Kampar Peninsula
Science Based Management Support Project

Summary Interim Report, April-December 2007

Introduction to the SBMS Project and preliminary results to date

Editor: Al Hooijer, Delft Hydraulics, April 2008

Brief Summary

Peat soil consists of 90% water and 10% vegetation remains. Peatlands therefore are not really ‘land’ but are wetlands, and in some ways need to be managed rather like water bodies to prevent loss of the water that supports the peat surface, i.e. to prevent subsidence. Until now most peatland water management in SE Asia does not recognize this fact and can therefore not result in sustainable peatland development or conservation. Widespread overdrainage is resulting in loss of conservation forest, in CO_2 emissions and ultimately in loss of productivity through flooding caused by subsidence. The Kampar Science Based Management Support Project was instigated and funded by APRIL in line with its commitments to develop methods of sustainable peatland and water management that will reduce impacts in and around its plantations on the Kampar Peninsula.

The SBMS Project aims to help mitigate drainage impacts as follows:

A. Bring up plantation water levels, and reduce water table variations including flooding.
B. Minimize drainage impacts in adjoining conservation forest.
C. Provide guidelines for responsible plantation management and planning in the Kampar Peninsula peatlands.

The SBMS Project team consists of a group of consultants and scientists working with APRIL staff on practical management issues on the basis of scientific understanding of the peatland system, i.e. interactions between hydrology, peat soil and vegetation (natural forest and plantation forest). This understanding is based on field monitoring, surveys and model studies in Pilot areas where water management improvements are first trialled and their effects monitored, before being ‘rolled out’ to other plantations.

Preliminary SBMS Project results show that the impacts of past overdrainage in APRIL peatland plantations have been as expected on the basis of findings elsewhere. Subsidence has been in the order of 10% of drainage depth, i.e. over 10cm/y where average water depths have been over 1 metre. Water tables in APRIL conservation areas upslope of plantations have been lowered over several kilometres, and forests have been affected by this.

However the project results also show that significant improvement in plantation water management can be achieved. Such improvement has started in 2007, offering promise of benefits not only to conservation but also to plantation productivity (through decreased subsidence as well as decreased frequency of flooding and water deficits).

Long-term conservation of the Kampar Peninsula peatland forest and carbon resources will require integrated land and water management over the whole area, i.e. a Master Plan, and co-operation between stakeholders: Government, companies active in the area, conservation NGOs, local communities, and possibly carbon funds that may contribute to conservation of carbon and forest resources in the area. Two elements are especially essential to planning for long-term conservation:

- Only entire peatland landscape units, peat domes and river basins within peatlands, can be protected from degradation caused by drainage. The peatland landscape should therefore be the basis not only for development planning by companies but also for concession allocation.
- Responsibly managed buffer zones with no or limited drainage, of several kilometres wide, are required between drained areas and conservation areas.

Contents

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Introduction

Why do peatlands require specific management?

Peatlands develop as the result of a delicate balance between hydrology, ecology and landscape morphology, allowing water (90%) and vegetation remains (10%, most of which is carbon) to accumulate over thousands of years. They are not really 'land' but wetlands, in fact they function more like lakes than like mineral soil areas in many respects, and they should be managed as such. A change in one of the system components will lead to changes in the other components and in peat accumulation rate. Human intervention in the peatland hydrological system will result in lower water tables and hence in subsidence (peat loss), forest loss, CO_2 emissions, enhanced fire risk and ultimately production loss. In tropical peatlands the impacts of drainage are much greater than in temperate peatlands, because decomposition rates are far higher (due to higher temperatures) and hydraulic conductivities are also higher (resulting in greater extent of drainage impact). Moreover, tropical peatlands are relatively little studied and their water management requirements are poorly understood.

Most of the global tropical peatland extent is in SE Asia, where there are some 27 million hectares. This represents a globally significant carbon store and biodiversity 'hotspot'. Over 80% of these peatlands are in Indonesia, and about half of this has in recent decades been cleared of natural forest and drained. Remaining peatland forest and carbon resources are vulnerable to a range of pressures including plantation development, logging and fires. Large areas of natural peatland forest, as still present on the Kampar Peninsula, were common not long ago but have now become rare and of high conservation value. Conservation requires careful planning of any new development, and improved water management in existing and new developments. Improved water management will also be to the benefit of production in developed peatland areas as it will mitigate the effects of droughts, floods and subsidence.

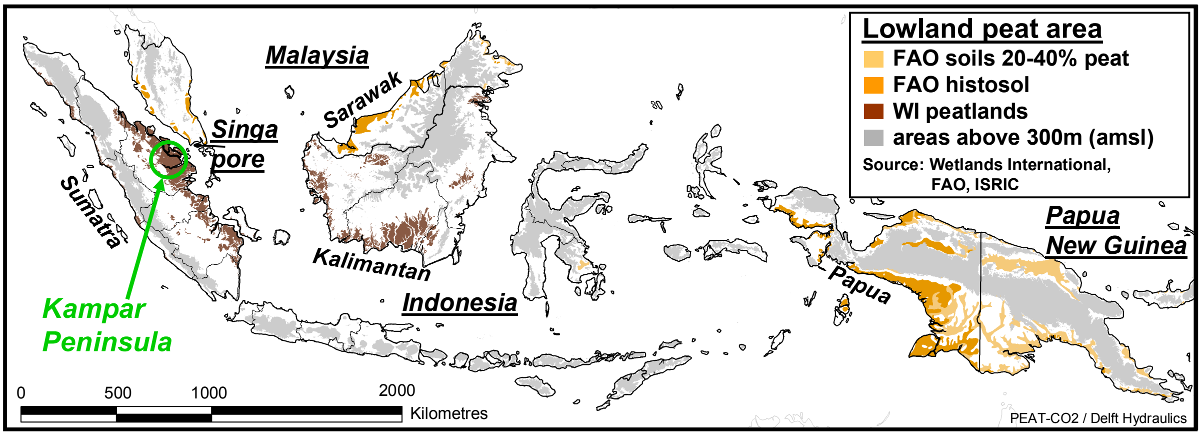

Figure 1 Location map of the SBMS Project area, the Kampar Peninsula in Riau, Sumatra.

Conditions on the Kampar Peninsula

On the Kampar Peninsula there is a total of some 700,000 hectares of contiguous peatlands. Of this some 404,000 is east of the Rawa and Kutup Rivers (see Figure 16) that are sometimes seen as the western boundary of the Kampar Peninsula, and some 280,000-

300,000 ha is to the west of these rivers in what is sometimes referred to as the Siak/Pelalawan area. While most these 700,000 hectares were covered in pristine jungle only 25 years ago, the rivers now separate two rather different landscapes.

The SBMS Project studies peatlands both East and West of the Rawa and Kutup rivers, as they are connected hydrologically and ecologically, and we refer to the entire area as the Kampar Peninsula peatlands.

To the West of Rawa and Kutup Rivers, most forest has been cleared for plantation development; APRIL alone has 72,000 of acacia plantations (planted net area) on peatland in and around the Pelalawan area to the South, and APP has plantations in the Siak peatlands to the North. In the middle a large protected forest area is still left around the Tasik Besar lake, and smaller areas of natural forest are left between plantations. Most of these forest areas are degraded by logging and by drainage impacts of surrounding plantations; many smaller areas can not be sustained for conservation and the Tasik Besar area requires improved water management around it, and an end to illegal logging, if it is to be preserved. As water management is being improved on the APRIL side, the main threats to the Tasik Besar forest are now on its Northern boundary; however the area will only be viable in the long term if it remains linked to the forests to the East.

Most of the peatland to the East of Rawa and Kutup Rivers is still covered in forest, though much of that is impacted to some degree by logging (legal and illegal; HPH logging started in the mid-1980s) with the associated drainage canals, and the richest forest near the coast has been largely cleared. Smaller areas near the Kutup river and on the eastern tip have been converted to acacia plantations by APRIL and APP; rapid clearing and development by a number of companies and community groups is taking place along the northern edge of the Peninsula. However the overall hydrological integrity of the area is still largely intact. This, and the extent and quality of the remaining forest, makes it one of the very few last remaining large peatland forest areas in Sumatra (and in fact in the world) that may be conserved in the long term.

The Kampar Peninsula peatlands are not only extensive and relatively well-preserved, they are also extremely deep. Available data (although limited) suggest that average peat depth is probably over 10 metres. This makes it one of the greatest reservoirs of peat carbon in SE Asia, and a focus of worldwide attention now that it has become clear that peatland drainage in SE Asia is a major source of atmospheric carbon and a significant contributor to climate change.

Considering the globally significant biodiversity and carbon values of the Kampar Peninsula, and the threats to its hydrological and ecological integrity, there clearly is a need for initiatives in support of responsible management of soil, carbon and forest resources in the area.

The Kampar Science Based Management Support Project

The Kampar Science Based Management Support Project (SBMS Project) was developed with APRIL by a group of consultants and scientists aiming to support improvements in water management and forest conservation in and around pulp wood plantations on peatlands on the Kampar Peninsula (KP), Riau, Sumatra. The project is lead by Delft Hydraulics with inputs from APRIL staff, University of Leicester, ProForest, University of Helsinki, University of Wageningen and freelance consultants. The project started April 2007 and will last 3 years, with most outputs provided after 2 years.

In short, the main SBMS Project aims are to:

A. Bring up plantation water tables and reduce water table variations including flooding.
B. Minimize drainage and degradation in adjoining conservation forest.
C. Provide guidelines for responsible plantation management and planning in peatlands.

Key activities in the SBMS Project are:

- Monitor and assess relations between water depth (and other land management factors) and peat subsidence, CO_2 emissions and conservation forest conditions.
- Apply these relations in long-term impact projections for different water management strategies, especially subsidence- and CO_2 emission rates over 50 years, for plantations and adjoining conservation areas.
- Define plantation water management targets that will minimize impacts, help design and implement improved water management structures and systems, and evaluate in Pilot areas to what extent targets are met.
- Most of the work in the project focuses on the existing APRIL plantations on the southwestern end of the Kampar Peninsula, and adjoining conservation areas. However one activity is to support forest and carbon conservation on the KP by developing a 'science-based recommended land use zoning map' for the whole area, applying findings in and around plantations. This will be used in planning of further APRIL plantations, including evaluation of to what extent and under what conditions plantations could be designed and managed to minimize drainage impacts and maximize protection for the central KP forest and carbon values, hopefully within the context of a balanced production-conservation Master Plan for the KP as a whole.

Most project activities focus on three 'pilot areas' where water management measures are trialled and their effects monitored closely. Each pilot area consists of a drained plantation and an upslope area of conservation forest. The challenge of course is to demonstrate that subsidence in the plantation areas and degradation of the adjoining conservation areas can be limited in the short and long term.

All final results of the Kampar SBMSP will be in the public domain; preliminary results will be available for distribution as soon as the scientists and consultants involved find this. It is expected that the findings will also help improvement of water management systems in other tropical peatlands.

Kampar SBMSP Work Packages and consultants

The SBMS Project is organized in 6 Work Packages, each executed by one or several organizations with APRIL:

- WP 1.1 Pilot studies of system and structure design.
- WP 1.2 Operational water management system software development.
- WP 1.3 Hydrological studies & database development.
- WP 1.4 Peatland management strategy assessment tool development.
- WP 1.5 Subsidence and carbon emission studies and management support.
- WP 2.1 Development of a recommended land use zoning map for the KP.

Consultants contribute to the project as indicated in the table below (more will be involved).

	Organization	**Work Package Involvement**						
		1.1	**1.2**	**1.3**	**1.4**	**1.5**	**2.1**	**Mgt**
Dr Al Hooijer	Delft Hydraulics	X	X	X	X	X	X	X
Dr Rinus Vis	Delft Hydraulics						X	X
Mr Geert Prinsen (Eng)	Delft Hydraulics	X	X	X				
Ms Marjolijn Haasnoot (MSc)	Delft Hydraulics				X		X	
Dr Jyrki Jauhiainen	Un. Helsinki			X		X		
Dr Henk Wösten	Un. Wageningen					X		
Dr Susan Page	Un. Leicester			X		X	X	
Mrs Agata Hoscilo (MSc)	Un. Leicester				X	X		
Dr Ruth Nussbaum	ProForest						X	X
Dr Christopher Stewart	ProForest						X	
Mr Ad van den Eelaart (Eng)	freelance	X		X				
Mr Arnoud Haag (Eng)	freelance	X		X				

This summary report

This report, 9 months into the 3-year project, briefly presents the aims and methods of the Kampar SBMS Project, and some preliminary project results. As this is a science-based project we follow thorough scientific procedure; presentation of final results will be possible after sufficient data have been collected, analysed and verified. The next summary report, in early 2009, is expected to present the first final results; full results will be reported by early 2010. Meanwhile, we hope that presenting preliminary findings and project methods will provide a basis for discussion of how project results can help develop a strategy for responsible management of the Kampar Peninsula peatlands, and possibly other peatlands in SE Asia as well.

Pilot studies of system and structure design (WP 1.1)

Aim

Where the other SBMS Project work packages aim to find out what is required to manage the Kampar Peninsula peatlands responsibly, this work package focuses on how this can be done in water management practice, answering questions like:

- How can peatland plantation water levels be kept higher and within a limited range, while minimizing construction costs and maximizing robustness under extreme conditions. What types of dams and bypasses are suitable, in terms of design, materials, construction and operational/maintenance requirements?
- How can water levels in forest conservation areas adjoining plantations be kept high?

Method

The water management trials required to answer these questions are concentrated in three Pilot areas in different representative situations within the peatland landscape. Here, measures to raise and control water levels are implemented and their effects monitored closely. Each pilot area consists of a drained plantation and an upslope area of conservation forest; impact monitoring extends at least 2 kilometres into the conservation forest. Pilot areas are designed and instrumented to be able to determine all water fluxes: rainfall (measured), groundwater flow from upstream conservation forest (modelled), changes in groundwater storage (measured through groundwater depth monitoring, Figure 9), sideways inflows and outflows (blocked with dams), and downstream outflows (measured).

This work package is carried out in close co-operation between APRIL staff, who construct and operate water management structures and monitoring systems in the field, and SBMSP consultants, who help design the water management and monitoring systems and who evaluate performance using monitoring data in analyses and hydrological models (in WP 1.2 and WP 1.3).

The structures consist of dams that help achieve higher water levels, and bypasses and spillways that help limit water table fluctuations both to the upside (floods would harm tree crops), and to the downside (low water tables cause subsidence and CO_2 emissions). APRIL has committed to such improvements in water management in its operations as shown in Table 1, aiming to achieve water depths between 0.6 and 0.8 in acacias plantations by 2008 (where they were estimated at 1.2 metre on average in 2006), and between 0.2 and 0.6 metre in buffer zones adjoining conservation forest (where they were also 1.2m in 2006).

Table 1 APRIL water depth targets as defined late 2006 at the start of the SBMS Project.

Operational Water Management Goal	Water table depth to surface[1]		
	Min	Max	Mean
[1] 90% compliance (90% of observations from frequent sampling of 100% compartments)			
2006 situation (before SBMS Project start) Water steps 1 m max, water gates adjusted quarterly, canal levels fluctuate +/- 0.3 m			
(a) without mid-field drain (70% of Pelalawan)	0.5 m	1.8 m	1.2 m
(b) with mid-field drain (30% Pelalawan)	0.6 m	1.5 m	1.0 m
2008 target Water steps 0.2 m, water gates adjusted daily, water levels stabilized as guided by 'tuned' water model, additional structures etc. and operational procedures			
(a) Acacia with mid-field drain (90% of Pelalawan)	0.6(0.5) m	0.8 m	0.7 m
(b) Buffer zone Melaleuca compartments	0.2 m	0.6 m	0.4 m

First results

Monitoring instrumentation in the three pilot areas was largely completed by late 2007, and data are being collected that allow first analyses. Implementation of the water management infrastructure in Pilot areas (dams, bypasses) is ongoing.

Parallel to the trials and research work in the Pilot areas, water management infrastructure has been added throughout plantations. There are now hundreds of dams in all APRIL plantations on Kampar Peninsula peatlands. Though this number needs to be doubled at least, and the water management system needs to be refined to achieve greater control (also required to avoid flooding), overall water levels in plantations have already been raised somewhat as is shown in Figure 2.

After considering and trialling different options in 2007, a standardized dam-and-bypass system has been designed based on the experimental design shown in Figure 6 and Figure 7, and is now being implemented at a larger scale starting in Pilot areas. The design, which will further evolve when we learn more from experience in practice, consists of the following elements in plantations:

A. A dam constructed of compacted peat, which must be high enough and wide enough to not flood or break even after extreme rainfall.
B. A collector canal around the dam, which receives water from bypasses and spillway.
C. A spillway, which is only about 0.4m deep but at least 10m wide, so it has sufficient discharge capacity to prevent the dam and plantations from flooding in extreme conditions. The spillway is simply dug in the peat, without protective cover as it should only be flooded a few days per year (weeks at most) and flow velocities over it should be limited.
D. One or more bypasses. These are deeper than the spillway, with the bottom at 1m below the general peat surface, plus some 0.2-0.3m of sand bags, i.e. with an overflow at 0.8-0.7m depth. Bypasses should allow control of the water level within the target range for 90% of the time. Because flow velocities here can be high and flows are permanent, the peat soil in bypasses must be protected by a geomembrane cover. The overflow level is raised or lowered, as required, by adding or removing sand bags made of durable geotextile. The width and/or number of bypasses is optimized to accommodate the expected peak discharge (e.g. 1 in 5 year event), which can be

calculated from the upstream catchment area once the typical discharge reaction of the peatland is understood from the Pilot area experiments.

This set-up has the following benefits:

- Speed and low cost: the main materials are peat, wood and mineral soil which are all locally available. The use of expensive geotextile and geomembrane is minimized.
- High robustness i.e. low maintenance requirements. Rigid structures are avoided as they will sink and/or be deformed in the 'soft' peatland environment. Spillways provide a safety valve, preventing water levels to get to the stage where dams and bypasses will be damaged and the system becomes unmanageable.
- Operational flexibility:
  - Dams made of peat can easily be removed and rebuilt when canals are required for transporting acacia wood in barges after harvesting.
  - Using sandbags, overflow heights can be adjusted easily when required.

Dams in buffer zones in principle have no bypasses and no or very shallow spillways, as the aim here is to keep water levels as high as possible while avoiding flooding. As most buffer zones are located further up the peat domes, where peat is deep and permeable and surface slope is significant (in peatland terms that is: over 0.5m/km), much water will be lost from here as groundwater flow and water depths are expected to be below spillway level most of the time even without bypasses.

An example for the Madukoro Atas Pilot area of a cascade of dams and its effect on water depths is shown in Figure 4. Although more dams are needed in this Pilot Area to achieve the water depth target, results to date confirm that they do indeed bring up water levels even where surface slopes are significant and where the peat is fibric in nature (i.e. highly permeable) allowing part of water flow to take place underground where it can not be controlled. Under such conditions, which are common especially around conservation areas, more dams at closer intervals will be needed to bring water levels within the target range than are needed where peat slope and permeability is lower. Dam spacing and operational requirements for achieving the stated water depth targets can be calculated once enough monitoring data from the Pilots are available to develop a hydrological model for the area, including surface water – groundwater interactions.

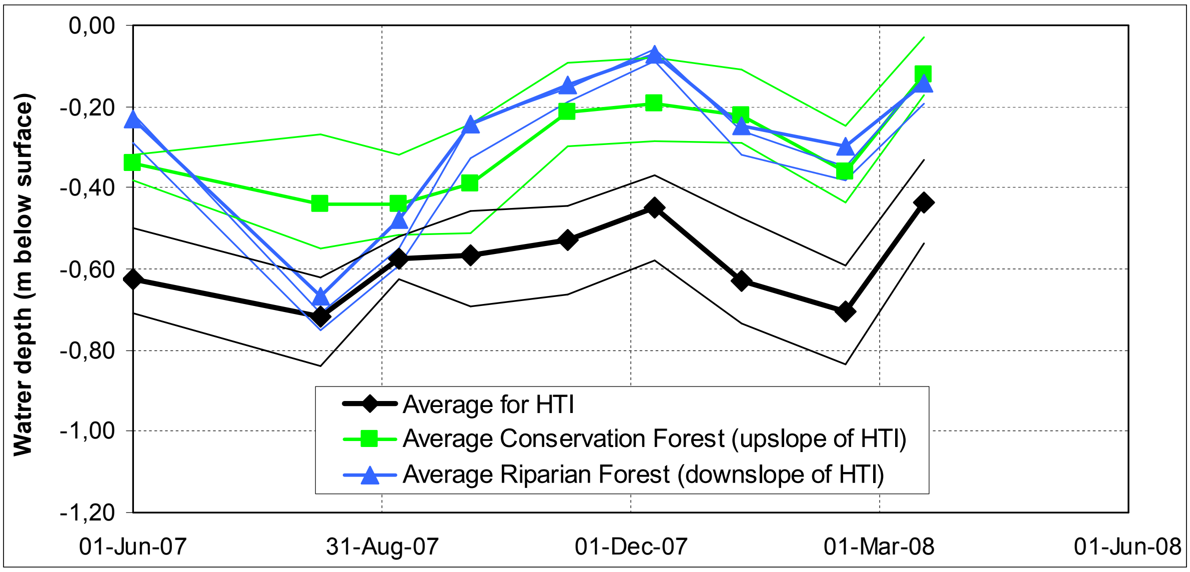

Figure 2 Average monthly water depth record for the Madukoro Bawah Pilot Area. Percentiles (25% and 75% values) are also shown to indicate the range in water depths during each time step.
Madukoro is the latest plantation area to be developed, and drainage design and dams aim to keep water depths in plantation areas (HTI) within the new target range of 0.8-0.5 metres, and in adjoining conservation areas at natural depths. Latest dams were built July-September 2007. More work will be needed to optimize the system, but efforts to improve water management are beginning to show good results here.

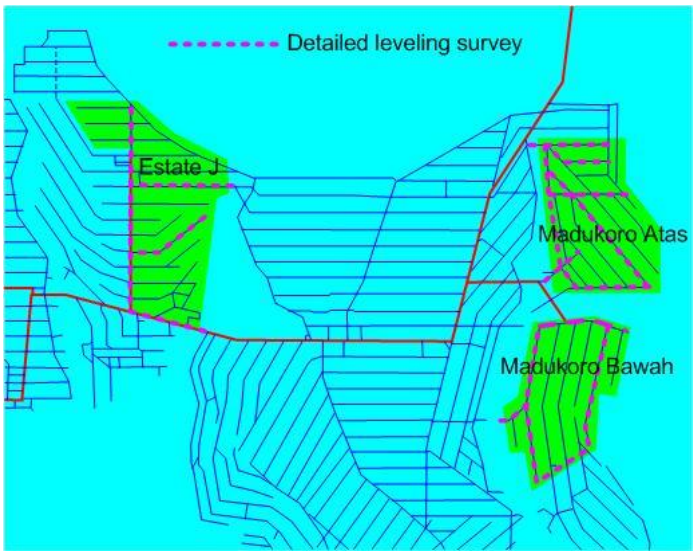

Figure 3 Pilot Areas within APRIL acacia plantations, and requirements for detailed elevation levelling. Conservation areas upslope from each pilot plantation area are included in the study.

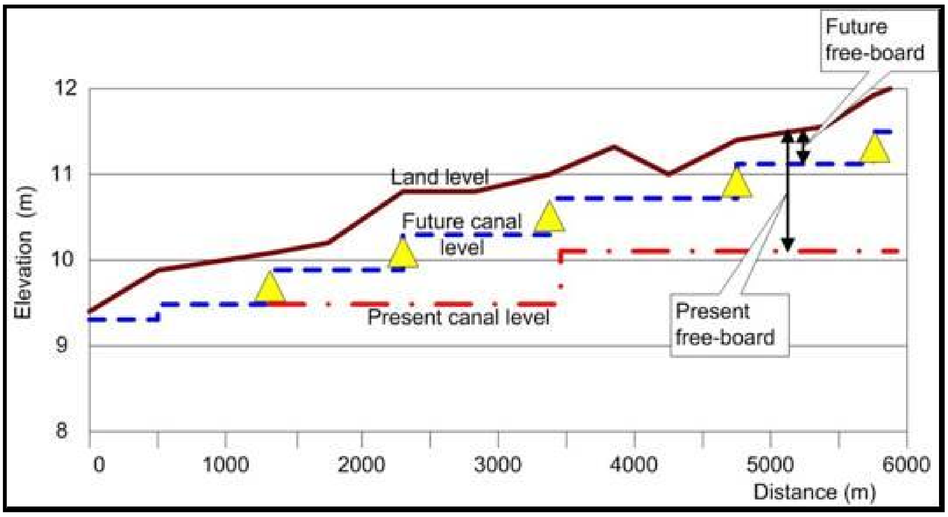

Figure 4 Schematic drawing of a cascade of dams to bring up water levels in the Madukoro Bawah Pilot area. Yellow triangles indicate planned dam locations.

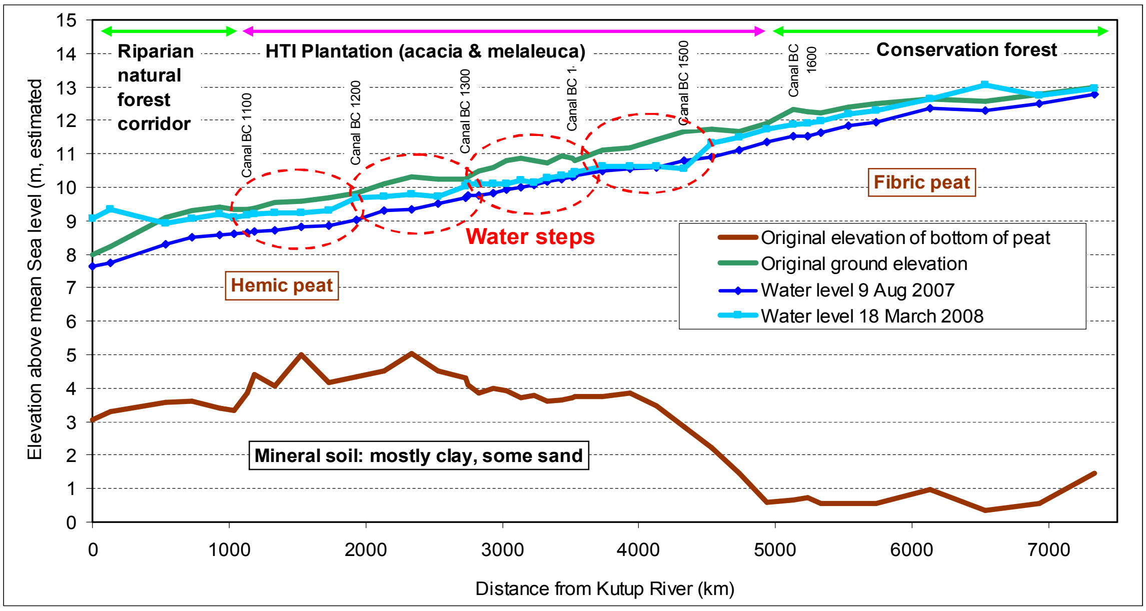

Figure 5 Water depth in dipwells and canals along transect in Madukoro Bawah Pilot Area. Water table fluctuations for this area are shown in Figure 2.

Note:

- *Dams have been built that aim to maintain water levels within target range, with target water steps of 0.4m over dams. However water steps over 0.5m are visible between canals, bringing mid-field water depths below the target range at some points. Water depths can be further reduced by building more dams in 2008 and by adjusting the mid-field drainage system between canals.*
- *2 years after implementing drainage, the peat subsidence effect is visible in the peat surface which is lowered most nearest to the drains, in addition to an estimated 0.5-1m overall subsidence.*
- *Water levels are affected by drainage 2 kilometres away from the last canal, though this only results in a few decimetres lowering through much of the year. This is already a major improvement on the previous system of maintaining great water depths (often over 1.5 metres) in perimeter drains between plantations and conservation areas, that is still found in many other plantations in peatlands. No perimeter drains are built in APRIL plantations anymore, and existing perimeter drains are being closed off with dams to bring up water levels.*

Figure 6 Example of APRIL Operations dam and bypass structures (2 still under construction) in a plantation canal. The main canal is closed with a peat dam, and water diverted around it through bypasses in which water levels can be controlled. A spillway (not shown) has now been added to this design, and dimensions have been modified to achieve greater robustness under extreme flow conditions.

Figure 7 Example of APRIL Operations bypass design that is in process of improvement with SBMSP advice. The distance between bypasses has been increased to 10m to avoid series of bypasses being washed away during extreme flow events (as has happened in 2007).

Operational water management system support tool (WP 1.2)

Aim

Water levels in peatland plantations and adjoining conservation forest areas can only be maintained within the ‘responsible management’ target range if water management systems succeed in storing enough water for long enough between rainfall events to prevent water levels from dropping too much in dry periods (which can be severe and long), while releasing enough water quick enough to prevent flooding following extreme rainfall events. As these requirements can be conflicting, smart system design and event-based system adaptations are required.

In a system as large and complex as the APRIL plantations on the Kampar Peninsula peatlands, system design optimization (in terms of location and dimensions of structures) requires hydrological models that can test performance of the system for extreme drought and rainfall conditions, not only for present conditions but also for the future when peat subsidence will have altered the hydrological system. Moreover, a ‘water management system support tool’ (OWMS) is needed to help operational water managers take adequate actions in response to rainfall and drought events. Such a hydrological model, and a derived OWMS, is produced in this work package. These are first developed for the pilot areas; they will be used to test designs in the short term, and can be the basis for a real-time operational water management system (OWMS) support tool.

Method

The basis for peatland OWMS tool development is modelling of the hydrology of peatland water management systems, consisting of plantations and adjoining peatland forest conservation areas. Hydrological models are produced (in SOBEK[1]) for 3 separate pilot areas (developed in WP 1.1), representative for different typical conditions in and around the peatland plantations. Models simulate water flows through canals and through the peat itself, in response to rainfall, evapotranspiration and management interventions (canal and structure design and operation). This is done for a number of water management scenarios and taking into account the resulting changes in hydrology due to peat subsidence. Model results are implemented in a custom-made tool (in the FEWS[1] platform) that will provide early warning of the need for operational management interventions (changes in bypass crest height, modifications in dam lay-out) if receiving real-time data on rainfall and water levels in the system. The OWMS support tool also allows rapid access and screening of hydrometeorological data.

First results

A prototype OWMS support tool has been developed that allows screening and display of the hydrological data collected in the APRIL plantations, as shown in Figure 8. For further development of the tool, hydrological models first require field data that will become available in the second half of 2008.

[1] SOBEK and FEWS are standard Delft Hydraulics software: http://www.wldelft.nl/soft/intro/index.html

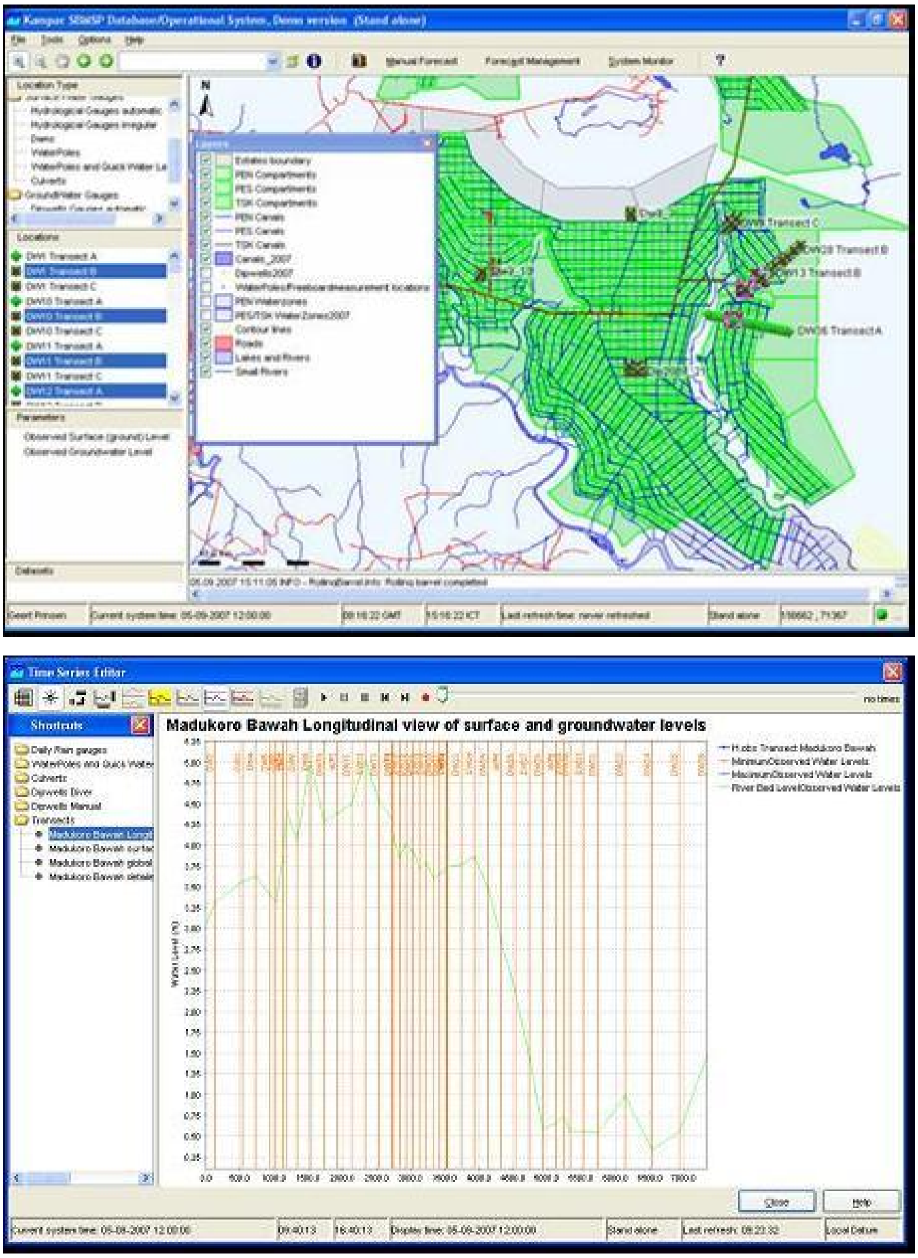

Figure 8 First prototype interface of the Operational Water Management System support tool (OWMS), already giving easy access to monitoring data through maps (top) and graphs (below).

Hydrological studies & database (WP 1.3)

Aim
This work package consists of collection and analysis of hydrometeorological (and related) data, and provides essential input to all other work packages. Water depth is the most important factor in peatland functioning, and is controlled by water fluxes: rainfall, surface water flow, groundwater flow and evapotranspiration.

Hydrometeorological data are collected in and around the Pilot areas and are used to quantify the relations between water depths and fluxes in plantations and in adjoining conservation forest areas, both through analyses and by using models (developed in WP 1.2). The following parameters (amongst others) need to be quantified:

- Rainfall rates and spatial variability in extreme rainfall intensities.
- Discharges and discharge capacity of plantation canals and natural streams, for which canal dimensions, gradients and flows must be known.
- The rate of groundwater flow in peat with different depth and characteristics, for which hydraulic conductivity must be known.
- Evapotranspiration from forest (natural and acacia) and peat surface, i.e. water loss to the atmosphere. This is complex as forest is in different stages of logging/growth; an estimate may suffice.

Method
The monitoring system is largely in place by early 2008, and covers the following main parameters:

- Rainfall is monitored by using manual and automatic recorders.
- Groundwater depth (i.e. changes in groundwater storage) is monitored in dipwells (anchored in the mineral peat substrate so they also act as subsidence poles), both manually and automatically.
- Soil moisture changes over unsaturated zone profiles will be monitored.
- Surface water outflows from pilot areas will be measured.

Data are quality controlled and will be stored in a database that is graphically accessible through the OWMS tool (produced in WP 1.2). Analyses and modelling (in WP 1.2) can start when at least 9 months of full data is available, covering both dry and wet periods.

First results
A preliminary but important finding of the hydrological analyses is that average hydraulic conductivity of the peat appears to be high at up to 30 m/d (with a transmissivity of up to $200m^2/d$ in 7m of peat). Moreover, it appears that this high conductivity is not restricted to the top of the peat deposit as is sometimes assumed, although there will be a decrease with increasing depth and decomposition. The consequence of this is that peatland water flow in peatlands, especially once drained, takes place underground to a significant extent. This flow component is not affected by surface water management interventions (dams, bypasses), and its significance must be understood very well before decisions can be taken on which parts of peatlands can be drained without risking water levels below target. The concept of groundwater flow in peatland is shown in Figure 10.

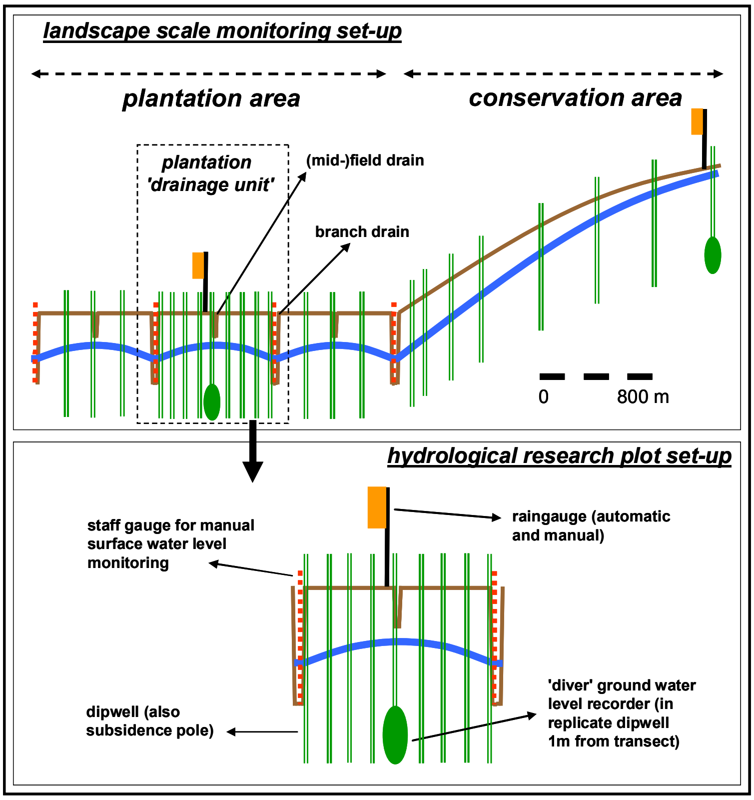

Figure 9 Schematized set-up of hydrometeorological monitoring transects within pilot areas.

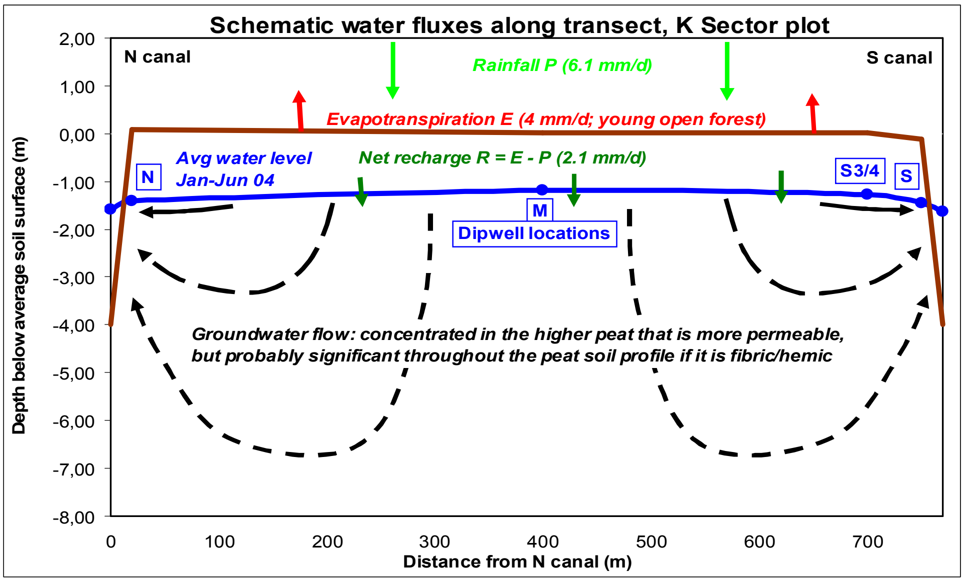

Figure 10 Schematization of water fluxes between parallel canals in a plantation. Note the near-flat shape of the average groundwater table, indicating rapid groundwater discharge due to high hydraulic conductivity of the peat. Hydraulic conductivity, and therefore water loss to groundwater, will be greatest in the deepest and least decomposed peat, i.e. further away from rivers.

Peatland management strategy assessment tool (WP 1.4)

Aim

This work package develops an analysis tool for the KP peatland area that allows exploration of the land and water management strategies, and quantification of the impacts in terms of peat subsidence, CO_2 emissions and conservation forest degradation. Strategies will take into account the current situation with plantations and roads already in place, and will include options for mitigated water management now piloted in the SBMS Project. Apart from use within the project (especially in WP 2.1) and by APRIL, the aim is to make the tool and results available to all stakeholders in the future of the KP, hopefully as part of a wider conservation effort and master plan initiative.

Drainage has unique impacts in peatlands, both in space and time:

- Draining one area for plantations or logging will affect water depth and therefore habitat suitability in a larger area of adjoining peatland forest. The extent and degree of this impact depends on many parameters including drainage depth, peatland morphology, peat depth and peat characteristics.
- Greater water depths inevitably result in subsidence i.e. changes in the peatland landscape, causing reduced drainability and increased flooding that affects all peatland functions: agriculture/silviculture, conservation of natural forest, downstream hydrology. Another impact is CO_2 emission from peat decomposition.

A number of different responses to these impacts are seen in Indonesia, and will be possible on the Kampar Peninsula (from least to most impact):

- A peatland conservation strategy for the long term will include careful planning of developments taking into account the peatland landscape and hydrology, so as to reduce overall drainage impacts on the peatland and avoid drainage impacts in conservation areas.
- Where drainage exists or is inevitable, drainage mitigation measures are required to reduce impacts, including:
    - Reduced water depths in plantations, as APRIL is now implementing.
    - Further reduced water depths in buffer zones, as now piloted in the SBMSP.
    - Adjusted planning of plantation location, and drainage design and structures.
- Continuation of non-mitigation management practice, accepting continued maximum impacts, as is still the case in many plantations on the Kampar Peninsula.
- If peatland drainage continues, even in mitigated form, subsidence and CO_2 emission will continue for decades until it is stopped by one of several feedback mechanisms:
    - Where the peat depth does not extend below the drainage limit, mineral soils will be exposed eventually and subsidence and CO_2 emissions will cease.
    - Where the peat depth extends to below the drainage limit (as is the case on the KP), loss of drainability will result in production loss sooner or later. This may eventually result in production areas being abandoned and water levels may rise again if canals are closed off.
    - In a worst-case scenario, and as already seen in some peatlands in SE Asia, the response to reduced drainability will be to further deepen drains for short-

term reduction of flooding, thereby in fact increasing fire risk and longer-term flood risk, and hastening the moment that production will be impossible.

Method

The strategy assessment tool is developed in HABITAT[2]. Knowledge rules are derived from literature and other SBMS Project work packages, including: water depths in plantations and away from them in conservation forest, annual subsidence as a function of water depth, conservation forest condition as a function of water depth, CO_2 emission as a function of subsidence, drainability as a function of hydraulic gradient and distance to drainage base, management feedback mechanisms, etc. These rules are then applied to layers of spatial information: drainage system map, elevation model, peat depth map, peat type map, natural forest map, forest condition map, etc. This results in maps of annual subsidence and CO_2 emission rates, habitat suitability, as well as maps of peatland morphology, cumulative CO_2 emission and drainability in 10, 25 and 50 years.

First results

A prototype strategy assessment tool is now used for trials; further knowledge rule development is awaiting field data to be collected in the Pilots. A Digital Elevation Model (DEM) was developed as part of this work package, as no accurate model of the Kampar Peninsula existed and elevation and gradients are key parameters in strategy assessment and modelling. Several data sources were used: field surveys by APRIL all around the KP, a DEM derived from SRTM data (by SarVision), the pattern of natural streams, and other sources for the NW part of the area. The result (shown in Figure 11) is still not accurate within a metre but it does credibly represent the landscape and gradients of the KP.

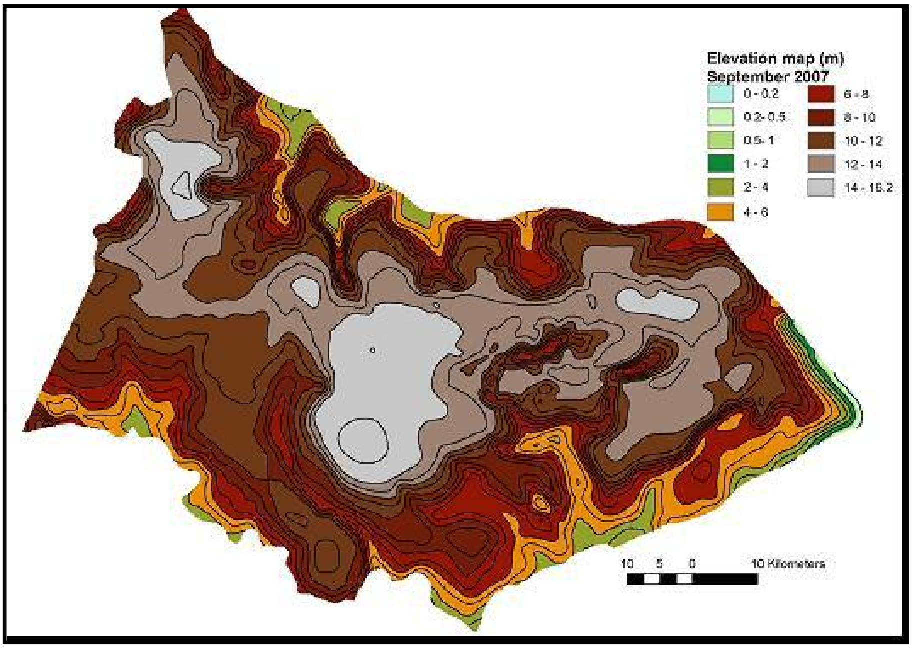

Figure 11 Kampar SBMS Project elevation map for the situation prior to drainage (2000), the basis for strategy assessments.

[2] HABITAT is Delft Hydraulics software.

Subsidence and carbon emission studies (WP 1.5)

Aim

After initial assessments of peat surface levels, APRIL has recognized that significant subsidence and carbon dioxide (CO_2) emissions are occurring in and around its drained peatland plantations, and aims to reduce these. Helping the company to achieve this reduction is one of the main goals of the Kampar SBMS Project, and this work package is responsible for the data collection and analyses required. Rates of subsidence and CO_2 (and methane, CH_4) emission are established, and relations between water depth (and other controlling factors, as far as possible) are identified for use in strategy assessment (WP 1.4).

Method

Subsidence has been monitored by APRIL since 2003, by measuring the height of the top of dipwells (anchored in the mineral substrate) relative to the peat surface, as they seem 'pushed out' when the surface subsides. A large number of additional dipwells has been installed in 2007 to extend this approach. Subsidence is also monitored through repeated land surface surveys, linked to permanent concrete benchmarks. The difficulties with subsidence monitoring are that it is a very slow process and that it is not easy to define the 'ground level' that is monitored; it will take several years before subsidence rates can be quantified with great accuracy. It will also take a few years before subsidence reduction (and CO_2 emission reduction) due to improved water management will be evident, not only because analysis of year-to-year variations in subsidence rate is not very accurately, but also because decomposition rates may reflect earlier management conditions for some time while soil conditions adjust to the new equilibrium.

A CO_2 monitoring system using gas emission chambers is developed in a number of plots in representative peatland plantation areas, as shown in Figure 12. Water depth, soil characteristics, soil moisture and CH4 emissions are monitored at the same locations.

First results

First analysis of subsidence monitoring data over 2003-2007 and other sources has yielded a high preliminary estimate of average recent subsidence rates: 0.1 m/y to 0.14 m/y. It should be noted that this figure applies to the years after the first year of drainage, when subsidence rates are highest, and that it is the result of the low water depths (estimated at 1.2m on average, see Table 1) that existed before APRIL's current effort to bring plantation water levels up. First analysis has also yielded a tentative relation between water depth and subsidence rate, as shown in Figure 13 and applied in Figure 14. This relation will be refined during the project when more data become available, but it is already an improvement over existing simple linear relations as it is a three-stage curve (or 's-curve') reflecting some important aspects:

- When the depth of the water table as measured in a dipwell is only a few decimetres (0.1 to 0.4 metre, depending on peat type), the peat will in fact be saturated to the surface (through capillary action) and decomposition/subsidence will be very limited.
- When the water table is deep enough to create an unsaturated zone, decomposition/subsidence rate will increase.
- When the water table depth exceeds a threshold, somewhere around 1 metre, further water depth increase appears to result in a limited further increase in decomposition rate. The cause and level of this threshold will need to be further investigated.

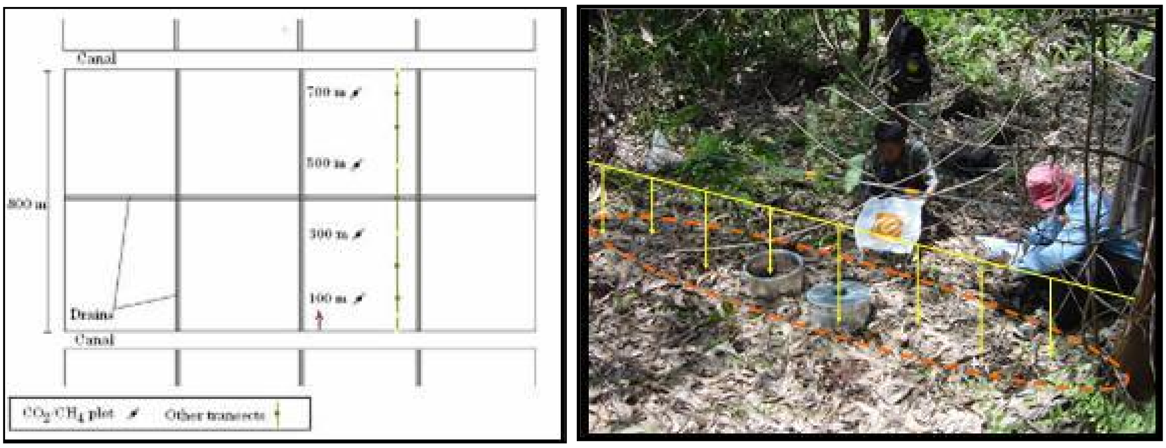

Figure 12 Schematic setup for soil C-gas (CO_2 and CH_4) emission measurements in drained acacia plantations, showing sampling locations across plantation compartments (left) and between trees (right). The sampling scheme is set up to A) distinguish between emissions resulting from decomposition and root respiration, and B) relate decomposition emissions to water depths.

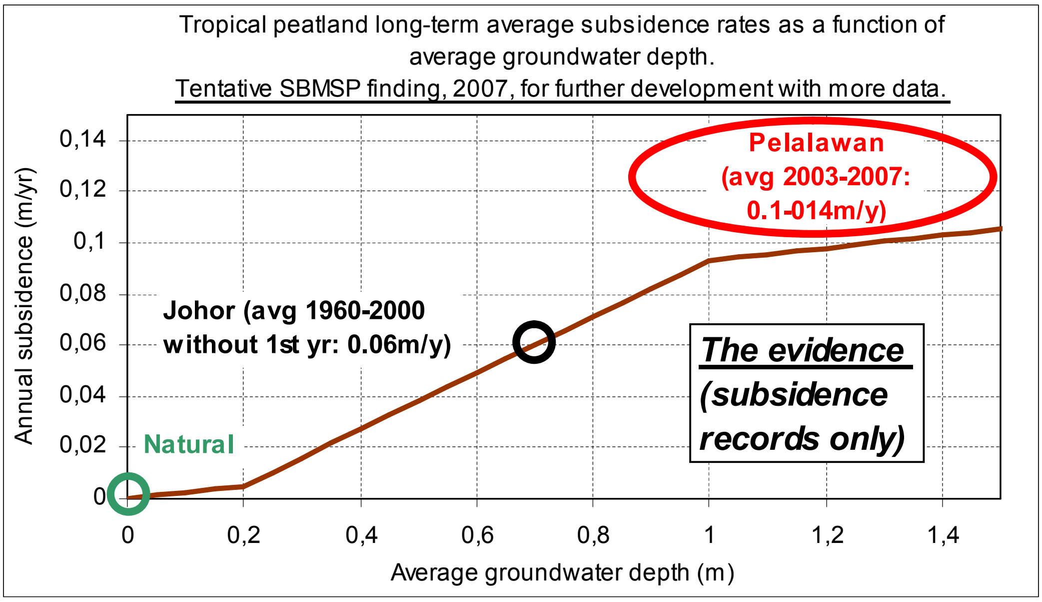

Figure 13 Tentative subsidence–water depth curve now applied in the Kampar SBMSP. Note that this applies to average subsidence over 50 years of drainage. The very high subsidence rate observed at Pelalawan plantations in recent years applies to the early years after drainage is implemented, and are the result of drainage to 1.2m water depth on average over this period; this rate will be reduced in coming years.

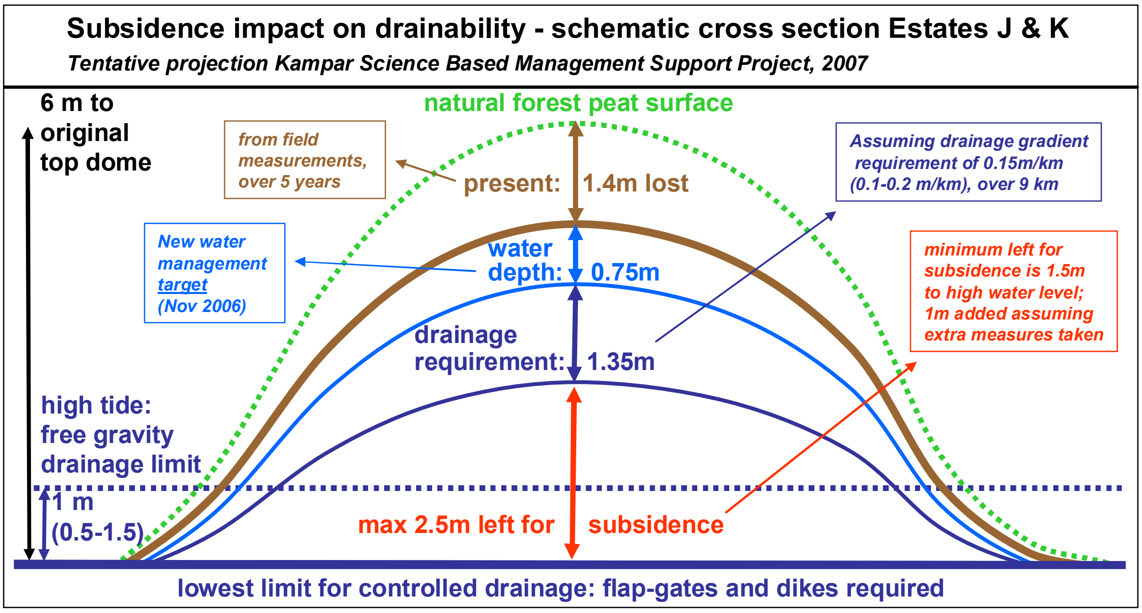

Figure 14 Subsidence impacts on drainability in schematic cross section through Estates J & K (in Pelalawan).

Long-term subsidence rates were derived from Figure 13.

For this location, which appears to be representative for many other plantations in Pelalawan in terms of peat depth and drainage gradient, it was found that up to 2.5m subsidence can be sustained before the area will become undrainable and less suitable for plantations. Note that 1.4m of subsidence has already occurred here, within 6 years, as water management practice in these plantations has been well below 'APRIL best practice'; dams are now being constructed to bring up water levels to target range and to reduce subsidence.

The following tentative conclusions were drawn on expected plantation drainability lifespan:

- *About 25 years if water management continued as up to 2006 (previous water management target).*
- *About 50 years if water management on current (new, 2007) target and subsidence reduced to 5 cm/y (on average; more in first years, less in later years). Additional water management measures would be required within 25 years; drainage to 1m below the 'free gravity drainage limit would be possible through construction of dikes and flap-gates that will keep out tidal waters.*
- *A plantation drainability lifespan over 50 years requires a further reduction of subsidence rate by raising water levels above the current target. This may require use of alternative pulp wood species that are more tolerant to high water levels.*

Development of a recommended land use zoning map (WP 2.1)

Aim
While the other five SBMS Project work packages investigate ways of reducing drainage impacts in peatland plantations and adjoining conservation forest, this work package aims to apply lessons learnt in other work packages (and in other projects) to the Kampar Peninsula as a whole, with a focus on forest and carbon conservation. The aim is to define the optimum (and minimum) requirements for viable forest landscape conservation, in terms both of area and location within the peatland landscape and of mitigation measures required in adjoining plantations. The work package considers requirements and options from a scientific perspective (i.e. not including stakeholder consultations or accounting for specific actual development plans), but aims to provide the basis for responsible planning in practice.

Method
The following main steps are planned:

- The starting point of the analysis is assessment and mapping of the natural forest types and patterns present in the area, from remote sensing images (Figure 15).
- Following this, we will delineate where forest is left at present, what state it is in, and what threats to its integrity (drainage, logging) currently exist. This is done with remote sensing images for 2007/2008 (high resolution cloud-penetrating radar).
- To see where forest and carbon can be conserved in the long term, we will determine viable conservation units from a peatland hydrology/morphology perspective, i.e. individual river catchment areas and peat domes plus buffer zones, as derived from a Digital Elevation Model using the assessment tool developed in work package 1.4.
- By overlaying (in the strategy assessment tool) maps of A) forest type/pattern, B) forest status/threats, and C) viable peatland conservation units, areas are identified that should have priority in conservation plans. The widely accepted HCVF (High Conservation Value Forest) assessment method will be adapted to become more suitable for tropical peatlands, and applied in the current analysis. Thus, a 'core conservation area' can be recommended that should be widely acceptable.
- At this point of the analysis, 4 general land cover classes will have been identified. Outside A) the core conservation areas, that must be maintained in their natural state entirely if conservation is to succeed in the long term, there will be B) areas that have already been successfully developed and will likely remain productive, as well as C) areas that have been deforested but are not productive or are unlikely to remain productive, and D) degraded or fragmented forest areas outside the core conservation area. The latter two types (C and D) may be considered for rehabilitation into natural forest or for productive development.
- Responsible future use of unproductive deforested areas, and degraded/fragmented forest areas, should be considered on the basis of an integrated management master plan for the Kampar Peninsula, taking into account forest and carbon conservation requirements and options (including the APRIL 'Ring plantation' concept, carbon market financing, and developments in Indonesian forest conservation legislation) as well as existing pressures on the area (including illegal logging and activities by companies other than APRIL). The Kampar SBMS Project team could support such integrated planning, providing science-based advice as required.

First results

The relation between plantation water depth and width of the impact zone in conservation forest varies with peatland morphology, peat type and forest type. The processes involved will be better understood when more data become available in the SBMS Project. However based on first field assessments of conservation forest near plantations, and on current understanding of peatland hydrology, it can be concluded tentatively that drainage in the Kampar Peninsula peatlands will within a few years lower water levels over one to two kilometres into conservation areas. The water depth impact zone will widen in the longer term, possibly to as much as 5 kilometres where peat is fibric and highly permeable (as is the case in much of the Kampar Peninsula peatlands), as water tables in conservation areas are lowered further with progressive plantation subsidence. As peatland conservation forest requires high water tables but has some resilience to drought, the forest degradation impact zone will expand with the water depth impact zone, but may be somewhat less extensive.

A consequence of this tentative finding is that, as a rule, only large hydrological units within the peatland landscape (i.e. entire peat domes and river basins with buffer zones) can be conserved. Many existing conservation areas of less than 4 kilometres across (and possibly up to 10 kilometres in fibric deep peatland), adjoining drained areas, are not viable in the long term. There may be exceptions where conservation forest is located in low-lying areas within the peatland landscape, making them less vulnerable to drainage.

A tentative map of natural forest types on the Kampar Peninsula is shown in Figure 15. This is based on analysis of a 1990 satellite image in order to understand the condition of the vegetation before large-scale land development and illegal logging activities had become established. This analysis has shown that natural vegetation patterns on the KP are very complex and heterogeneous. At one end of the ecological continuum (series) of vegetation types are the tall riverine and mixed swamp forest types, which grade into successively lower growing forest types on the higher parts of the peatland domes. This transition between forest types is linked to changes in peat depth and slope gradients, which influence depth of groundwater, period of waterlogging, and water/nutrient supply rates. Methods for a more detailed analysis of current forest patterns and status are being developed and further analysis will take place in 2008. It is already clear, however, that while large areas of poorer 'pole' forest remain on the Kampar Peninsula, the richest forest on shallower peat has already largely been lost or degraded, through logging and development. As these forests have the highest conservation value (being preferred by key species like tigers and gibbons), protecting and rehabilitating such areas should be a priority in an integrated management strategy for the Kampar Peninsula. Another point that is already clear is that much of the remaining forested peatland is impacted by drainage to some extent, not only around plantations and roads but also by the numerous recent and old logging tracks. Identifying the extent of this impact is a priority in the project, field data collection has started.

The Elevation Model developed in WP 1.4 has allowed development of the first catchment map for the Kampar Peninsula (Figure 16). Tentative forest status assessment has allowed identification of two largely intact catchments that cover much of the inner part of the Kampar Peninsula and would, with the addition of forested buffer zones for protection of ecological and hydrological values, need to be part of the 'core conservation area' in their entirety.

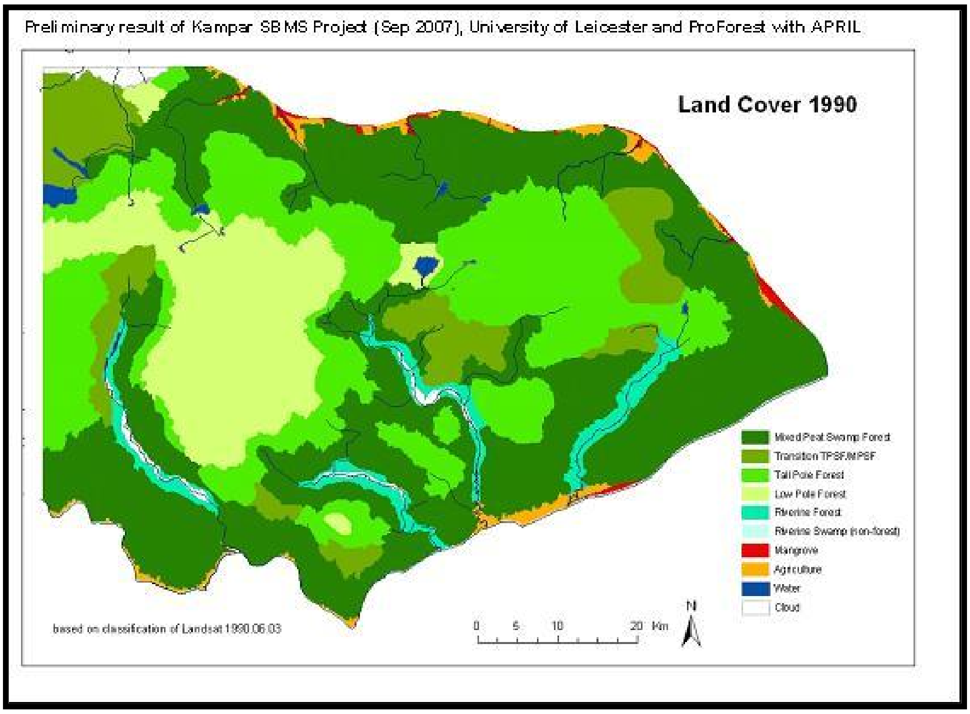

Figure 15 Tentative map of land cover and forest types on the Kampar Peninsula in 1990. Note that much forest has disappeared at present; a land cover map for 2007 is in development.

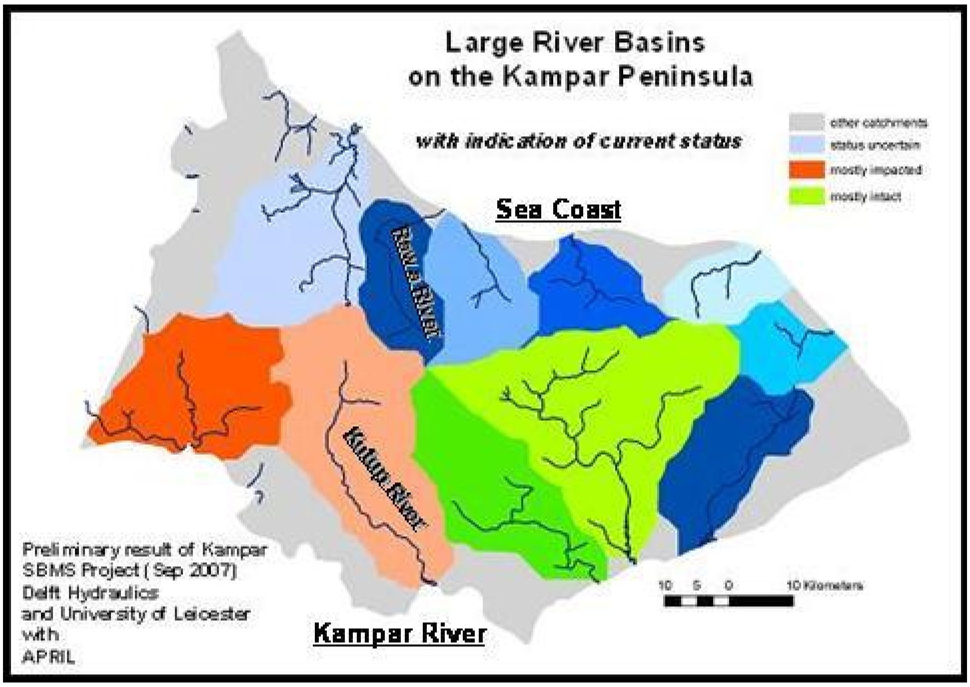

Figure 16 River basin map for the Kampar Peninsula peatlands as derived from the elevation model shown in Figure 11. This will be an important component of a recommended land use zoning map.

Note that the indication of current status is very tentative, based on limited information, and will be refined in 2008. However it is already clear that any conservation plan would have to include the two relative intact river basins draining to the south, plus buffer zones of at least 5 kilometres around them. If these river basins are affected by intensive drainage (they are already affected by drainage for logging), it becomes physically impossible for much of the Kampar Peninsula peatlands and forests to be conserved.