume remains constant)	100,000
Rate of change (assume remain constant)	0%
FV of CF at ($/ha)	$2.00
Baseline TEV (2010) (millions USD)	**$0.2**
Baseline NPV 10 yrs @ 8% (millions USD)	**$1.4**

Using a value of $30/ha for biodiversity, the estimated TEV and NPV are shown in Table 4.12.

Table 4.12 Biodiversity TEV and NPV

Biodiversity	
Forest Study Area (ha)	760,000
Forest loss based on annual production rate	-1%
FV biodiversity value based on $/ha.	$30
Baseline TEV (2010) (millions USD)	**$23**
Baseline NPV 10 yrs @ 8% (millions USD)	**$156**

4.4.8 Forest Ecosystem Services

Studies on forest hydrological services in Cambodia were not found in the literature reviewed. However, CDRI valuation studies provided several case studies within the South East Asia region, which this study assumes are relevant and applicable to this assessment.

Watershed protection and soil erosion mitigation values are typical measuring tools for estimating watershed services provided by a forest (Hansen & Neth, 2006). In a case study by Emerton, *et.al.*, in Lao PDR, the value of water conservation and soil conservation is estimated at $70/ha/year and $60/ha/year respectively (2001). This study indicated that deciduous forests can only provide benefits when a constant crown covers is established; however, forest ecosystem services are provided by the entire forest and, therefore, applied to the entire study forest area.

The TEV and NPV of watershed protection and soil erosion for the forest are shown in Table 4.13.

Table 4.13 Forest Ecosystem Services TEV and NPV

Forest Ecosystem Service (FES)	
Forest Area (ha)	760,000
Forest loss based on annual production rate	-1%
FV of FES at $/ha (assumed watershed protection-$70; soil erosion $60)	$130
Baseline TEV (2010) (millions USD)	**$99**
Baseline NPV 10 yrs @ 8% (millions USD)	**$676**

4.4.9 Summary of Economic Valuation

The separate TEV for direct and indirect use values are $189 million and $122 million respectively. When considering only DUV of the forest, timber is the largest contributor with approximately $68 million. Fisheries and rice each account for $49 million followed by NTFP at $17 million and tourism at $6 million. In total, these contribute about 1.7% to Cambodia's GDP of $11 billion (EIC, 2010; WB 2010). Alternately, when IUV are taken into account, the TEV of the 2010 baseline is drastically altered, and the total contribution to GDP is 2.8%. However, the IUV are based on limited and very subjective resources at this time. Further valuing of ecosystems is necessary before their values can reliability be incorporated into TEV. On the other hand, even the DUV are subject to uncertainty based on the limited resources, although not quite as subjective. One potential way to overcome part of the difficulties is to define ranges between reasonable worse case (RWC) and reasonable best case (RBC) and interpolate a reasonable most likely case within the range limits. Like BCA and the sustainability matrix, RWC, and RBC are best defined by consensus.

In summary the total 2010 economic value of the study area is $311 million, contributing 2.8% to the overall GDP of Cambodia. The NPV projection over the 10-year assessment at 8% discounted rate for the Baseline “continuing to do business as usual (BAU) is estimated at $2.9 billon. Table 4.14 summarizes the TEV and NPV values generated in this Section

Table 4.14 Baseline TEV, NPV, and GDP Contribution

	STUDY AREA BASELINE			
	USE VALUES	**Economic Value (2010)** (USD Millions)	**Baseline TEV contribution to GDP**[1] **%**	**NPV 10 YR Projection - Baseline** (USD Millions)
Direct Use Values	Timber	$68	0.6%	$487
	NTFP	$17	0.2%	$114
	Fisheries	$49	0.4%	$352
	Tourism	$6	0.1%	$49
	Agriculture	$49	0.4%	$348
	PES	$0.2	0.0%	$1
	Subtotal DUV	***$189***	*1.7%*	***$1,352***
Indirect Use Values	Carbon	$0	0.0%	$671
	Biodiversity	$23	0.2%	$156
	FES	$99	0.9%	$676
	Subtotal IUV	***$122***	*1.1%*	***$1,503***
	TOTAL TEV	**$311**	**2.8%**	**$2,855**

4.4.10 Baseline Sustainability Matrix

The Sustainability Matrix provides a means to consider the external indirect considerations which are not captured in the economic and financial models, but have an equal and often far more significant effect on the decision making process. If not taken into account, decisions made today may be much regretted in the future; there are enumerable examples. The complete Baseline Sustainability Matrix as completed in its entirety can be found in the appendix of the Primary Assessment Report. Its total scores are summarized in Table 4.15.

Table 4.15 Baseline Sustainability Scores

Potential Forest Impacts	Economics				Social				Environmental				
	I	V	CL	S	I	V	CL	S	I	V	CL	S	**S**
Economics	3	3	0.8	264	3	3	0.8	270	3	2	0.9	204	**739**
Social	3	3	0.7	157	3	3	0.7	176	3	3	0.8	206	**540**
Environmental	3	3	0.7	246	3	3	0.7	246	3	3	0.9	275	**767**
Average CL/Sum of S			0.7	**667**			0.7	**692**			0.8	**685**	**2045**

The importance (I) was held constant for each of the individual parameters, since all were considered to be of high importance (3), however, importance would not be constant in most cases, since different stakeholders will see things differently. On the other hand, value (V) varied from 3 to 1 as rated from good to bad. The confidence level (CL) is higher than in the scenario matrices, since the relevant data was more readily available.

The Baseline Sustainability Scores present an indication of how current conditions are perceived, and becomes the benchmark by which progress is measured, or in assessing how the scores change when one IP adjusted while all other remain constant (i.e. sensitivity analysis). And finally the baseline score as compared to target score provides the spread from "where we are now", relative to where we would like to be. The target score is the ideal ultimate sustainability score determined by all the stakeholders. It serves as the beacon to strive for, while intermediary targets are set to measure, monitor, and evaluate progress to ensure accountability and allows the course to be reset as new information becomes available.

5. CONCLUSIONS and RECOMMENDATIONS

The Assessment concluded that there is insufficient information to reach a quantitative decision regarding the management of the Prey Lang Forest. Until such time as adequate information is available, a multi-criteria analytical methodology was presented to qualitatively assess the existing data to provide an interim basis to compare policy options.

While the Primary Assessment worked through the multi-criteria solution for illustrative purposes, the example was not intended to serve as an ultimate decision, which can only be accomplished with full participation of all stakeholders. However, it can be concluded with a reasonable level of confidence that the Prey Lang Forest is a highly valuable natural asset to Cambodia, and that development of the forest and the natural resources within the Study Area without implementing prudent and diligent management will significantly affect the hydrology, with the potential to cause traumatic stress to the Tonle Sap Water Basin Lake and the Mekong Delta.

RECOMMENDATIONS

The Assessment is a good starting point to decide upon optimum resource management strategies, fill data gaps, and provide methods to serve as a screening tool providing a way and means to establish priorities, evaluate thematic interrelations, and identify the most helpful information needed. As a reliable and credible information base is created, a phased comprehensive interagency national integrated resource management program can be prepared to ensure Cambodia's social, economic and environment goals are attained prudently and sustainably.

Building upon the RGC National Forest Programme and this study, the following actions are recommended:

1. Conduct workshops to train the Forest Administration personnel in the application of methodologies used in the report, so they can further develop and incorporate this analytical approach into economic decision analysis by Cambodian policy makers.
2. Conduct stakeholder participation workshops to establish parameters that best represent Cambodia's best interest.
3. Identify information gap priorities and organize funding sources, academic and government institutions and NGOs to conduct the research and investigation necessary to ensure the quality of the information is sufficient to reach sound decisions with the highest level of confidence.
4. Using the expanded data base establish values for Cambodia's ecosystems that are uniquely applicable to Cambodia to ensure that the values and costs are adequately accounted for in the decision analysis process.
5. Prepare a holistic integrated resource management plan starting with the Prey Lang Forest as a model including but not limited to:
    1. Community Forests
    2. Surface and ground water hydrology
    1. Enhanced agricultural practices and food security

2. Land use practices and rights
3. River dynamics hydraulics
4. Tonle Sap/Mekong River protection
5. Fish Habitat and migration path protection
6. Biodiversity protection
7. Concession management
    1. Mining
    2. Plantation
8. Rigorous performance measurements, monitoring and evaluation are critical to early detection of problems, and proactive follow-up with vigorous follow-through is essential to resolving the problems.

6. APPENDIX A

6.1. Supplemental Update Of Baseline Conditions

6.1.1 Introduction

- The following is an informal follow-up to the Summary of Baseline Conditions of the Rapid Socio-Economic and Hydrological Assessment of the Prey Lang Forest to which it is included as an appendix. The original Rapid Assessment was dated July 2011 and is referred to herein as the Primary Assessment Report or PAR. This summary report is a supplement to the main body of this report. The purpose of this summary is to review some of the events that have transpired since the original PAR was submitted that might affect results or recommendations. It is based on a review of reports and files available online and presented in the Cambodia news media. It is not intended to provide a numeric update of PAR scoring results, taking into account the new developments, which is beyond the scope of this review, but is highly recommended.

- In addition to the literature search, AE staff interviewed recognized authorities of Cambodian forest management and practices, namely Dr. Keo Omaliss, the Deputy Director of the Forestry Administration's Department of Wildlife and Biodiversity and the Cambodian National REDD Focal Point. Dr. Omaliss provided invaluable input into the original PAR, as well as FA follow activity since then. In addition, Sokheng Seng, who is a proactive advocate for protecting the forest, offered insight into what is happening from the perspective of the Kuy people who live within the forest and to whom "Prey Lang" literally means "Our Forest".

- Overall, the general status of the forest has remained the same, although the Forest Administration (FA) is proactively introducing conservative forest management strategies to conserve the Prey Lang Forest. Recognizing the need for more accurate data, which was one of the major conclusions of the PAR, the Ministry is actively trying to close the data gaps in order to be able to make informed decisions based on adequate reliable information, a major recommendation of the PAR. In addition, while REDD funds have not been forthcoming, the FA continues to prepare REDD initiatives and practical science-based surveys such as biodiversity, carbon and non-carbon studies, biomass and wetlands inventories to reinforce long term carbon controls and storage. New initiatives include the demarcation of the Prey Lang, the need for which was also discussed in the PAR. The FA commented that the workshop conducted by AE and Forbes was very beneficial and suggested that more should be conducted.

6.1.2 Illegal Logging and migration

- While illegal logging was occurring and addressed during the original Assessment, apparently it has increased significantly since that time. Reportedly, concessionaires are logging outside concession areas and then reporting the timber as concession production. If confirmed, this would cause discrepancies in forest clearing accounting and making it difficult to reconcile different forest clearing measurement methods. In addition, emigration is increasing as land is cleared as a result of development, thus causing important demographics shifts. The growing population increases the reliance of low income families on resin income from trees, which are the very same trees that are being logged. These demographic and economic changes place a significant stress on the indigenous people historically living and caring for “our forest”, increasing poaching of the wild animals and effecting not only biodiversity, but compounding the loss of ecological services further increasing pressures on the forest and its inhabitants. The unintended consequences highlight the value for establishing a good basis for baseline conditions for the forest using SuDeX methods and following up on the original assessment recommendations. The resulting positive feedback loop is indicative of the need to measure the consequences in order to identify changes using the scoring process to indicate which to prioritize and how to adjust accordingly.

6.1.3 REDD+

- An important finding of this review is the apparent confirmation of the uncertainty that REDD+ can assure revenues that can be counted on over time to subsidize the storage of carbon and support the preservation of the forest. Therefore, as a backup if not replacement, some sort of economic alternative to REDD+, needs to be developed, such as sustainable forest management practices to ensure reliable income, while concurrently assuring the hydrological cycle is sustained to support reliable long time fish supply, river flow (and therefore hydropower), as well as the possibility of a passive but economically promising ecotourism market, as pointed out in the original Prey Lang assessment.

- The basis for the reported loss of $911,00O payment to Cambodia for carbon under REDD+ is not known, but on any scale and metric it is relatively low compared to the potential value of carbon saved and/or the economic value of the resource itself. To be a viable business option, the profit margin must be worth the investment. However, to consider the nearly one million dollar, without taking into account the ecological services that would be saved, significantly dilutes the real value of the investment. The tradeoff is pay today or pay tomorrow. If the REDD+ program is to be viable, it be must be able show that short term gain is comparable to the options, and more importantly perhaps is that can be relied upon; any investment and protection scheme is based on the aversion of risk by its potential investors and stakeholders; uncertainty and unreliability are not conducive to mitigating risk concerns. Any economic scheme that does not rely on real market dynamics is subject to the whims of political regime in power at the time. Real market trends are subject to the same whims as well, but in the long run the basic inherent forces of the market will overcome any policies that do not take them into account. The worth of the forest is not in the short term financial value of the timber alone, but in the net long term value of the inherent natural services and economic resources it provides. The value and importance of the natural services are not easy to recognize or appreciate, until threatened, typically long after they are depreciated. SuDeX Sustainability Matrix method provides a way to recognize and measure the net value, but the value is only sustainable if appreciated.

- The original PAR used a very conservative value of $3.50 per ton of forest biomass, because of the uncertainty what the market and/or REDD would pay. Currently, a more realistic value is cited at $7/ton, which is below the competitive price of $15 per ton, if the value of forest is measured only in terms of timber products. In addition, the FA states that the $100 per ha rather than the $1000 used in the PAR is closer to the real market value. It is these types of estimates offered with progressive higher levels of confidence as more accurate and reliable information and experience is acquired, that illustrate the scalability of the methods introduced in within the PAR that eventually lead to a quantitative basis for reaching an optimum decision.

6.1.4 FA Conservation Objective

- The FA seeks to implement a conservation strategy to manage the forest, because it understands the long term implications and consequences of following either the preservation or total conversion policy. In order to garner the support needed to implement the strategy, it must be able to convince the government, stakeholders, and the public that the net gain by maximizing the positive and minimizing the negative consequences is real and can be achieved. This can be accomplished, in part at least, by following up on the recommendations provided in the original assessment and outlined in this summary.

6.1.5 Large Development Projects

- In addition to the expansion of the development issues discussed above and that were on going during the original study, three major development initiatives that will have a significant effect on the Prey Lang landscape, are reportedly at some stage of planning. It is unclear where, when and if they will actually materialize. The reports vary diametrically from already in place to not even on the drawing board, with an apparent lack of intercommunications between the relevant agencies, indicating a lack of transparency which is vital if the tradeoffs are to be accurately evaluated, and an optimum decision can be reached.

- The projects include mining exploration and exploitation, additional hydropower dams, and an expanded railroad network throughout SE Asia. What is known for certain is that each will have major economic advantages and social benefits, with significant social tradeoffs and environmental sacrifices. What is uncertain is whether the initial probable financial gain will offset the ultimate environmental impact, causing future financial setbacks as the one renewal natural resource, water, is almost certainly depleted without its natural cycle to recover. All this is based on using money as the primary unit, but what about the loss of services that the ecosystem provides in support of local biodiversity, regional hydrological, river and stream hydraulics, and groundwater hydrogeological stability, and of course carbon storage capacity…all of which human existence is dependent upon, and arguably (perhaps) has much greater importance, then but not limited to financial return?

6.1.6 Potential Mining Projects

- At the time of the original assessment, mining and potential mining projects were talked about almost as if rumors and originating source unknown. Currently the mines seem much better defined; there is still a great deal of apparent uncertainty, especially regarding scale and impact. Since that time, there have been numerous reports of large mining ventures at various stages of development, but formal reliable information is still lacking and conflicting. The full magnitude of the impact of the mining operation is not known, but how they will affect the Prey Lang forest most assuredly will be significant. Whether the net affects are negative or positive will require an additional study.

- Reportedly, an Environmental Impact Assessment (EIA) of the proposed mining operations has not been conducted (as of March 2013). This type of study takes a great deal of field investigation, research and modeling over an extended period of time in order to have any quantitative decision making value. To proceed without a carefully done EIA would be quite risky environmentally, socially and economically. These developments do not alter the recommendations of the PAR, but rather reinforce the need and place a greater urgent priority on them. This will benefit all stakeholders ensuring the best interests of all are incorporated into the planning.

6.1.7 Railroad

- In conjunction with the mining reports are reported plans to construct a major railroad from the mining area in the southern portion of Preah Vihear Province to a proposed port in Koh Kong. If constructed, the railroad will be Cambodia's largest development project reportedly costing $11.2 Billion USD. It seems unlikely that such an undertaking would be based on one project alone. However, as is typically the case information is sorely lacking. Improving Cambodia's transportation system including restoring old railways and building new roads will have a major impact on Cambodia's development. As always there will be tradeoffs and it is not known at this time where the optimum coverage is or how the Prey Lang forest will be affected, but this study alone would have major benefit for Cambodia. Such a study would take considerable time and effort, although the cost would be relatively low as compared to that of the projects and most likely the cost would be recovered by being able to make an informed decision and more effective and efficient plans.

6.1.8 Dams

- Dams were addressed by the PAR and there was a considerable controversy at the time concerning the eleven dams proposed on the lower Mekong in addition to the four built by China on the upper reaches. The controversies are mired with insufficient and timely information. The controversy continues today with the increased fervor, conjecture, and urgency. The nonbinding Mekong River Commission recently restated its recommendation made in December of 2011 for a ten year moratorium on dam building. It reportedly had little affect with the 1,280 MW Xayaburi Dam in Laos reportedly moving forward. But the reports are conflicting, although one reporter claims to have visited the construction site, while ministry head claim not to know about it, since they were “not invited”.

- How can a reasonable assessment be made without a reliable source of information? Yes the dams will have great economic benefit and provide needed electricity to many people, and yes the dams will cause significant environmental degradation, loss of ecological services, and disrupt biodiversity, but to what objective extent is not known. The best case scenario is brilliant for the near future, with the gains far exceeding the losses, while in the worst case the benefits are short term and loses will be devastating, long term, and difficult to reverse. The most reasonable likely case lies somewhere in between, but where, who determines, how and when? The methods provided in the PAR offer one alternative, and at the very least provide a relatively easy starting point, but by no means the final answers, which require comprehensive, objective, scientific, engineering and social studies.

6.1.9 Political Will

- It has only been two and half years since the original PAR was completed, and yet much has happened, on paper at least, but the migration issues and the letting of the Economic Land Concessions are real and disconcerting and the proposed large project development are both promising and ominous. All these considerations will affect the SuDeX Sustainability Matrix Score in a negative direction, although the net gain or loss is difficult to predict. What is known with a high level of confidence is that to proceed too quickly without some basis for making decisions will have dire consequences. The lack of transparency, accountability, communication, and information all compound the difficulties. However, two of the most promising finding of this informal and cursory review is the continued conscientious and thoughtful direction the various forest administration ministries are attempting to follow despite the presumed many pressures there must be to promote development and ignore the illegal activities.

- One of the more unexpected findings of this review, that has the greatest potential to ensure the best interest of Cambodia are met, is the reported actions of the government to cancel four economic land concessions totaling approximately 40,000 hectares in the Prey Lang Landscape because of its highly sensitive and unique environmental qualities. Such action was unlikely 2 years ago and with all the contentious development that has occurred since then, this cancelation is seen by many is a strong indication of the willingness of the Government to proceed and enforce policies to meet their stated goals. It is only with political will and financial wherewithal that any policy can be realized. This is not to imply that this action alone ensures the policies can be efficiently and effectively administered, managed and maintained. Without transparency, accountability, and communication that are generally lacking, as discussed earlier no system can be sustained.

6.1.10 Summary

- The mining and railroad will have direct impact on the Prey Lang forest, both positive and negative, and will also affect the Mekong River and Tonle Sap Great Lake. The proposed dams along that reach of Mekong River bordering the Forest boundary will be affected as well potentially increasing sedimentation, altered hydraulics, and effecting fish migration and spawning. The effect of the dams on the forest may be less direct, but the dams present much greater impacted area with far reaching political consequences. Collectively, these large projects, the deforestation, emigration into the area, along with the increased infrastructure needed to support the growth, will most certainly require a great deal of planning, political will and resource management to promote prudent responsible growth, which presents its own set of social, environmental and economic considerations. To fully evaluate the immediate and potential long term consequences all must be considered.

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