Rapid Assessment of Prey Lang Forest

Final Report

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1 Executive Summary

Aruna Technology Ltd. was contracted in April 2009 to conduct a rapid assessment of Prey Lang Forest which covers parts of four provinces in North-Central Cambodia (See Figure 1). The study focused on preparing a recent base map, analysing historical change in forest cover, preparing a GIS analysis and discussion of development and conservation issues and an associated analysis providing a rough basis for estimating the total value of different scenarios of development of the Prey Lang Forest area.

1.1 Current Situation

Examination of the region covered by the Study Area as shown in Figures 1 and 2 reveals thirteen different forest areas of varying composition and condition with Prey Lang Evergreen Forest comprising by far the largest undisturbed area (the "Core Zone", approximately 1,870 km²). It is centrally located and adjacent to several of the other forests, plays a key role in the regional ecosystem and likely contains the richest biodiversity in the region. It also comprises a major part of the Stung Chinit watershed and any impacts on the forest will have a significant effect on the ongoing irrigation and rural development investments downstream. The Prey Lang Evergreen Forest formerly included two other large areas that have since been logged and are in the process of being increasingly converted into a mosaic forest of different land use (the Upper and Lower Prey Lang Evergreen Forests, total areas 232.2 and 2,471.2 km² respectively).

Analysis of forest cover change since 1973 has shown that while rates of clearing have greatly increased in the last few decades, the rate of clearance has and continues to be less than 1% of the forested area per year. Based on the mapping of the 2009 satellite imagery, there remains approximately 925,000 Ha of forest in the study area. Degradation of the forest is an important issue through activities such as shifting cultivation and logging but can be difficult to map as the impact on the forest canopy may be minimal (in the case of logging) and re-growth can commence within a few short years. By some estimates approximately half of the remaining forested area has been disturbed, based on proximity to roads and villages.

There have historically been relatively few economic land concessions in the study area apart from the Tumring rubber plantation, though land conflicts are relatively common. Approximately 50% of the villages reported land conflicts in 1997(CDB 1997) for a total of 339 reported conflicts. These are likely to increase with the implementation of large land concessions announced in 2009, such as the Kuwaiti Hydropower\Irrigation project in Chey Saen and Rovieng districts and the plans by the State-owned Vietnam Rubber Group to plant "100,000 ha" of Rubber in Cambodia. Mineral exploration areas account for 334,000 ha, or about 30% of the study area with three being adjacent to the Core Zone (Kenertec Iron Ore, Vannymex Phnom Chi Gold and CIMG). The Prey Lang Evergreen Forest area is entirely within four timber concessions, with the largest two (Colexim and Everbright, both currently suspended) covering more than 87% of the Core Zone.

Based on the 2007 Commune Database (CDB), there are approximately 140,000 people living in the study area, comprising 28,000 households in 209 villages. 15% of the families in the study area rely on Chamkar farming, especially in Thala Barivat district. There are approximately 80 resin camps in the study area (Source: NRPG) and 110,000 Ha of delineated

community forest. In addition there about 6 community forest areas that are not as yet delineated.

Development adjacent to or near the Prey Lang Evergreen Forest is increasing particularly along its Western, Southern and Northern flanks where road networks have preceded increasing settlement and expansion of population and farming. This is likely to continue and could accelerate rapidly if planned or ongoing plantation and mineral concessions are fully implemented. Similar patterns are seen in the other forest areas within the Study Area where logging or concessions provide roads which eventually lead people into moving into the area to farm. Once the roads are in place, forest degradation and encroachment inevitably occurs and the forest eventually becomes a mosaic of secondary forest patches of different condition separated by roads and tracks and interspersed with chamkar and paddy fields, plantations, degraded forest, scrub, and grasslands. An encouraging trend within these areas is the establishment of a number of community forest areas within these secondary forests by the adjacent village associations. There are overlaps between these designated community forest areas and concession areas.

1.2 Scenario Analysis

In order to better understand the potential impacts of the changes proposed for the region in general and Prey Lang Forest in particular, two different scenarios were analyzed:

- The Conversion Scenario – this assumes that a development approach is taken with the logging of the Prey Lang Evergreen Forest Core Zone resulting in its degradation followed by the progressive conversion of land into agriculture, plantations and a mosaic landscape as seen in the Upper and Lower Prey Lang Forest areas.

- The Conservation Scenario – this assumes that the Core Zone is gazetted as a Protected Area and measures are taken to conserve the forest including stopping the progressive degradation of the Western and Southern Tips.

The issues examined were primarily of hydrology including the impacts of the conversion on soil and water conservation, precipitation, flooding and seasonal flows. There was also a brief examination of other relevant issues including the impacts on livelihoods, biodiversity and downstream investments.

1.3 Conclusions from Scenario Analysis

The indicative conclusions of the hydrological analysis of the Conversion Scenario were:

- The Conversion Scenario would increase water flows and availability downstream due to decreased evapo-transpiration unless large-scale plantations replace the forest;

- Baseflows and rainfall will not be significantly affected unless large-scale clearing and conversion of the forest into plantations occurs;

- The impact on flooding downstream will not change significantly;

- The **most significant impact** hydrologically will be a **large increase in soil erosion and subsequent sedimentation** of the eroded soil **downstream**.

Additional impacts can be expected in terms of livelihoods, fisheries, biodiversity and downstream impacts:

- Local livelihoods will be negatively affected by loss of the resin trade and income and food from non-timber forest products (NTFPs). This will reduce sustainable income generating opportunities and affect nutrition and food security of the local people who depend on the forest. On the other hand, conversion of the forest can open up additional farmland for cropping and plantations and other investments can provide off-farm labour. The large increase in land available would inevitably result in rapid in-migration.

- A major negative impact will result on the downstream Stung Chinit Integrated Rural Infrastructure Project due to sedimentation of the reservoir and the distribution network of canals and drains. This will reduce the capacity of the reservoir for dry season irrigation, give rise to shallow water vegetation and increased water losses from evaporation and evapo-transpiration. The only way to remediate the problems would be expensive dredging of the reservoir.

- This will result in severe damage to or complete loss of the planned fisheries investment within the Stung Chinit reservoir that is a key component of the foreseen benefits planned. The fisheries within the catchments overall will likely be negatively affected primarily due to increased sedimentation and changes in water quality and habitat.

- There will be an enormous loss of biodiversity in plants, terrestrial animals, birds and insects with indirect impacts in other nearby forests designated as wildlife conservation areas.

1.4 Economic Values and Impacts

The economic valuation presented within this brief study is indicative and based on a simple model and assumptions and therefore serves only as a rough approximation of different potential costs and benefits. It is sufficient to show that there is great economic value in Prey Lang Forest in both scenarios with likely revenue generation potential of hundreds of millions of dollars. Based on the analysis, the following is concluded in terms of the economic values of the conversion scenario:

- By far the largest value of the Conversion Scenario is gained in extracting the timber – this provides the easiest and fastest way for the Government to convert the natural resources into revenue.

- The Conversion Scenario incurs a large opportunity cost from the loss of carbon credits that would otherwise be available from the conservation of the Prey Lang Evergreen Forest Core Zone and other areas. This could provide a revenue stream well in excess of that required for improving conservation of the forest while keeping the ‘capital’ of the commercial timber which will increase in value.

- The loss of the carbon stocks from the Conversion Scenario could potentially count against the country's overall carbon stock balance, resulting in reduced carbon credits available for forest carbon projects elsewhere in Cambodia. The value of these carbon stocks will multiply the opportunity cost since they would count as a loss within the National Carbon Accounting System.

- Additional ongoing revenues and benefits would be gained by the increase in settlement and agriculture in the area, although these would be offset by the required investment in infrastructure and services for the populations that would have to be provided by the Government. Increased settlement could also support government macro-economic policy goals.

- The Conversion Scenario would severely compromise the $24.3 million dollar investment in the Stung Chinit Integrated Rural Infrastructure Project and result in its becoming uneconomical. These losses compromise any benefits gained from agriculture and plantations.

- Large-scale conversion of the Core Zone to plantations would likely have significant negative impacts on water availability and flows and would further increase the soil erosion and sedimentation and fisheries problems downstream. The likely productivity of the plantations would be low due to the poor underlying soil quality.

1.5 Conclusions of Economic Analysis

1. The economic values of the two scenarios are roughly equal in terms of the likely funds that could be accessed.

2. The Conservation Scenario would generate long-term financing for protecting and monitoring the Prey Lang Forest and for sustained government revenues while maintaining the forest's core assets and ecological functions.

3. The Conversion Scenario provides the easiest means of accessing short-term funding but would incur external costs and ecological damage that would significantly reduce the benefits over the long-term.

4. Currently, a strong economic case can be made to conserve the forest only in the context of soil conservation and the carbon market – research into the economic value of the biodiversity, livelihoods and fisheries impacts is urgently needed.

5. The comparative differences between the two cases narrow if Reduced Impact Logging is practiced as this could significantly reduce the sedimentation of the Stung Chinit and carbon stock losses.

1.6 Potential Development and Its Impacts

The potential development projects in or around the Prey Lang Evergreen Forest Core Zone are listed in order of importance in terms of their potential impact on the Core Zone are listed as follows:

1. The Existing Timber Concessions Covering the Prey Lang Evergreen Forest Core Zone;
2. The Existing Road Networks and Plantations;
3. Expansion of Plantations;
4. The Kuwait Fund Stung Sen Hydropower/Irrigation Project;
5. The Mineral Concessions in the Lower Prey Lang Degraded Evergreen and Phnom Bokpou Semi-Evergreen Forest;
6. Mineral Concessions in the Upper Prey Lang Degraded Evergreen Forest;
7. The Sambor Mainstream Mekong Hydropower Dam.

The region as a whole is relatively undeveloped and has a low population, hence the area is mostly forest. Progressive settlement and conversion of the forest is occurring at a slow rate (<1%/year) with relatively little external stimulus, and logging has stopped since 2001 and the timber concessions are currently suspended. However, there are now a large number of ongoing and planned investments in mining and agricultural plantations, indicating the strong interest of the Government in accelerating economic activity especially as population pressure elsewhere grows and funding pressure increases.

While there are a range of plans for development within the different ministries, no overall coordinated plan exists and the investments are managed by different companies dealing with different agencies. As such, they are likely to proceed piecemeal according to their own considerations. Increased development is considered highly likely given the government priorities and the interests of the investors, several of whom have deep pockets.

The key in whether this development is beneficial is whether a balance is struck in managing the critical natural resources in the area and the interests of the local people, both existing and in-migrants. Having an overall plan that incorporates all of the different interest groups and examines natural resource management in the context of all of the development being considered is an important need.

Given that some development is going to occur, it makes sense to prioritize actions to maximize the likelihood of the conservation of the Core Zone. This would include as the first priority having the Core Zone gazetted as a Protected Area to ensure cancellation of the timber concessions and provide a legal framework for its protection. Contact and dialogue should be maintained with involved investors and agencies for projects that move forward to try to reduce potential negative impacts. A start should be made towards accessing carbon credits through the voluntary carbon market.

1.7 Study Conclusions

1. The Study Area is composed of a number of different forests ranging from the primary evergreen forest of the Prey Lang Core Zone, to other good quality, degraded and secondary evergreen forest, good quality and degraded semi-evergreen forest and a large area of lower quality dry deciduous forest. The unique nature of the Prey Lang Evergreen Forest Core Zone within this landscape of other biomes and connection and proximity to wildlife reserves emphasize the importance of the area for biodiversity.

2. The area is seeing a number of plans being proposed for development that would involve large foreign direct investment in a range of potential projects including timber concessions, hydropower and large-scale irrigation projects, new roads, mineral concessions and plantations. The planned developments would require a major increase in the local population and provide large employment opportunities and a major upgrade of infrastructure in the region. This is occurring in an area already in a state of flux as communication networks and settlements increasingly encroach on the already fragmenting forest areas of the region.

3. The scenarios developed for this Study are rough approximations intended as a means of better understanding the complex interactions and impacts that conversion of the Prey Lang Forest Core Zone could bring. Much more research and analysis would be required to improve the scenario accuracy and applicability.

4. Despite these caveats, the scenario comparison demonstrated that very significant financial benefits could derive from the conservation of the forest primarily through increased soil conservation and prevention of loss of carbon stocks and that these benefits are reasonably equivalent if not greater than the royalties and other receipts that could derive from conversion of the forest. Given that the high value timber is liquidated in and the serious negative external impacts resulting from the conversion scenario, the benefits in this case primarily are that this is the quickest and easiest means for the Government to access ready funds. Any long-term analysis will likely demonstrate that this is a poor choice.

5. Thus, the fundamental conclusion is that the Prey Lang Evergreen Forest Core Zone is of considerable value both in realizable economic terms as well as less easily quantified environmental and livelihood functions. The Consultant strongly supports the recommendations of previous studies of the area recommending its conservation as a better alternative to conversion.

6. A balance will have to be struck between the drive for development and the need for conservation in order to meet Government priorities and in consideration of realpolitik. How investments are implemented will determine to what extent they cause negative impacts on the conservation of the Prey Lang Evergreen Forest Core Zone and efforts should be made to engage investors and Government partners to maximize the quality of these projects.

1.8 Study Recommendations

Given the complexity of the situation and the limited resources available, priority should be given to addressing the most pressing needs that would best ensure the conservation of the Core Area, namely:

1. The Government needs to prepare an overall regional plan that considers all of the various development and conservation options currently on the table in close consultation with the local populace and other stakeholders to better prioritize development options, preserve critical natural resources and livelihoods and ensure quality implementation.

2. The Prey Lang Evergreen Forest Core Zone needs to be gazetted as a Protected Area and arrangements secured for its protection and monitoring including cancellation of the existing Timber Concessions;

3. The access points to the Core Zone identified in Section 7.2 need to be sealed off from vehicular traffic;

4. The economic value of the biodiversity, carbon, NTFPs, fisheries and other positive impacts from conservation of the forest need to be better quantified and documented for inclusion in the case for conservation;

5. The threatened Southern and Western Tips of the Core Zone should be focused on to prevent their further degradation and access in order to at minimum preserve them as a buffer zone;

6. The local populace living within and on the edges of the Core Zone need to be engaged to better understand their situation, support continuation of the existing community forestry and to improve land management on the periphery of the forest.

7. Conservation groups must engage with and maintain involvement with investors and agencies promoting proposed projects to try to mitigate the largest potential problems and steer the investments towards a better result that contributes to the conservation of the Core Zone.

8. The Ministry of Water Resources and Meteorology should be contacted to gain an ally within the government based on their interest to avoid damage to the downstream Stung Chinit Integrated Rural Infrastructure Project.

9. Preparatory work should begin on accessing carbon credits through the Voluntary Carbon Market to gain a better understanding of the requirements, benefits and timeframes and move towards gaining tangible economic benefits from conservation.

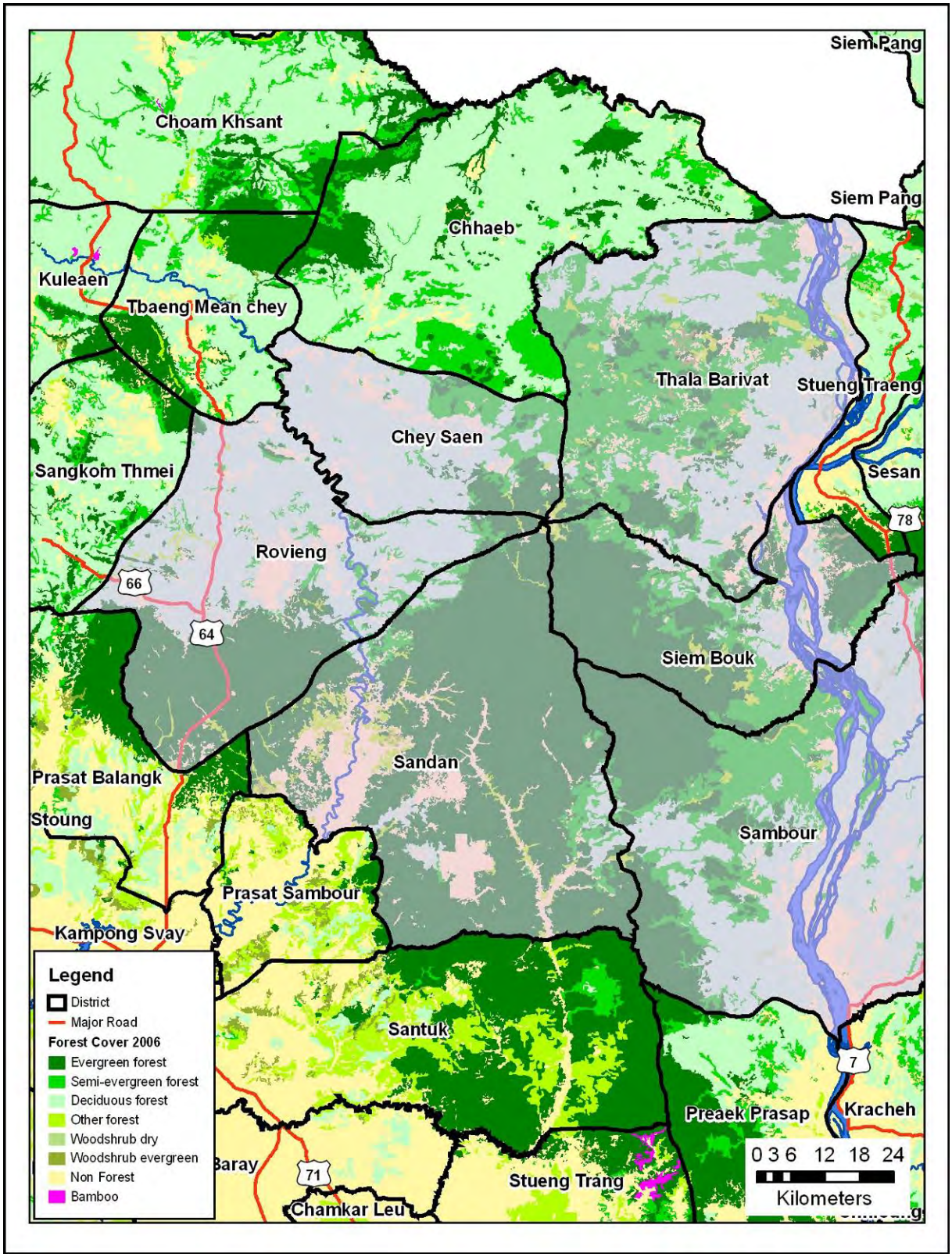

Figure 1: Study Area Location Map

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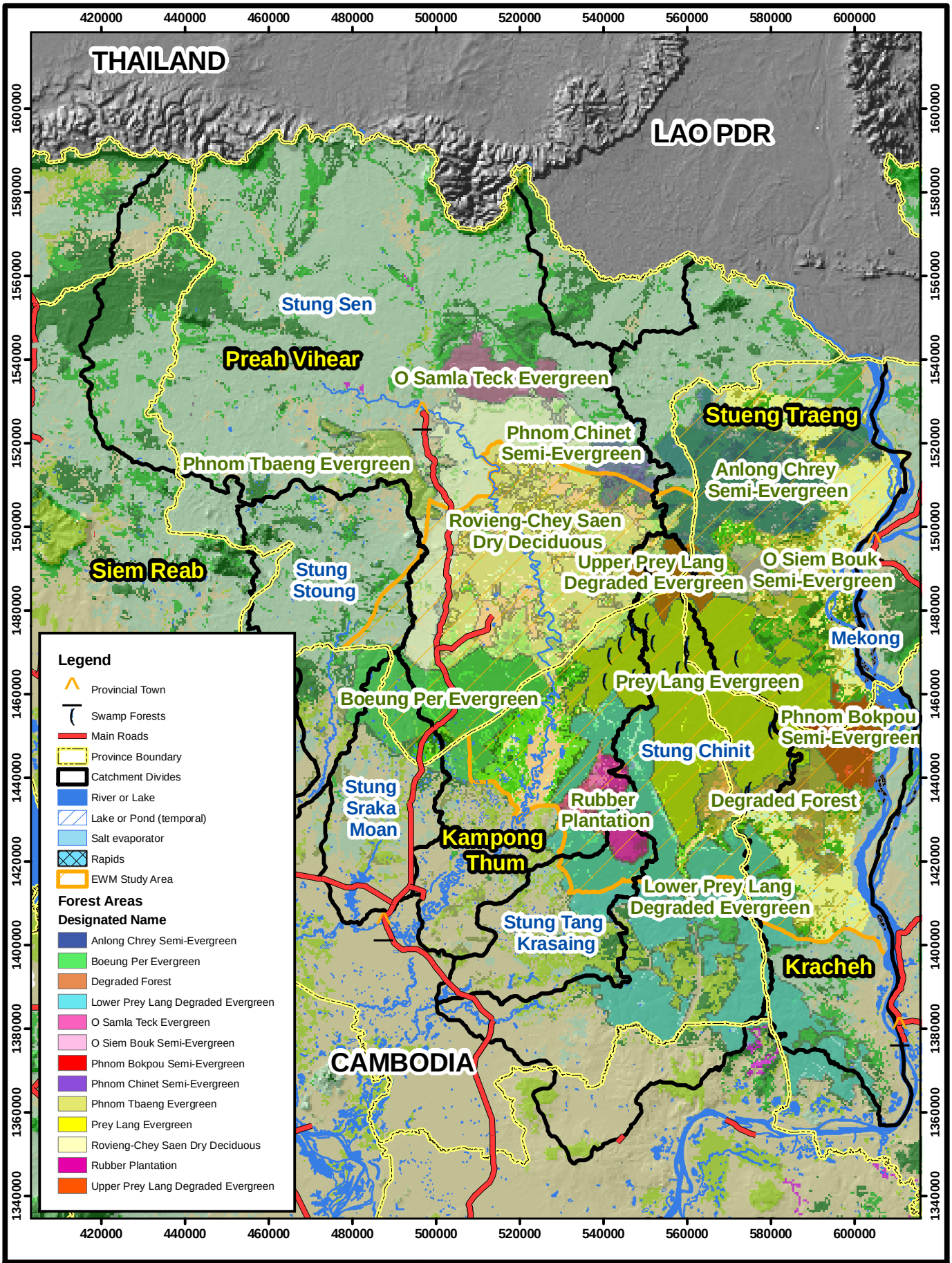
2 Introduction

This report was prepared by Aruna Technology Ltd. ("Aruna", the Consultant) for the East-West Management Institute (EWMI) as the final output for a contract to conduct a rapid assessment of the Prey Lang Forest in North-Central Cambodia. This Final Report combines the two parts previously submitted, Part 1 (Base Mapping, Time Series Analysis and Basic Classification) and Part 2 (Analysis of Scenarios for Development and Economic Values).

3 Study Area

The Study Area, as shown in Figure 1, was defined by administrative boundaries rather than natural boundaries such as catchment or land cover. Prey Lang Forest is described within the ***Independent Forest Sector Review*** (Danida, 2004) and defined roughly as a rectangular area in the references provided (Ashwell, D.A., 2008 and Olsson, A. & Barnett, D., 2007). The Study Area includes a significantly larger area surrounding Prey Lang Forest in order to assess the impacts of the different development scenarios in the region.

As seen in Figure 2, the Study area includes a mosaic of several distinct forest areas of different composition and condition. For convenience of discussion, these forests were defined roughly based on the land cover classification and examination of land conversion, roads, settlements and other activities that have degraded and converted the forest. The names of the forest areas in the map have been assigned for convenience by the Consultant and their names and approximate areas are listed in Table 1.



0 5 10 20 30 40

Kilometers

1 centimeter equals 15 kilometers

Figure 2: Prey Lang Catchments and Forest Areas

Coordinate System: UTM Zone 48, Horizontal Datum: WGS84
Forest Areas Approximate - Names Designated By Consultant

Table 1: Approximate Forest Areas and Forest Areas within Catchments

Forest Area	Total Forest Area (km²)	Mekong River	Stung Sen	Stung Chinit	Stung Taing Krasang	Stung Sraka Moan	Stung Stoung
	Catchment Area (km²) and Proportion (%)						
Anlong Chrey Semi-Evergreen	1,048.0	1,033.6	10.8	3.5			
%	9.9%	98.6%	1.0%	0.3%			
Boeung Per Evergreen	890.4		549.6			242.3	98.5
%	8.4%		61.7%			27.2%	11.1%
Degraded Forest	352.2	207.9		144.3			
%	3.3%	59.0%		41.0%			
Lower Prey Lang Degraded Evergreen	2,471.2	432.6	330.6	1,281.6	275.5		
%	23.3%	18.6%	14.2%	55.2%	11.9%		
O Samla Teck Evergreen	271.2		271.2				
%	2.6%		100.0%				
O Siem Bouk Semi-Evergreen	166.5	165.8		0.7			
%	1.6%	99.6%		0.4%			
Phnom Bokpou Semi-Evergreen	298.8	298.8					
%	2.8%	100.0%					
Phnom Chinet Semi-Evergreen	192.0	0.2	191.8				
%	1.8%	0.1%	99.9%				
Phnom Tbaeng Evergreen	246.0		229.1				16.9
%	2.3%		93.1%				6.9%
Prey Lang Evergreen	1,871.7	512.0	277.4	1,081.7			
%	17.7%	27.4%	14.8%	57.8%			
Rovieng-Chey Saen Dry Deciduous	2,328.4	22.0	2,275.8	29.3			1.3
%	22.0%	0.9%	97.7%	1.3%			0.1%
Tumring Rubber Plantation	257.8		158.4	32.2	67.2		
%	2.4%		61.4%	12.5%	26.1%		
Upper Prey Lang Degraded Evergreen	232.2	61.4	44.1	126.7			
%	2.2%	26.4%	19.0%	54.6%			
TOTAL	**10,600.4**	**2,734.4**	**4,305.0**	**2,707.7**	**342.7**	**242.3**	**116.7**

Of these forests, Prey Lang Evergreen, also referred to as the Prey Lang Evergreen Core Zone and as the Core Zone, is the forest in the most undisturbed condition as shown in the map in Annex 2: Forest Disturbance. The other forest area nearby that appears to be in the least disturbed condition is the Phnom Bokpou Semi-Evergreen Forest.

4 Mapping

4.1 Current Base Map of Study Area

The most current base map of this area is of small scale (1:100,000) and is now 10 years old. Given the substantial infrastructure development in the area, an up-to-date base map was prepared showing roads, tracks, village areas and rivers and streams.

The primary data source for the base map of the study area was ALOS AVNIR satellite imagery, which has a resolution of 10m. Four images covering 60km x 60km each were acquired from January and March 2009 as shown in Figure 3. The images were ortho-rectified using existing ground control, a process which reduces terrain errors and allows integration and overlaying with other data.

Mapping was performed by on-screen digitalisation in ArcGIS at a scale of approximately 1:20,000. Roads and tracks were classified by type, following the standard for topographic maps in Cambodia.

Data for the base map was also acquired from government sources, including village and administrative boundaries (2005) and village survey data (2007). These data will allow the preparation of maps showing population, livelihood indicators and social indicators. The base map of the study area has been delivered in hardcopy and digital format, the catalogue for which is given in Annex 3.

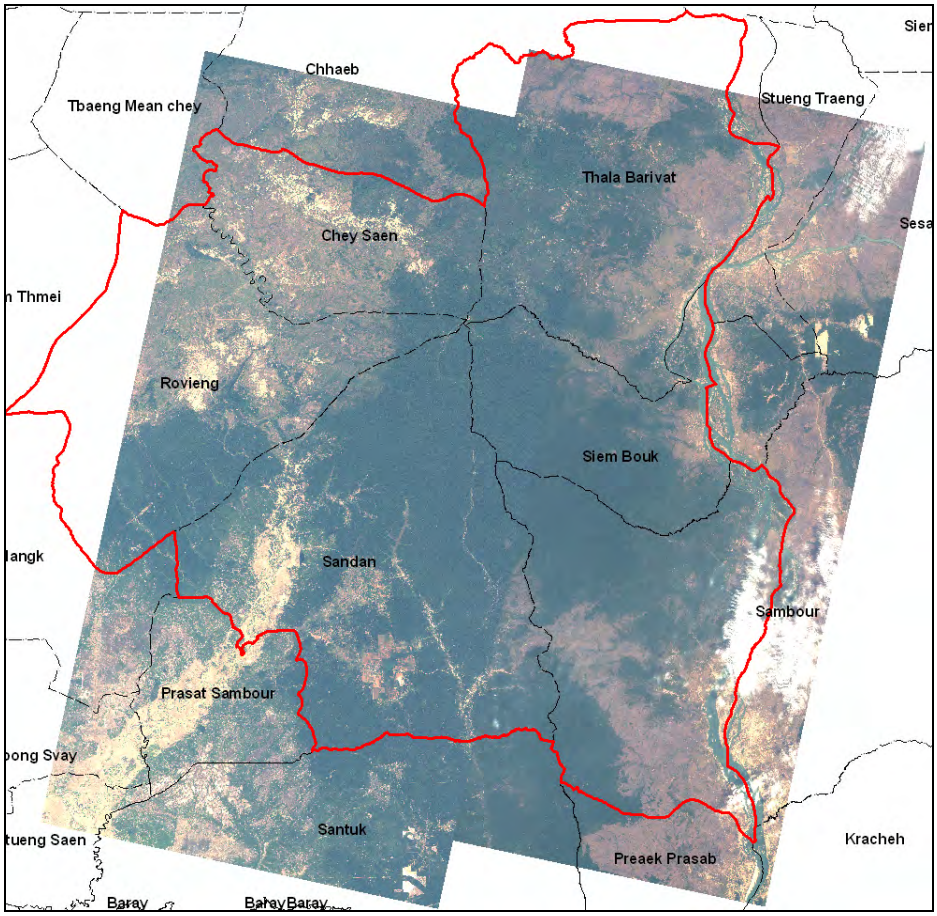


Figure 3: ALOS AVNIR 10m Imagery Acquired for the Study

4.2 Time Series Analysis of Satellite Imagery

4.2.1 Approach

LandSAT satellite imagery is available covering the project area since the early 1970s. Having a time series of imagery was allowed observation of changes in forest cover in these locations. The following images were used in the present study

No.	Year	Date	Satellite
1	1973	3-Jan-73	Landsat1 MSS
2	1984	11-Dec-84	Landsat1 MSS
3	1990	4-Dec-90	Landsat5 TM
4	1997	5-Dec-97	Landsat5 TM
5	2000	31-Dec-00	Landsat7 ETM+
6	2005	26-Dec-04	Landsat7 ETM+
7	2009	30-Jan-09	Landsat5 TM

An additional year, 2009, was added to the list after the project started, when it was discovered that a good image was available from January. The years 1990, 2000 and 2005 as these are the years that are considered important for REDD assessment, which could be undertaken as a further study.

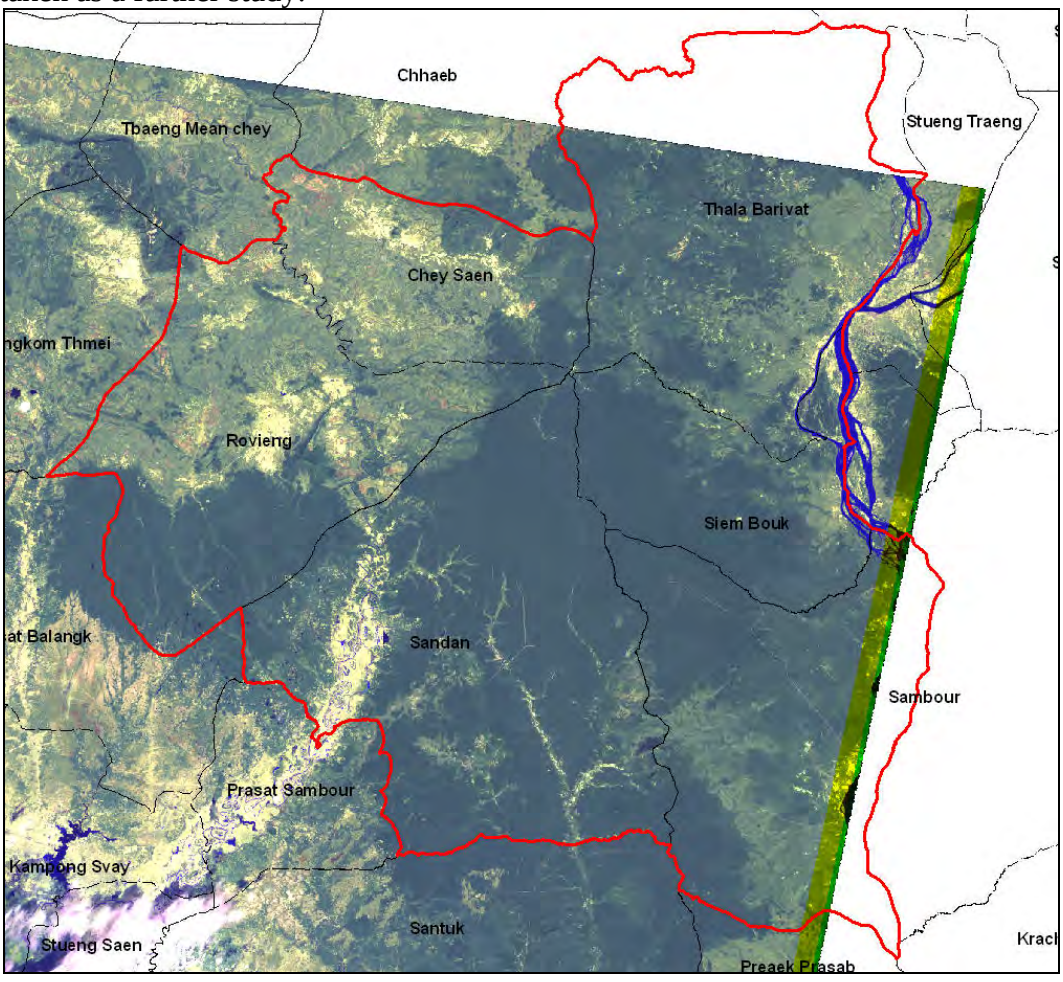


Figure 4: Study Area overlaid on a typical Landsat image

It should be noted that due to the large size of the study area, there was generally about 90% coverage in a given year as shown in Figure 3. The northern part of Thala Barivat and parts of Sambour district were not covered.

Change detection was undertaken by merging images into date pairs (i.e. 1973-1984, 1984-1990) and then running an unsupervised classification on the merged pair. The goal of unsupervised classification is to automatically segregate pixels of a satellite image into groups of similar spectral character. Classification is done using a statistical routine generally called "clustering" where classes of pixels are created based on their shared spectral signatures. Clusters are split and /or merged until further clustering doesn't improve the explanation of the variation in the scene. For this project, ISO Data unsupervised classification was used as it is generally considered the most robust for land cover studies. The change detection methodology is illustrated below in Figure 5.

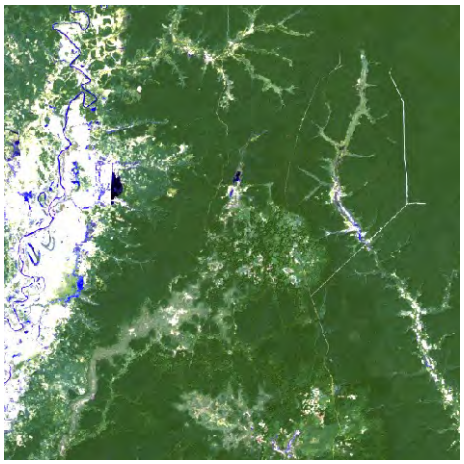
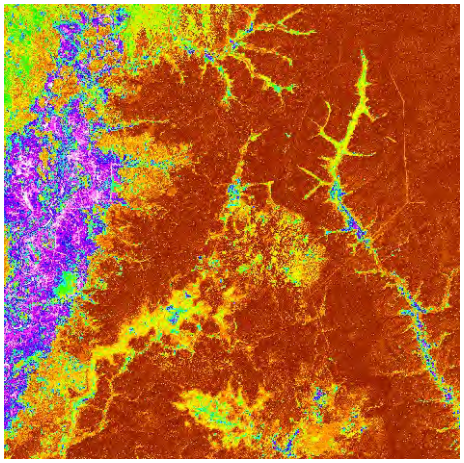
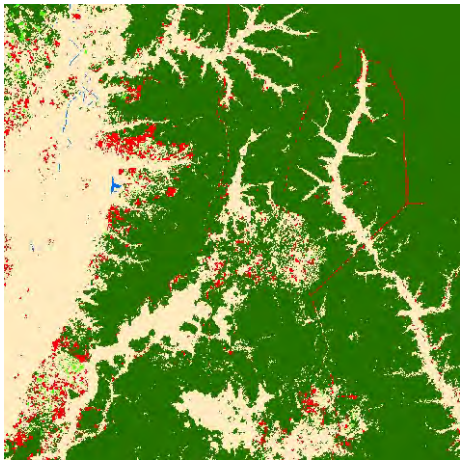
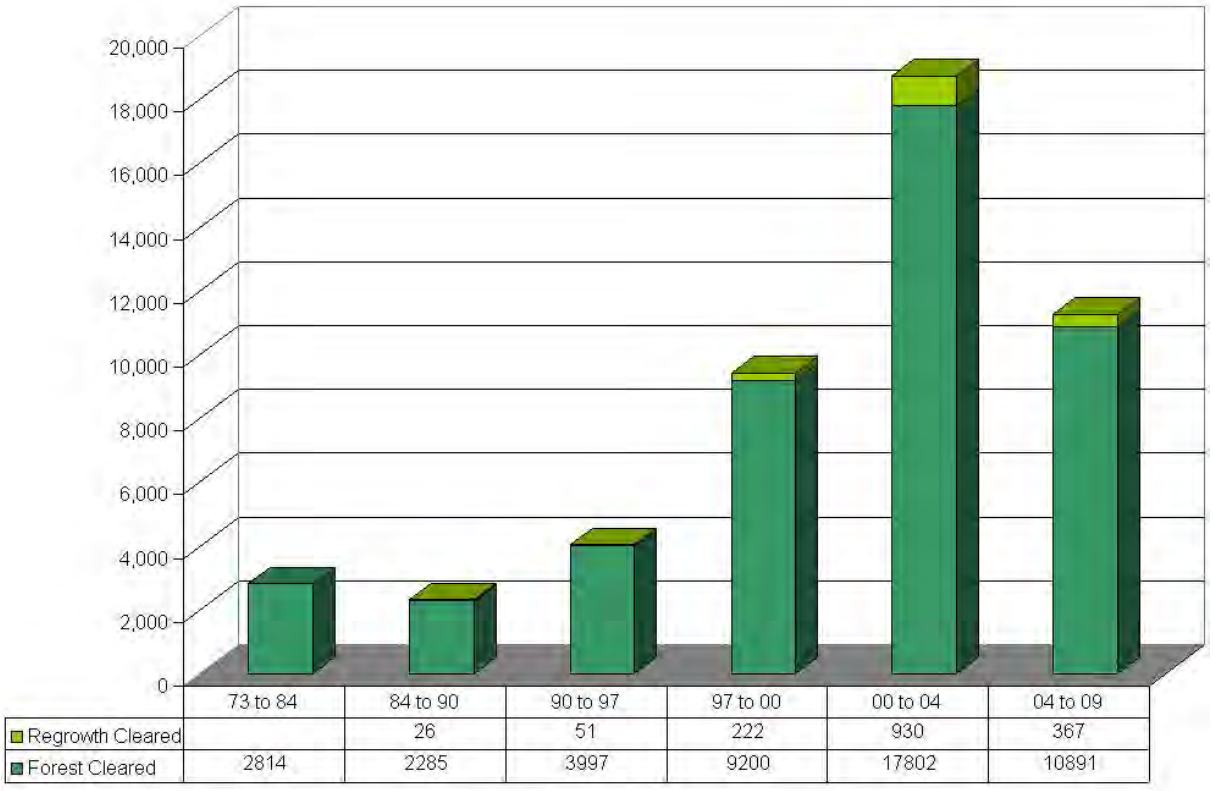
	Original image displayed with three of 6 image bands displayed as Red, Green, Blue.
	Classified image, with each image pixel assigned to a class based on spectral similarity. The image is thus reduced from a multiple image channels to a single image channel with values from 0 to 255. Classes are then aggregated by visual inspection in to one of the following categories (a) Forest (b) Forest clearing (c) Non-forest (d) water. Only the forest clearing class is examined in a high level of detail. The other classes are not accurately defined, but rather serve to assist the identification of clearing.
	The aggregated result where the image is now reduced to four categories. Forest (Green), Forest clearing (Red), Non-forest (Buff) and Water (blue).

Figure 5: Change Detection Steps

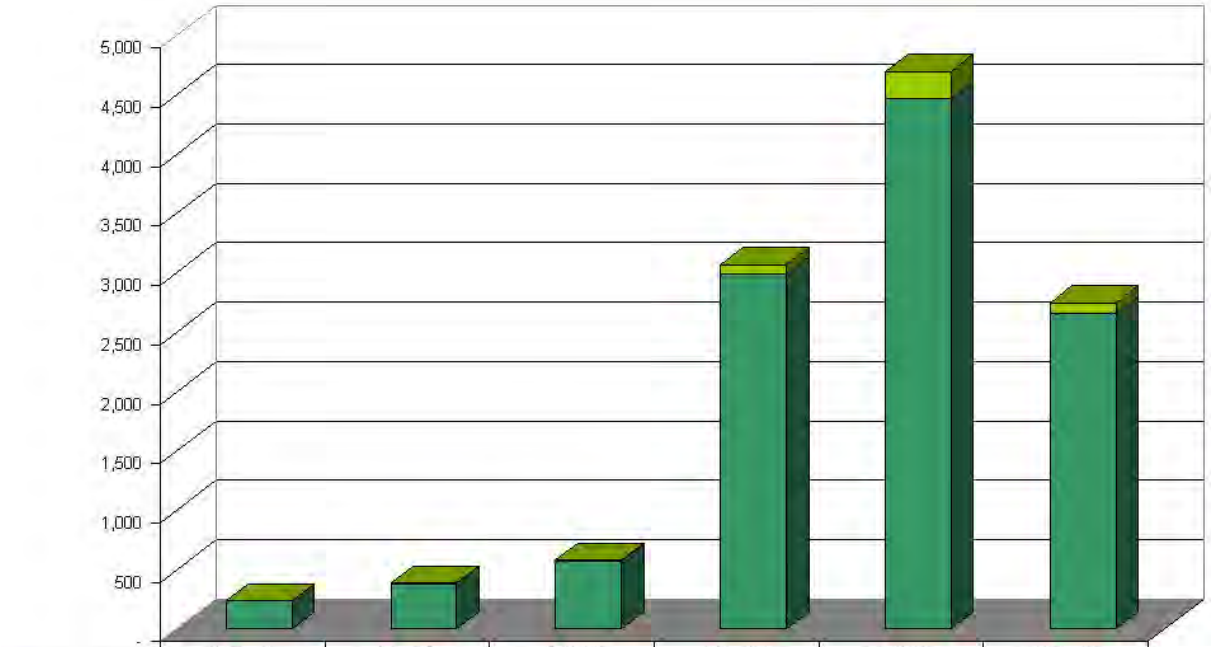
4.2.2 Results of Change Analysis

As can be seen from in Figure 6 and Figure 8 below, the rates of clearing have greatly increased since 1997 compared to earlier years, though in the most recent period (2004 to 2009) the rate has decreased slightly.



	73 to 84	84 to 90	90 to 97	97 to 00	00 to 04	04 to 09
Regrowth Cleared		26	51	222	930	367
Forest Cleared	2814	2285	3997	9200	17802	10891

Figure 6: Total Area Cleared (Ha) for each time period



	73 to 84	84 to 90	90 to 97	97 to 00	00 to 04	04 to 09
Regrowth Cleared	-	4.35	7.28	72.22	233.14	89.54
Forest Cleared	235.58	381.88	570.33	2,992.87	4,462.73	2,657.23

Figure 7: Annual Rates of Clearing (Ha) for each time period

In context, these rates of clearing are very low in percentage terms (<1% per year), given that this study has estimated there to be about 840,000 Ha remaining in 2009. See Table 2 below. As previously noted, the 2009 analysis covered about 90% of the entire study area (1,190,410 Ha) due to slightly limited satellite coverage the coverage.

ID	Class	Ha '06	% '06	Ha '09	% '09
1	Evergreen Forest	431,908	41.1%	406,884	38.8%
2	Semi-Evergreen Forest	185,861	17.7%	160,724	15.3%
3	Degraded Forest/Other Forest	23,743	2.3%	80,178	7.6%
4	Deciduous Forest	282,891	27.0%	192,398	18.3%
	Sub-Total Forest	*924,403*	*88.1%*	*840,184*	80.0%
5	Non-Forest	125,252	11.9%	209,471	20.0%
	Total	**1,049,654**	**100.0%**	**1,049,654**	**100.0%**

Data Sources: 2006 (Forestry Administration), 2009 (Current Study)

Table 2: Comparison of Forest Cover in 2006 and 2009

Caution should be exercised in direct comparison of the 2006 mapping by the Forestry Administration and 2009 forest cover mapping undertaken as part of the current study. The 2006 mapping is based on manual interpretation while the 2009 mapping is based in semi-automated mapping. In particular, mapping of forest classes with low canopy density, such as deciduous forest by automated methods is quite difficult and it tends to be classified as non-forest. Therefore, the figure for Deciduous forest for 2009 given above is a slight underestimate, while the estimate for non-forest is probably a slight overestimate.

Although the present study did not produce land cover maps for each year in the analysis, this information is available from other sources and can be used for general comparisons. If we examine the 1976 land cover mapping from the MRC and compare it to the 2006 mapping from the Forestry Administration, there has been a loss of approximately 7% of the forest cover in this time period.

Clearing of forest has occurred mostly by shifting agriculture, agricultural expansion and the development of or large plantations, most notably the Tumring rubber plantation. Timber extraction in Prey Lang is typically very selective and dispersed so is not a large component of the clearing rates shown here. A typical logging operation is shown in Figure 8 below.

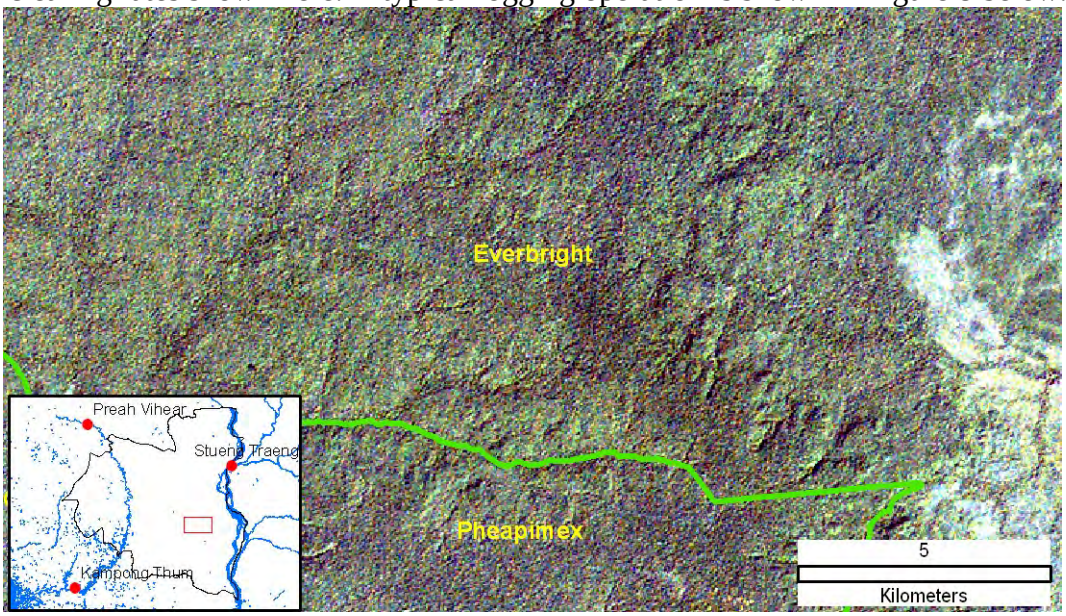


Figure 8: Satellite Image Dec 1997, prior to logging

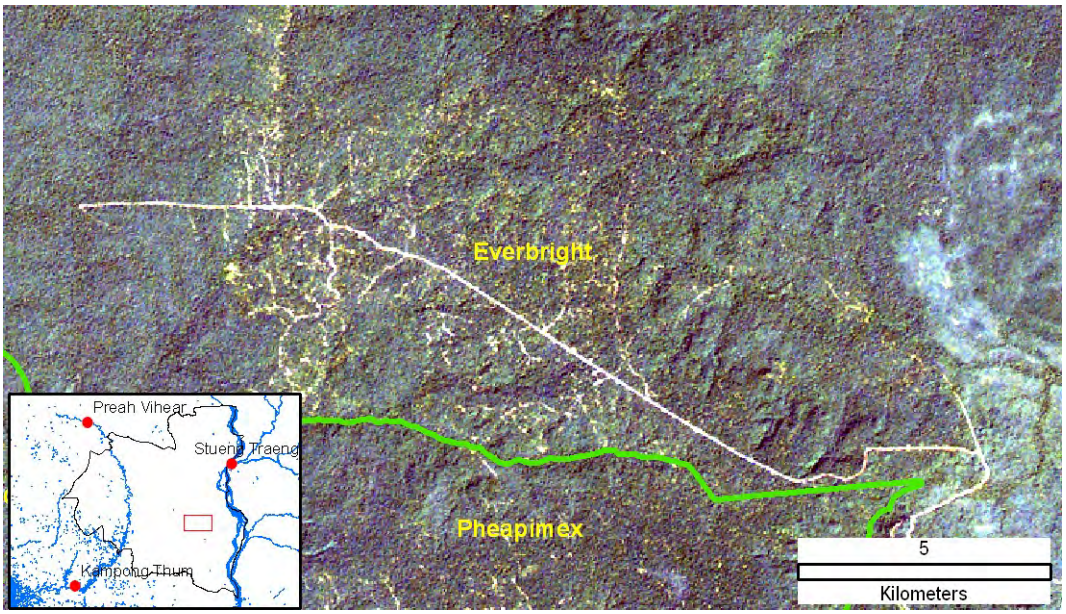


Figure 9: Dec 2000 image with new road and extensive logging trails shown in Everbright and Pheapimex Forest Concessions.

It should be noted that while the change detection and mapping was conducted with a high degree of rigour, it was not within the scope of the current project to validate the results in the field. In particular, it is very difficult to precisely define degraded forest from intact forest especially where there have been low levels of degradation e.g. selective logging. Forest that has been cut, especially due to shifting cultivation re-grows very quickly and can form a relatively dense canopy with a few years. Whilst such re-growth would obviously have lesser biodiversity and carbon stocks than intact forest, it can be very difficult to distinguish the two by remote sensing methods. Similarly, when a clearing event is identified, it is difficult to know precisely what the age and conservation value of the cut forest was and in some cases may represent clearing of re-growth. Although field verification was not undertaken, validation and refinement of the mapping was undertaken by reference to other data sources, such as forest cover mapping conducted by the Forestry Administration, Ministry of Agriculture, Forestry and Fisheries.

Although forest degradation can be difficult to map some studies have modelled disturbance based on proximity to human activity such as roads and villages. According to the analysis of forest disturbance conducted by DANIDA/FA in 2002, there was approximately 432,000Ha of “Less disturbed Forest” or approximately 50% of the total forest cover in the study area.

5 Classification of the Recent Satellite Image

Classification of the 2009 ALOS satellite imagery has already been mentioned in brief as part of the forest cover discussion above. The full classification schema along with areas and percentages for each class is given below.

ID	Class	Hectares	%
1	Evergreen Forest	406,884	38.8%
2	Semi-Evergreen Forest	160,724	15.3%
3	Degraded Forest	80,178	7.6%
4	Deciduous Forest	192,398	18.3%
	Total Forest	*840,184*	*80%*
5	Woody Shrubland	24,631	2.3%
6	Grass	117,574	11.2%
7	Plantation	12,101	1.2%
8	Paddy	39,507	3.8%
9	Bare	4,049	0.4%
10	Water	11,290	1.1%
11	Cloud	319	0.0%
	Total Non-forest	*209,471*	*20%*
	Grand Total	**1,049,654**	**100%**

Table 3: Full Classification Schema of 2009 Image

The map of the resulting classification can be seen in Annex 2 – Maps.

The process to classify the imagery was as follows:

- Run unsupervised classification, evaluate results to see how well classes separated;
- Label classes with appropriate land cover class by visual inspection
- Aggregate sub-classes into main classes.
- Filter small polygons and vectorise results, smooth lines;
- Manual cleanup and quality control;
- Calculation of areas and map preparation.

6 Scenario Analysis

6.1 Catchments

As seen in the Catchment Map of, the Study Area includes parts of six different catchments as listed below with their areas[1]:

Table 4: Approximate Catchment Areas and Percentage Within Study Area

Catchment	Area (Sq. Km)	Within Study Area (Sq. Km)	Within Study Area (%)	Study Area as % of Catchment
Mekong	7,442	5,265	44%	0.7%
Stung Sen	13,696	4,097	34%	30%
Stung Chinit	4,485	1,965	17%	44%
Stung Taing Krasang	1,126	220	2%	20%
Stung Sraka Moan	1,234	201	2%	16%
Stung Stoung	1,968	155	1%	8%
Total	**29,950**	**11,904**	**100%**	**N/A**

Each of these catchments is described in detail in relation to its topography, land cover, development trends, ongoing or planned concessions and issues in relation to Prey Lang Forest and other forests going from Upstream to downstream in Annex 6.

6.2 Basic Scenarios for Comparison

In order to discuss the impacts of soil and water conservation, it is necessary to define the scenario being examined as an infinite range of possibilities exist and the topic is by nature extremely complex. It must be understood that this is a brief study and attempts to place the issues within an approximate economic and physical context. The specific impacts of potential or planned investments such as timber concessions, plantations or mining concessions are discussed in Section 5 including those in respect of soil and water conservation.

The scenarios to be compared are:

- The Conversion Scenario – this assumes that a development approach is taken and the Prey Lang Evergreen Core Zone is converted into degraded and secondary forest and other land use.

- The Conservation Scenario – this assumes that the Core Zone is protected and further degradation stopped through improved management.

The basic assumption in the analysis is that not intervening to gazette the Prey Lang Evergreen Forest Core Zone as a Protected Area and/or otherwise protect it, will inevitably

[1] The Mekong River Catchment in total is much larger of course this area refers to the particular section of the river's catchment indicated on the map. The area within Study Area in relation to the total catchment of the Mekong River is listed in the final column.

result in its being partitioned and converted into patches of degraded evergreen forest within a mosaic landscape along with a steady increase in conversion to plantations.

This is based on examination of what has happened within the Upper and Lower Prey Lang Degraded Evergreen Forest area where timber concessions removed the high value timber and built logging roads and trails into the forest thus partitioning it followed by expansion of settlement and farmland into the area with several of the areas becoming community forest. In this scenario, it is likely that most of the concessions within the area would proceed, however these will be examined individually and as a whole in Section 5. In addition to what has happened within the Lower Prey Lang Forest, there is a serious possibility of a major increase in conversion of large areas into plantations to meet the strong demand from international investors.

6.3 Soil and Water Conservation

A number of issues can be discussed and assessed based on the hydrological situation and conditions described above. These are briefly outlined below.

Much of the analysis is based on the previous work of and recent paper published by Dr. L.A. Bruijnzeel regarding the hydrological functions of tropical forests which represents the current state of the art in terms of understanding of these issues compiled from ongoing research (Bruijnzeel 1990; Bruijnzeel 2004 – summary of issues from Bruijnzeel 2004 included as Annex 4: Summary of Bruijnzeel, 2004). The findings are summarized for the effects of converting tropical forest in Southeast Asia terms of soil and water issues.

Issue	Applicability to Conversion of Prey Lang Forest
1. Precipitation	• The impact of the conversion of Prey Lang Forest on precipitation locally and regionally would likely be minimal given that the conversion would be gradual and not involve clearing of large areas and a recovered response would follow relatively quickly from regeneration of secondary forest and vegetation.
2. Changes in Catchment Water Yield (the amount of rainfall that flows from the streams of the catchment)	• The degradation and removal of significant amounts of Prey Lang Forest will cause progressive increases in total water yield as areas are logged and converted, with the amount of water yield increasing with more biomass removed; • Overall the Prey Lang Forest area will have reduced impacts in terms of changes as a result of its lower elevation, lack of steep slopes and relatively deep soils; • Practices in the conversion have a major impact on soil and water conservation.
3. Changes in Water Yield with Forest Regeneration	• The increase in water yield is initially high then falls as forest regrows as evapo-transpiration increases; • Values of an annual increase in water yield of 250 mm/year and a regrowth of 3-5 years are reasonable estimates for conversion of Prey Lang Forest and subsequent secondary forest regrowth.
4. Changes in Water Yield Following Forest Conversion	• As the likely conversion scenario would include an increase in population and concurrent increase in agricultural land area, this will be considered in the analysis with water yield increases of 150 mm/year; • As plantations are a likely future land use in the conversion of Prey Lang Forest, these factors will be included within the analysis.
5. Effects of Scale	• Any analysis must be speculative and a number of different scenarios and models should be considered – this is not possible under the scope of the current Terms of Reference (TOR); • Any model must incorporate a wide range of data and research into specific local parameters should be encouraged.
6. Changes in Flow Regime – Dry Season Flow	• Given Prey Lang's deeper soils, impact of changes in the flow regime would likely be accentuated, but it is not foreseen within the scenario that there would be large-scale changes in terms of conversion to plantations or other uses that would involve a significant change in the surface runoff coefficients enough to affect baseflows; • This issue does need to be considered in the case of conversion of the forest into large-scale plantations of fast-growing tree crops.
7. Changes in Flow Regime – Stormflows and Floods: Local Effects	• Given Prey Lang Forest's low slopes, soils, and rainfall patterns (high intensity/ duration storms on occasion), can expect medium impacts in terms of increases in flood flows after conversion; • A value of 20% is considered reasonable for most local areas given that large amounts of land clearing and heavy machinery use are not anticipated within the scenario; • This emphasizes the importance not only of what conversion of forest is to but also how that conversion is managed – promotion of good

	practice can dramatically reduce soil and water losses.
8. Changes in Flow Regime – Stormflows and Floods: Off-Site Effects	• Impacts cumulatively on downstream flooding within the Stung Sen and Mekong Catchments will be minor since the Prey Lang Forest constitutes only a small part of their respective catchments; • Impacts cumulatively on the Stung Chinit Catchment will be more significant as it comprises 24.1% of the total catchment area, however as noted in extreme events land cover effects are minimal. Furthermore, hydrological modeling analysis of the Stung Chinit Hydropower Dam to estimate peak flood flows demonstrated that the long and thn shape of the catchment results in significant attenuation of flood flows from the top of the catchment; • Impacts can be more severe depending on land conversion practices however any changes that occur in flood flows are not expected to cause significant damage downstream other than a small loss of available water in the wet season for the Stung Chinit Irrigation System due to increased spilling.
9. Hydrological Effects of Reforestation	• Effects of reforestation on peak and stormflows will be dependent on land development and use practices but these are mainly governed by the size of the rainfall event; • Effects of regeneration of secondary forest will likely restore the previous situation in respect of peak and stormflows so have little impact other than during the first 3 years of regrowth.; • There are no discernable effects of reforestation on baseflows.
10. Catchment Sediment Yield – General	• Soil erosion and sedimentation is the most significant hydrological issue in conversion of the Prey Lang Forest; • Low suspended sediment yields can be expected from the Prey Lang Forest in the present situation with large increases dependent on the soil conditions, conversion and land use practices; • Impacts from sedimentation will be attenuated through the system with the degree and scale of the impacts dependant on the amount and type of erosion, climactic events, geo-physical and morphological considerations.

11. Surface Erosion	• The present situation with Prey Lang Forest intact consists of very low surface erosion and this will not change significantly unless poor management practice or damaging cropping systems or plantations are what replace the forest;
	• Good management through community forestry can contribute positively to reduce soil erosion in damaged areas;
	• Conversion practice is the main surface erosion factor in increased surface erosion through logging operations and construction or roads and settlements;
	• From Table 5, we can infer the following approximate values for land cover surface erosion rates:
	  • Natural Forest/Fallow Secondary Forest – 1 ton/ha/year;
	  • Plantations with Ground Cover – 3 tons/ha/year
	  • Shifting Agriculture – 3 tons/ha/year
	  • Plantations without Ground Cover – 50 tons/ha/year

12. Gully Erosion	• Gully erosion is a significant factor in soil conservation and is mostly related to design and implementation of infrastructure and settlements.
13. Mass Wasting	• Mass wasting is not likely a significant factor given the geology and slopes of the Prey Lang Forest for deep-seated landslides; • For shallow slides, land cover has an influence however these contribute relatively little to stream sediment loads; • Therefore, this issue can be neglected in the analysis for Prey Lang Forest.

14. Catchment Sediment Yields	• From Figure 11 below, we can infer the following approximate values for suspended sediment yield for different land uses:
	  • Undisturbed Forest – 1 ton/ha/year;
	  • Logged Forest (non-Reduced Impact Logging) – 150 tons/ha/year
	  • Logged Forest (RIL) – 0.4 tons/ha/year
	  • Cleared Forest – 40 tons/ha/year
	  • Medium-large basins, mixed land use – 30 tons/ha/year
	  • Urbanized – 40 tons/ha/year
	  • Mining and Road Building – 100 tons/ha/year
	• The impacts of logging urbanization and roads will subside significantly after a few years due to revegetation and stabilization.

Table 5: Surface Erosion rates in tropical forest and tree crop systems (tons/ha/year)[2]

	Minimum	Median	Maximum
1. Natural forests (18/27)[a]	0.03	0.3	6.2
2. Shifting cultivation, fallow phase (6/14)	0.05	0.2	7.4
3. Plantations (14/20)	0.02	0.6	6.2
4. Tree gardens (4/4)	0.01	0.1	0.2
5. Tree crops with cover crop/mulch (9/17)	0.10	0.8	5.6
6. Shifting cultivation, cropping phase (7/22)	0.4	2.8	70
7. Agricultural intercropping in young forest plantations ('taungya') (2/6)	0.6	5.2	17.4
8. Tree crops, clean-weeded (10/17)	1.2	48	183
9. Forest plantations, litter removed or burned (7/7)	5.9	53	105

[a] (a/b) = number of locations/number of 'treatments'.

Based on the rough conclusions drawn above, one can estimate an approximate value to the conversion of the Prey Lang Evergreen Forest Core Zone and Degraded Forest into other uses in terms of soil and water conservation is described in Table 6 on the following page. Based on this, we can conclude the following:

- The impact in terms of water availability downstream will be positive as overall water yields will increase with removal of the forest, reflecting the reduced evapotranspiration from the new land use. Baseflows and rainfall will not be significantly affected unless large-scale clearing and conversion of the forest into plantations occur;

- While there are local impacts from changes in land use, the impact on flooding downstream will not be significant as the changes are relatively minor and will be

[2] After Wiersum, 1984. Bruijnzeel, L.A., 2004

attenuated. The size of a major rainfall event is the only important factor in this regard;

- The major impact from the conversion of the forest in terms of hydrology will be in the amount of soil erosion. This will cause losses of soil carbon and result in costs for downstream infrastructure in terms of reduced service life or water availability, problems with increased vegetative growth and anaerobic conditions within the shallower reservoir and greatly increased maintenance costs for dredging to remove sediment.

Figure 10: Catchment Sediment Yields as a function of land use and geology[3]

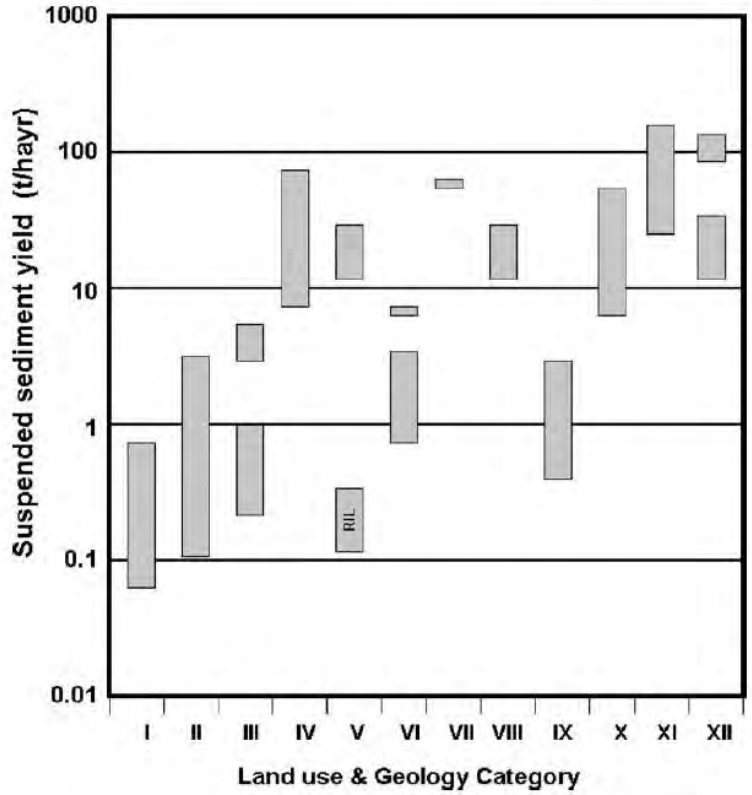


Fig. 10. Ranges in reported catchment sediment yields in southeast Asia as a function of geological substrate and land use. Categories: I, forest, granite; II, forest, sandstones/shales; III, forest, volcanics; IV, forest, marls; V, logged (RIL: reduced impact logging); VI, cleared, sedimentary rocks (lower bar: micro-catchments); VII, cleared, volcanics; VIII, cleared, marls; IX, medium-large basins, mixed land use, granite; X, idem, volcanics; XI, idem, volcanics plus marls; XII, urbanised (lower bar), mining and road building (upper bar).

[3] Bruijnzeel, L.A., 2004

Table 6: Underlying Assumptions and Parameters Used in Scenario Development

Conversion	Rainfall	Overall Water Yield	Baseflow	Peaks & Stormflows	Sediment Yield
Forest to Agriculture	Effects on rainfall overall are negligible unless large-scale clearing and conversion to plantations	Increase 200 mm/year	Effects on baseflow overall are negligible unless large-scale clearing and conversion to plantations	Increase 20%	1-5 ton/ha/year depending on soil conservation practice – use 3 ton/ha/year as per shifting agriculture
Forest to Degraded Forest		Increase 250 mm/year for 3 years		Increase 10% for 3 years	20 tons/ha/year for 3 years
Forest to Cleared Forest		Increase 250 mm/year for 5 years		Increase 20% for 5 years	40 tons/ha/year for 5 years
Forest to Logged Forest		Increase proportional to biomass removal		Increase 20% for 3 years	150 tons/ha/year[4] for 2 years
Forest to Plantation		No Change unless Groundwater Mining		Increase 10%	50 tons/ha/year[5]
Forest to Settlements		Increase to Rainfall Value = ~1,500 mm/year		Increase 30%	40 tons/ha/year
Forest to Roads		Increase to Rainfall Value = ~1,500 mm/year		Increase 30%	100 tons/ha/year for 5 years
Forest to Mining		Increase to Rainfall Value = ~1,500 mm/year		Increase 30%	100 tons/ha/year
Forest no change	No Change	No Change	No Change	No Change	1 ton/ha/year

6.4 Livelihoods Support

The livelihoods support function provided by the forest includes at present the resin extracted from trees, fuel wood for charcoal and timber for buildings, and non-timber forest products gathered by local residents. There is hunting and trapping for food and for the illegal wildlife trade as well.

Conversion of the forest through logging has in the past resulted in the destruction of the resin trees as they are valued species for timber concessionaires and enforcement of the rules that require the non-cutting of these trees is limited. It is thus expected that logging of the Prey Lang Evergreen Forest Core Zone would destroy the local resin business.

[4] This assumes that Reduced Impact Logging is not implemented as it is understood that this is the norm in Cambodia.
[5] This assumes clean weeded tree crops or forest plantations with litter removed or burned. Otherwise plantation sediment losses are likely 3 tons/ha/year.

Conversion of the forest would also reduce the availability, quality and value of wild game and NTFPs. The loss of dietary vitamins, protein and fats that are gained from NTFPs and hunting can be critical in terms of food security for people living near the forests with limited amounts of paddy rice. Their loss or reduction could push some of these people into poverty and result in nutrition and health problems.

Opening up the undisturbed forest would also provide access to large amounts of potential farmland and employment as labour for plantations. These would only partially make up for the loss of the forest resources given the soil is low productivity for agriculture. The large land areas available and investments would inevitably spur a rapid increase in migration to the area for land and jobs with associated economic and social benefits and problems.

6.5 Fisheries

As noted in the proposal, the Consultant does not have expertise in fisheries so will not examine this aspect from a technical point of view. It can be expected that the changes in water quality from increased suspended sediment will negatively impact fisheries while the increased water in the streams will increase fisheries. Increased sedimentation throughout the system will result in higher stream beds, changes in breeding grounds, more sandbars and obstructions to flow and migration paths which will negatively affect fisheries.

An overriding issue in fisheries is the impact of the conversion on the downstream Stung Chinit Integrated Rural Infrastructure Project. This $24,300,000 project experienced cost and time overruns and is only marginally economically beneficial in terms of rate of return. Much of the benefit derives from planned major fisheries production within the reservoir area formed by the reconstructed dam and water gates. The sedimentation described in Section 6.3 will make it shallow, increasing the water temperature and growth of algae and water plants and making the water quality unsuitable for the major production of fisheries.

Fisheries in this reservoir would also likely be badly affected by the development of the mining concessions outside of the Prey Lang Evergreen Forest Core Zone that would introduce toxic chemicals as well as fertilizer, herbicide and pesticide pollution from agro-industrial plantations.

6.6 Functional Forest

A major issue in the consideration of Prey Lang Evergreen Forest is its retaining its core zone of primary forest and its various environmental benefits as a functional forest. This topic is outside of the scope of this current consultancy, and is well described in the previous studies by Ashwell and Macdonald and in the ***Independent Forest Sector Review*** (Danida, April 2004). The primary issues in this respect include biodiversity first and foremost.

Observation of the area using the mapping undertaken during this consultancy points out some additional considerations that should be considered in these respects however:

- There is significant value in maintaining contiguous and transition forest zones where Prey Lang Core Zone connects to other undisturbed forest of good quality

of a different type. In particular, the Phnom Bokphou Semi-Evergreen Forest appears to present a major opportunity.

- The swamp forests within and nearby the Prey Lang Evergreen Forest have not been sufficiently studied or mapped but appear to be unique in terms of biodiversity so efforts should be made to better know their location, extent and importance.

- Another issue requiring investigation is the whether there exist any migration corridors between the Boeung Per Wildlife Reserve and the Prey Lang Evergreen Forest Core Zone area. In particular, it needs to be determined if wildlife cross the Stung Sen in the section around and between Dang Kambet Commune and Sampreang Village (as shown in Figure 2).

- The biggest danger in terms of maintaining functional forest is logging or other economic concessions, as once started the roads partition the forest and serve as conduits for settlement and conversion to other uses.

6.7 Downstream Impacts

The primary impact of the conversion of Prey Lang Forest downstream will be on the Stung Chinit Integrated Rural Infrastructure Project (SCIRIP). This project includes a major investment in irrigation of approximately $15,000,000 for design, infrastructure works, construction, training and support of farmers and agricultural investment for approximately 7,000 hectares of investment. As noted above, the likely impacts on the Stung Chinit will be:

- Slightly increased peak flows and stormflows and increased catchment water yield – this will increase water availability within the Stung Chinit Irrigation System as peak flows will likely attenuate and come from more local storms so can be stored and distributed for use as irrigation water. This will positively impact the SCIRIP project as reliability of flow and total amount of water available will increase and potential cropped area could increase.

- A significant amount of soil erosion will occur in the Prey Lang Forest area as a result of its conversion which will be deposited in the Stung Chinit River Catchment. This will eventually flow down to the dam for the SCIRIP Project where it will be impounded below as sediment within the reservoir area and distribution network of canals and drains. This will negatively affect the SCIRIP Project by increasing maintenance costs for cleaning the sediment from the distribution network and removal costs for eventually dredging the reservoir area as well as the impacts on fisheries discussed in Section 6.5.

- The increased soil erosion will also contribute to sedimentation downstream of the SCIRIP Project within the freshwater flooded forest and Tonle Sap River and basin, negatively affecting fisheries habitats and productivity.

6.8 Economic Impacts of Prey Lang Conversion Scenario

6.8.1 Soil and Water Conservation

In order to assess the potential impacts of conversion of Prey Lang Forest, a model was build based on the most likely scenario of change, that being what has occurred in the Lower Prey Lang Degraded Forest area. While it must be clearly understood that any model is only an approximation and will provide different results based on different parameters and assumptions, the situation of Prey Lang is quite complex so modeling is an appropriate means of considering what potential impacts might occur from change and their relative scale. The model can then serve as a framework for future improvement as investigations into different parameters and underlying assumptions and field survey and experimentation improve the understanding. The scenario is presented in Annex 5. The assumptions used for the model are described within the Annex and summarized in Table 7Table 7: Rough Estimation of Potential Benefits of Conversion of Prey Lang Core Zone to Mosaic Secondary Forest with Agriculture and Plantations over 10 Years. As care has been taken to identify parameters from research on similar situations and a conservative outlook applied, the Consultant believes that the model is a reasonable representation of the sorts of effects that might be expected as a result of the complete conversion of Prey Lang Evergreen Forest Core Zone. The basic assumptions for the scenario are:

- The current relatively constant rate of forest conversion to agriculture and degraded forest continues at 1%/year with half in each category;
- Cleared forest occurs after logging as a result of operations and people following the logging operations at a rate of 1%/year of the logged area;
- Logging operations commence for Colexim in 2010 and they completely log their concession area within 5 years; The Everbright and remaining small areas under other concessions begin operations in 2011and similarly completely log their concessions during a 5-year period (this is a pessimistic scenario in that there is a reasonable chance that logging would be delayed or extended beyond this period);
- Roads and settlements are initially created by the logging company and then are used for pioneer farming expansion following the roads with the road density similar to that seen in the Lower Prey Lang Degraded Evergreen Forest;
- Logged forest reverts to degraded forest after two years, and degraded forest regenerates to 80% of its previous function after 3 years.

The conclusions from running the model for this scenario are:

1. A significant benefit can expect to be accrued from the increased water yield from the catchment which will provide additional and more timely water for the Stung Chinit Irrigation System. Using the approximations and assumptions in the model, the benefits would provide an average increase in cropped area/yields of over 14%, equivalent to roughly $2,900,000 over a 10-year period;

2. The benefit gained from increased water availability will be quickly lost from the increased costs and losses in system efficiency as a result of the huge increase in sediment in the reservoir area and distribution network. Even if only 2% of the estimated additional sediment deposited into the Stung Chinit catchment deposits

within the reservoir and system area, the costs for its removal will exceed the benefits from the additional water. It is expected that the actual sedimentation rates will be much higher than 2%, and will quickly cause operational problems and additional costs for the project that will make the system unviable economically[6].

3. The large amounts of sediment will also affect downstream floodplain areas and the Tonle Sap Lake with associated environmental costs on fisheries and maintenance of the diminishing freshwater flooded forest.

6.8.2 Livelihoods

The impact on livelihoods from the conversion of the Prey Lang Evergreen Forest Core Zone will be difficult to assess. The overall benefit will likely be significantly positive since the conversion of the forest will ultimately lead to its being converted into a mosaic of agricultural, plantation secondary forest and community forest. This will increase the agricultural land area available and lead to a likely large influx of migrant families without land into the area. This could be beneficial if managed well, and options such as Social Concessions would seem likely possibilities at a future point.

On the other hand, the impact of the communities living near the forest already who are using it for resin tapping, hunting and collection of fuel wood, timber and NTFPs will be significantly negative. The impacts could affect their food security and push marginal families into poverty. However, they will also likely benefit from being able to move into new farmland within the degraded forest areas.

- The impact of the conversion of Prey Lang Forest in respect of livelihoods can be summarized as being significantly positive from a macro-level perspective as it opens up a large new area for settlement that was previously inaccessible forest. On the micro-level, it will cause significant negative impacts on the existing local communities. The positive impacts have been included within the economic analysis on the basis of approximate land market values of similar low grade farmland and household land in remote upper terrace locations. The negative impacts have not been estimated due to the lack of data.

6.8.3 Overall Economic Impacts

It is beyond the scope of this assessment to examine in detail all of the economic impacts of the conversion of the forest into other land uses. Some rough figures can be instructive however. The Conversion Scenario would result in the mosaic of land use with approximate values as described in Table 7.

As seen there, this value for the conversion of the forest consists primarily of the extractive value for removing the commercial wood and the value of new land that becomes available for farming or plantation.

[6] This impact could be mitigated substantially by implementation of Reduced Impact Logging. However, it is not clear whether there has been a successful instance of this being practiced in Cambodia so the assumption within the scenario has been "business as usual".

Table 7: Rough Estimation of Potential Benefits of Conversion of Prey Lang Core Zone to Mosaic Secondary Forest with Agriculture and Plantations over 10 Years

Item	Assumptions	Total Area (Km^2)	Value per Ha (USD)	Total Value (USD)
Forest to Agriculture	Continues at 0.5%/year	93.6	$100/ha/year	$5,053,590
Forest to Logged Forest	Colexim starts 2010 for five years completely logging their section of Prey Lang Forest, then Everbright starts in 2011	1,871.7	Royalty of $80/cubic meter x 20 cubic m/ha, 80% area with commercial trees	$148,465,945
Logged Forest to Plantation	Assume start after logging at 2%/year	194.7	Royalty of $25/ha/year	$2,433,845
Forest to Settlements	Assume settlements follow logging roads similar to Lower Prey Lang Degraded Forest Area and cover 5% of the road area	8.9	$100/ha/year	$689,540
Forest to Roads (road length x 25m)	Assume roads follow pattern similar to Lower Prey Lang Degraded Forest Area then expand at 10%/year afterwards	715 km	Cost of $10,000 per km for upgrade and maintenance	-$7,154,890
Stung Chinit Irrigation System	Increasing sedimentation result in loss of all benefits from investment and costs for remediation	N/A	Loss of investment plus returns and cost for additional remediation works	-$24,300,000
TOTAL				**$125,188,030.00**

The figures used are estimations for illustrative purposes based on what appear to be typical yields and market values for royalties for tropical hardwood and plantation concessions.

However, it must be emphasized that **this value does NOT include some of the significant negative external impacts** that will be caused by the conversion of the forest. These include the loss of biodiversity and impact on local livelihoods, impacts on Stung Chinit fisheries and contribution to reduction in Tonle Sap fisheries production, and, especially, the loss of potential carbon credits. These are significant negative costs that will reduce the estimated benefits from the conversion scenario, however, there is no basis available currently for their estimation. Efforts should be made to better understand and quantify the economic values of these issues. The issue of carbon credits is examined in the following section.

It should be noted that the income from plantations is not that significant. The soils on which the Prey Lang Evergreen Forest stands are relatively deep but poor ancient alluvium with relatively low fertility. They will experience a large amount of erosion of the topsoil unless Reduced Impact Logging (RIL) is practiced, further reducing their fertility. This will further reduce production from plantations. The hydrological analysis assumed a relatively moderate

expansion of plantations into the area of approximately 2% per year, resulting in a total area of around 10% of the Prey Lang Forest becoming plantation after 10 years.

On the other hand, if a large-scale conversion of the logged areas to plantations were implemented, this could significantly increase the negative impacts on water flows, seasonality and availability and soil erosion. This would increase the presumed economic benefits from the plantations to approximately 9 times the estimated value but would greatly increase the water use, thereby reducing the availability of water downstream. It would furthermore exacerbate the soil erosion and sedimentation problems and cause significant pollution that would affect the important fisheries downstream.

7 Carbon Markets

Estimates of carbon stocks must be necessarily very approximate and should follow the principle of conservativeness. A rough estimate of 140 tons C per hectare of above and below-ground carbon for the existing Prey Lang Evergreen Forest Core Zone is used for the scenario development based on the more conservative figures estimated by the Oak Ridge National Laboratory (Olson, J.S. 1983 as listed within Adams web page).

Cambodia has an active and developing voluntary carbon market forest sector as several projects are in preparation or being implemented. It is likely that Cambodia will undertake national REDD (Reducing Emissions from Deforestation and Forest Degradation) within the next five years. Carbon credits available within the REDD framework are 3-4 times higher price than those within the voluntary carbon market. There are also higher transaction and administration costs and all credits will require some of the funds to be used for monitoring.

While prices of carbon credits are known and a fungible commodity within the Voluntary Carbon Market, much variance exists in the different standards used for verification of credits; the requirements for implementing REDD are in utero as part of a large international effort to develop standards and rules. Higher risk in maintenance and proper measurement and verification of stocks is instead reflected in higher buffer requirements, so that for example 50% or more of the area receiving credits must be set aside in case the foreseen carbon sequestration or loss avoidance does not occur. The buffers can be reduced with improved standards and demonstrated compliance and transparency as national systems develop.

The availability of credits will depend on the historical rate of change of carbon stocks over time, with the time periods for comparison being 1990, 2000, 2005 and whenever Cambodia sets the national REDD Benchmark Map (ideally 2010 or soon after). Credits from REDD derive from reducing the rate of change rather than from simply adding up and totaling carbon stocks. This adds some additional important considerations:

- The setting of the year for the REDD Benchmark Forest Map will have a major influence on the carbon credit availability. Starting logging prior to the setting of the benchmark would count the losses as part of the historical trend, meaning it would provide an actual benefit in terms of accessing carbon credits because future rates of loss would be lower;

- There are a number of other voluntary carbon market mechanisms (different standards such as "the Gold Standard", CarbonFix or the Climate, Community and Biodiversity Standard (CCBS) are examples of these) that can provide avenues for accessing voluntary credits for avoiding implementation of planned concessions or developments;

- There are incentives available within the voluntary carbon markets for demonstrating appropriate participation of local communities and protection of biodiversity (CCBS);

- It is not certain whether soil carbon will ultimately be included within REDD;

- The overall amount of credits available nationally will determine the total availability of the amount of credits for the carbon market for the Cambodia forest sector and the Prey Lang Forest is only a part of the overall carbon stock. This may lower or increase the importance of the carbon stocks within Prey Lang Forest.

The same caveats noted within the rest of the analysis apply for the scenario results run in respect of carbon credits with the assumptions and estimates noted therein. The results are presented below:

Table 8: Rough Estimation of Potential Carbon Credit Benefits of Non-Conversion of Prey Lang Core Zone

Item	Assumptions	Total Avoided Carbon Stock Decrease (tons C)	Value on Voluntary Market (US$ 3.50/ton C)	Value on REDD Market (US$ 17.50/ton C)
Forest to Agriculture	Complete loss of forest carbon stock	1,310,190	$4,585,665	$22,928,325
Forest to Degraded Forest	Assume 40% biomass removal in logging then gradual increase to 80% of previous level after 5 years	354,465	$1,240,629	$6,203,145
Forest to Cleared Forest	Complete loss of forest carbon stock	1,664,655	$5,826,294	$29,131,470
Forest to Logged Forest	Assume 40% Carbon Removal during Logging Operations	9,852,629	$34,484,201	$172,421,004
Logged Forest to Plantation	Assume complete removal of remaining forest carbon (60%)	1,635,530	$5,724,356	$28,621,782
Forest to Settlements	Complete loss of forest carbon stock	15,301	$53,553	$267,763
Forest to Roads (road length x 25m)	Complete loss of forest carbon stock	329,554	$1,153,440	$5,767,199
Logged Forest to Degraded Forest	Progressive gain of 4% biomass per year from logging time to maximum 80%	-44,432	-$155,512	-$777,561
TOTAL		**15,117,892**	**$52,912,626.00**	**$264,563,127.00**

The likelihood of the area being eligible for providing credits for both the voluntary and REDD carbon markets is very good. It must be understood that this will require significant investment as would development of a logging concession and this is similarly not considered within the costs. As noted above, only a percentage of the credits estimated above would be able to be turned into actual funds, and the amounts will depend on the degree of effort, expertise and transparency applied to the work.

In terms of the likely tangible and realistic benefits to be gained via carbon credits, the value of the Voluntary Market is a better guide and more conservative approach. Accessing this market can occur without requirement of the development of the national Benchmark Forest Map and Historical Forest Maps necessary under REDD that will take several years to develop when REDD is eventually implemented. It makes sense to proceed on that basis and by doing so gain early financial benefits and contribute to the development of a quality approach for forest carbon in Cambodia.

A further consideration in the valuation of the forest for carbon credits is the loss of carbon stocks from the Core Zone which would contribute to the determination of the overall carbon available within national REDD. Once the Benchmark Forest Map is set, any losses from that point in time count against the rate of reduction in deforestation and forest degradation within the National Carbon Accounting System (NCAS). This results in loss of potential carbon credits that can be gained elsewhere. In this regard, each credit lost could potentially almost double in value.

8 Comparison of Economic Costs and Benefits of the Conversion of Prey Lang Forest

As described in Sections 6.8.3 and 5 above, the rough and illustrative scenario indicates that in terms of overall economic value of the different scenarios, the following appears to be the case:

- Converting the forest into a mosaic landscape over 10 years would likely produce the highest returns in terms of actual cash receipts and tradeable value within a short period of time. Most value would be derived from royalties from logging the primary forest. On the other hand, the actual value for royalties paid to the Government of Cambodia apparently differs greatly from the international market and may be on the order of 1/3 or less of this value. The conversion would as noted also eliminate the economic benefits from the SCIRIP Project unless major changes are made in logging and land management practices.

- The royalty benefits that could be potentially gained through large-scale conversion of the Prey Lang Evergreen Forest into plantations will be significantly reduced by the low soil productivity and costs incurred downstream from water losses, pollution, soil erosion and sedimentation.

- The actual funds from carbon credits would be more difficult to access and require commitments and investment by the Government to ensure conservation of the Prey Lang Forest. As noted above, the actual credits accessed are likely to be a fraction of the total amount of avoided carbon losses that could potentially be gained. As such,

the actual value would likely be closer to that of the voluntary carbon market at present with a possibility to access higher prices with improved management in future. The future value of the carbon stocks conserved would significantly positively affect the total credits available for Cambodia. This in effect acts as a multiplier for the economic value of the credits.

- Negative Externalities produced by the conversion of the forest that are not included within the cash receipts and tradeable value of the scenarios are very significant and include major losses of biodiversity, negative impacts on local livelihoods and major losses in fisheries productivity. Future valuation of these aspects will significantly increase the economic value of the Conservation Scenario.

- A major benefit of the preservation of the Prey Lang Forest would be that the commercially valuable timber remains in place (and will likely gain value within a more regulated timber market) while revenues are being generated as opposed to conversion which is essentially a rapid liquidation of the forest's highest valued components. These could then be harvested selectively and carefully to generate additional revenue in future.

Conclusions

1. The economic values of the two scenarios are roughly equal in terms of the likely funds that could be accessed.

2. The Conservation Scenario would generate significant and long-term financing for protecting and monitoring the Prey Lang Forest and for sustained government revenues while maintaining the forest's core assets and ecological functions.

3. The Conversion Scenario provides the easiest means of accessing short-term funding but would incur external costs and ecological damage that would significantly reduce the benefits.

4. Currently, a strong economic case can be made to conserve the forest only in the context of soil conservation and the carbon market – research into the economic value of the biodiversity, livelihoods and fisheries impacts is urgently needed.

5. The comparative differences between the two cases narrow if Reduced Impact Logging is practiced as this could significantly reduce the sedimentation of the Stung Chinit and carbon stock losses.

9 Potential Development and Its Impacts

Similar to the discussion and analysis presented of the potential change scenario for the conversion of the Prey Lang Forest, a wide range of potential scenarios exist with respect to the development of the Study Area. The area currently has a low population and state of development in respect of investments and infrastructure. The large number of potential investments being discussed are a clear indication of Government intentions to greatly increase the economic activity generated in the region. However, each project is a separate proposal with different actors so there is unlikely to be a coordinated and well-planned regional development.

As such, it makes more sense to examine the projects individually rather than as a whole. At the same time, each must be understood within the context that there is a strong likelihood of some of the development taking place. In addition, there will be an inevitable increase in populations as land scarcity is already being experienced in many areas in the country and current land pressures in the region are low. Many of the areas where the projects have been proposed have or are already experiencing degradation and settlement

The Prey Lang Evergreen Forest Core Zone is not overlapping with any of the planned investments other than the current Timber Concessions for Colexim, Everbright and Pheapimex. Some small areas were within the now terminated Mieng Ly Heng Timber Concession. All other potential development projects are outside of the Core Zone.

The potential development projects in or around the Prey Lang Evergreen Forest Core Zone are listed in order of importance and discussed as follows:

8. The Existing Timber Concessions Covering the Prey Lang Evergreen Forest Core Zone;
9. The Existing Road Networks and Plantations;
10. Expansion of Plantations;
11. The Kuwait Fund Stung Sen Hydropower/Irrigation Project;
12. The Mineral Concessions in the Lower Prey Lang Degraded Evergreen and Phnom Bokpou Semi-Evergreen Forest;
13. Mineral Concessions in the Upper Prey Lang Degraded Evergreen Forest;
14. The Sambor Mainstream Mekong Hydropower Dam.

9.1 Existing Timber Concessions Covering the Prey Lang Evergreen Forest Core Zone

The situation of the Prey Lang Evergreen Forest Core Zone in respect of previous and existing Timber Concessions is summarized in the table below and can be seen in the Figure 11. It is understood that the timber concessions are currently suspended, but that this is not a permanent situation. From this, one can conclude the following:

- The key concessions are the Colexim and Everbright Timber Concessions which together cover 87.1% of the total Prey Lang Core Zone. Of these two concessions, the Colexim area is the most under threat and contains the largest amount of the central part of the forest;

Table 9: Concessions within the Prey Lang Evergreen Forest Core Zone

Concessionaire	Concession Status	Concession Area within Prey Lang Evergreen Forest Core Zone (km²)	Percentage of Prey Lang Evergreen Forest Core Zone
Mieng Ly Heng	Previous Concession, Now Terminated	93.9	5.0%
Everbright	Current Timber Concession, Not Active	777.5	41.5%
Colexim	Current Timber Concession, Not Active	853.0	45.6%
Pheapimex	Current Timber Concession, Not Active	146.6	7.8%
GAT Kg. Thom/Kratie	Previous Concession, Now Terminated	0.8	0%
TOTAL		**1871.8**	**100%**

- The Mieng Ly Heng and Pheapimex areas are likely to have been logged previously but the change could likely not be detected because of rapid secondary regrowth in-between the intervals when the compared satellite images were taken;

As described in the scenario, the implementation of the logging in the active concessions is by far the biggest threat to the viability of the Prey Lang Evergreen Forest Core Zone as it would inevitably lead to the partitioning of the forest and eventual creation of a mosaic landscape. Conservation efforts should focus on gazetting the Core Zone as a Protected Area and permanent cancellation of these concessions to ensure this doesn't happen.

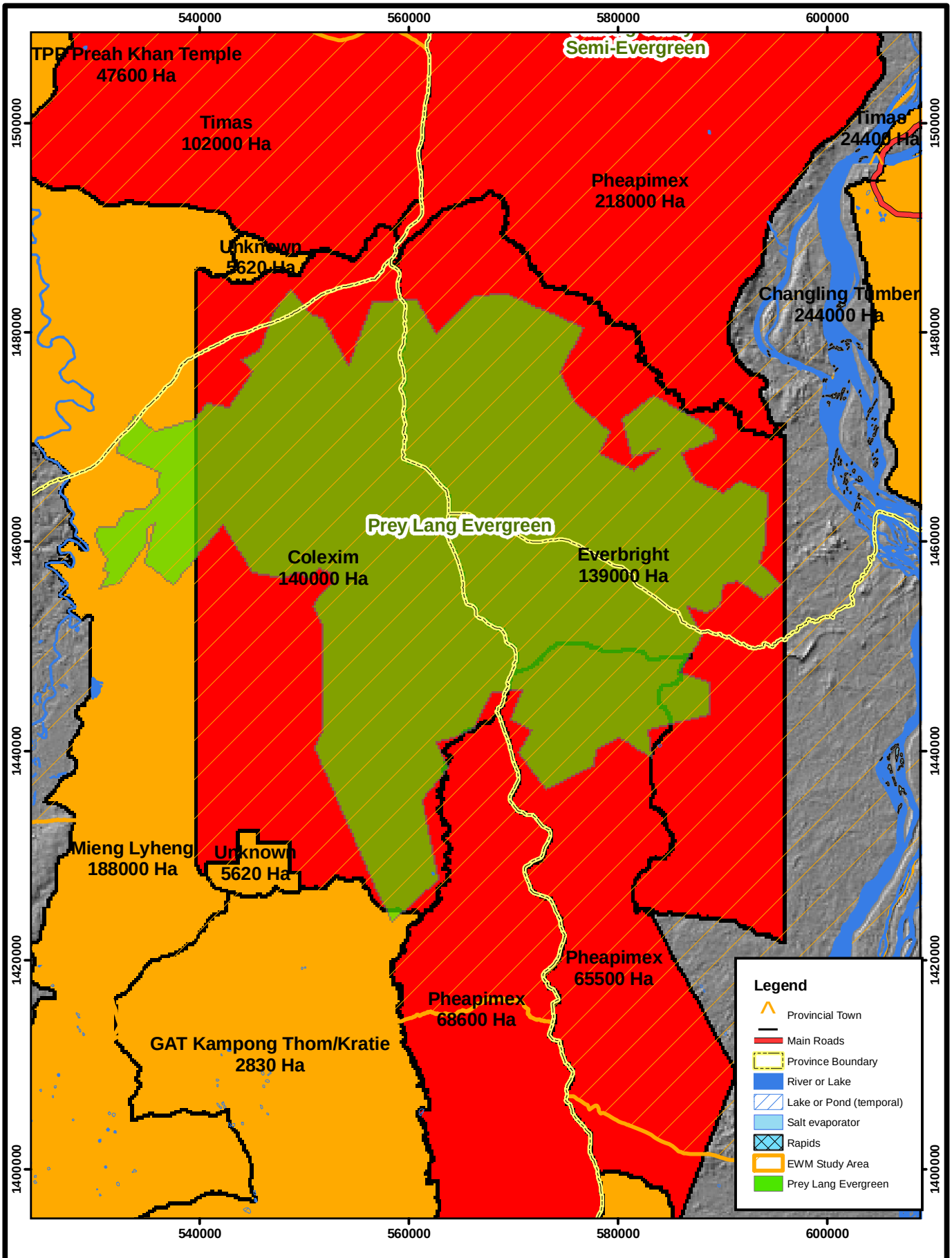
9.2 The Existing Road Networks, Settlements and Plantations

Section 2.1 Hydrology described the changes in the different catchments and forest areas in detail including the locations where roads have resulted in the degradation of the Prey Lang Evergreen Forest.

The roads also result in people settling around the outside of the Core Zone area, where the settlements and plantations serve as "beachheads" for populations to probe deeper into the forest. This happens primarily along old logging roads initially in the Southern and Southwestern extremeties of the forest, then expands as people move into the area and start farming the lower elevations.

People are also establishing lowland paddy and chamkar farms along the Stung Porong and O Long Streams from the North and South and thereby further extending manmade activity deeper into the Core Zone. Similar to the roads, this could partition the Core Zone right up the center with very damaging effect to the viability of the forest. The developments of greatest concern are listed below in order of importance:

1. The Road Connecting Sandan District, Kampong Thom via Tumring Plantation through the Phnom Chi Area and then to Sambor District, Kratie;



0 2 4 8 12 16

Kilometers

1 centimeter equals 5 kilometers

Figure 11: Prey Lang Evergreen Forest and Timber Concessions

Coordinate System: UTM Zone 48, Horizontal Datum: WGS84
Forest Areas Approximate - Names Designated By Consultant

This "road" is a series of tracks but is passable by motorized vehicles. Improvement to a District Level road would likely doom the Southern Tip of the Core Zone which is already experiencing significant human activity. It would also increase pressure on the Southeastern edge of the Core Zone via the old Pheapimex logging roads. This will almost certainly occur if the Phnom Chi mineral concession starts operation.

2. The Expansion of Roads and Agriculture from the Upper Prey Lang Degraded Evergreen Forest Area;

   The community in this area is well established and likely cannot be convinced to move. There is expansion of roads and farming in the direction of the Core Zone as the existing settlement is being used as a "jump off" point for people moving along the stream valleys to farm within the Core Zone. This area could also be heavily affected by the development of the Kenertec Iron Ore Mineral Concession that covers more than half of the forest area (discussed further below).

3. Increased Settlement and Roads Expansion Around and From the Rubber Plantations;

   The road north from the Northern Rubber Plantation is of particular concern as it leads to the resin camp tracks and has been improved. Other roads are beginning to cut into the Southern Tip of the Core Zone from the West;

4. The Rehabilitation of the Logging Roads into the Eastern Tributary Catchments of the Stung Porong within the Core Zone;

   These logging roads appear to have been abandoned but could form a bridgehead for access in future, especially if the Dambok Sor Mineral Concession within the Phnom Bokphou Semi-Evergreen Forest becomes operational.

5. The Upgrade of Roads into the Northeastern Edge of the Core Zone from Siem Bouk District in Kratie Province;

   This forms another potential avenue into the Core Zone from Kratie.

9.3 Expansion of Plantations

There are currently no areas designated for plantations within or near the Prey Lang Evergreen Forest Core Zone other than the existing Tumring and Smallholder Plantations surrounded by the Lower Prey Lang Degraded Evergreen Forest to the Southwest of the Core Zone. These plantations are located on basalt outcrops so are unlikely to expand further given the lack of suitable soils.

- In the event of conversion of the forest, it is likely that some and perhaps a large part of the areas that are logged would be assigned for plantation development. Currently there are many concessionaires trying to find suitable land and a regional shortage, hence there is strong demand.

- There are concerns about the suitability of the relatively poor agricultural soils of the Core Zone for large-scale plantations, particularly rubber.

- Experience from Lao PDR on agricultural concessions has demonstrated that care needs to be taken in agricultural concession management to ensure that appropriate plantation crops are planted and management is done well.

- There have been large negative socio-economic and environmental impacts from poor implementation by concessionaires. The quality of the company and their expertise and management of the land are critical in reducing negative impacts from soil erosion and pollution. Concessionaires often convert forest into plantation in order to harvest the wood.

- Plantations would take up as much water as the forest previously had and could potentially take more if water intensive tree crops are planted. Potential exists for groundwater mining if the wrong conditions are in place;

- The demand for land for agricultural plantation concessions will contribute to pressure for conversion of the forest and there are major concerns in respect of the quality of their implementation.

9.4 The Kuwait Fund Stung Sen Hydropower/Irrigation Project

Only limited information is available about the scope, location and scale of this project or its potential benefits. The basis of the project is investment from the Kuwait Fund as part of a package that would include a large no-interest loan to the Royal Government of Cambodia. The benefits for Kuwait would be a large long-term agricultural concession land holding for production of staple food crops for their national food security.

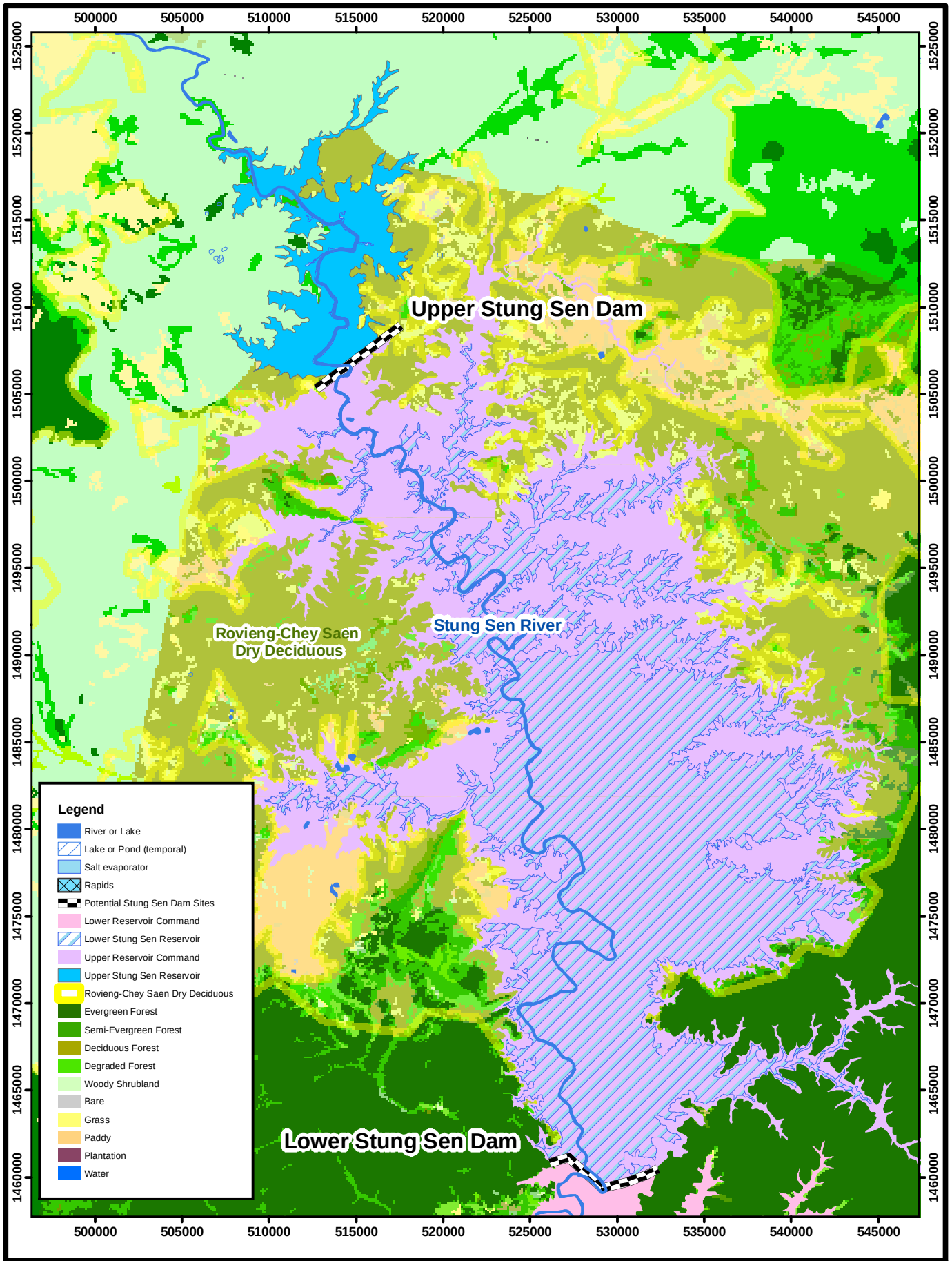
There are two likely potential locations for major works as shown in Figures 12 and 13:

1. A dam/reservoir somewhere above Reaksa Commune near the Phnom Tbaeng Evergreen Forest that could command irrigation of around 86,500 ha that is currently the Rovieng-Chey Saen Dry Deciduous Forest and farmland (Figure 12);

2. A dam/reservoir around Dang Kambet Commune that would flood a significant part of the Rovieng-Chey Saen Dry Deciduous Forest and farmland and could command irrigation approximately 34,000 ha that is currently mostly occupied lowland paddy and upper alluvial terrace in the Stung Sen River valley (Figure 13).

It is anticipated that both of these sites will also be examined in terms of their potential for hydropower. There may be additional considerations in the project such as plantation land areas or other locations. The interest-free loan was reported to be of US$ 500,000,000 value. A number of considerations can be observed in respect of this potential project:

- The benefits accruing to the Government from such a large loan on favourable terms could be quite considerable. With reduced administrative and transaction costs compared to other development aid loans and given the difficulty of obtaining such funds in today's credit-crunch economy, the value of this loan could be as high as 20% of the capital in use per annum. This would quickly outstrip any alternative economic uses for the area.



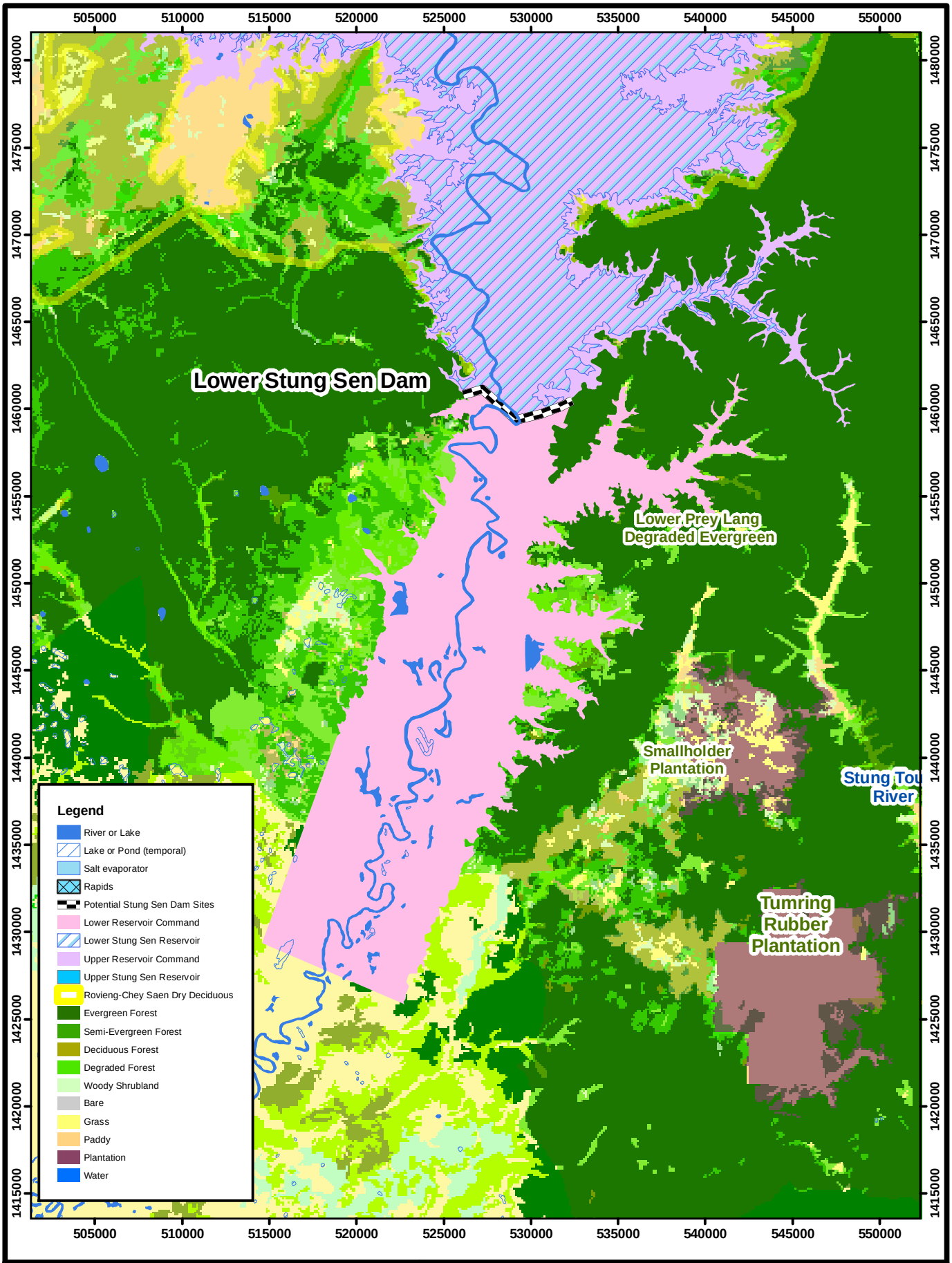
0 1 2 4 6 8

Kilometers

1 centimeter equals 3.0 kilometers

Figure 12: Stung Sen River Upper Dam, Reservoir and Command Area

Coordinate System: UTM Zone 48, Horizontal Datum: WGS84
Forest Areas Approximate - Names Designated By Consultant



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Kilometers

1 centimeter equals 3.0 kilometers

Figure 13: Stung Sen River Lower Dam, Reservoir and Command Area

Coordinate System: UTM Zone 48, Horizontal Datum: WGS84
Forest Areas Approximate - Names Designated By Consultant

- The likely investment in irrigation is being made for macro-level food security reasons rather than in response to market forces. As a result, the investor would be best served to take a long-term approach and practice more intensive and expensive development and management since they have "deep pockets" and no underlying economic constraints.

- The area that is likely to be converted in the Rovieng-Chey Saen Dry Deciduous Forest is relatively low quality forest that is being progressively converted into paddy by local farmers. The resulting loss of carbon stocks, biodiversity or other values as a result of its wholesale conversion into agricultural land will thus be much lower than any of the other forest areas in the Study Area.

- The soils underlying this forest are thin and poor quality, and can easily erode and become wasteland with over-intensive management and the wrong crops. The previously noted high investments, long-term approach and focus on staple food crops means it is likely that rice will be grown – this is the most appropriate usage for the conversion of this forest as paddy is a soil and water conservation measure that will maintain the landscape.

- A key question that will determine how beneficial the investment is will be the involvement of the local people and the impacts of the project on the local economy and socio-economics. An intensive investment in a large irrigation scheme would require much construction labour followed by a large and organized labour force. The scheme would likely require significantly more people than currently live in the area so would attract in-migration. Any scheme in the lower area would involve major issues of resettlement unless some sort of large-scale contract farming arrangement is foreseen.

- Treatment of workers in terms of their conditions, wages and number of work-days will be critical in the implementation of such a project. If done properly, the project could serve as a source of steady employment for the majority of the local populace in the Stung Sen River Valley in Rovieng and Sandan Districts and for other landless or poor migrants. This could reduce the pressure on the Prey Lang Forest Core Zone. On the other hand, if employment is not a satisfactory substitute for their existing family farms, the project could result in people pushing into other areas including the forest and putting more pressure on these resources.

- If serious plans are made and the project subsequently does not proceed partially or fully because of alternatives such as conservation of the area, the carbon that would have been lost can be eligible for credits under some mechanisms of the voluntary carbon market. However, the value of this will be small compared to the alternatives since the carbon stock of this type of forest is low and the benefits from other uses high.

- The Lower Stung Sen Dam would flood much of the area that could potentially be commanded by the Upper Stung Sen Dam. As the resettlement problems for the Lower Command Area would be considerable as most of the arable land is already being farmed, it is considered unlikely that this would be the preferred option.

- There will be no direct physical impacts from the project on the Prey Lang Evergreen Forest Core Zone unless the agreement also includes provision of land for plantations within the Core Zone.

9.5 Mineral Concessions in the Lower Prey Lang Degraded Evergreen and Phnom Bokpou Semi-Evergreen Forest

Existing Mineral Concessions just outside of the Prey Lang Evergreen Forest Core Zone are listed in the table below and can be seen in Figure 14. It is understood that artisanal gold mining has been in place for many years in Phnom Chi while initial study and surveying activities are in progress by the concessionaires in both locations.

Table 10: Concessions within the Prey Lang Evergreen Forest Core Zone

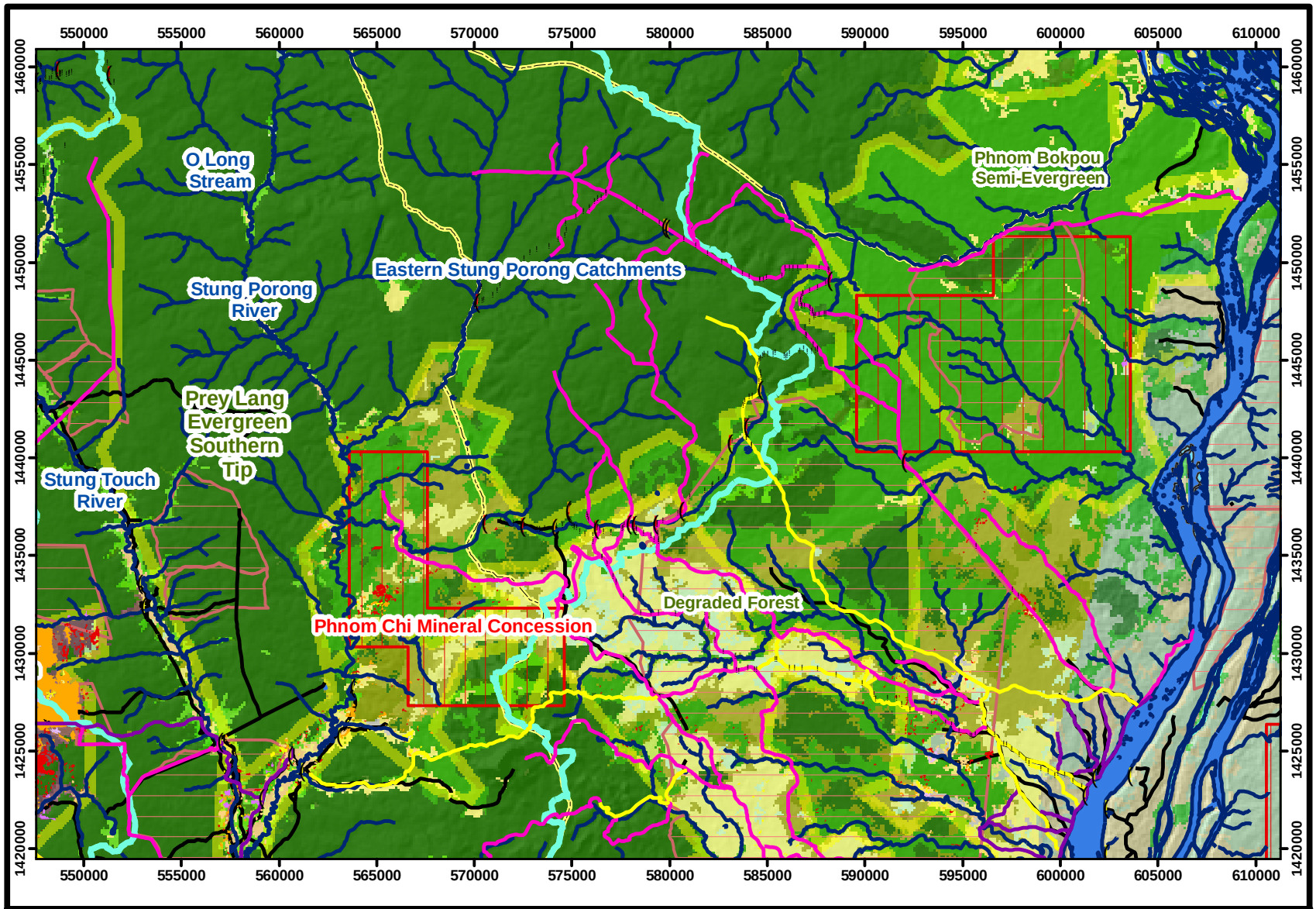
Concession Name	Concessionaire	Concession Area (km²)
Phnom Chi	Vannymex Co. Ltd.	78.0
Dambok Sor	Cambodia International Mining Group	133.0
TOTAL		**211.0**

- The Phnom Chi Mineral Concession could result in the upgrade of the road between Sandan District in Kampong Thom and Sambor District in Kratie. In addition, it would attract a significant amount of staff and serve as another concentration of population on the fringes of the Core Zone. This would increase pressure on the Southern Tip of the Core Zone. The completion of this road would effectively cut the Stung Chinit Catchment in two and partition the Lower Prey Lang Degraded Evergreen Forest from the Core Zone.

- The Phnom Chi Mineral Concession could also result in increased sediment and pollution of toxic chemicals downstream with negative impacts on the Stung Chinit Irrigation System and fisheries.

- The Phnom Bokpou Semi-Evergreen Forest is as noted previously an interesting adjacent forest to the Core Zone that would be of significant value for preservation as habitat. Development of the Mineral Concession over the bulk of the Core Zone of this forest would likely destroy it. This would also cause concerns in terms of contamination of the Mekong River fisheries with chemical pollutants.

- There are no direct physical impacts from the mineral concessions on the Prey Lang Evergreen Forest Core Zone.



Legend

- Provincial Town
- FERP Irrigation Projects
- Swamp Forests
- Resin Camps
- Road Points
- District Centers - Study Area
- Commune Centers - Study Area
- Villages - Study Area

Road Construction

Year Detected

- Unknown
- 1984
- 1990
- 1997
- 2000
- 2004
- 2009
- Main Roads
- Roads
- Waterways
- Catchment Divides

Change Detection 1973 to 2009

Change Period

- 04_09
- 00_04
- 97_00
- 90_97
- 84_90
- 73_84
- Province Boundary
- River or Lake
- Lake or Pond (temporal)
- Salt evaporator
- Rapids
- Community Forest
- Mineral Concession
- Forest Areas
- Evergreen Forest
- Semi-Evergreen Forest
- Deciduous Forest
- Degraded Forest
- Woody Shrubland
- Bare
- Grass
- Paddy
- Plantation
- Water

0 1.252.5 5 7.5 10

Kilometers

1 centimeter equals 3.0 kilometers

Figure 14: Mineral Concessions Forest Areas, Land Use and Development

Coordinate System: UTM Zone 48, Horizontal Datum: WGS84
Forest Areas Approximate - Names Designated By Consultant

9.6 Mineral Concessions in the Upper Prey Lang Degraded Evergreen Forest

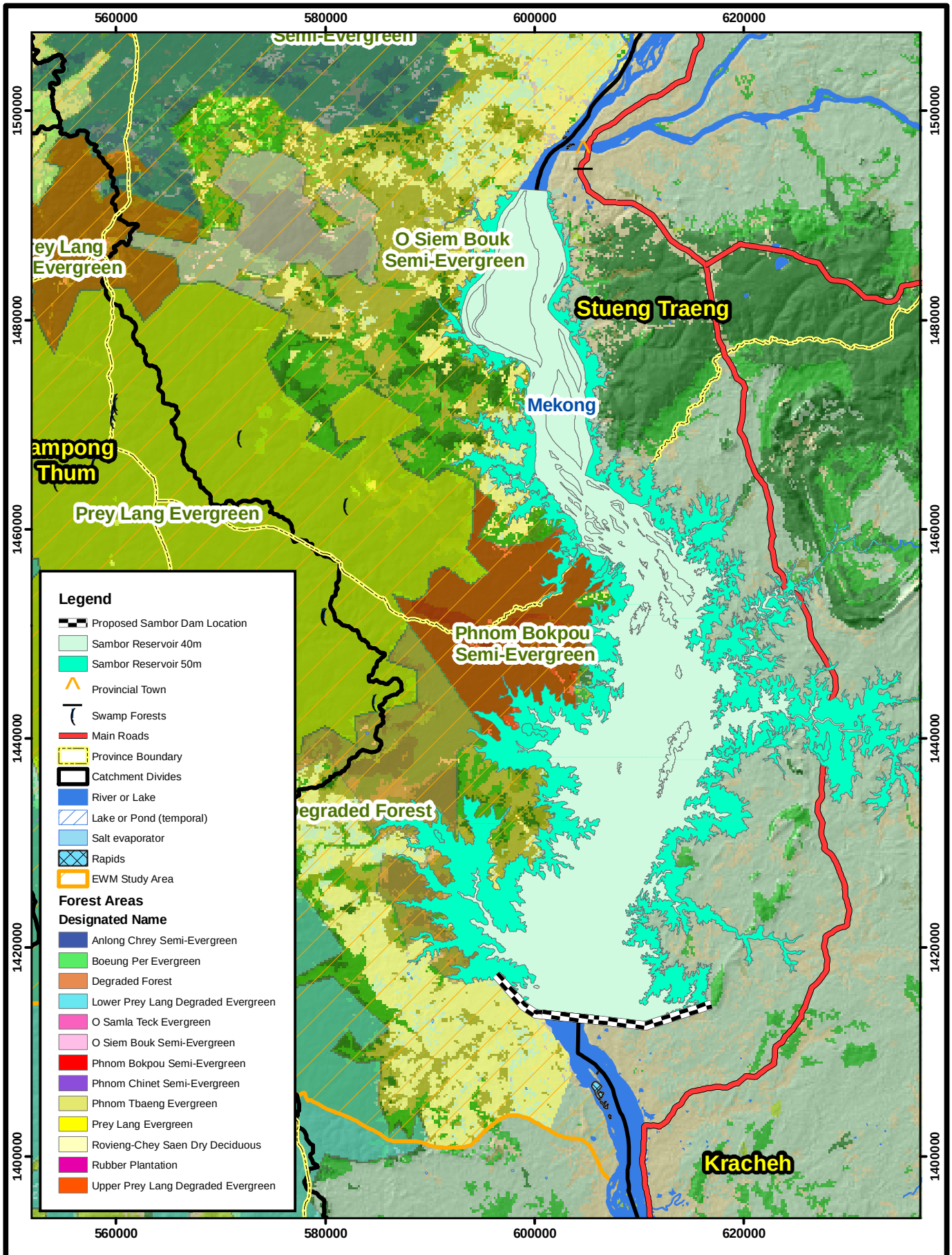
This refers primarily to the Kenertec Iron Ore Mineral Concession to the North of the Prey Lang Forest Core Zone at the top of the Stung Chinit Catchment as seen in Figure 3. This could potentially become a large extraction operation with major environmental impacts. It is not known where the iron would be processed, but any actual operations in this regard would include large tailings of waste material and major impacts on water quality in the catchment.

- The concern about this concession is primarily one of soil erosion and downstream contamination from chemicals. This would also affect the communities living within and downstream of the concession and the production fisheries planned for the SCIRIP Project.

9.7 The Sambor Mainstream Mekong Hydropower Dam

The proposed Sambor Mainstream Mekong Hydropower Dam location and likely reservoir extent are shown in Figure 15. As seen there, the reservoir would extend partially into the Phnom Bokpou Semi-Evergreen Forest Area but otherwise would not directly impact on any of the designated forest areas, including the Prey Lang Core Zone.

- The only issue in respect of the potential implementation of this project and the Prey Lang Forest Core Zone is that of the likely additional development that would be spurred as a result of such a large investment. The associated works would likely include upgrading of the road between the dam and Sandan District, thus providing a full land link between Kratie Town and Kampong Thom. This would further exacerbate the problems described in Section 7.2 as at least that road would stop at the Mekong River.



0 2 4 8 12 16

Kilometers

1 centimeter equals 15 kilometers

Figure 15: Sambor Mainstream Mekong Dam and Reservoir Areas

Coordinate System: UTM Zone 48, Horizontal Datum: WGS84
Forest Areas Approximate - Names Designated By Consultant

10 Conclusions

1. The Study Area is composed of a number of different forests ranging from the primary evergreen forest of the Prey Lang Core Zone, to other good quality, degraded and secondary evergreen forest, good quality and degraded semi-evergreen forest and a large area of lower quality dry deciduous forest. The unique nature of the Prey Lang Evergreen Forest Core Zone within this landscape of other biomes and connection and proximity to wildlife reserves emphasize the importance of the area for biodiversity.

2. The area is seeing a number of plans being proposed for development that would involve large foreign direct investment in a range of potential projects including timber concessions, hydropower and large-scale irrigation projects, new roads, mineral concessions and plantations. The planned developments would require a major increase in the local population and provide large employment opportunities and a major upgrade of infrastructure in the region. This is occurring in an area already in a state of flux as communication networks and settlements increasingly encroach on the already fragmenting forest areas of the region.

3. The scenarios developed for this Study are rough approximations intended as a means of better understanding the complex interactions and impacts that conversion of the Prey Lang Forest Core Zone could bring. Much more research and analysis would be required to improve the scenario accuracy and applicability.

4. Despite these caveats, the scenario comparison demonstrated that very significant financial benefits could derive from the conservation of the forest primarily through increased soil conservation and prevention of loss of carbon stocks and that these benefits are reasonably equivalent if not greater than the royalties and other receipts that could derive from conversion of the forest. Given that the high value timber is liquidated in and the serious negative external impacts resulting from the conversion scenario, the benefits in this case primarily are that this is the quickest and easiest means for the Government to access ready funds. Any long-term analysis will likely demonstrate that this is a poor choice.

5. Thus, the fundamental conclusion is that the Prey Lang Evergreen Forest Core Zone is of considerable value both in realizable economic terms as well as less easily quantified environmental and livelihood functions. The Consultant strongly supports the recommendations of previous studies of the area recommending its conservation as a better alternative to conversion.

6. A balance will have to be struck between the drive for development and the need for conservation in order to meet Government priorities and in consideration of realpolitik. How investments are implemented will determine to what extent they cause negative impacts on the conservation of the Prey Lang Evergreen Forest Core Zone and efforts should be made to engage investors and Government partners to maximize the quality of these projects.

11 Recommendations

Given the complexity of the situation and the limited resources available, priority should be given to addressing the most pressing needs that would best ensure the conservation of the Core Area, namely:

1. The Government needs to prepare an overall regional plan that considers all of the various development and conservation options currently on the table in close consultation with the local populace and other stakeholders to better prioritize development options, preserve critical natural resources and livelihoods and ensure quality implementation.

2. The Prey Lang Evergreen Forest Core Zone needs to be gazetted as a Protected Area and arrangements secured for its protection and monitoring including cancellation of the existing Timber Concessions;

3. The access points to the Core Zone identified in Section 7.2 need to be sealed off from vehicular traffic;

4. The economic value of the biodiversity, carbon, NTFPs, fisheries and other positive impacts from conservation of the forest need to be better quantified and documented for inclusion in the case for conservation;

5. The threatened Southern and Western Tips of the Core Zone should be focused on to prevent their further degradation and access in order to at minimum preserve them as a buffer zone;

6. The local populace living within and on the edges of the Core Zone need to be engaged to better understand their situation, support continuation of the existing community forestry and to improve land management on the periphery of the forest.

7. Conservation groups must engage with and maintain involvement with investors and agencies promoting proposed projects to try to mitigate the largest potential problems and steer the investments towards a better result that contributes to the conservation of the Core Zone.

8. The Ministry of Water Resources and Meteorology should be contacted to gain an ally within the government based on their interest to avoid damage to the downstream Stung Chinit Integrated Rural Infrastructure Project.

9. Preparatory work should begin on accessing carbon credits through the Voluntary Carbon Market to gain a better understanding of the requirements, benefits and timeframes and move towards gaining tangible economic benefits from conservation.

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Annex 1: Village Summary in the Study Area

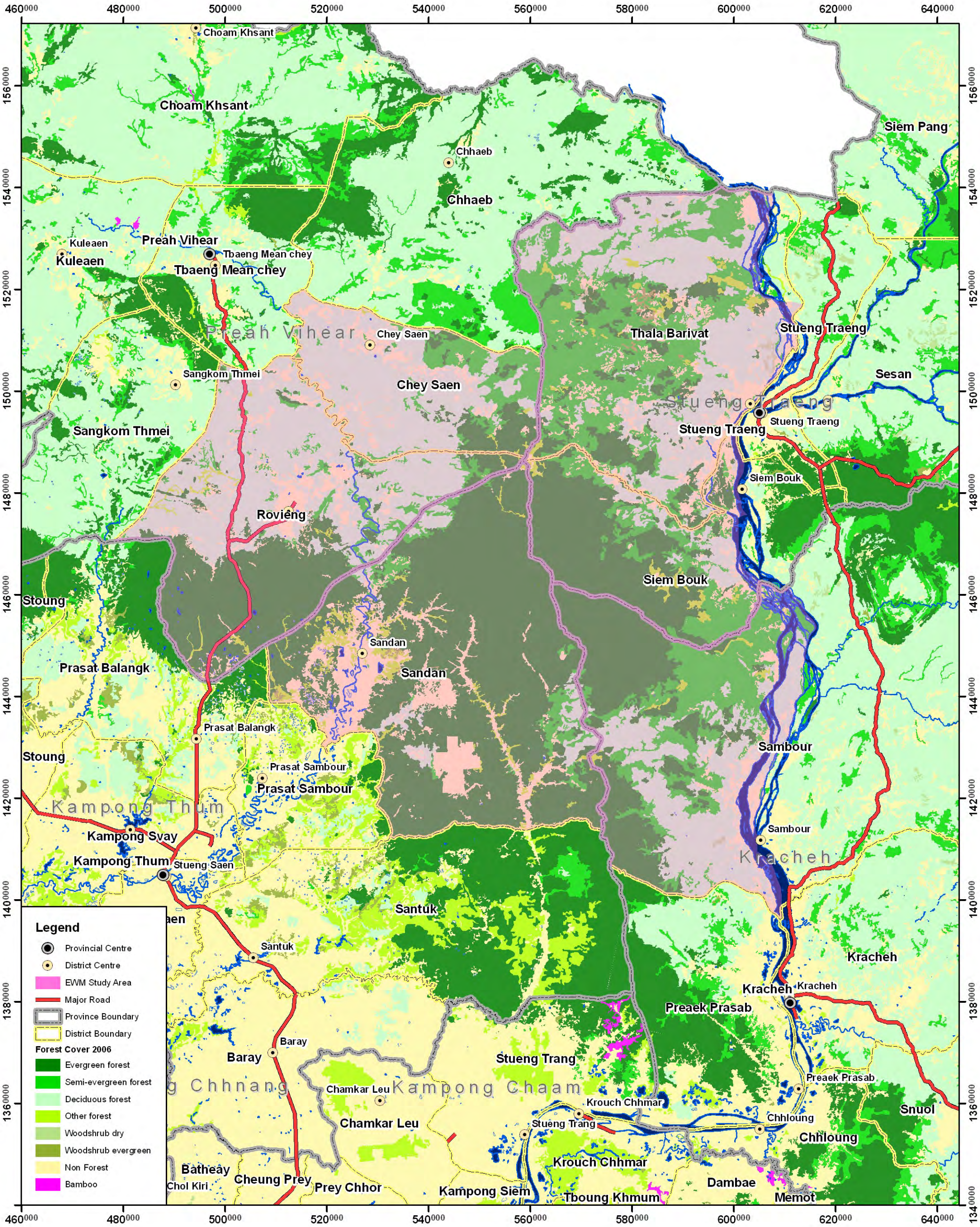
VILLAGE	Commune	District	Province	Total Popoulation	Total Households
Chheu Teal	Chheu Teal	Sandan	Kampong Thom	1343	275
Boeng Rolum	Chheu Teal	Sandan	Kampong Thom	566	113
Kampong Ta Baen	Chheu Teal	Sandan	Kampong Thom	571	117
Samret	Chheu Teal	Sandan	Kampong Thom	1086	226
Veal Pring Kraom	Chheu Teal	Sandan	Kampong Thom	936	180
Kae Rang	Chheu Teal	Sandan	Kampong Thom	1098	213
Boeng Pra	Chheu Teal	Sandan	Kampong Thom	690	134
Andoung Pring	Chheu Teal	Sandan	Kampong Thom	964	181
Prey Kanlaeng	Chheu Teal	Sandan	Kampong Thom	66	12
Srae Khsach	Dang Kambet	Sandan	Kampong Thom	311	68
Srae Veal Khang Lech	Dang Kambet	Sandan	Kampong Thom	313	65
Srae Veal Khang Kaeut	Dang Kambet	Sandan	Kampong Thom	674	128
Sampoar Touch	Dang Kambet	Sandan	Kampong Thom	268	50
Sampoar Thum	Dang Kambet	Sandan	Kampong Thom	500	87
Peam Klaeng	Klaeng	Sandan	Kampong Thom	321	74
Roka Chuor	Klaeng	Sandan	Kampong Thom	816	188
Tuek Vil	Klaeng	Sandan	Kampong Thom	374	102
Prey Choar	Klaeng	Sandan	Kampong Thom	357	74
Klaeng	Klaeng	Sandan	Kampong Thom	897	196
Kumpout Chhuk	Klaeng	Sandan	Kampong Thom	368	84
Trakuon	Klaeng	Sandan	Kampong Thom	202	52
Kantir	Mean Ritth	Sandan	Kampong Thom	513	117
Boeng	Mean Ritth	Sandan	Kampong Thom	535	118
Sam Aong	Mean Ritth	Sandan	Kampong Thom	889	232
Choam Svay	Mean Ritth	Sandan	Kampong Thom	795	128
Tboung Tuek	Mean Ritth	Sandan	Kampong Thom	1377	261
Trapeang Tralach	Mean Ritth	Sandan	Kampong Thom	394	76
Rang Khnay	Mean Ritth	Sandan	Kampong Thom	359	74
Chek Muoy Stong	Mean Chey	Sandan	Kampong Thom	350	74
Veal Snay	Mean Chey	Sandan	Kampong Thom	534	105
Roneam	Mean Chey	Sandan	Kampong Thom	846	198
Trabaek	Mean Chey	Sandan	Kampong Thom	533	119
Rumpuh	Mean Chey	Sandan	Kampong Thom	589	125
Choan Leaeng	Mean Chey	Sandan	Kampong Thom	919	186
Choam Phal	Mean Chey	Sandan	Kampong Thom	714	172
Samrom	Mean Chey	Sandan	Kampong Thom	295	75
Popueng	Mean Chey	Sandan	Kampong Thom	350	85
Phtoul	Mean Chey	Sandan	Kampong Thom	347	75
Thmei	Mean Chey	Sandan	Kampong Thom	761	148
Dang Totueng	Ngan	Sandan	Kampong Thom	459	91
Khmaer	Ngan	Sandan	Kampong Thom	712	126
Krang Daeum	Ngan	Sandan	Kampong Thom	351	67
Rovieng	Ngan	Sandan	Kampong Thom	898	200
Sralau	Ngan	Sandan	Kampong Thom	406	79
Ngon	Ngan	Sandan	Kampong Thom	1613	304
Samphi	Ngan	Sandan	Kampong Thom	499	94
Troeb	Ngan	Sandan	Kampong Thom	398	90
Veal Pring Leu	Ngan	Sandan	Kampong Thom	331	62
Tang Krasau	Ngan	Sandan	Kampong Thom	673	146
Krabei Prey	Ngan	Sandan	Kampong Thom	486	104
Ou Tnaot	Ngan	Sandan	Kampong Thom	464	87
Svay	Ngan	Sandan	Kampong Thom	443	87
Danghet	Sandan	Sandan	Kampong Thom	827	177
Chhuk	Sandan	Sandan	Kampong Thom	402	80
Krasang	Sandan	Sandan	Kampong Thom	874	166
Srae Chang	Sandan	Sandan	Kampong Thom	608	116
Prasat Andaet	Sandan	Sandan	Kampong Thom	702	150
Kbal Khla	Sandan	Sandan	Kampong Thom	172	37

VILLAGE	Commune	District	Province	Total Popoulation	Total Households
Svay	Sandan	Sandan	Kampong Thom	626	127
Chor	Sandan	Sandan	Kampong Thom	1016	245
Tuek Mleang	Sandan	Sandan	Kampong Thom	685	165
Sandan	Sandan	Sandan	Kampong Thom	485	106
Kampong Trabaek	Sandan	Sandan	Kampong Thom	807	162
Ba Chey	Chheu Teal	Sandan	Kampong Thom	892	200
Prey Kokir	Sandan	Sandan	Kampong Thom	516	107
Rumchek	Sochet	Sandan	Kampong Thom	358	61
Krang	Sochet	Sandan	Kampong Thom	508	89
Pou Roung	Sochet	Sandan	Kampong Thom	500	101
Tayang	Sochet	Sandan	Kampong Thom	298	54
Ansa	Sochet	Sandan	Kampong Thom	253	61
Pren	Sochet	Sandan	Kampong Thom	409	66
Srae Pring	Sochet	Sandan	Kampong Thom	147	23
Leaeng	Tum Ring	Sandan	Kampong Thom	524	131
Roneam	Tum Ring	Sandan	Kampong Thom	232	60
Ronteah	Tum Ring	Sandan	Kampong Thom	639	138
Tum Ar	Tum Ring	Sandan	Kampong Thom	1042	222
Kbal Damrei	Tum Ring	Sandan	Kampong Thom	310	78
Samraong	Tum Ring	Sandan	Kampong Thom	411	91
Sralau Sraong	Tum Ring	Sandan	Kampong Thom	511	111
Khaos	Tum Ring	Sandan	Kampong Thom	804	161
A Chen	Kampong Cham	Sambour	Kratie	1432	301
Tonsaong Thleak	Kampong Cham	Sambour	Kratie	2006	308
Yeav	Kampong Cham	Sambour	Kratie	1452	299
Kaoh Sam	Voadthonak	Sambour	Kratie	807	190
Anlong Preah Kou	Voadthonak	Sambour	Kratie	959	180
Vodthonak	Voadthonak	Sambour	Kratie	1041	229
Ta Nguon	Voadthonak	Sambour	Kratie	659	143
S'ang	S'ang	Chey Saen	Kratie	1456	281
Tuek Lich	S'ang	Chey Saen	Preah Vihear	376	72
Kouk	S'ang	Chey Saen	Preah Vihear	909	183
Tasu	Tasu	Chey Saen	Preah Vihear	989	193
Thmei	Tasu	Chey Saen	Preah Vihear	383	66
Samraong	Tasu	Chey Saen	Preah Vihear	702	145
Khyang	Khyang	Chey Saen	Preah Vihear	950	215
Meun Reach	Khyang	Chey Saen	Preah Vihear	1204	245
Slaeng	Khyang	Chey Saen	Preah Vihear	1461	312
Pakdevoat	Chrach	Chey Saen	Preah Vihear	626	118
Chrach	Chrach	Chey Saen	Preah Vihear	760	145
Chamraeun	Chrach	Chey Saen	Preah Vihear	482	94
Phlaoch	Chrach	Chey Saen	Preah Vihear	561	113
Pramoul Phdom	Chrach	Chey Saen	Preah Vihear	482	91
Damnak Trach	Chrach	Chey Saen	Preah Vihear	382	61
Thmea	Yhmea	Chey Saen	Preah Vihear	1877	406
Srae Veal	Yhmea	Chey Saen	Preah Vihear	640	136
Phneak Roluek	Yhmea	Chey Saen	Preah Vihear	514	97
Kampong Putrea	Putrea	Chey Saen	Preah Vihear	1051	224
Peuk	Putrea	Chey Saen	Preah Vihear	2536	547
Veal Bar	Putrea	Chey Saen	Preah Vihear	839	210
Rovieng Cheung	Robieb	Rovieng	Preah Vihear	589	135
Tnaot Mlu	Robieb	Rovieng	Preah Vihear	1223	227
Tang Trak	Robieb	Rovieng	Preah Vihear	1089	235
Bak Kdaong	Robieb	Rovieng	Preah Vihear	1215	155
Boeng	Robieb	Rovieng	Preah Vihear	354	76
Ou	Robieb	Rovieng	Preah Vihear	293	85
Damnak Chen	Reaksmei	Rovieng	Preah Vihear	374	70
Ta Tong	Reaksmei	Rovieng	Preah Vihear	307	71

VILLAGE	Commune	District	Province	Total Popoulation	Total Households
Chambak Ph'aem	Reaksmei	Rovieng	Preah Vihear	344	71
Trapeang Ruessei	Reaksmei	Rovieng	Preah Vihear	412	81
Thkaeng	Rohas	Rovieng	Preah Vihear	597	143
Kampot	Rohas	Rovieng	Preah Vihear	631	65
Sangkae Rung	Rohas	Rovieng	Preah Vihear	337	59
Kak Poun	Rohas	Rovieng	Preah Vihear	234	41
Chamlang	Rohas	Rovieng	Preah Vihear	380	73
Anlong Svay	Rohas	Rovieng	Preah Vihear	554	119
Thnal Kaeng	Robieb	Rovieng	Preah Vihear	1214	245
Rovieng Tboung	Robieb	Rovieng	Preah Vihear	640	121
Boh Pey	Rung Roeang	Rovieng	Preah Vihear	866	156
Srae Thum	Rung Roeang	Rovieng	Preah Vihear	1108	230
Pal Hal	Rik Reay	Rovieng	Preah Vihear	631	95
Boh	Rik Reay	Rovieng	Preah Vihear	664	140
Doung	Rik Reay	Rovieng	Preah Vihear	862	155
Chhnuon	Ruos Roan	Rovieng	Preah Vihear	860	168
Tonloab	Ruos Roan	Rovieng	Preah Vihear	701	136
Ruessei Srok	Ruos Roan	Rovieng	Preah Vihear	495	109
Ker	Rotanak	Rovieng	Preah Vihear	1436	249
Khnar	Rotanak	Rovieng	Preah Vihear	337	66
Samret	Rotanak	Rovieng	Preah Vihear	639	137
Samprieng	Rotanak	Rovieng	Preah Vihear	191	44
Prey Snuol	Rotanak	Rovieng	Preah Vihear	178	40
Slaeng Toul	Rieb Roy	Rovieng	Preah Vihear	282	66
Srae	Rieb Roy	Rovieng	Preah Vihear	424	89
Bangkan	Rieb Roy	Rovieng	Preah Vihear	730	148
Doun Ma	Reaksa	Rovieng	Preah Vihear	648	137
Samraong	Reaksa	Rovieng	Preah Vihear	244	46
Preal	Reaksa	Rovieng	Preah Vihear	382	67
Kak Poun	Reaksa	Rovieng	Preah Vihear	320	53
Rumdaoh	Reaksa	Rovieng	Preah Vihear	250	33
Sanlung Chey	Reaksa	Rovieng	Preah Vihear	206	43
Poleakkam	Reaksa	Rovieng	Preah Vihear	355	61
Sralau Sraong	Reaksa	Rovieng	Preah Vihear	451	98
Thnal Kaong	Rumdaoh	Rovieng	Preah Vihear	1223	288
Svay Pat	Rumdaoh	Rovieng	Preah Vihear	776	177
Kouk Ampil	Rumdaoh	Rovieng	Preah Vihear	507	79
Ovloek	Rumdaoh	Rovieng	Preah Vihear	1161	189
Trapeang Totuem	Romtom	Rovieng	Preah Vihear	939	185
Ou Talouk	Romtom	Rovieng	Preah Vihear	727	142
Tuol Rovieng	Romtom	Rovieng	Preah Vihear	547	114
Bangkaeun Phal	Romtom	Rovieng	Preah Vihear	607	116
Svay Damnak Chas	Romtom	Rovieng	Preah Vihear	747	143
Svay Damnak Thmei	Romtom	Rovieng	Preah Vihear	375	78
Rumchek	Romoniy	Rovieng	Preah Vihear	1006	210
Ou Pour	Romoniy	Rovieng	Preah Vihear	627	144
Chi Aok	Romoniy	Rovieng	Preah Vihear	719	162
Phnum Daek	Romoniy	Rovieng	Preah Vihear	995	225
Srae Thnong	Romoniy	Rovieng	Preah Vihear	348	79
Sma Kaoh	Kaoh Sralau	Siem Bouk	Stung Treng	570	126
Svay	Kaoh Sralau	Siem Bouk	Stung Treng	1050	240
Phchul	Kaoh Sralau	Siem Bouk	Stung Treng	651	137
Kang Daek	Kaoh Sralau	Siem Bouk	Stung Treng	889	194
Siem Bouk	Siem Bouk	Siem Bouk	Stung Treng	635	122
Ou Lang	Siem Bouk	Siem Bouk	Stung Treng	641	148
Tonsang	Siem Bouk	Siem Bouk	Stung Treng	322	52
Ph'av	Anlong Phe	Thala Barivat	Stung Treng	548	105
Anlong Phe	Anlong Phe	Thala Barivat	Stung Treng	423	85

VILLAGE	Commune	District	Province	Total Popoulation	Total Households
Toal	Anlong Phe	Thala Barivat	Stung Treng	560	85
Veal Pou	Anlong Phe	Thala Barivat	Stung Treng	490	103
Spong	Anlong Phe	Thala Barivat	Stung Treng	505	98
Rumdeng	Chamkar Leu	Thala Barivat	Stung Treng	730	152
Chamkar Leu	Chamkar Leu	Thala Barivat	Stung Treng	596	128
Run	Chamkar Leu	Thala Barivat	Stung Treng	284	53
Kaes	Kang Cham	Thala Barivat	Stung Treng	423	84
Doung	Kang Cham	Thala Barivat	Stung Treng	339	71
Kang Cham	Kang Cham	Thala Barivat	Stung Treng	1334	274
Kang Kngaok	Kang Cham	Thala Barivat	Stung Treng	629	120
Kampong Pang	Kang Cham	Thala Barivat	Stung Treng	377	84
Kaoh Snaeng	Kaoh Snaeng	Thala Barivat	Stung Treng	1030	187
Kaoh Sralau	Kaoh Snaeng	Thala Barivat	Stung Treng	515	98
Choam Thum	Kaoh Snaeng	Thala Barivat	Stung Treng	359	72
Anlong Chrey	Anlong Chrey	Thala Barivat	Stung Treng	991	193
Mon	Anlong Chrey	Thala Barivat	Stung Treng	726	179
Sralau	Anlong Chrey	Thala Barivat	Stung Treng	137	26
Ou Rai	Ou Rai	Thala Barivat	Stung Treng	857	181
Pong Tuek	Ou Rai	Thala Barivat	Stung Treng	564	120
Anlong Svay	Ou Rai	Thala Barivat	Stung Treng	741	138
Kaoh Hib	Ou Svay	Thala Barivat	Stung Treng	407	90
Leu	Preah Rumkel	Thala Barivat	Stung Treng	596	116
Kandal	Preah Rumkel	Thala Barivat	Stung Treng	880	195
Kaoh Chheu Teal Touch	Preah Rumkel	Thala Barivat	Stung Treng	498	105
Krala Peas	Preah Rumkel	Thala Barivat	Stung Treng	642	141
Kraom	Preah Rumkel	Thala Barivat	Stung Treng	859	184
Anlong Svay	Preah Rumkel	Thala Barivat	Stung Treng	646	139
Samang	Sam'ang	Thala Barivat	Stung Treng	768	166
Chhvang	Anlong Chrey	Thala Barivat	Stung Treng	613	132
Srae Ruessei	Srae Ruessei	Thala Barivat	Stung Treng	570	114
Anlong Kramuon	Srae Ruessei	Thala Barivat	Stung Treng	491	107
Thalabarivat	Thala	Thala Barivat	Stung Treng	1589	335
Ou Trael	Thala	Thala Barivat	Stung Treng	1506	260
Kang Dechou	Thala	Thala Barivat	Stung Treng	425	83
Veal Khsach	Thala	Thala Barivat	Stung Treng	689	132

Annex 2: Thematic Maps of Prey Lang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Sesan
Sangkom Thmei
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Siem Bouk
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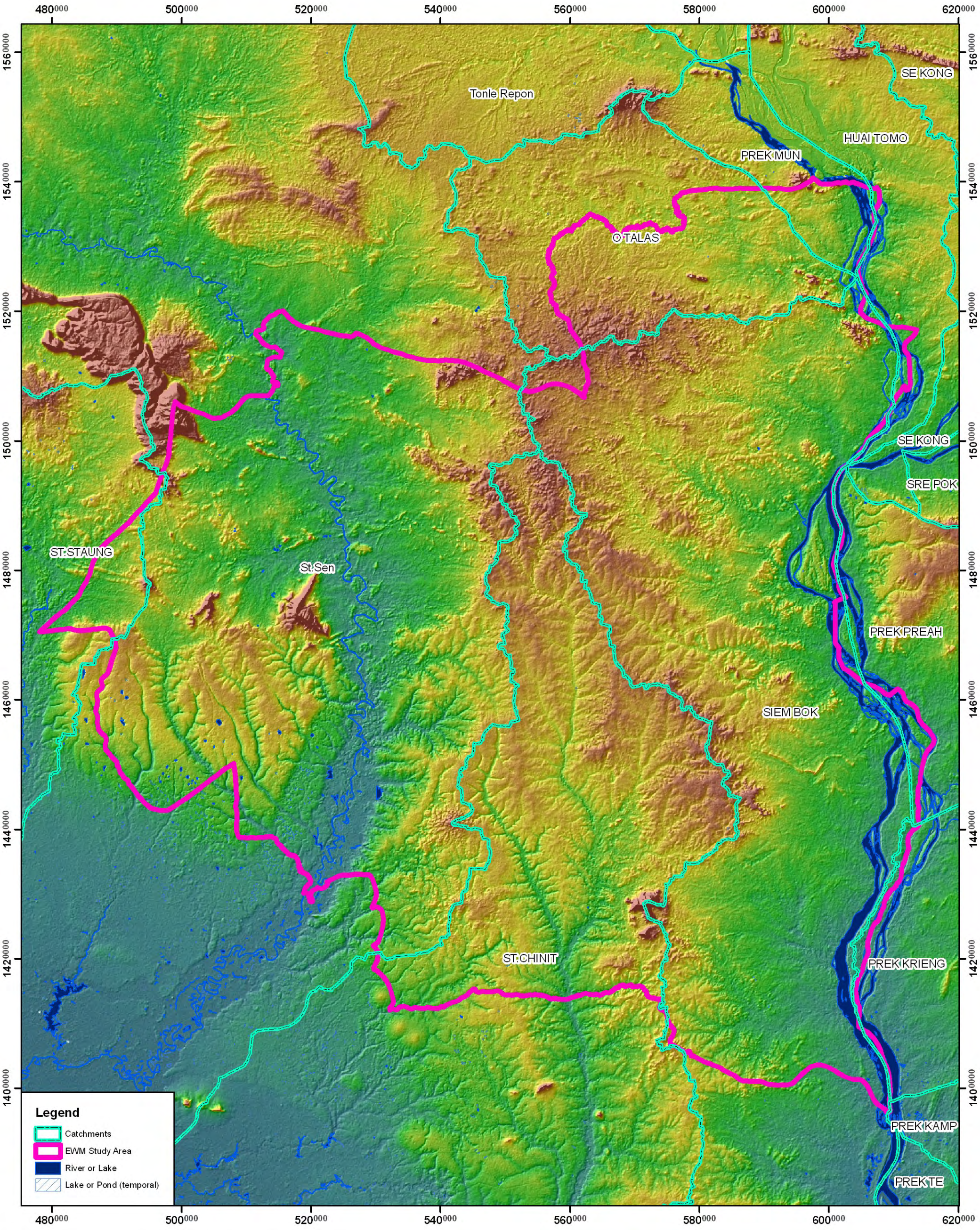
Baray
Baray
Stueng Trang
Kampong Chhnang
Chamkar Leu
Kampong Chaam
Preaek Prasab
Krouch Chhmar
Snuol
Chamkar Leu
Stueng Trang
Chhloung
Chhloung
Krouch Chhmar
Batheay
Cheung Prey
Chol Kiri
Prey Chhor
Kampong Siem
Tboung Khmum
Dambae
Memot
Legend
Provincial Centre
District Centre
EWM Study Area
Major Road
Province Boundary
District Boundary
Forest Cover 2006
Evergreen forest
Semi-evergreen forest
Deciduous forest
Other forest
Woodshrub dry
Woodshrub evergreen
Non Forest
Bamboo
N
0
10
20
40
Kilometers
1 centimeter equals 7,000 meters
Prey Lang
Location Map
Sources:
Data provided by EWMI
Coordinate System: UTM Zone 48, Horizontal datum: Indian 1960



N

0 10 20 40

Kilometers

1 centimeter equals 5,500 meters

Prey Lang GIS Atlas

Coordinate System:

UTM Zone 48, Horizontal datum: Indian 1960

480000 500000 520000 540000 560000 580000 600000 620000

1560000 1540000 1520000 1500000 1480000 1460000 1440000 1420000 1400000

Preah Vihear

Stueng Traeng

Kampong Thum

Kracheh

Legend

Village Popoulation 2007

- 66 - 250
- 251 - 500
- 501 - 1000
- 1001 - 1500
- 1501 - 2536

- Major Road
- EWM Study Area
- Province Boundary
- River or Lake
- Lake or Pond (temporal)

Forest Cover 2006

- Evergreen forest
- Semi-evergreen forest
- Deciduous forest
- Other forest
- Woodshrub dry
- Woodshrub evergreen
- Non Forest
- Bamboo

480000 500000 520000 540000 560000 580000 600000 620000

N

0 10 20 40

Kilometers

1 centimeter equals 5,500 meters

Prey Lang GIS Atlas

Coordinate System:

UTM Zone 48, Horizontal datum: Indian 1960

480000 500000 520000 540000 560000 580000 600000 620000

1560000 1540000 1520000 1500000 1480000 1460000 1440000 1420000 1400000

Choam Khsant
Chhaeb
Siem Pang
Kuleaen
Tbaeng Mean chey
Thala Barivat
Stueng Traeng
Chey Saen
Sangkom Thmei
Sesan
Rovieng
Siem Bouk
Sandan
Sambour
Prasat Sambour
Santuk
Preaek Prasab
Kracheh
Baray

Legend

Land Conflicts 2007

- 0
- 1 - 5
- 6 - 10
- 11 - 15
- 16 - 25
- Villages 2005
- EWM Study Area
- Major Road
- Indochine Mineral Concession
- Resin Camps
- Community Forest
- Proposed_Reservoir
- District Boundary
- River or Lake
- Lake or Pond (temporal)

Forest Cover 2006

- Evergreen forest
- Semi-evergreen forest
- Deciduous forest
- Other forest
- Woodshrub dry
- Woodshrub evergreen
- Non Forest
- Bamboo

N

0 10 20 40

Kilometers

1 centimeter equals 5,500 meters

Prey Lang
Community and Land Issues

Sources:
Land Conflicts - Commune Database 2007
Forest Cover 2006 - Forestry Administration
Other data provided by EWMI
Coordinate System: UTM Zone 48, Horizontal datum: Indian 1960

480000 500000 520000 540000 560000 580000 600000 620000

1560000 1540000 1520000 1500000 1480000 1460000 1440000 1420000 1400000

Legend

- Villages 2005

Road Construction

Year Detected

- Unknown
- 1984
- 1990
- 1997
- 2000
- 2004
- 2009
- Proposed Extension '09
- EWM Study Area

Forest Cover 2006

- Evergreen forest
- Semi-evergreen forest
- Other

N

0 10 20 40

Kilometers

1 centimeter equals 5,500 meters

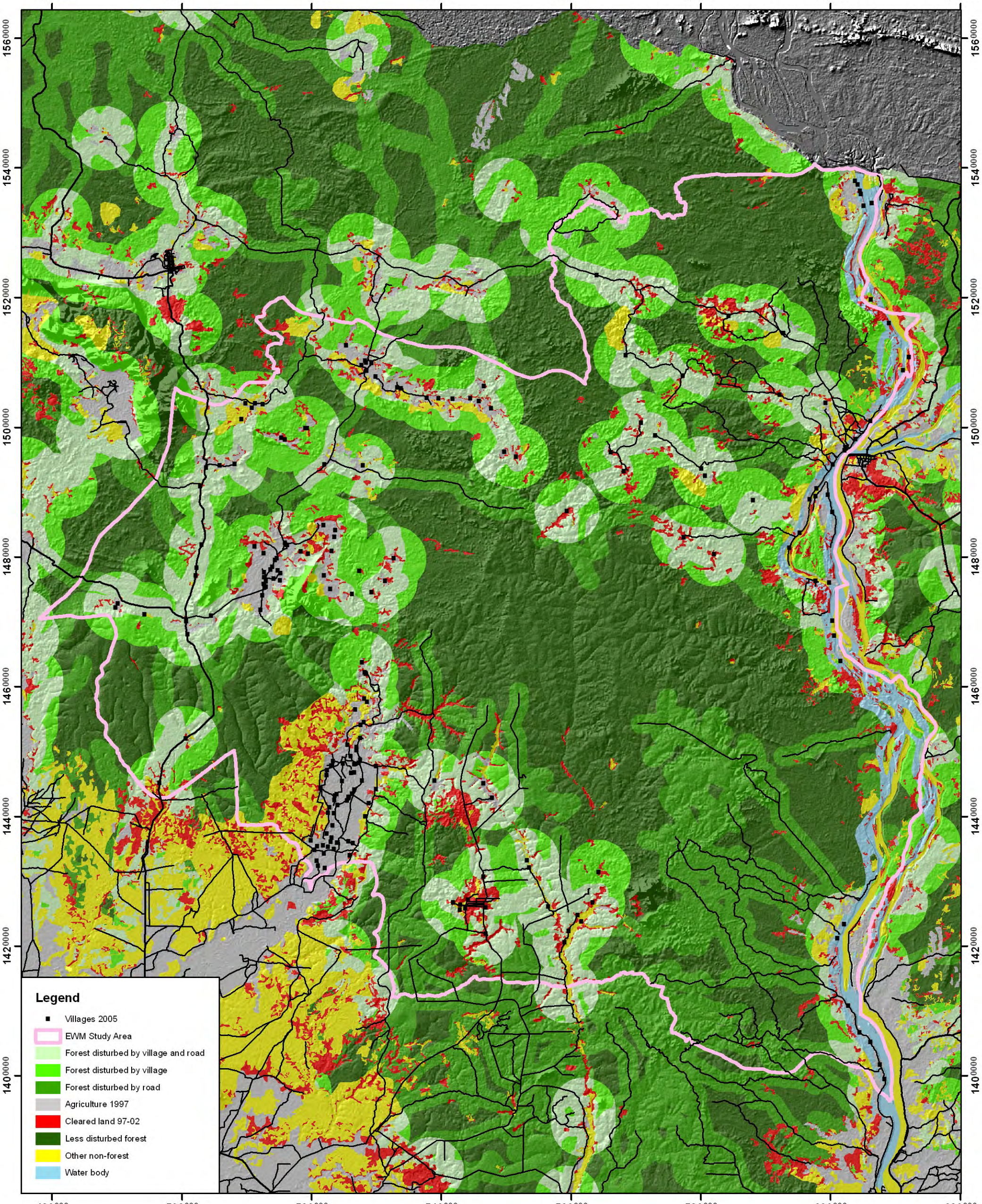
Prey Lang GIS Atlas

Coordinate System:

UTM Zone 48, Horizontal datum: Indian 1960

480000 500000 520000 540000 560000 580000 600000 620000

1560000 1540000 1520000 1500000 1480000 1460000 1440000 1420000 1400000



N

0 10 20 40

Kilometers

1 centimeter equals 5,500 meters

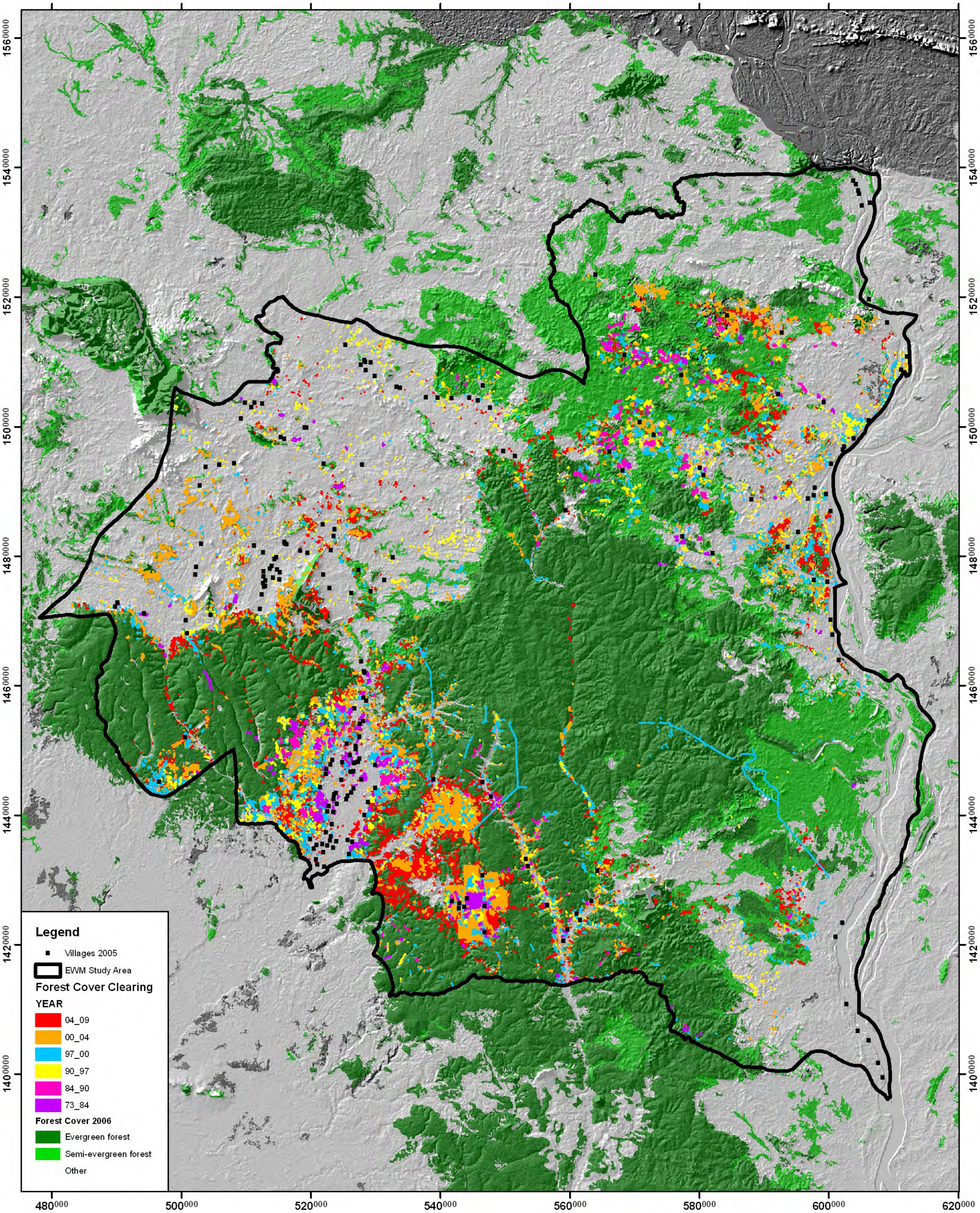
Prey Lang
Forest Disturbance 2002

Source: DANIDA\FA

Coordinate System: UTM Zone 48, Horizontal datum: Indian 1960

480000 500000 520000 540000 560000 580000 600000 620000

1560000 1540000 1520000 1500000 1480000 1460000 1440000 1420000 1400000



N

0 10 20 40

Kilometers

1 centimeter equals 5,500 meters

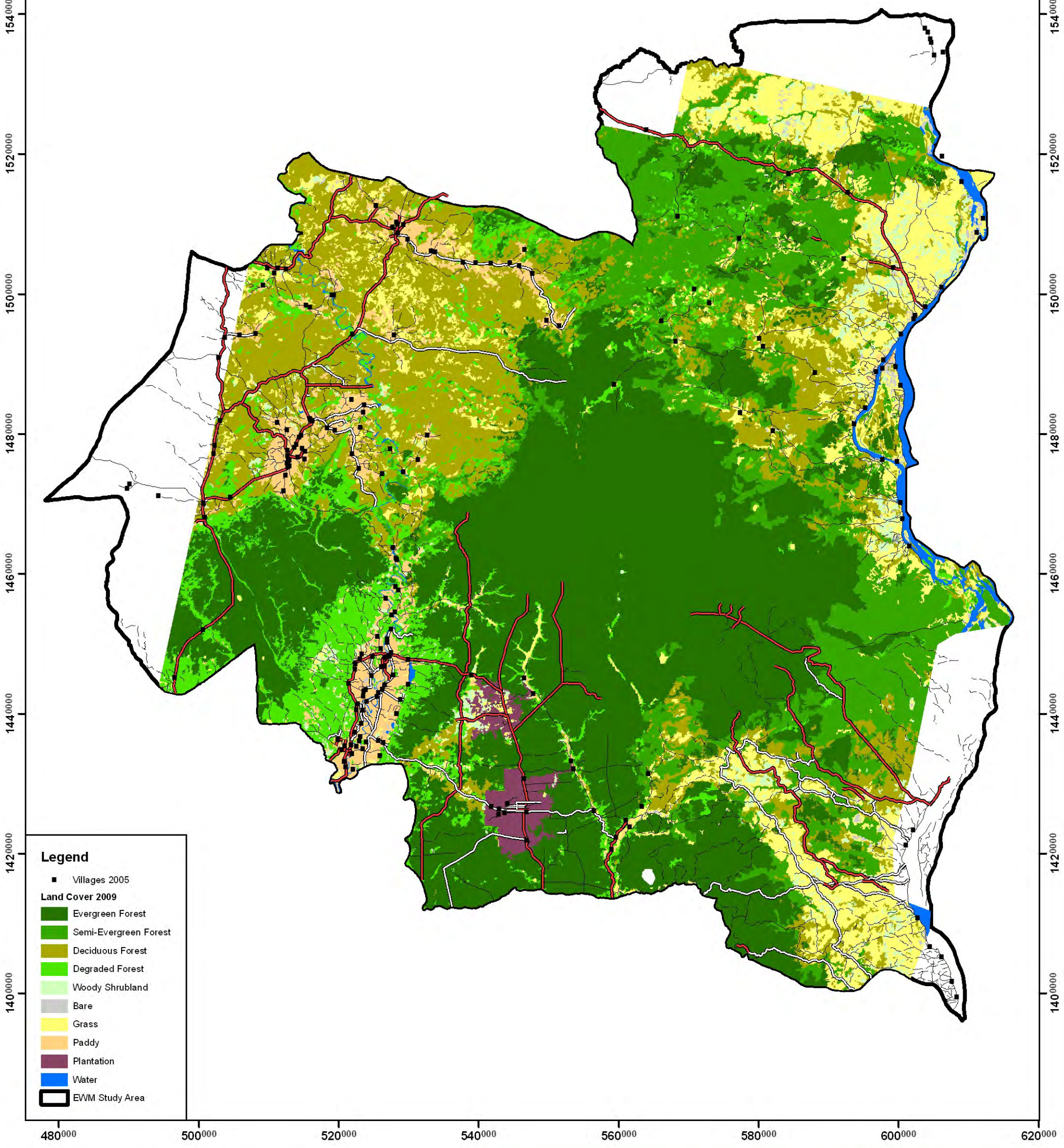
Prey Lang Forest Clearing

Coordinate System: UTM Zone 48, Horizontal datum: Indian 1960

Source: Rapid assessment conducted by Aruna Technology for EWMI

480000 500000 520000 540000 560000 580000 600000 620000

1560000 1540000 1520000 1500000 1480000 1460000 1440000 1420000 1400000



Legend

- Villages 2005

Land Cover 2009

- Evergreen Forest
- Semi-Evergreen Forest
- Deciduous Forest
- Degraded Forest
- Woody Shrubland
- Bare
- Grass
- Paddy
- Plantation
- Water
- EWM Study Area

N

0 10 20 40

Kilometers

1 centimeter equals 5,500 meters

Prey Lang
Land Cover 2009

Coordinate System: UTM Zone 48, Horizontal datum: Indian 1960

Source: Rapid assessment conducted by

Aruna Technology for EWMI

480000 500000 520000 540000 560000 580000 600000 620000

1560000 1540000 1520000 1500000 1480000 1460000 1440000 1420000 1400000

Choam Khsant
Chhaeb
Siem Pang
Kuleaen
Tbaeng Mean chey
Thala Barivat
Stueng Traeng
Chey Saen
Sangkom Thmei
Sesan
Rovieng
Siem Bouk
Sandan
Sambour
Prasat Sambour
Santuk
Preaek Prasab
Kracheh
Baray

Legend

CDB2007_Prey_Lang_Vill_Update

FAM_CHAMK / HH_TOTAL

- 0%
- 0.1% - 25%
- 25.1% - 50%
- 50.1% - 75%
- 75.1% - 100%
- Villages 2005
- Villages 2005
- EWM Study Area
- Resin Camps
- Community Forest
- District Boundary

Forest Cover 2006

- Evergreen forest
- Semi-evergreen forest
- Deciduous forest
- Other forest
- Woodshrub dry
- Woodshrub evergreen
- Non Forest
- Bamboo

N

0 10 20 40

Kilometers

1 centimeter equals 5,500 meters

Prey Lang
% of Families with Chamkar

Sources:
Commune Database 2007
Forest Cover 2006 - Forestry Administration
Other data provided by EWMI
Coordinate System: UTM Zone 48, Horizontal datum: Indian 1960

480000 500000 520000 540000 560000 580000 600000

1540000 1520000 1500000 1480000 1460000 1440000 1420000 1400000 1380000

Kenertec D
18445 Ha

Kenertec E
7063 Ha

Kenertec B
41383 Ha

Kenertec F
10845 Ha

Kenertec G
22086 Ha

Mong Good Luck Mining Co. Ltd.
9000 Ha

Try Pheap Co. Ltd.
4200 Ha

Ratanak Stone Cambodia Development Co. Ltd.
3600 Ha

Kenertec A
11522 Ha

Transol Titan
20400 Ha

Try Pheap Co. Ltd.
1800 Ha

Kenertec H
29039 Ha

Kenertec H2
20643 Ha

Ratanak Stone Cambodia Development Co. Ltd
3200 Ha

Kenertec C
23973 Ha

Lohak Aphivath (Cambodia) Co,Ltd.
30594 Ha

Chhong Kor Chhean Pean Co. Ltd
6000 Ha

Ratanak Stone Cambodia Development Co. Ltd
375 Ha

-Null-
12860 Ha

Delcom Cambodia PTE. LTD
16200 Ha

Metallic Minerals Exploration
28012 Ha

Cambodia International Mining Group
13300 Ha

Indochine Resource
51788 Ha

An Mady Group
10451 Ha

Vannvymex Co. Ltd.
7800 Ha

Sambo Plantation Station FA
15666 Ha

Tomring
6200 Ha

Chhong Kor Chhean Pean
4985 Ha

Gold Foison
11686 Ha

Indochine Resource
29993 Ha

Camchy International
26668 Ha

Indochine Resource
29993 Ha

Indochine Resource
29193 Ha

Legend

- Villages 2005
- EWM Study Area
- Major Road
- Land Concession Areas
- Mineral Concession

Forest Cover 2006

- Evergreen forest
- Semi-evergreen forest
- Deciduous forest
- Other forest
- Woodshrub dry
- Woodshrub evergreen
- Non Forest
- Bamboo

N

0 10 20 40

Kilometers

1 centimeter equals 5,500 meters

Prey Lang Concessions

Sources:
Data provided by EWMI
Coordinate System: UTM Zone 48, Horizontal datum: Indian 1960

Annex 3: GIS Data Catalog

EWM
GIS Database Structure

- **National**
  - **I-Baseline Data**
    - ❖**Raster Data**
      - ✧ALOS
        - ✦ALOS_AVNIR_10m_030309.pix
        - ✦ALOS_AVNIR_10m_170109.pix
        - ✦ALOS_2pt5m_Color_Mar08toJan09.jpg
      - ✧Image
        - ✦Concession
      - ✧Landsat
        - ✦LM5_126051_20091205.pix
        - ✦LT7_126051_20041226.pix
        - ✦LT7_126051_20001231.pix
        - ✦oLT5_126051_19971215.pix
        - ✦LT4_126051_19901204.pix
        - ✦LM5_126051_19841211.pix
        - ✦LM1_135051_19730103.pix
    - ❖**Vector Data**
      - ✧**Administrative**
        - ✦AOI_Communes.shp
        - ✦Ckhet99.shp
        - ✦Ckhum99.shp
        - ✦Cphum99.shp
        - ✦Csrok99.shp
        - ✦Dist_Proj_Clip.shp
        - ✦Dist_Proj_Clip_Resel.shp
        - ✦Khet99.shp
        - ✦Khum.shp
        - ✦Phum05_Intersect.shp
        - ✦Srok99.shp
        - ✦Villages.shp
        - ✦EWM002_Study_Area.shp
        - ✦CSrok_Study_Area.shp
        - ✦CKhum_Study_Area.shp
        - ✦Village_Study_Area.shp
        - ✦poverty_mergev2.shp
        - ✦level1-2001.shp
        - ✦village-census.shp
        - ✦khm_provinces.shp
        - ✦khm_districts.shp
        - ✦khm_communes.shp
        - ✦cphum2006.shp
        - ✦srok.shp
        - ✦ckhet.shp
        - ✦b-counbnd_arc_land.shp
      - ✧**Biodiversity Survey**
        - ✦Community_Survey.shp
        - ✦Community_Survey_PVH_ST.shp
      - ✧**Community Forest**
        - ✦Community
          - ✶Kampong_Cham
            - ✧Kampong_Cham_Community.shp
            - ✧sreprang.shp
            - ✧sreprang-1.shp
          - ✶Kampong_Chhnang
            - ✧Kampong_Chhnang_Community.shp
          - ✶Kampong_Thom
            - ✧Kampong_Thom_Community.shp

- ✶Kos_Kong
  - ✧Krang check_p.shs
- ✶Pursat
  - ✧Pursat_Community.shp
- ✶Siem_Ream
  - ✧Siem_Reap_Community.shp

✦Cover
- ✶Forest community.shp
- ✶Forest community_point.shp

✦Recoftc
- ✶CF_data_KPT_KRT_1.shp

✦Community_Forest.shp
✦Community_All-p.shp
✦Resin_camps.shp
✦Swamp_forests.shp

✧Contours

✦Contours20m
- ✶Contours.shp

✦srtm_dem.img
✦srtm_dem_hs.img

✧Forest Cover

✦FC 2006
- ✶Forest cover 2006.shp

✦Forest Disturbance
- ✶forest-dist.shp

✦FC 2002
- ✶Forest cover 2002.shp

✦Aruna_ChangeDetection73to09.shp

✧Protected Area

✦FAAreas
- ✶FAAreas.shp

✦MoEAreas
- ✶MoEAreas.shp

✦Protected_Areas_up2.shp

✧Roads

✦Mainroad.shp
✦Roadl99.shp
✦Road Extension.shp
✦Road point.shp
✦rd_lin.shp
✦rr_lin.shp
✦Roads2009.shp

✧Mineral Concession Area

✦Indochine
- ✶Indochine2.shp

✦Mining_Location.shp
✦Mine_Location_Point.shp

✧Land Concession Area

✦Land_Concession_Area.shp
✦FC_Land.shp

✧Land Use ???

✦LandUse2002 ???
- ✶LandUse2002.shp

✦LU_All.shp

✧WWF data

✦WWF BCI
- ✶Buffer_of_villages_5km.shp
- ✶mdk_bci_zones.shp
- ✶mdk_bci_zones_agri_concession.shp
- ✶mdk_bci_zones_communes.shp
- ✶mdk_bci_zones_dams.shp
- ✶mdk_bci_zones_districts.shp

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					✶mdk_bci_zones_outline.shp
					✶mdk_bci_zones_pass.shp
					✶mdk_bci_zones_road.shp
			✧**MRC Data**		
				✦MRC	
					✶Watershed Classification
			✧**Hydrology**		
				✦River	
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					✶Rivers99.shp
				✦Stream	
					✶Stream.shp
				✦dn_pol.shp	
				✦dn_pol_lin.shp	
				✦dn_lin.shp	
				✦Proposed_Reservoir.shp	
			✧**Watershed**		
				✦EWM_Watershed.shp	
			✧**Infrastructure**		
				✦health-centers.shp	
				✦school.shp	
			✧**Land Cover 2009**		
				✦Land_Cover_2009.shp	
			✧**CDB**		
				✦CDB2007_Prey_Lang_Vill.shp	
	II-Map Project				
		❖**Keep all the map document (*.mxd)**			
	II-Map Export				
		❖**Keep all the map document export to jpg or pdf (*.jpg or *.pdf)**			

Annex 4: Summary of Bruijnzeel, 2004

Issue	Summary from Bruijnzeel 2004
1. Precipitation	• Very complex and difficult issue, but through time series analysis and modeling, a better picture is known; • In maritime-influenced tropics, underlying sea-surface temperature is most important factor, and land effects are more limited; • Of late there is increasing observational evidence that forest conversion over areas between 1,000-10,000 km² causes feedbacks in the timing and distribution of clouds. • It is concluded that effects of forest disturbance and conversion on rainfall will be smaller than the average decrease of 8% predicted for a complete conversion to grassland in Southeast Asia because the radiative properties of secondary regrowth quickly resemble those of the original forest again.
2. Changes in Catchment Water Yield (the amount of rainfall that flows from the streams of the catchment)	• In all cases, the removal of more than 33% of forest cover resulted in significant increases in annual streamflow during the first three years. Initial gains in water yield after complete forest clearance ranged between 145 and 820 mm per year; • In addition, increases in water yield proved to be roughly proportional to the fraction of biomass removed; • Important to distinguish between the effect of forest clearing on total water yield and on the seasonal distribution of flows; • Under mature tropical rain forest, typically 80-95% of incident rainfall infiltrates into the soil, of which ~1,000 mm per year is transpired again by trees…whereas the remainder is used to sustain streamflow…in the form of baseflow.
3. Changes in Water Yield with Forest Regeneration	• Generally, the initial increassin total water yield following forest clearing exhibit a more or less irregular decline to pre-clearing levels with time, reflecting the development of the regenerating or newly planted vegetation and year-to-year variability of rainfall; • A rapid return to pre-disturbance levels of streamflow during forest regeneration after logging or clearing in the humid tropics may be expected in view of the generally vigorous growth of young tropical secondary vegetation; • The water use of young secondary vegetation in Southeast Asia may be estimated as being ~250 mm per year lower than that for mature forest.
4. Changes in Water Yield Following Forest Conversion	• Permanent increases in annual water yield are usually associated with the conversion of forest to agricultural cropping ranging from 140-410 mm/year and an increase in permanent streamflow as well (150-300 mm/year depending on rainfall); • Sometimes conversion to plantation returns water yield to original levels and may in some cases lower the permanent water yield (eucalyptus); • On much deeper soils (>8m), the annual water use of the plantation exceeded annual rainfall considerably, suggesting ‘mining’ of soil

	water reserves that had accumulated previously in deeper layers during years of above-average rainfall; • Planting of eucalypts, particularly in sub-humid climates, should therefore be based on judicious planning, i.e. away from water courses and depressions or wherever the roots would have rapid access to groundwater reserves.
5. Effects of Scale	• Effects discussed above pertain to mostly small headwater catchment areas…such effects are often more difficult to discern in larger catchments which usually have a variety of land use types and temporal changes therein; • There are complications wherever rainfall exhibits strong spatial variability and withdrawals of water for municipal, agricultural and industrial purposes are large; • Increases in streamflow (by ~30%) during slash and burn cultivation in French Guyana disappeared rapidly once the forest was allowed to regenerate.
6. Changes in Flow Regime – Dry Season Flow	• Continued exposure of bare soil after forest clearance to intense rainfall, the compaction of topsoil by machinery or overgrazing, the gradual disappearance of soil faunal activity, and the increases in area occupied by impervious surfaces such as roads and settlements all contribute to…increases in storm runoff during the rainy season [that] may become so large as to seriously impair the recharging of the soil and groundwater reserves feeding springs and maintaining baseflow; • If, on the other hand, soil surface characteristics after clearing are maintained sufficiently to allow the continued infiltration of (most of) the rainfall, then…will show up as increased dry season flow; • Infiltration opportunities may be conserved through the establishment of a well-planned and maintained road system plus the careful extraction of timber in the case of logging operations, or by applying appropriate soil conservation measures after clearing for agricultural purposes. • Simulations clearly show that baseflow levels are little affected by forest clearing as long as surface runoff coefficients remain below 15% of the rainfall. • Dry season flow diminished more rapidly following severe surface disturbance in the case of deep soils with large storage capacity than in the case of more shallow soils having little capacity to store water anyway.
7. Changes in Flow Regime – Stormflows and Floods: Local Effects	• Local Effects – depends on the interplay between climactic, geological and land use variables. Key parameters…include the hydraulic conductivity of the soil at different depths, rainfall intensity and duration, and slope morphology; • Generally speaking, infiltration capacities of undisturbed forest soils are such that they easily accommodate most rainfall intensities; • Variation in runoff response as a result of differences in soils…ranged between 7.3% and 34.4%....a distinction can be made between basins where the groundwater table tends to be close to the surface in the valley bottom and catchments where this is not the

	case; • The better the soils were drained, the smaller the runoff response; • Even with minimum soil disturbance, there will still be increases in peak flows after forest removal; • Relative increases in response tend to be largest for small raimfall events (roughly 100-300%) but decline to 10% or less for large events; • Normally, peaks produced by some form of overland flow are more pronounced than those generated by subsurface types of flow; • Dramatic increases in peakflows /stormflows…often reported after logging or land clearing operations using heavy machinery; • Shallow heavy clay soils…storm runoff coefficients under such conditions are typically >30% of incident rainfall. Conversely…for forested upland catchments on deep porous volcanic deposits in Java are typically less than 5%, but these may increase to 10-35% after clearing depending on …settlements and roads.
8. Changes in Flow Regime – Stormflows and Floods: Off-Site Effects	• One has to be careful to extrapolate such local effects to larger areas…high stormflows generated by rain on a misused part of a river basin may be 'diluted' by more modest flows from other parts receiveing less or no rainfall at the time, or having regenerating vegetation c.q. better land use practices; • Increased wet season flows are one thing but truly devastating and large-scale floods quite another. The latter are generally the result of an equally large and persistent field of extriem rainfall, particularly when this occurs at the end of a rainy season when soils have already become wetted thoroughly by antecedent rains. Under such extreme conditions, basin response will be governed almost entirely by soil water storage opportunities rather than topsoil infiltration capacity or vegetation cover; • Nevertheless, it cannot be excluded that widespread forest removal, followed by poor cultivation practices and rampant soil degradation, may have a cumulative effect.
9. Hydrological Effects of Reforestation	• Evidence of reductions in peak and stormflows after reforestation and the digging of contour trenches (by 65-70%) comes from…Northern India; • Despite the widespread intuitive feeling that reforestation or conservation measures will restore the flow from dried-up spring, the only apparently successful case known to the present author is…in eastern Indonesia; • The key question is, therefore, whether the reductions in storm runoff generating overland flow incurred by such soil physical improvements can be sufficiently large to compensate the extra water use by the new forest, and so (theoretically) boost low flows...there is no easy answer to this question for several reasons…the only documented 'real world' case in which the infiltration compensation mechanism seems to have occurred may be the White Hollow catchment in Tennessee, US; • Observed maximum differences between annual water use of pines or eucalypts and short vegetation (grass, crops) under well-watered

	(sub-) tropical conditions attain values of 500-700 mm at the catchment scale, and even higher values (>1,000 mm) on individual plots with particularly vigorous tree growth…the hydrological benefits incurred by the limited increases in topsoil infiltration observed after reforestation of degraded land…are simply dwarfed by such high water requirements.
10. Catchment Sediment Yield – General	• Surface erosion and catchment sediment yield normally show dramatic increases; • It is helpful to distinguish between surface erosion, gully erosion, and mass movements, because the ability of a vegetation cover to control these various forms of erosion is rather different; • Suspended sediment yields from rain forested catchments may be as low as 0.25 tons/ha/year in tectonically stable areas underlain by soils that are neither subject to significant surface erosion nor extensive gullying or mass wasting…conversely, in tectonically active steepland areas prone to hillslope failure, this may increase to 35-40 tons/ha/year whereas still higher values have been reported for situations where both surface erosion and mass wastage are rampant (up to 65 tons/ha/year); • It is equally important to make a distinction between on-site erosion and downstream (or 'off-site') effects because not all of the eroded material will enter the drainage network (streams) immediately…the time lag between on-site events and off-site events tends to increase with catchment size as well; • Dramatic contrast in stream sediment load (6 tons/ha/year) and sideslope soil displacement by heavy machinery (equivalent to 1,200 tons/ha/year) during a forest clearing operation in French Guyana.; • Stream sediment loads tend to vary enormously in time, with values being disproportionately higher during very wet periods or years, or even during individual extreme events.
11. Surface Erosion	• This form of erosion is rarely significant in areas where the soil surface is protected against the direct impact of the rain, be it through a litter layer maintained by some sort of vegetation or through the application of a mulching layer in an agricultural context; • Surface erosion [is] minimal in those cases where the soil is adequately protected (categories 1-4). Erosion rates increase somewhat upon removal of the understory (category 5) but rise dramatically only when the litter layer is removed or destroyed (categories 8-9); • The initial effect is rather small…but becomes considerable upon repeated disturbance of the soil by burning, frequent weeding or overgrazing, which all tend to make the soil compacted or crusted, with impaired infiltration and accelerated erosion as a result; • Margins for forest management with respect to soil surface protection against erosion are much broader than those associated with grazing or animal cropping; • Grasslands are often more prone to fire, overgrazing and

	landsliding; • Erosion on well-kept grassland, moderately grazed forest and agricultural fields with appropriate soil conservation measures on otherwise stable slopes is usually low; • Increasing evidence that erosion rates on and around such compacted surfaces as skidder tracks and log landings, roads, footpaths and settlements can be very high, especially shortly after construction (35-500 tons/ha/year). In addition, the very considerable volumes of runoff generated by such surfaces may promote downslope gully formation and mass wastage. Therefore, as already noted for runoff, sediment contributions to the stream network by roads and settlements may be disproportionately large for their relatively small surface area.
12. Gully Erosion	• Gully erosion is a relatively rare phenomenon in most rain forests, but may be triggered during extreme rainfall when the soil becomes exposed through treefall or landslips; Gullies may form by the collapse of subsurface soil 'pipes'; • Active gullying in formerly forested areas is often related to compaction of the soil by overgrazing or the improper discharging of runoff from roads, trails and settlements; • If gullies are not treated at an early stage, they may reach a point where restoration becomes difficult and expensive. The moderating effect of vegetation on actively eroding gullies is limited and additional mechanical measures such as check dams, retaining walls, and diversion ditches will be needed.
13. Mass Wasting	• Mass wasting in the form of deep-seated (>3m) landslides is not influenced appreciably by the presence or absence of a well-developed forest cover. Geological, topographical and climatic factors (notably rainfall) are the dominant controls; • The presence of a forest cover is generally considered important in the prevention of shallow (<1m) slides, the chief factor being mechanical reinforcement of the soil by the tree root network; • Although often occurring in large numbers, such small and shallow slope failures usually become quickly revegetated and, because of their predominant occurrence on the higher and central portions of the slopes, contribute relatively little to overall stream sediment loads, in contrast to their more deep-seated counterparts.
14. Catchment Sediment Yields	• No 'typical' values can be given for the changes in catchment sediment yield upon tropical forest disturbance or conversion. Nevertheless, a fairly consistent picture emerges…which summarises the results obtained by more than 60 studies of (suspended) sediment yield from small to medium-sized (<<100 km^2) catchments in Southeast Asia as a function of geological substrate, land cover and degree of disturbance; • Under undisturbed forested conditions, suspended sediment yields are generally below 1 ton/ha/year for very small (<50 ha) headwater catchments. Somewhat higher values (typically 3-5 tons/ha/year) are obtained for forested catchments of a few square kilometers in size on sedimentary rocks and young volcanics, whereas a much

	higher sediment yield (66 tons/ha/year) was reported for a forested catchment of intermediate size (45 km²); • The construction of roads, skidder tracks and log landings during mechanized logging and clearing operations represents a serious disturbance to the forest and generally causes sediment yields to rise 10-20 times. However, the effect usually subsides within a few years as skidder tracks become revegetated, roadsides stabilize and (in the case of clearing) the new vegetation establishes itself Increases in sediment yields associated with reduced impact logging (RIL) are generally much lower than for the average commercial operation; • Sediment yields of medium-sized catchments with mixed land use (including forest in various stages of regrowth) increase in the sequence granite < young volcanics < marls; • The dramatic effects of such drastic disturbances as urbanization, mining and road building are clearly borne out by the few data that are available, regardless of geological substrate; • The physiographic setting is of paramount importance; • In view of the disproportionately large influence on runoff and sediment generation exerted by roads, trails and settlements, particular attention would need to be paid to the proper discharging c.q. trapping of excess runoff and sediment from such areas; • An important conclusion to be drawn is that increases in sediment yields during logging and clearing operations can be kept low by reduced impact logging techniques which minimize surface disturbance; • Although published data on the positive effect on sediment yield incurred by soil conservation measures or reforestation in the humid tropics seem to be limited to zero-order catchments (i.e., having no perennial flow), an equally large effect may be expected in catchments not plagued by extensive mass wasting; • The frequently voiced expectation that upland reforestation will solve downstream problems does require some specification of the spatial and time scales involved.

Annex 5: Scenario Model

Stung Chinit Catchment Land Cover Changes, Conversion Scenario													
Item	**Assumptions**	**Area (Km²)**											
		2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**Total**
Forest to Agriculture	Continues at 0.5%/year	0.0	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	54.1
Forest to Degraded Forest	Continues at 0.5%/year then recovers after 3 years of degraded forest to forest	0.0	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	16.2
Forest to Cleared Forest	Starts during logging at 1% logged area/year.	0.0	1.0	2.0	2.0	2.0	2.0	1.1	0.0	0.0	0.0	0.0	10.2
Forest to Logged Forest	Colexim starts 2010 for five years completely logging their section of Prey Lang Forest, then Everbright starts in 2011	0.0	96.4	203.5	203.5	203.5	203.5	106.5	0.0	0.0	0.0	0.0	1016.8
Logged Forest to Plantation	Assume start after logging at 2%/year	0.0	0.0	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6	194.7
Forest to Settlements	Assume settlements follow logging roads similar to Lower Prey Lang Degraded Forest Area and cover 5% of the road area	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.6
Forest to Roads (road length x 25m)	Assume roads follow pattern similar to Lower Prey Lang Degraded Forest Area then expand at 10%/year afterwards	0.0	0.9	1.9	1.9	1.9	1.9	1.0	1.0	1.0	1.0	1.0	13.6
Forest to Mining	Not relevant as not within Prey Lang Core area but will accelerate development in southern tip and Phnom Bokphou Semi-Evergreen Forest Areas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Logged Forest to Degraded Forest	After 2 years effects of logging, 3 years of degraded forest to forest	0.0	0.0	0.0	48.2	179.8	179.8	180.7	180.8	83.9	0.0	0.0	853.2
Forest No Change	Reduced or increased from above factors, cumulative	1081.7	972.6	863.5	623.6	389.0	154.7	54.1	185.7	337.9	491.1	644.1	694.5
Total		1081.7	1081.7	1103.5	911.7	808.8	574.4	376.0	400.0	455.3	524.6	677.6	2853.9

Stung Chinit Catchment Land Cover Changes, Conversion Scenario													
Item	**Assumptions**	**Catchment Water Yield (MCM)**											
		2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**Total**
Forest to Agriculture	200 mm/year increase,	0.0	1.1	2.2	3.2	4.3	5.4	6.5	7.6	8.7	9.7	10.8	59.5
Forest to Degraded Forest	250 mm/year for 3 years	0.0	1.1	2.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	29.2
Forest to Cleared Forest	250 mm/year for 5 years	0.0	0.2	0.6	1.0	1.4	1.8	1.8	1.4	1.0	0.6	0.2	88.7
Forest to Logged Forest	Average Logging Yields ~30 cubic M/ha, biomass removal higher, 80% correlation to water yield	0.0	3.1	6.5	6.5	6.5	6.5	3.4	0.0	0.0	0.0	0.0	32.5
Logged Forest to Plantation	Not Applicable	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest to Settlements	Equals rainfall at 1,500 mm/year	0.0	0.0	0.1	0.2	0.4	0.5	0.7	0.7	0.8	0.9	0.9	5.2
Forest to Roads (road length x 25m)	Equals rainfall at 1,500 mm/year	0.0	1.4	2.9	7.2	10.1	13.0	14.6	16.0	17.5	18.9	20.4	122.1
Forest to Mining	Not applicable	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Logged Forest to Degraded Forest	Returns to previous value so no net change	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest No Change	No change	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	Total MCM	0.0	6.8	14.4	21.4	26.0	30.5	30.2	29.0	31.2	33.4	35.6	337.2

		Stung Chinit Catchment Land Cover Changes, Conversion Scenario											
Item	**Assumptions**	**Catchment Sediment Load Increase (tons)**											
		2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**Total**
Forest to Agriculture	3 tons/ha/year, cumulative	0	1,623	3,245	4,868	6,490	8,113	9,735	11,358	12,980	14,603	16,226	89,240
Forest to Degraded	20 tons/ha/year for 3 years	0	10,817	21,634	32,451	32,451	32,451	32,451	32,451	32,451	32,451	32,451	292,059
Forest to Cleared Forest	40 tons/ha/year for 5 years	0	3,855	11,994	20,133	28,271	32,555	28,678	20,539	12,401	4,262	0	381,299
Forest to Logged Forest	250 tons/ha/year for 2 years	0	1,445,692	4,497,709	6,104,033	6,104,033	6,104,033	4,650,228	1,598,212	0	0	0	30,503,940
Logged Forest to Plantation	50 tons/ha/year indefinitely and	0	0	108,170	216,340	324,510	432,680	540,850	649,020	757,190	2,596,080	973,530	6,598,370
Forest to Settlements	40 tons/ha/year indefinitely and cumulatively	0	0	184	573	962	1,351	1,740	1,943	2,138	2,332	2,526	13,750
Forest to Roads (road length x 25m)	100 tons/ha/year for 5 years	0	9,211	28,655	48,100	67,545	77,779	68,517	58,789	49,062	39,334	38,869	485,860
Forest to Mining	Not applicable	0	0	0	0	0	0	0	0	0	0	0	0
to Degraded Forest	previous value so no net change	0	0	0	0	0	0	0	0	0	0	0	0
Forest No Change	No change	0	0	0	0	0	0	0	0	0	0	0	0
Total	Total Tons	0	1,471,197	4,671,591	6,426,498	6,564,263	6,688,962	5,332,199	2,372,312	866,221	2,689,062	1,063,602	38,364,519

	Prey Lang Evergreen Forest Core Zone Land Cover Changes, Conversion Scenario												
Item	**Assumptions**	**Area (Km²)**											
		2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**Total**
Forest to Agriculture	Continues at 0.5%/year	0.0	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	93.6
Forest to Degraded Forest	Continues at 0.5%/year then recovers after 3 years of degraded forest to forest	0.0	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	28.1
Forest to Cleared Forest	Starts during logging at 1% logged area/year.	0.0	1.4	2.3	1.8	1.5	1.2	1.1	0.0	0.0	0.0	0.0	9.3
Forest to Logged Forest	Colexim starts 2010 for five years completely logging their section of Prey Lang Forest, then Everbright starts in 2011	0.0	142.2	227.6	182.1	145.7	116.5	113.8	0.0	0.0	0.0	0.0	927.9
Logged Forest to Plantation	Assume start after logging at 2%/year	0.0	0.0	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6	194.7
Forest to Settlements	Assume settlements follow logging roads similar to Lower Prey Lang Degraded Forest Area and cover 5% of the road area	0.0	1.4	2.2	1.7	1.4	1.1	1.1	0.0	0.0	0.0	0.0	8.9
Forest to Roads (road length x 25m)	Assume roads follow pattern similar to Lower Prey Lang Degraded Forest Area then expand at 10%/year afterwards	0.0	54.4	87.0	69.6	55.7	44.5	43.5	0.0	0.0	0.0	0.0	354.7
Forest to Mining	Not relevant as not within Prey Lang Core area but will accelerate development in southern tip and Phnom Bokphou Semi-Evergreen Forest Areas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Logged Forest to Degraded Forest	After 2 years effects of logging, 3 years of degraded forest to forest	0.0	0.0	0.0	-115.9	148.9	114.8	79.4	94.9	92.2	0.0	0.0	414.3
Forest No Change	Reduced or increased from above factors, cumulative	1871.7	1653.6	1435.5	1076.1	789.8	555.0	245.3	204.1	288.3	337.0	401.2	453.0
Total		1871.7	1871.7	1794.9	1255.7	1183.3	873.5	524.6	339.4	420.8	377.4	441.6	2484.4

		Prey Lang Forest Carbon Credits, Conversion Scenario											
Item	**Assumptions**	**Economic Value USD**											
		2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**Total**
Forest to Agriculture	Complete loss of forest carbon at 140 tons/ha	$0	$0	$187,170	$280,755	$374,340	$467,925	$561,510	$655,095	$748,680	$842,265	$935,850	$5,053,590
Forest to Degraded Forest	40% biomass removal then increase to 80% after 5 years	$0	$52,408	$47,562	$42,716	$37,870	$33,024	$28,178	$28,178	$28,178	$28,178	$28,178	$354,465
Forest to Cleared Forest	Complete loss of forest biomass, no regrowth	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Forest to Logged Forest	40% biomass removal in logging	$0	$22,759,680	$36,415,488	$29,132,390	$23,305,912	$18,644,730	$18,207,744	$0	$0	$0	$0	$148,465,945
Logged Forest to Plantation	Removal of remaining biomass (60%)	$0	$0	$54,085	$108,170	$162,255	$216,340	$270,425	$324,510	$378,595	$432,680	$486,765	$2,433,825
Forest to Settlements	Complete loss of forest carbon above-ground stock estimated at 140 tons/ha	$0	$13,594	$35,345	$52,745	$66,666	$77,802	$88,678	$88,678	$88,678	$88,678	$88,678	$689,540
Forest to Roads (road length x 25m)		$0	$761,274	$1,218,038	$974,431	$779,544	$623,636	$609,019	$0	$0	$0	$0	$4,965,942
Forest to Mining	N/A	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Logged Forest to Degraded Forest	Gain of 4% biomass per year from logging time to maximum 80%	$0	$0	$0	$1,947	-$1,852	-$2,113	-$2,811	-$2,682	-$2,525	-$1,048	-$516	-$11,599
Forest No Change	No change	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total	Total Value	$0	$23,586,956	$37,957,688	$30,593,154	$24,724,735	$20,061,343	$19,762,742	$1,093,778	$1,241,605	$1,390,753	$1,538,954	$161,951,708

Annex 6: Hydrology

6-1 Stung Sen

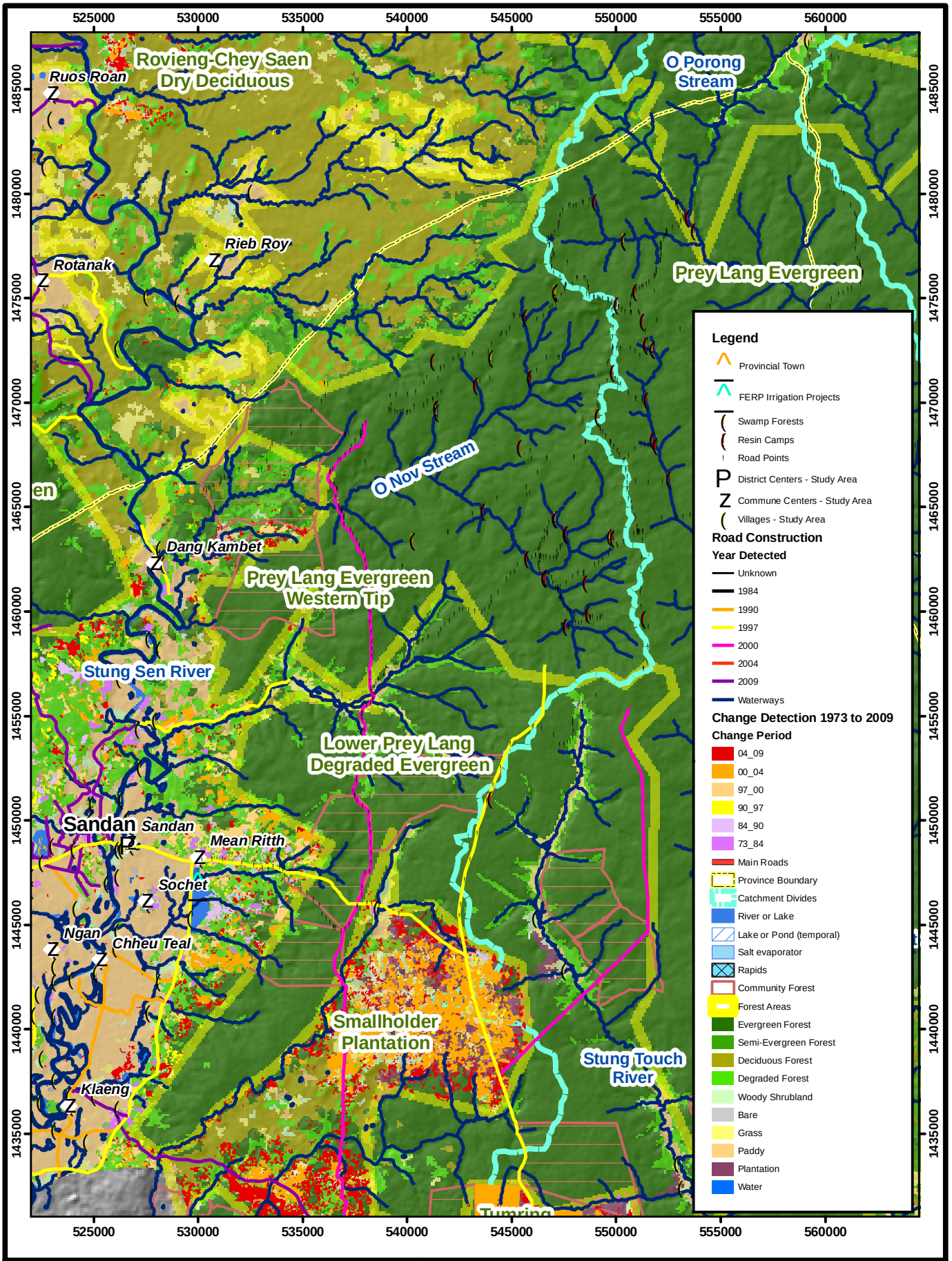
The Stung Sen catchment is shaped similar to the continent of Africa, with the largest part of the watershed in the upper third consisting of flat open dry deciduous forest with some more heavily forested rocky outcrops.

The Study Area includes the middle third of the watershed, mostly consisting of the large area of deciduous forest comprising Dry Dipterocarp Forest on thin and poor soils with Mixed Deciduous Forest mostly along streams and rivers (the Rovieng-Chey Saen Dry Deciduous Forest). These are low volume open forests in gently rolling terrain. As is common practice in the region, this forest is being progressively converted into paddy farms for pioneering populations moving into the area following the roads. These roads have been built over the last five years primarily, and are concentrated around Rovieng and Chey Saen District Towns and the communes within the Stung Sen River valley in the south, along the East-West roads leading from the right bank of the Mekong River and Reaksa Commune on the Northwestern edge of the area.

The southwestern portion of the Study Area includes the Boeung Per Evergreen Forest, which is part of the Boeung Per Wildlife Sanctuary. This forest is separated from the Prey Lang Forest by the Stung Sen River. It is experiencing progressive encroachment around its periphery, particularly from the populations within the adjacent Stung Sen river valley and lowlands and up along its stream valleys. In addition, it is bisected by National Road No. 61from Kampong Thom to Preah Vihear Province. It remains at present a good quality forest West of NR 61that has not been a timber concession in the past but these pressures are likely resulting in increasing degradation of the forest and reduction of the wildlife population.

The Eastern part of the catchment includes approximately 15% of the Prey Lang Evergreen and Lower Prey Lang Degraded Evergreen forests. The area of the Stung Sen catchment with the Prey Lang Evergreen forest is shown in Figure 2. As seen there, this area consists of the O Nov stream watershed along with part of the northern half of the catchment of the next stream to the south. This catchment comprises approximately 27% of the core Prey Lang Evergreen Forest that is in good condition. The area is however in a state of flux along the western edge of the forest within Dang Kambet Commune where land is being progressively converted into agricultural farmland along the O Nov and its smaller tributaries. This area may also have been denuded when it was part of the Mieng Ly Heng Timber Concession. This area is also now within a community forest, so it is possible that an improved management regime is developing. This Western Tip of the Prey Lang Evergreen Forest Core Zone, comprising the area within the Stung Sen River Catchment is one of its most vulnerable parts.

The area within the upper watershed includes a number of resin camps with access trails leading from the road heading north from the Tumring Rubber Plantation area through the O Nov. These trails are generally along catchment divides or stream valleys and appear to be relatively small. The area remains part of the core area of Prey Lang Forest that is in very good condition but is closest to where change is occurring as development increases. Included within this area are also some small swamp forests, unique areas within the Prey Lang Evergreen Forest formed in small depressions along the stream valleys that likely are particularly important for biodiversity.



0 1 2 4 6 8

Kilometers

1 centimeter equals 2.5 kilometers

Figure 16: Stung Sen River Catchment, Forest Areas, Land Use and Change

Coordinate System: UTM Zone 48, Horizontal Datum: WGS84
Forest Areas Approximate - Names Designated By Consultant

The area below this, designated as "Lower Prey Lang Degraded Evergreen Forest", is the lower part of the original Prey Lang Evergreen Forest which has been and continues to be affected by anthropogenic degradation and conversion as seen in Figure 2. While several reasonably good quality areas of forest remain, these are being gradually encroached upon and partitioned into increasingly smaller patches by roads and chamkar farming along river valleys. The Northern part of this small tributary area on the edge of the Stung Sen River valley appears to be in reasonably good condition and includes areas designated as community forest. Part of the catchment supplies the O Kranhak Irrigation System in Sochet Commune, an irrigation system of approximately 1,233 ha command area that was rehabilitated during the World Bank's Flood Emergency Rehabilitation Project in 2003 for a total cost of $354,000.

The Southwestern part of the O Kranhak Catchment appears to be a Smallholder Plantation area north of and connected to the Tumring Rubber Plantation. These plantations are set up on the basaltic outcrop surrounded by the Southeastern edge of the original Prey Lang Evergreen Forest area. The surrounding Evergreen Forest area was part of three different timber concessions (Mieng Ly Heng, GAT and Colexim) and was extensively logged and degraded between 1997 and 2000. While the logging roads remain, several of the areas have now been designated as community forest. These areas have been designated as part of the Lower Prey Lang Degraded Evergreen Forest.

There are larger roads leading from the plantation areas that connect to Sandan District town and points north to the Rovieng-Chey Saen Dry Deciduous Forest and south to Prasat Sambor District and Kampong Thom Town. Other smaller roads and tracks lead across the Stung Chinit Catchment and River to Phnom Chi Mountain and into Sambor District in Kratie Province on the west side of the Mekong River.
Below this point, the Stung Sen Catchment is lowland terrace and floodplain leading into the Tonle Sap Great Lake.

6-2 Stung Chinit

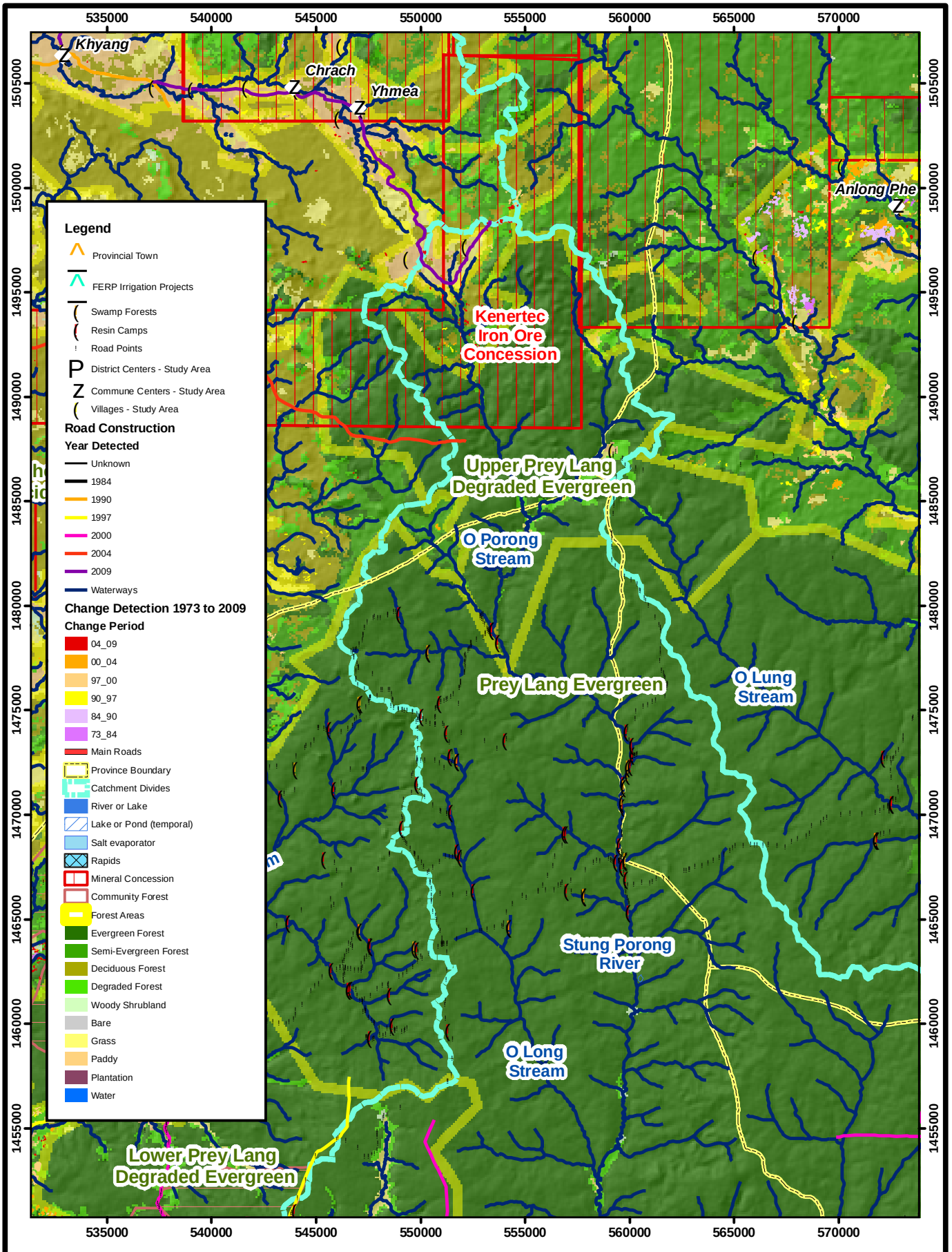
The Stung Chinit River Catchment contains the largest part of the Prey Lang Evergreen Forest. The catchment drains from north to south a narrow corridor of approximately 15 km width and 39 km length into the Stung Porong before opening into a wider (>40 km) more typical fan-like dendritic pattern. Here, two smaller tributary catchments also draining into the Stung Porong from the East before the Stung Porong joinms with the Stung Touch from the West. At the point where these streams meet and at the same latitude as the Tumring Rubber Plantation, the catchment narrows again to 30-35 km width for an additional 37 km before the river turns to the West and flows through Route 6 and eventually into the Tonle Sap floodplain. Prior to Route 6, a large Khmer Rouge constructed dyke and canal system forms the Stung Chinit Irrigation System connecting the Stung Chinit and Stung Tang Krasaing catchments. This is being rehabilitated as part of the Stung Chinit Integrated Rural Infrastructure Project (SCIRIP) funded by the Asian Development Bank for $23,800,000 including 7,000 ha of irrigation and drainage[7].

The top of the Stung Chinit River Catchment is formed by the Upper Prey Lang Degraded Evergreen Forest and is approximately 10 km wide and 18 km long (See Figure 3). It has already been settled and is in the process of changing into a typical agricultural mosaic as farmers cultivate the small stream valleys and move progressively into the higher lands. This area has almost certainly been completely logged at some point. There are three villages established within this area, two at the very top of the O Porong Catchment and one along its small tributary on the East. Pioneer farming extends down the Stung Porong from this area and into the core zone of the Prey Lang Evergreen Forest below. A road from Thala Barivath District on the Mekong River via Anlong Phe Commune cuts directly through this area and continues onto Kampong Putrea Commune on the Stung Sen River within the area of the Rovieng-Chey Saen Dry Deciduous Forest. The Kenertec Iron Ore Mineral Concession covers at least half of this section of the forest and could have a potentially large impact on the area as discussed in Section 5. An additional unnamed mineral concession also is apparently in place adjacent to and East of the Kenertec area.

The next section of the Stung Chinit River Catchment is divided into the Stung Porong on the East and O Long on the West as seen in Figure 3. This area includes numerous resin camps and associated trails for the resin tappers, including one that transects the Stung Chinit catchment from Southwest to Northeast. Despite these trails, the area appears to remain in near pristine condition and is in the centre of the core zone of the Prey Lang Evergreen Forest. There are several swamp forests along the Stung Porong, O Long and other small tributary streams within this part of the forest which as discussed in the previous section are of potentially large importance in respect of biodiversity.

The widest part of the Stung Chinit River Catchment below this can be divided into three distinct sections as seen in Figure 4. The Stung Porong mainstream stem running down the center of the catchment; the Eastern tributaries to the Stung Porong in Kratie Province; and the Eastern half of the Stung Touch Catchment below the Smallholder Plantation Area. The

[7] These are approximate figures based on earlier stages of the design. A more recent project document was not able to be obtained during the limited time available for the Study.



0 1 2 4 6 8

Kilometers

1 centimeter equals 2.5 kilometers

Figure 17: Stung Chinit Upper River Catchment, Forest Areas & Land Use

Coordinate System: UTM Zone 48, Horizontal Datum: WGS84
Forest Areas Approximate - Names Designated By Consultant

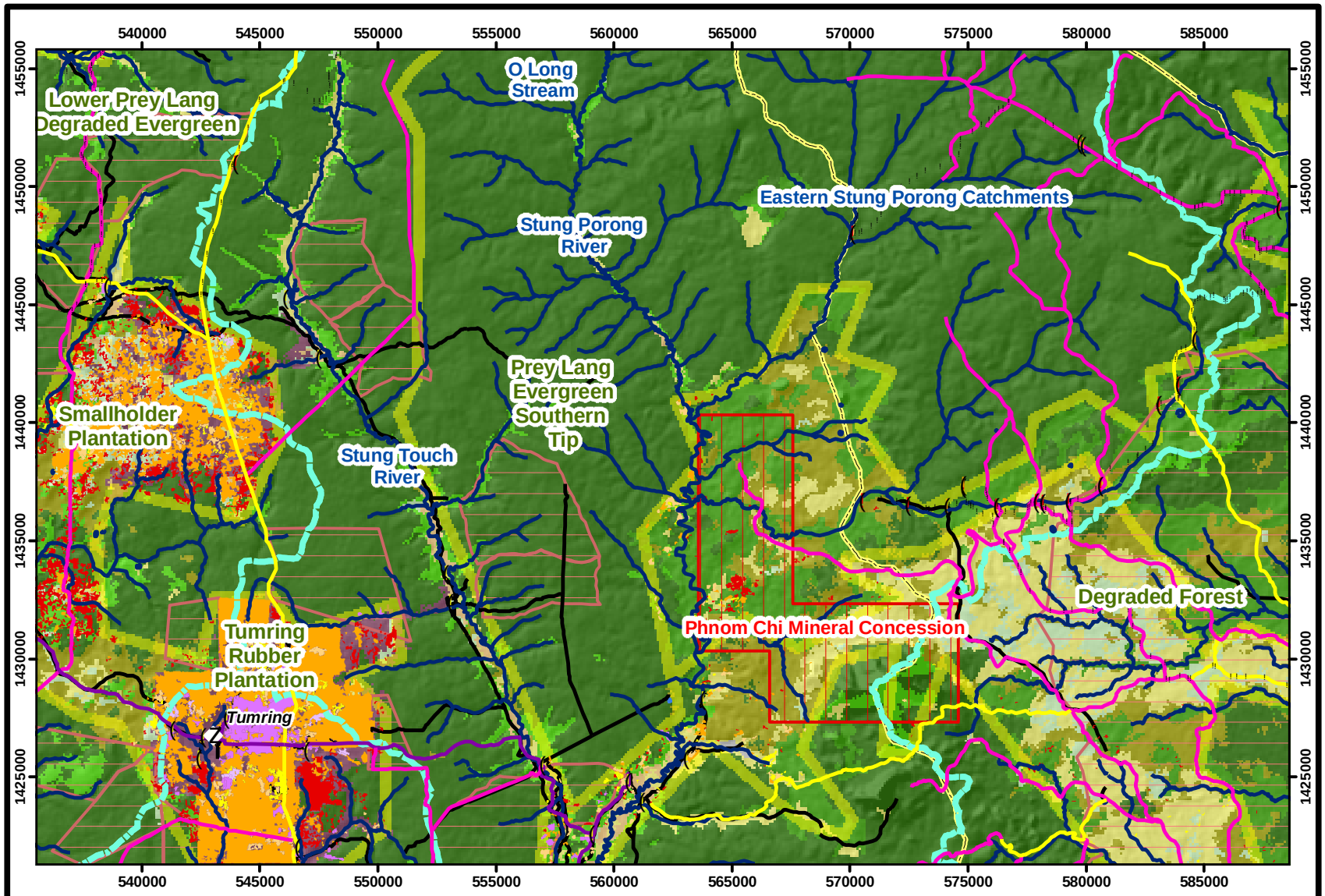


Figure 18: Stung Chinit Middle River Catchment, Forest Areas, Land Use and Development

Coordinate System: UTM Zone 48, Horizontal Datum: WGS84
Forest Areas Approximate - Names Designated By Consultant

Stung Porong mainstream stem forms the centre of the Prey Lang Evergreen Forest core zone and has been the least affected by any outside impacts so likely contains primary forest except along the Stung Porong River valley.

The Southwest part of this zone in-between the Stung Touch and Stung Porong appears to have been logged in the past as part of the Colexim Timber Concession and is currently on the frontier of the encroachment happening on the Southern edge of the Prey Lang Evergreen Forest so forms one of the most vulnerable areas of the Prey Lang Evergreen Forest Core Zone ("the Southern Tip").

The Eastern Tributaries are likewise relatively untouched recently however these areas were logged as part of the Pheapimex and Everbright Timber Concessions between 1997 and 2000 so are in a more degraded condition. Rapid regrowth of secondary forest may have obscured the extent of logging between the acquired satellite imagery as this does not show up within the change detection. The existence of the logging roads is a concern as these could form a transport conduit into the pristine part of the Core Zone.

The upper part of the Stung Touch is designated as part of the Lower Prey Lang Degraded Evergreen Forest and is likely significantly degraded as it has been heavily affected by development next to the Northern Rubber Plantation, up the Stung Touch River valley and along the old logging roads extending through the area. The remainder of the Lower Prey Lang Degraded Evergreen Forest includes the areas described previously within the Stung Sen River Catchment and surrounding the rubber plantations and extends across the Stung Chinit below the Prey Lang Evergreen Forest down to the lowlands where the Stung Chinit turns westwards. These areas have all been heavily logged as part of previous and ongoing timber concessions and are criss-crossed by a series of roads constructed progressively since the 1960's, hence are likely quite degraded. The majority of this area exists outside of the Study Area however.

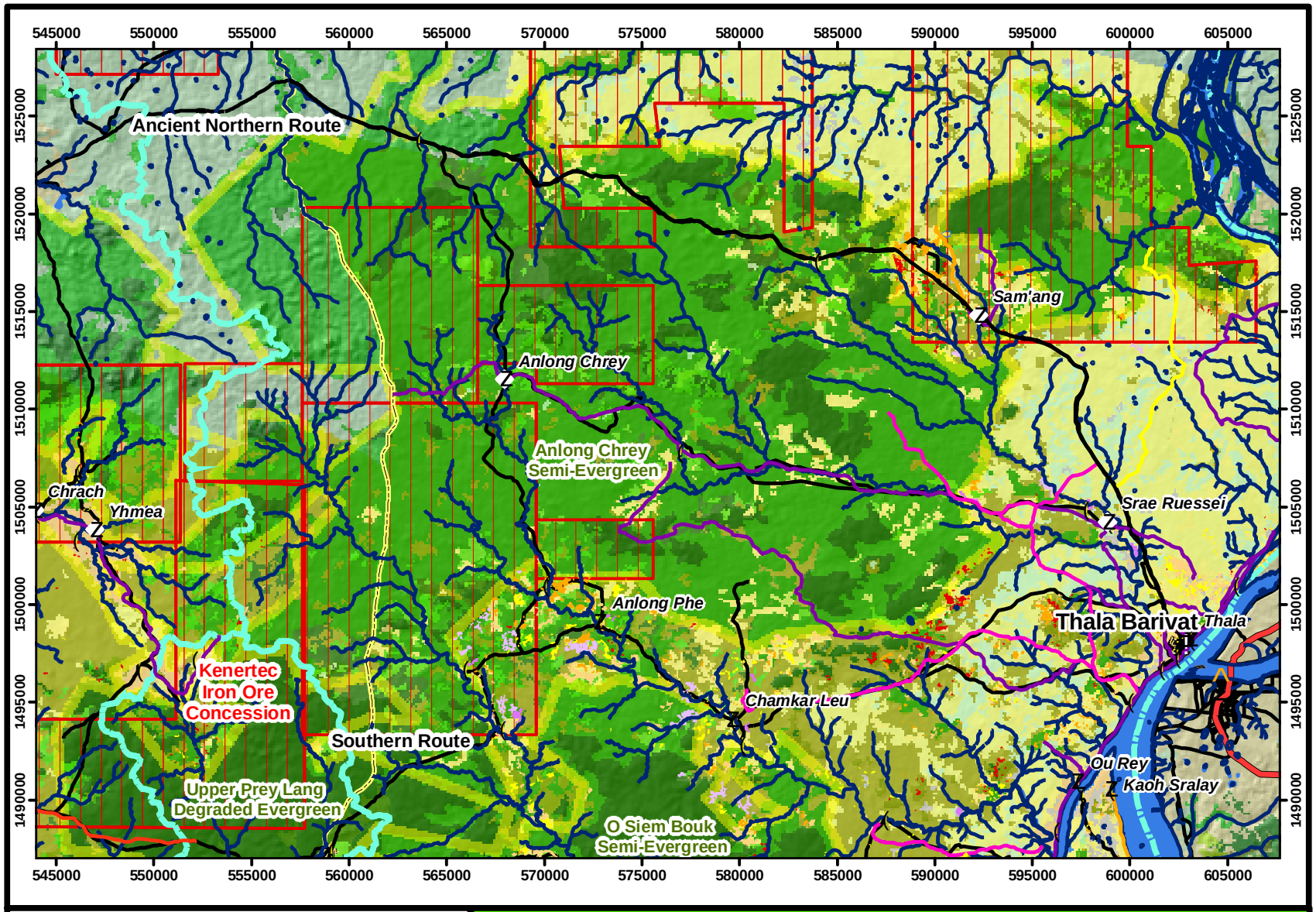
These connecting roads remain small, but as noted in Ashwell 2008, improvement of the road connecting Sambor and Sandan Districts would partition the Prey Lang Forest at this point and be a threat to its integrity. Land use change is inevitably observed wherever the roads lead.

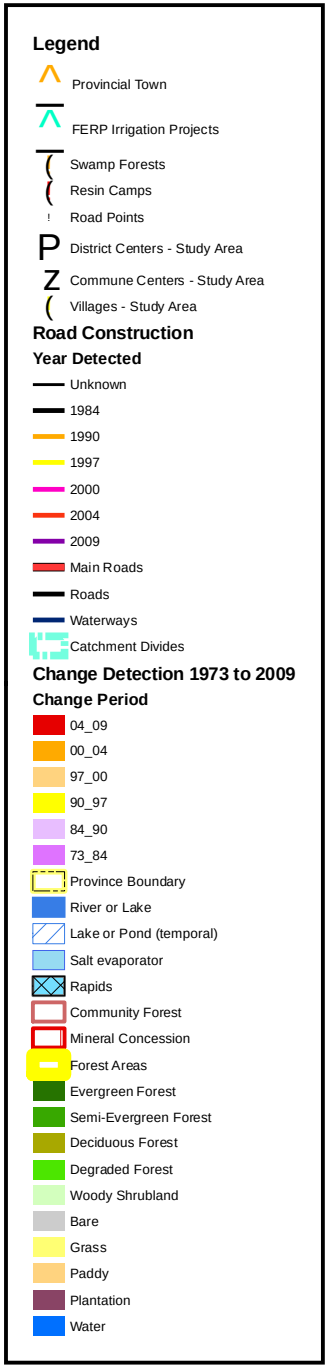
6-3 Mekong

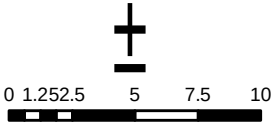
The Mekong River Catchment in the context of the Study Area consists of smaller tributary streams with catchments of 30-70 km length draining into the Mekong River. The upper catchments of these streams are generally forested, with lowland alluvial terraces surrounding the streams and extending out from the Mekong River.

Above the Study Area and extending into the northern part of it is an area of primarily Dry Deciduous (dipterocarp) Open Lowland Forest with mixed stands of Evergreen and Semi-Evergreen Forest. North of the Study Area, this includes parts of the Preah Vihear Wildlife Sanctuary.

After a transition through a small stream with a catchment of primarily grasslands, the Anlong Chrey Semi-Evergreen Forest drains into three streams that discharge into the Mekong River. The Anlong Chrey Semi-Evergreen and Siem Bouk Mixed Evergreen Forests are being



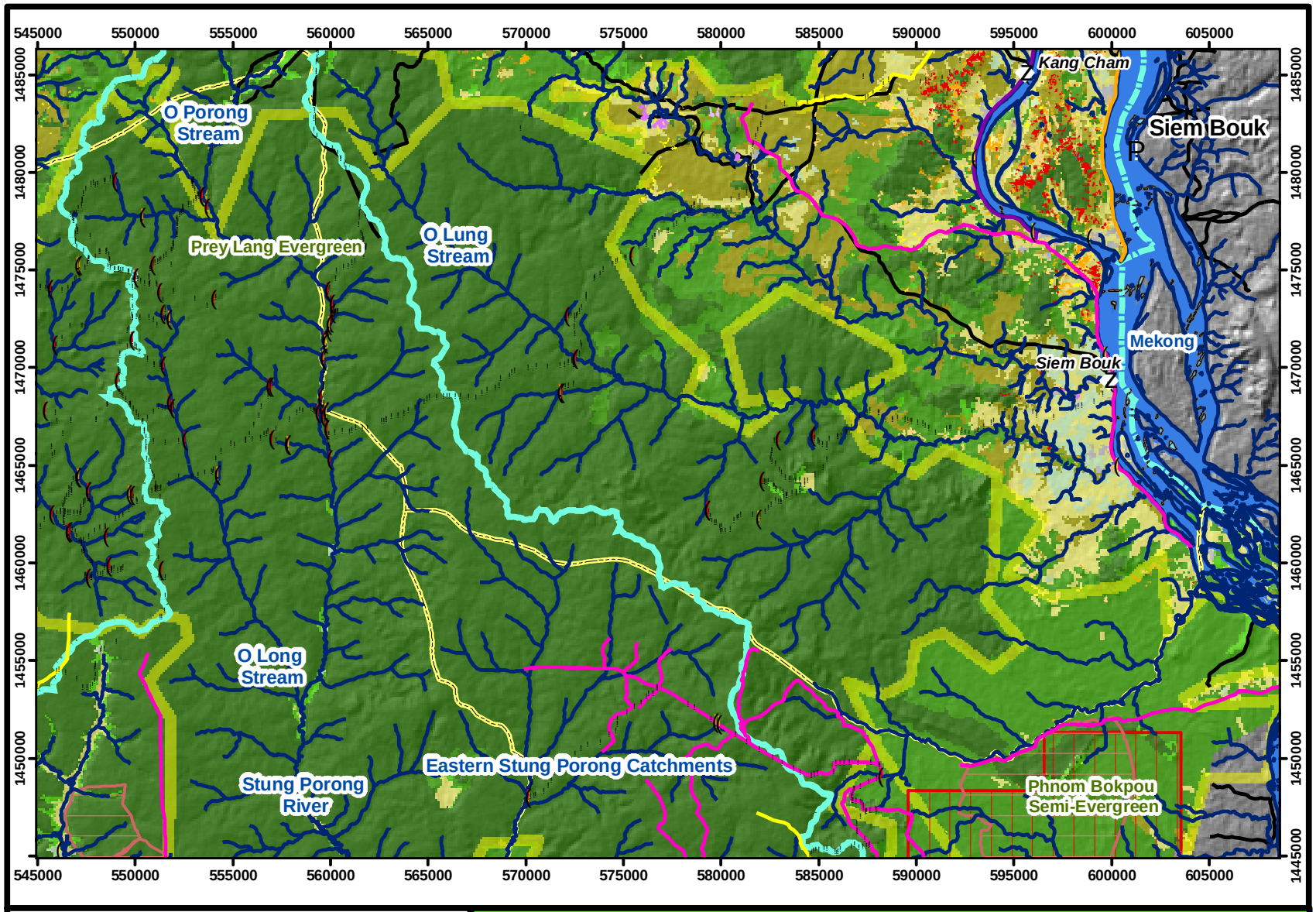




1 centimeter equals 3.0 kilometers

Figure 19: Upper Mekong River Catchment, Forest Areas, Land Use and Development

Coordinate System: UTM Zone 48, Horizontal Datum: WGS84
Forest Areas Approximate - Names Designated By Consultant



Legend

- Provincial Town
- FERP Irrigation Projects
- Swamp Forests
- Resin Camps
- Road Points
- District Centers - Study Area
- Commune Centers - Study Area
- Villages - Study Area

Road Construction

Year Detected

- Unknown
- 1984
- 1990
- 1997
- 2000
- 2004
- 2009
- Main Roads
- Roads
- Waterways
- Catchment Divides

Change Detection 1973 to 2009

Change Period

- 04_09
- 00_04
- 97_00
- 90_97
- 84_90
- 73_84
- Province Boundary
- River or Lake
- Lake or Pond (temporal)
- Salt evaporator
- Rapids
- Community Forest
- Mineral Concession
- Forest Areas
- Evergreen Forest
- Semi-Evergreen Forest
- Deciduous Forest
- Degraded Forest
- Woody Shrubland
- Bare
- Grass
- Paddy
- Plantation
- Water

0 1.252.5 5 7.5 10

Kilometers

1 centimeter equals 3.0 kilometers

Figure 20: Middle Mekong River Catchment, Forest Areas, Land Use and Development

Coordinate System: UTM Zone 48, Horizontal Datum: WGS84
Forest Areas Approximate - Names Designated By Consultant

progressively settled forming a mosaic landscape of paddy and chamkar farming along the stream valleys and following the roads (see Figure 5). The development of the area started initially along the northern edge of the forest following the ancient northern road to Siem Reap. The area is part of the Pheapimex Timber Concession and so may have been logged. Within the last five years, roads have been extended up the three tributary catchments and through the forest to the West, with the Northern route continuing west and a Southern route going through the northern tip of the Stung Chinit Catchment after which both go through the Rovieng-Chey Saen Dry Deciduous Forest. As a result, this area is considered likely to be heavily degraded and in the process of being progressively developed.

Downstream of Siem Bouk, the O Lung Stream drains the Northeastern edge of the Prey Lang Evergreen Forest (See Figure 6). This is part of the Core Zone and likely includes forest in good condition that has not yet been logged, or settled; there are no roads into the area except for the old logging roads within the Southernmost part. There are two tracks that lead to resin camps, one connecting the resin camp trails through the Prey Lang Evergreen Forest core zone and the road from Kratie Province and another leading directly to the resin camps from Siem Bouk Commune. There are at least two swamp forest areas within this part of the forest, and likely more given that these are known since they are along the resin camp trails.

In between the Prey Lang Evergreen Forest and the Mekong River is the Phnom Bokphou Semi-Evergreen Forest including the catchments of two small tributary streams. The northern catchment appears to be in good condition with no roads, settlements or land use changes, while part of the southern area was logged as part of the Everbright Timber Concession. This forest is of potential interest as it appears to be the only semi-evergreen forest in good condition connected to the Prey Lang Evergreen Forest so could be of significant value for biodiversity.

The last part of the Study Area includes some small streams within the Lower Prey Lang Degraded Evergreen Forest forming the upper catchment leading into grasslands and lowlands with settlement along the Mekong River. These areas may be relatively non-degraded but are relatively small and isolated by roads leading into adjacent catchments.

6-4 Stung Tang Krasaing

The Stung Tang Krasaing River Catchment is a relatively small river that flows from the Tumring Rubber Plantation and the edge of the Lower Prey Lang Degraded Evergreen Forest from a general Northeast to Southwest direction before turning West and flowing through National Route No. 6 and into the Tonle Sap Floodplain similar to the Stung Chinit (See Figure 7). As noted above, the main dyke and canal of the Stung Chinit Irrigation System serve to connect the Stung Tang Krasaing and Stung Chinit so it also supplies water to this irrigation and drainage system of 7,000 ha.

As described previously, the top of this catchment has been converted into rubber plantation while the remaining upper watershed area is the more heavily degraded Lower Prey Lang Degraded Evergreen Forest. Below this area the land cover consists mostly of lowland paddy, scrub and low quality Dry Deciduous Forest and is accessed through a network of roads.

The area of this catchment within the Study Area is quite small, comprising only 2% of the overall area.

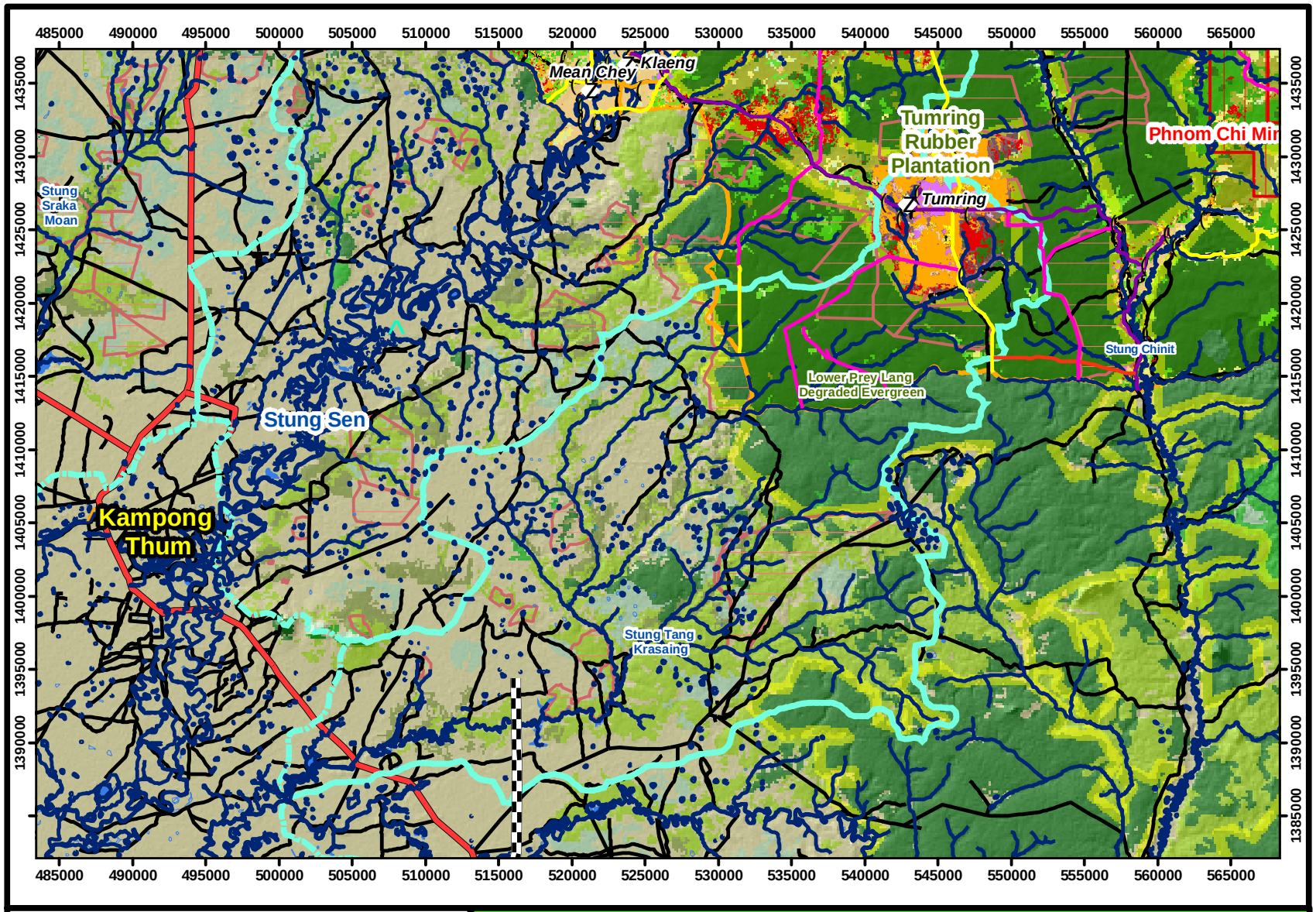


Figure 21: Stung Tang Krasaing River Catchment, Forest Areas, Land Use and Development

Coordinate System: UTM Zone 48, Horizontal Datum: WGS84
Forest Areas Approximate - Names Designated By Consultant

6-5 Stung Sraka Moan

The Stung Sraka Moan River is another relatively small river draining the area between the Stung Sen and Stung Stoung rivers. The upper watershed is entirely comprised of the Boeung Per Wildlife Sanctuary and Evergreen Forest on the ancient alluvial terrace surrounding the Tonle Sap Great Lake. This transitions through a region of scrub that is being gradually converted to lowland paddy or replanted as cashew plantations before collecting within a large lake above National Road No. 6 just above the floodplain.

The top of this catchment is forest in relatively good condition with no roads, settlements or encroachment occurring and having had no logging concessions in the past. National Road No. 61 passes through this forest at Sala Visey Commune, the District Town for Prasat Balang in Kampong Thom Province. There is significant amount of change around this area as farmland expands around the small streams at the bottom of the forest plateau.

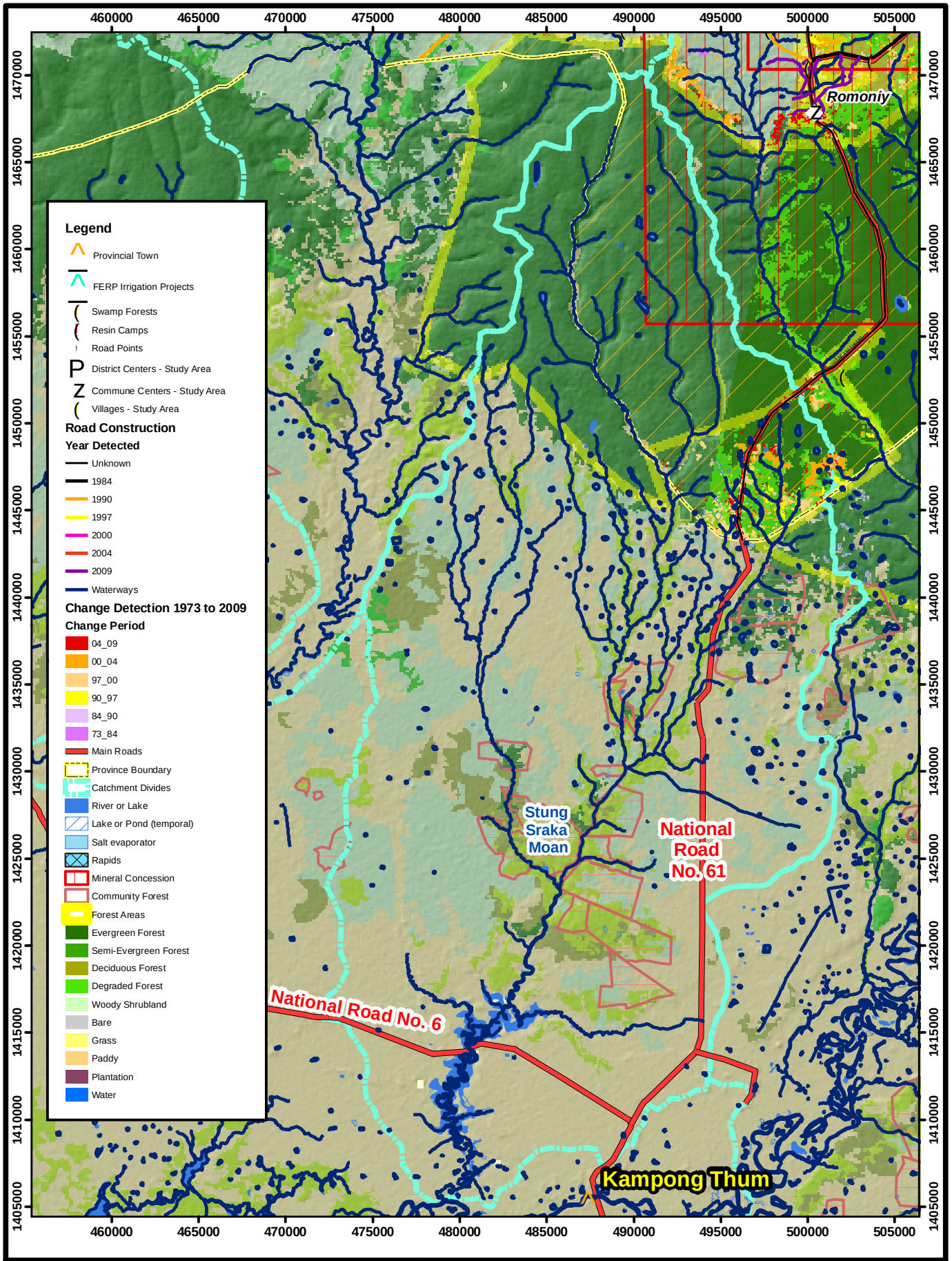
The area of this catchment within the Study Area is quite small, comprising only 2% of the overall area.

6-6 Stung Stoung

The Stung Stoung River is a medium-sized river with a wide catchment draining the area below the Stung Sen through a corridor between the Boeung Per Evergreen Forest and a similar Evergreen Forest to the West. The river follows a similar overall path to the Stung Chinit, draining North to South then veering West and flowing through National Road No. 6. Similar to the Stung Chinit, there is a large Khmer Rouge era dyke and canal system which is slated for rehabilitation using development aid funding (the Stung Stoung Irrigation System).

The upper catchment consists mostly of a flat expanse of Dry Deciduous Forest with occasional rock outcrops containing smaller patches of Evergreen and Semi-Evergreen Forest. Only relatively small areas of the two evergreen forests on the ancient alluvial deposit are within the catchment, and once through this region the area is primarily scrub and lowland paddy on relatively poor soils.

Only a very small part of this catchment is within the Study Area, consisting of a small part of the Rovieng-Chey Saen Dry Deciduous Forest and a tiny amount of the Boeung Per Evergreen Forest and comprising only 1% of the overall Study Area. The area is experiencing progressive conversion into agricultural land as farmers move into the area near National Road No. 61 and settle.



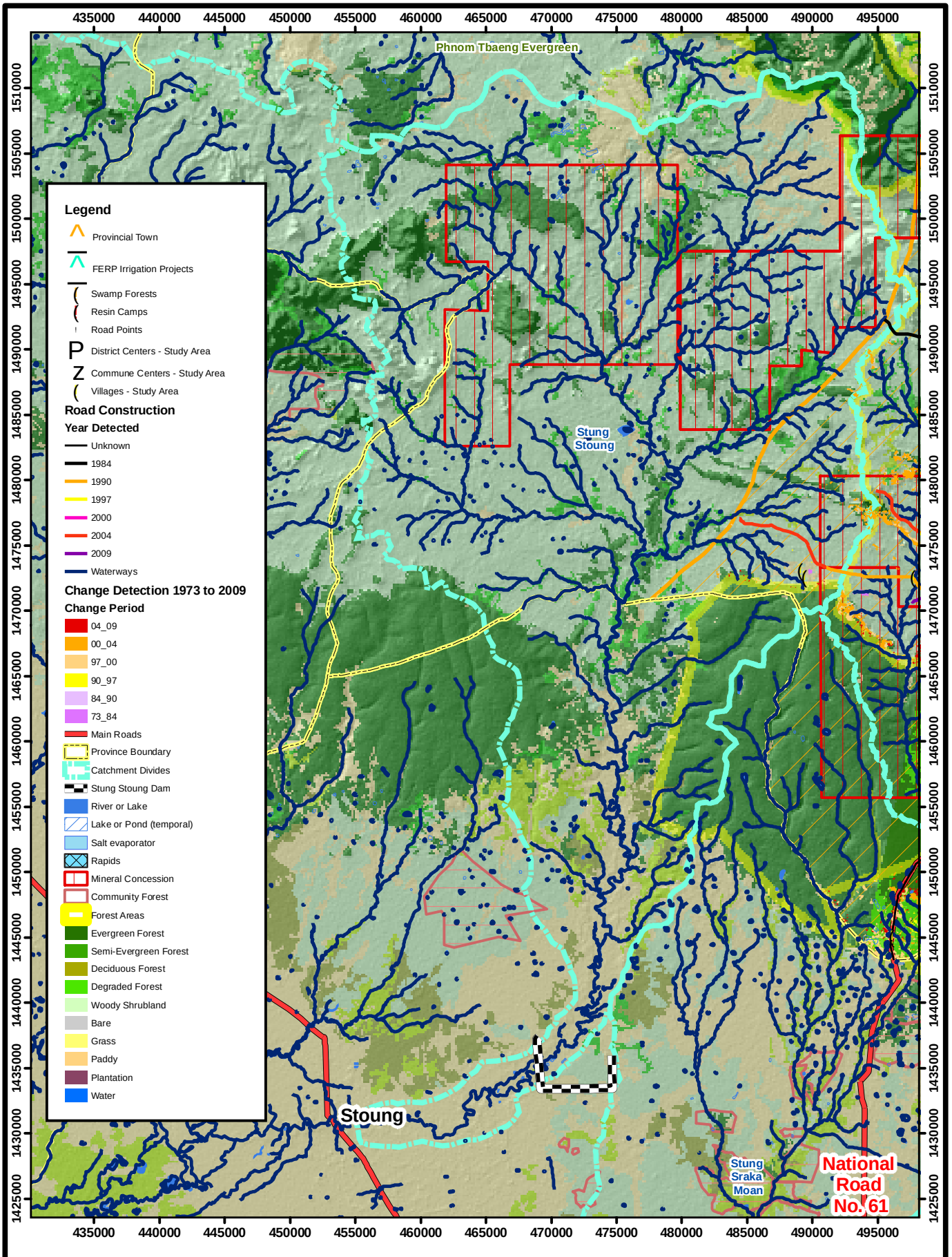
0 1.252.5 5 7.5 10

Kilometers

1 centimeter equals 3.0 kilometers

Figure 22: Stung Sraka Moan River Catchment, Forest Areas & Land Use

Coordinate System: UTM Zone 48, Horizontal Datum: WGS84
Forest Areas Approximate - Names Designated By Consultant



0 1.5 3 6 9 12

Kilometers

1 centimeter equals 4.0 kilometers

Figure 23: Stung Stoung River Catchment, Forest Areas & Land Use

Coordinate System: UTM Zone 48, Horizontal Datum: WGS84
Forest Areas Approximate - Names Designated By Consultant