Government of Central Kalimantan

Government of Indonesia

Government of the Netherlands

Master Plan for the Rehabilitation and Revitalisation of the Ex-Mega Rice Project Area in Central Kalimantan

LAND AND WATER MANAGEMENT IN THE EX-MEGA RICE PROJECT AREA IN CENTRAL KALIMANTAN

Technical Report No. 4

MARCH 2009

Euroconsult Mott MacDonald and Deltares | Delft Hydraulics
in association with
DHV, Wageningen UR, Witteveen+Bos, PT MLD and PT INDEC

Master Plan for the Rehabilitation and Rehabilitation of the Ex-Mega Rice Project Area in Central Kalimantan

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Land and Water Management in the Ex-Mega Rice Project Area in Central Kalimantan

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Abbreviations

APBD	Anggaran Pendapatan Belanja Daerah (regional budget)
APBN	Anggaran Pendapatan Belanja Nasional (national budget)
AWP	Annual Work Plan
Balai WS	Balai Wilayah Sungai (river basin management agency)
DAK	Dana Alokasi Khusus (Special Allocation Funds from APBN)
DS	Dry (cropping) season
EMRP	Ex-Mega Rice Project
GL	Ground level
GWL	Ground water level
HWL	High Water Level
ISDP-I	Integrated Swamp Development Project, Phase I
Inpres	Instruksi Presiden (Presidential instruction)
Juru Pengairan	Gate operator (O&M field staff)
KK	Kepala Keluarga (Head of family)
LWL	Low Water Level
LWMI	Land and Water Management & Infrastructure
LWMTL	Land and Water Management in Tidal Lowlands Project
Kolam	Retention pond in the UGM hydraulic design
KSO	Kerja Sama Operasional (mechanism for community involvement in maintenance contracts)
MP EMRP	Short for project title Master Plan Study EMRP Area
MRP	Mega-Rice Project, as PLG
mS	milli Siemens, unit for electric conductivity (mmho)
MSL	Mean Sea Level, common topographical datum
MWL	Mean Water Level
NGL	Natural ground level
NT	Neap Tide
O&M	Operation & Maintenance
P3A	Persatuan Petani Pemakai Air (Water Management Association)
Palawija	Dry land food crops, usually as secondary crop following rice
PAS(S)	Potential acid sulphate (soil)
Pengamat	Supervisor (O&M field staff)
PfW	Partners for Water/EVD (Dutch assistance)
PLG	Proyek Lahan Gambut (Peat Land Project)
Pola WS	Strategic plan river basin management
PP	Peratiuran Pemerintah (Government regulation)
PPL	Penyuluh Pertanaian Lapangan (agricultural extension worker)
ppm	parts per million
ST	Spring Tide
STLD	Strengthening Tidal Lowland Development (PfW project)
Dinas Pengairan	Water resources agency at provincial level
Sub-dinas Pengairan	Water resources agency at district level
Swakelola	‘eigen beheer’ (self-management)
UU	Undang-undang (Law)
WRM	Water Resources Management
WS	Wet (cropping) season

Chapter 1 Introduction

As part of the Master Plan for the Conservation and Development of the Ex-Mega Rice Project in Central Kalimantan, a preliminary, broad assessment of land and water management aspects was conducted in the EMRP project area.

Land and water management is a key factor in the conservation and rehabilitation of peat lands and the revitalisation of agricultural development, being the overall objectives of Inpres 2/2007. Land and water management is also part of the overall socio-economic development process, and interventions should be integrated with the socio-physical environment, agriculture, and local and regional development objectives.

Land and water management in the EMRP requires considerable improvement, (i) to counter over-drainage of the peat lands resulting in deforestation, fires, subsidence, and carbon emissions, and (ii) to ameliorate stagnant water conditions, accumulations of acids and toxicities, and delayed soil ripening, and to increase productivity in the development areas.

Land and water management measures in the peat lands will focus on restoring the water balance, the 'wise use' of peat lands, adapted land use behaviour, and minimal drainage. Land and water management in non-peat lands will aim at optimisation of agriculture, on one hand by increasing controlled drainage and improved land preparation, to increase soil and water quality and accelerate land development, and, on the other hand, by creating sustainable conditions for optimal development, crop growth and crop diversification.

Land and water management objectives may be conflicting, and are subject to change in the dynamic environment of the lowlands Conditions in the lowlands are also not as uniform as previously assumed, and the science itself is in flux, not only regarding the restoration of tropical peat lands, but also agricultural development in swamp schemes, as these are still going through the reclamation process. A flexible, adaptive, approach will be a critical part of the EMRP land and water management development strategy.

A serious constraint in the current land and water management assessment is the reliability and lack of data. The accuracy of the available Digital Elevation Map is in the range of 0.5-1 m (see Technical Report No. 2 on Hydrology of the EMRP Area). As tidal lowlands are relatively flat, with important land and water management classes only 0.25 m apart, more detailed topographical and hydrological information is required. Finalizing the topographical mapping and linking the land levels with the hydrology should be given top priority for next stages of the design and implementation of the Inpres 2/2007.

Detailed descriptions of land and water management conditions in the initial study areas, i.e. 6 representative villages, are provided in the report Survei Pengelolaan Tanah dan Air serta Infrastruktur di Tingkat Desa (2008). Similar reports were prepared describing the socio-economic conditions and agricultural development in these villages.

The report is not a comprehensive guideline on lowland water management. For more detailed descriptions of land and water management, see the reports listed under References.

Chapter 2 provides a review of land and water management in the EMRP. Chapter 3 describes the approach towards land and water management in the tidal lowlands and peat lands of the EMRP. Chapter 4 presents land and water management issues per Management Unit. Chapter 5 closes with conclusions and recommendations.

Chapter 2 The EMRP Area

The Ex-Mega Rice Project area is located in the south-eastern part of Central Kalimantan province and covers an area of 1,462,000[1] hectares, see Figure 1. The area is bounded by the Sebangau River in the west, the Java Sea in the south, the Barito River in the east and roughly follows the Palangka Raya – Buntok road in the north.

Since the MRP, the project area has been divided into five blocks, i.e. Blocks A, B, C, D and E. Most of the EMRP area falls within the administrative boundaries of Kapuas (43% of the area) and Pulang Pisau Districts (42% of the area) with the remainder falling within the municipality of Palangka Raya, and the Barito Selatan District.

2.1 Development History

2.1.1 Pre-Mega Rice Project

Prior to the MRP, a substantial part of the project area, was already developed for agriculture Most peat and non-peat land forests were already logged and had degraded to some extent.

Local settlers and spontaneous migrants began to develop the downstream riverbanks and tidal swamps in the EMRP area during the 1920s/30s, followed by government-sponsored transmigration in the swamp and peat land interiors in the 1970s/80s in Blocks C and D.

An early study (Nedeco-Euroconsult 1984c) concluded that parts of Block A (Lamunti and Dadahup) and Block D (centre) were suitable for new development, as the remainder of the area consists of deep peat (> 2 m), was subject to flooding, drainage limitations, or occupied.

2.1.2 The Mega Rice Project

In the 1990s the Orde Baru administration decided to go ahead with a long nurtured wish by then president Suharto on the development of Kalimantan as a main rice production area. The Mega Rice Project (MRP) or Proyek Lahan Gambut in Central Kalimantan came into being with the issuance of Presidential Decree No.82/1995.

Technical teams involved in the design of the MRP optioned for a cautious and phased development, starting in parts of the Block A, earlier identified as being suitable. A macro-network of drainage and supply canals was designed to improve soil and water management conditions. Under political pressure, works on the macro-infrastructure did not follow the same cautious approach and phasing, and started in the whole area, ahead of hydrological and topographical surveys, final design, and the environmental impact assessment (AMDAL).

[1] Block E of about 400,000 ha North of the main EMRP East-West oriented main SPI canal was not part of the original 'One Million' ha targeted for development

Construction of the PLG canal system resulted in a 187 km long main canal, connecting the Barito River (at Mangkatip), the Kapuas River (near Katunjung) and the Kahayan River (near Palangka Raya), 958 km of primary canals in Block A, B, C and D, and 973 km of secondary canals and 900 km of tertiary canals in Block A were constructed. The macro-infrastructure caused severe damage to peat domes resulting in over-drainage, subsidence, irreversible drying out, loss of habitat, and increase of fire-risks that were already a serious problem in the area. The infrastructure also provides access for (illegal) logging.

The new PLG settlement of Block A, with both local and outside transmigrants, saw initial hardships which are not unique, but rather typical for early reclamation stages in lowland development. Many settlers left, but this is partly due to ethnic background, as local settlers showed little interest in wetland cultivation, and often returned to their nearby place of origin.

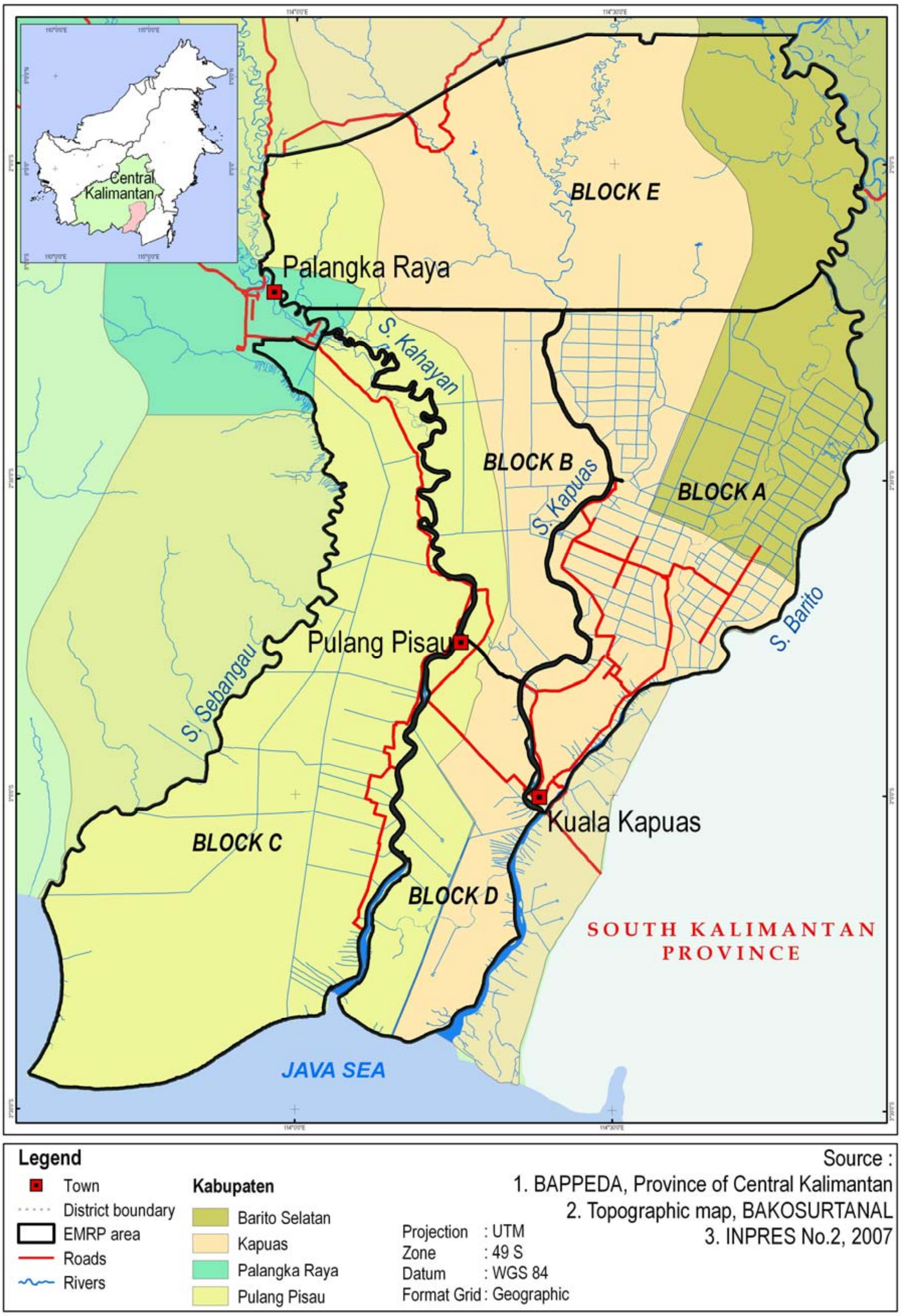
In the context of the international discussion on climate change and carbon emissions, the regional impact of the haze caused by wild-fires, and environmental concerns in general, the MRP created an international outcry. After Indonesia's political transition of 1998, and under international pressure, the project was abandoned and formally closed through Presidential Decree No. 80/1999, which recognized that part of the area, including the deep peat zone (> 3 m) needs to be conserved. The perceived failure of the MRP resulted in the loss of political support to the Indonesian lowland development cause, and this torpedoed efforts to develop a national and regional integrated lowland management strategy, addressing both conservation and development.

2.1.3 Post-MRP

From 2000 onwards, some rehabilitation work has been undertaken in the EMRP area, focusing on re-greening, agricultural development, and the provision of services and infrastructure by the Ministries of Forestry, Agriculture, Transmigration, Public Works and local government. International and local support focused on research and techniques for peat land conservation and restoration and fire-prevention as well as pilot projects focusing on rehabilitation and socio-economic development (CIMTROP, CKPP, and CIDA).

In 2002, the Minister for Accelerated Development of the Eastern Part of Indonesia formed a coalition of the Ad Hoc Team and the Core Team for the Mitigation of the EMRP. The team was made up of officials, scientists, and members of university and other professional organizations, with the provincial government being supportive to the restoration of the ecological functions of the area. The team was tasked to evaluate the EMRP and to seek mitigating measures and alternatives for future development.

Figure 1 - Situation map EMRP



The recommendations of the Team were presented in 2004:

- Restoration of hydrological functions of peat areas;
- No transmigration as long as settlers are unable to obtain sustainable livelihoods;
- Fire prevention and control;
- Development of tropical peat on the basis of scientific and socio-economic criteria.

The key policy guiding the rehabilitation and restoration of the EMRP area is Presidential Instruction No. 2/2007. The Inpres follows on from the report of the Ad Hoc Team and describes a 5-year multi-sector program, focusing on:

- Conservation, including the hydrological restoration of 1.1. million ha, ecosystem restoration, reforestation of 50.000 ha, and fire prevention and control;
- Agricultural revitalisation of 330.000 ha including the rehabilitation of hydraulic and agricultural infrastructure, and development of wet and dry food crops, horticulture, plantations, industrial timber estates, fisheries and livestock;
- Community empowerment including support to community development, rural infrastructure and provision of basic services, as well as new transmigration.

To prepare for the implementation of the ambitious Inpres, the Ministries of Public Works and Agriculture mobilized in 2007 several national consultants to survey (SID) sites in existing development areas, i.e. the ex-PLG schemes in Block A, Lamunti, Dadahup and Jenamas, and to check on sites earmarked for new transmigration.

2.2 Climate

The EMRP area is characterized by a humid tropical climate with mean daily temperatures varying from 25 to 33°C at sea level, high humidity (85- 90%) and a mean annual precipitation of approximately 2,400 mm. Normal dry seasons last from May/June to September. During El Niño-Southern Oscillation (ENSO) years, the dry season may begin as early as March and last until December.

Following the agro-climatic zoning of Oldeman (1980), the climate in the EMRP area is characterised as C2 near the coastal zone, with 2-3 consecutive dry months (<100 mm/month) and 5-6 consecutive wet months (>200 mm/month), to B1 in Block E, with 0-1 consecutive dry months and 7-9 consecutive wet months respectively. The rainfall pattern would allow for double cropping, but other hydrological and soil characteristics also need to be considered.

Although the exact impacts of climate change for Indonesia are difficult to assess, the direction of change is clear. For Indonesia, the most common climate related hazards are storms, floods and droughts. For coastal lowlands, sea level rise is particularly important, as changing rainfall amounts and patterns will impact the hydrology of these areas, thus affecting the coastal zone and inland agriculture.

Projections for extremes remain uncertain, but consensus is that increases in extremely warm and wet seasons are likely to occur, including extreme rainfall and winds associated with tropical cyclones. Projected average global sea level rise for this century ranges from 0.18 to 0.59 m, in predictions that do not account for rapid dynamic changes in ice flow, (IPPC 2007), while for Indonesia a sea level rise of 65 centimetres is predicted (Bappenas 2004), see also Box 1. A sea level rise will result in increased flood risks in the coastal zone, and affect the drainage of agricultural development schemes. Salt-water intrusion with declining river runoff, will impact agricultural activities and drinking water supply.

Box 1 - Climate change – projected scenario's for Borneo

- Temperature increase 1.05 ^{0}C by 2020 and 3.3 ^{0}C by 2080
- Longer dry periods
- Precipitation 2.4% increase in 2020 and 8.5% increase by 2080.
- Possible impact: longer dry periods: increased evaporation may overcome effect of increased precipitation. No changes in net carbon uptake,
- Remediation actions: maintain hydrological and ecological intactness: high water table and forest. Avoid deforestation and drainage

Source: Rieley, J.O. *et al* (2005)

2.3 Hydrology and Topography

The relation of hydrology and land levels is the most important factor to determine land and water management potentials in lowland development.

2.3.1 Topography

The land surface of the **tidal areas** is typically located around or just above average mean high tidal water levels. These vast, flat swamp areas are prone to stagnant water conditions either from rainfall or shallow tidal flooding. Controlled drainage, leaching and flushing is the key to the reclamation of these lands. Gravity drainage on the tidal river is possible during the daily low tide, if the tidal range is sufficiently large, the canal system well-designed and maintained, and the distance from the river not too far. During the daily high tides, supply flows into the schemes can be utilized for tidal irrigation in therefore suitable areas, and replenishment of canal and ground water with fresh (river) water.

The topography of the tidal lands, as are the soil conditions, is not uniform, with many micro-level variations. Land levels are also subject to subsidence caused by drainage and soil ripening. The development process in the lowlands is dynamic and variable, and site-specific measures will be required. Small differences of topography in relation to water levels have a large impact on land and water management options, including the soil and water quality.

In the **non-tidal areas** the land and water management options are mostly decided by the upland river flow regime, i.e. the occurrence of long-duration and deep floods, drainage limitations during the wet season, and the sophistication of the hydraulic infrastructure.

Due to their elevation, **peat domes** are less influenced by the rivers, but the hydrology of peat lands may influence bordering low-lying areas, e.g. through interflow and surface run-off. Drainage, such as that caused by logging operations and the PLG infrastructure, in combination with deforestation and fires has caused irreversible drying out and oxidation. Surface gradients around canals in the peat areas have increased since EMRP implementation. In Block A a 'mini-dome' topography has developed that now controls the hydrology (Deltares-WUR, 2008).

2.3.2 Hydrological Boundary conditions

Land and water management options within a swamp scheme are ultimately limited by the hydrological conditions surrounding the area. These consist of (i) the river, with its daily tidal and seasonal water-level fluctuations and salinity intrusion, and (ii) runoff from surrounding lands, see Annex 1. Boundary conditions are not under project control, but changes may occur as a consequence of large-scale changes in land use in the catchment areas, construction of reservoirs, construction of flood protection embankments limiting overland storage, etc.

The main rivers in the EMRP are the Sebangau, Kahayan, Kapuas and Barito, See Figure 1. The hydrology of the EMRP area is determined by rainfall, tides entering from the sea into the rivers, and the flow of the main rivers. The catchment of the Barito river is some 40,000 square km, about twice as large as that of the Kapuas and Kahayan River. The rivers are full tidal near the coast and non-tidal at the northern part of the EMRP.

2.3.3 River Water Levels

In the fully tidal stretch, river water levels in the EMRP are governed by the tide, which is mainly diurnal (one high water and one low water each day) and with a tidal range fluctuating from an average of 1.2 m during neap-tide to 2.4 m during spring-tide, with only minor variations throughout the year. An 18.6 year cycle (Deltares-WUR, 2008) in high sea water levels with variations of about 0.25 m determines the maximum tidal water level, which can become as high as 1.55 metres above mean sea level (MSL).

Upstream of the fully tidal river reaches the water-levels become more and more determined by the upland river flow, and seasonal fluctuations become more pronounced. Near the upstream boundary of the EMRP area tidal fluctuations are almost absent, and wet season river levels in the Barito and Kahayan Rivers can be periodically some 5 m above dry season levels, while in the Sebangau and Kapuas Rivers the seasonal difference is typically 2 m.

2.3.4 Flooding

Flooding in swamps has several causes and it is important for hydraulic design and water management to distinguish these differences. Flooding may be beneficial, as is the case with short-term and shallow tidal irrigations (only possible in small part of the tidal zone), or be a constraint as is the case with flooding in non-tidal areas with long-duration and deep floods. Flooding is also caused by stagnant drainage (rainfall), and water flowing from adjacent higher (peat) areas. A description of flood types in the EMRP area is presented in Box 2.

2.3.5 Drainage

Drainability of existing and new drainage schemes is a function of land surface gradients, river/tidal water level fluctuations, and hydraulic head losses in the drainage system between the land and the river. Because of flooding, high groundwater tables, and soil and water quality, drainage is essential for the development of the land. Drainage is required to evacuate excess water, to leach and flush out acid and toxic components, and soil ripening.

Areas closer to the tidal rivers can be drained by gravity during low tide, but drainage becomes increasingly difficult at greater distance from the rivers. Gravity drainage is also problematic for low areas along non-tidal river reaches (Jenamas). Drainability may become a problem in some areas after long periods of subsidence in both peat and mineral soils.

Not much is known yet regarding (future) drainability in the EMRP for which more details are required of relations between (average) river water levels, peat subsidence, (future) topography, and the distance from river. It is however estimated that in several parts of the EMRP drainability will be increasingly impeded. Further analysis is also required as to the effect of climate change on drainage and flooding.

Box 2 - Flooding types in the EMRP

Tidal Flooding - In the downstream parts of the EMRP, Block C and D, low-lying lands may be subject to flooding by high tides. Flooding depth can be up to several decimetres, and while the duration of a high tide is a few hours only, the land may remain flooded for some time after the high water has receded in the river or canal. In non-saline areas, tidal flooding can be beneficial for wetland rice cultivation (tidal irrigation).

River Flooding - Upstream of the tidal river reaches increased river flows during the wet season inundate adjacent lands. These river floods may last for weeks or even months, and flooding depth can be up to several meters depending on the local topography in relation to the river levels. Flooding from rivers is determined by water flows from the upstream river basins of the Barito, Kapuas, Kahayan and Sebangau Rivers. Hydrological model results and field observations show that large-scale and prolonged river flooding presently occurs mostly along the Barito River, affecting parts of Block A and D. Flooding is longest and deepest in the Jenamas area and, to a lesser extent, the Dadahup transmigration area.

Surrounding areas - Runoff from surrounding lands may cause flooding in the schemes, but can also be a useful source of water supply, and even gravity irrigation. Runoff from lowlands takes place as overland flow and through depressions and shallow creeks. Peat domes act in their natural state as a reservoir, gradually releasing their surplus water which can be used to provide additional water during periods of drought. Quantities of available water can only be roughly calculated from catchment water balances, and water quality may not be good. To protect the agricultural developments from hazardous floods and interflow with poor quality water, runoff from surrounding lowlands can be diverted through interception drains to the river or the primary canal system. This may be more difficult in the case of shallow depressions and creeks in the scheme area, which should retain their natural function.

Rainwater Ponding - The flat topography and high groundwater tables may result in rainwater ponding. The water accumulates in depression areas, which then remain inundated for weeks or even months. This type of flooding occurs both in depression areas in mineral soils and at the foot slopes of peat domes.

2.3.6 Water Management Classification

Useful hydrological and land and water management classifications in swamp lands of Indonesia include (i) categories based on river regime (stretch), to identify major boundary conditions, (ii) flooding classes for non-tidal swamps (upstream), and (iii) hydro-topographical categories in tidal lands based on hydrology and topography (downstream).

River categories - Four major land and water management zones are distinguished in the EMRP, based on the river hydrology, see Box 3. Figure 3 shows a tentative land and water management zoning of the EMRP area, based on this classification. It is assumed with this zoning that the higher peat areas are not influenced by the river water level fluctuations.

Box 3 – Macro land and water management classes

Zone I: Tidal in Wet and Dry Season - Rivers are full tidal during the wet and dry season. The tidal influence will dampen upstream into the river and canal systems. The tidal range will allow gravity drainage and tidal irrigation, depending on the distance from the river, the hydraulic infrastructure and the micro-topography. In low-lying areas of the swamp interior, drainability is limited, with stagnant water adding to acidity problems. Nearer to the coast, salinity intrusion occurs during the dry season, effecting drinking water conditions but also limiting possibilities for double cropping. Tidal flooding is shallow and of short duration.

Zone II: Reduced Tidal in Wet Season - The zone is part of the transition from the tidal to the non-tidal zone. High river discharges from the uplands during the wet season occasionally influence the tidal fluctuations, resulting in periods of limited drainage, and occasional flooding. Otherwise the zone has similar characteristics as Zone I.

Zone III: Non-Tidal in Wet Season - This zone is tidal during the dry season when upland river flows are small. During the wet season, normally the main cropping season, the river will be non-tidal, and drainage will be severely hampered. Long duration flooding may occur.

Zone IV: Non-tidal in Wet and Dry Season - This zone is non-tidal year round, and river water levels are determined by the upland flow. This zone is associated with the flood plain levee and back swamp landscape. Drainage is difficult with deep and long duration floods.

Non-tidal Swamp Categories - In the northern part of the EMRP the rivers are non-tidal, with high river water levels for a duration of months, and characteristically deep and long duration flooding of the backswamps, or even lakes, see Figure3[2].

Common land and water management classes in the non-tidal floodplains (rawa lebak) in Indonesia are usually based on flood depth characteristics:

- Class 1 – Shallow: flooding depth up to 1 m
- Class 2 – Medium deep: flooding depth between 1 – 2 m
- Class 3 – Deep: flooding depth over 2 m deep

[2] Insufficient data available to (tentatively) map out the non-tidal flooding classes

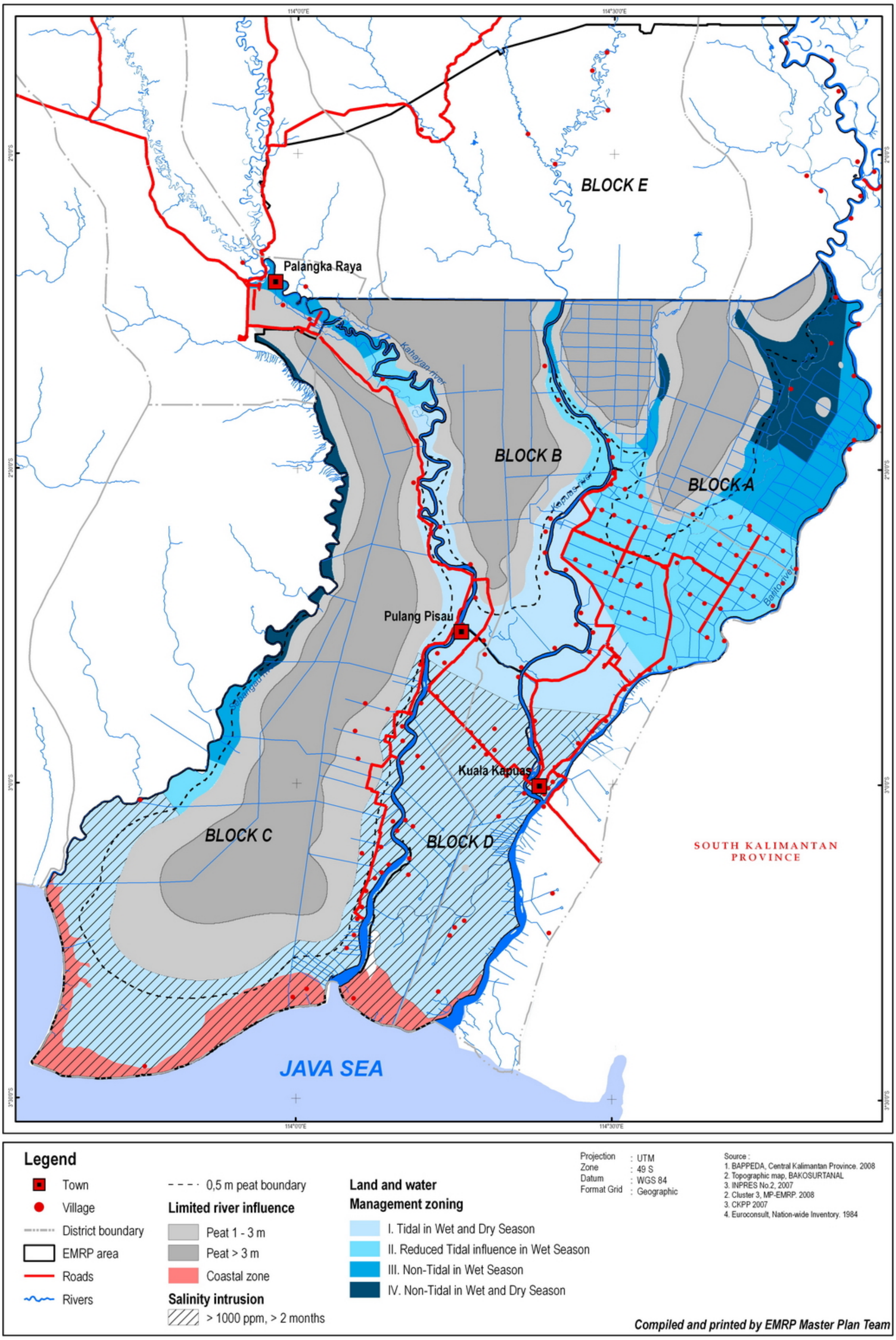
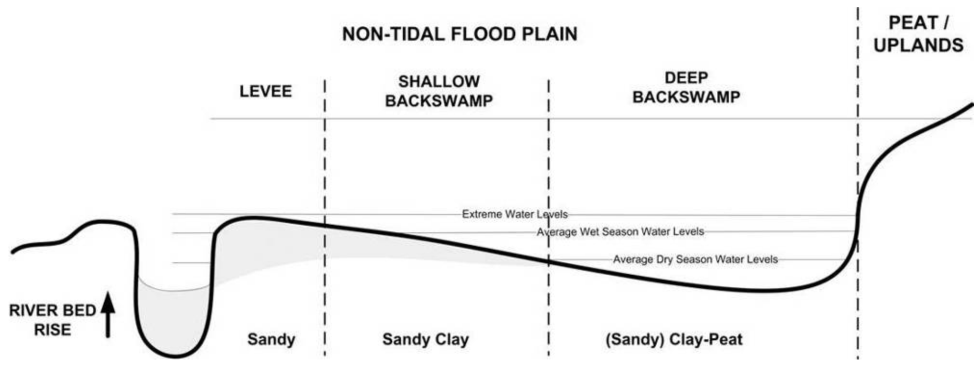


Figure 2 – Macro Land and Water Management Zoning in the EMRP

Figure 3 – Non-tidal swamps, flood plain, schematic



A distinction is to be made between duration of the floods, i.e. flash floods with shorter duration, and stagnant floods of long duration. The shallow flooded backswamps are usually suitable for traditional, seasonal wetland rice, grown on the receding flood waters after the rainy season. A long flood duration will reduce the growing season, but simple land and water management measures, such as flood protection and drainage, may improve the length of the cropping season. Gravity drainage is usually not feasible during the wet season, while in the deep and/or permanently flooded backswamps, polders and pumped drainage is required.

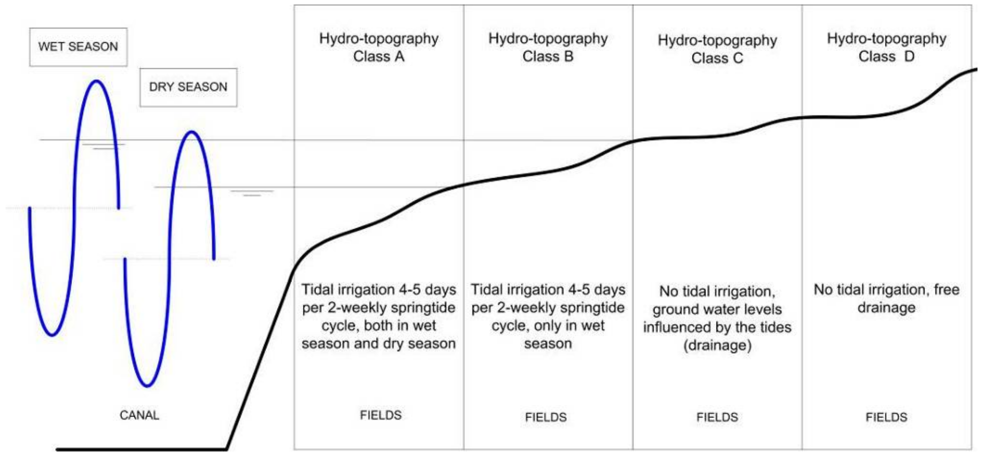
Tidal Lands Classification - The relation between field levels and water-levels is of crucial importance for the water management in tidal swamp lands. Four categories[3] are commonly distinguished, based on tidal irrigation potential. This function is determined by the relation between the tidal range in the river, the dampening of the tides in the drainage system (design, condition, operation), run-off from surrounding areas, and topography, see Figure 4.

The hydro-topographical categories are summarized as follows, see also Annex 2:

- *Class A.* Tidal irrigated areas where the fields can be flooded by at high tide for at least 4-5 days during a 14-day spring tide cycle[4] in both wet and dry cropping seasons. The class supports double cropping of wetland rice if salinity intrusion is < 2 months/year
- *Class B*. Tidal irrigated areas where the fields can be flooded at high tide for at least 4-5 days during a spring tide cycle, only during the wet cropping season, and where less water is available to maintain soil and water quality. This class would support a single tidal irrigated wetland rice crop, possibly followed by a palawija crop.
- *Class C*. Areas just above tidal high water, where the fields cannot be flooded at high tide but where the tides still influence groundwater levels, and where leaching of the root zone from acids and toxicants depends entirely on rainfall and percolation through controlled drainage. This class is suitable for a variety of crops, and especially in the early reclamation stages less so for (wetland) rice.
- *Class D*. Higher areas where the fields are not subject to tidal influence.

[3] Insufficient data available to (tentatively) map out tidal hydro-topographical classes
[4] The definition of tidal irrigation takes into account recommended requirements for percolation (8-10 mm day) for the leaching and flushing of acidity

Figure 4 – Tidal swamps, hydro-topography, schematic



The hydro-topography can be determined by field measurements, but this is usually complicated due to the high micro-variability. Over time, farmers will develop a better understanding of their land and water management position in the scheme. For macro-level review and design purposes, an approximation can be made by comparing field levels with tidal high water-levels in the rivers, taking into account an estimated damping of the tidal high water in each part of the canal system. For this, it is essential that river water levels are tied to the topographical levels.

Most tidal lands in Indonesia are of Category C. Areas which can be regularly flooded by the tides in both seasons, Category A, are very limited (estimated 5-10 %). Most of the EMRP area is expected to fall into Categories C/D, with some lower Class A/B areas in the southern parts of Block C/D and along the tidal rivers. The potential for tidal irrigation will be limited as during peak flows the head losses in the canals will be very high, even under the best of circumstances.

The hydro-topographical classification is based on high daily tidal water levels in relation to land levels. Drainage potential is however as important or even more so for land and water management. That is especially true in the majority of lowlands as these are dependent on rainfall and drainage for soil and water quality management.

There is an obvious correlation between drainability and hydro-topography, but drainage categories need to be established separately. Drainage classes[5] are based on requirements for wetland rice (0.30 m), dry land crops (0.30 m – 0.60 m), and tree crops (>0.60 m).

[5] Insufficient data available to (tentatively) map out the drainage classes in the EMRP

2.4 Land Units and Soils

2.4.1 Land Units

The EMRP area has been subject to drastic sea level and climate changes. Prior to the Holocene, the sea level was 80-120 m lower than current levels. The Barito river was then a contributory to the Sunda shelf river system. The subsequent Holocene sea-level rise resulted in the drowned-valley landscape of today, the boundary of which is located in the Block E area. Older mature deposits were overlain with younger sediments of marine and fluviatile origin. During the mid-Holocene, the sea-level was about 1-2 m higher than current levels.

The sedimentary marine environment would change over time into freshwater swamps, enabling the accumulation of peat. This process continued till the river influence became less and peat forest growth becomes fully dependent on rainfall, resulting in the typically dome-shaped deep peat formations. Deep peat areas extend beyond the 3 m conservation boundary towards the rivers with decreasing peat depth.

The remainder of the EMRP area consists of shallow organic soils (< 0.5 m depth), muck soils, pyritic or (potentially) acid-sulphate soils, and fluviatile soils, more so in the northern part. Soils in the (tidal) swamp interior are susceptible to acid production during the dry season and thus sensitive to stagnant water conditions, i.e. flushing and leaching would be required to remove acidity and toxicities resulting from the reclamation process.

There are basically four main land systems in the EMRP area, each having a different landscape setting and with different usage options and management requirements:

Non-tidal floodplain back swamp and levee system – This zone is typical of the non-tidal northern part of the EMRP, including parts of Block A and Block E. Under the riverine influence, well-drained, coarse textured river banks or levees are formed, with poorly drained and often long and deep-flooded non-tidal swamps (rawa lebak) consisting of finer material and organic soils behind the levees, see Figure 3.

Tidal swamp system - Tidal swamps are the low lying poorly drained areas located in the tidal river stretch, and include the 'mineral and shallow peat' areas of Block C and D and parts of Block A and B, see Figure 4. The areas are flat with weakly formed natural drainage systems, and under natural conditions they are subject to ponding from rainwater and/or shallow tidal flooding. Levees along the rivers are far less pronounced or absent and of finer material than in the non-tidal area, but are better drained compared to the hinterland. Soils are mainly of marine origin and have a high horizontal and vertical spatial variability, containing (shallow) organic soils, pyritic, muck soils, and non-pyritic soils. In slightly elevated terraces podsolidation may have taken place in pyritic soils, resulting in so-called white, low fertilility soils. Sandy beach ridges may occur along current and former coast lines.

Peat lands - Three continuous deep peat areas are found in the EMRP, i.e. Block C, Block B/E and Block A/E. The peat area in Block C can be seen as a typical coastal or basin peat land, i.e. elongated dome shaped peat overlying younger marine sediments at a low to medium elevation. The northern peat areas are most likely watershed peat lands, which accumulated over Giant podzol quartz-sand formations wedging up against the uplands.

Coastal zone - The EMRP coastal zone is mostly defined by alternating sandy beach ridges and swales with clayey and organic soils.

2.4.2 Soils

The extent of peat lands in the EMRP (including Block E) of more than 0.5 m depth is 927,000 ha or 63.5 %, of which 447,000 ha is very deep peat (> 3 m), see Table 1.

Table 1 – Peat depth by Block in the EMRP area (in ha)

Peat Depth	Block					Grand Total
	A	B	C	D	E	
> 3m	72,110	81,507	144,755	-	149,122	447,494
2 - 3	15,007	13,741	58.331	-	31,269	118,348
1 - 2	21,736	18,028	74,004	141	54,425	168,334
0,5 - 1	43,413	14,292	51,546	22,514	61,122	192,887
Mineral soil	158,470	30,760	121,325	117,210	104,640	532,405
Grand Total	**310,736**	**158,328**	**449,961**	**139,865**	**400,578**	**1,459,468**

The remaining 532,000 ha or 36.5 % of the EMRP, including Block E, is considered mineral soils and/or organic layers of < 0.50 m, see also Figure 5.

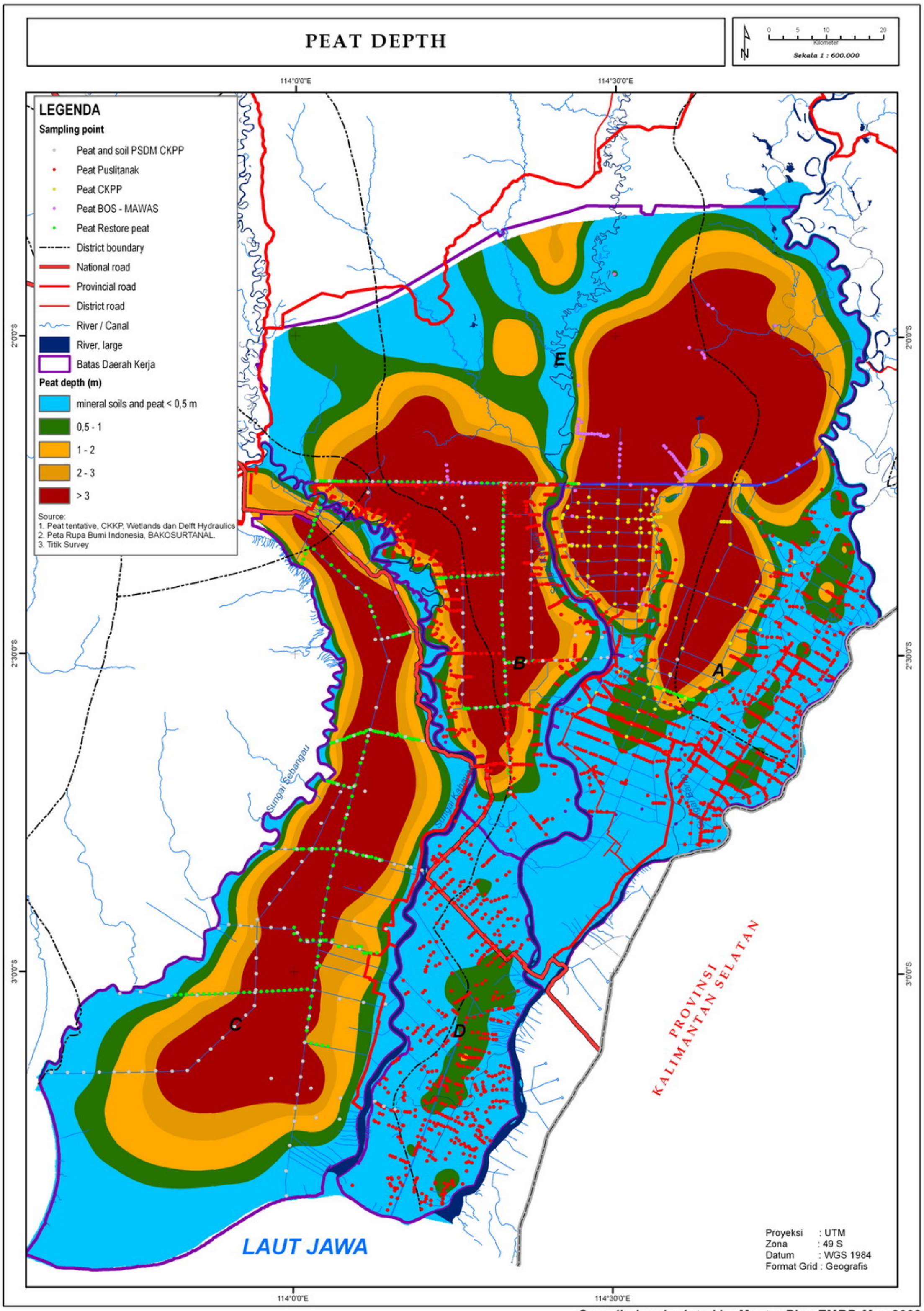
Mineral soils in the coastal swamp areas, as in the EMRP, are usually characterised by the presence of potential acid-sulphate, where upon oxidation sulphuric acids are produced to the extent that this may become harmful to crops and vegetation. In their original state, these soils are unripe, with a high organic matter content and low bearing capacity. Acidity and organic toxics are a major cause for chemical imbalances and adverse conditions for crop production.

Reclamation of these soils is possible but requires specific soil and water management measures, focusing on (controlled) drainage, flushing and leaching, and land preparation. The water management (drainage) potential in relation to field levels is the key to the successful reclamation and sustainable development of these soils. Based on these overriding land and water management requirements, often a simplified soil characterization is used, see Box 4.

Sandy soils are found as ridges along the coasts of Block C and D, and as the thick white quartz sand deposits underlying the deep peat in Block A/E and B/E. Whitish, low fertility soils, such as found near upland boundaries in the lowlands of Sumatera and elsewhere, have not been identified in the EMRP.

For reclamation and agricultural development the most important aspects are:
- Presence of peat soils
- Presence of acid sulphate soil material, pyrite
- Permeability and degree of ripeness

Figure 5 – Peat depth and mineral soil distribution in the EMRP



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Box 4 - Land unit, soil types

Tidal irrigated areas
All lands which can be regularly flooded at high tide by non-saline tidal water (hydro-topographical Class A). Soils can be mineral or organic, with or without sulphitic material.

Pyritic and muck soils
Mineral soils with sulphitic material (pyrite) at a depth of 1 m or less, or soils with organic material (total ash content >25 %). Regular flooding at high tide is not possible because either the land is too high (hydro-topographical Class B-D), or the water is saline.

Peat soils
Peat soils (total ash content less than 25%), including former peat soils which have been burnt into the clay layer recently and are still toxic.

Whitish, low fertility soils
Mineral soils with low fertility (CEC less than 5 me/100 g), high Aluminium saturation (more than 50%), and a low clay content (or in-active clays), with or without sulphitic material.

Non-pyritic soils
Mineral soils (CEC more than 5 me/100 g) with no sulphitic material at a depth of 1 m or less. Regular flooding at high tide is not possible because either the land is too high (hydro-topographical Class B-D), or the water is saline.

(Euroconsult 2000a)

2.5 Land and Water Management

Current land and water management practices in the EMRP area are closely related to the ethnic and cultural background of settlers and bio-physical conditions. Bio-physical boundary conditions for land and water management are defined by the climate, i.e. rainfall pattern, the river hydrology in relation to the topography, i.e. drainability, tidal irrigation, flooding, and salinity intrusion, and the soils, i.e. organic or mineral soils, acidity, ripeness.

The land and water management systems present in the EMRP area include that of the Dayak, Banjarese and transmigration communities, as well as those of the private sector plantations and coastal ponds (*tambak*), see Figure 6. Logging operations also contributed to the extensive network of canals in peat land areas.

The existing water infrastructure can be divided into (i) traditional handil rakyat systems of spontaneous and local settlers (Banjar and Dayak) along the rivers and tidal creeks, developed since early last century, (ii) the anjirs and agricultural schemes developed by the Dutch-Indies government, mostly during pre-war times, (iii) the large-scale government sponsored swamp reclamation schemes developed during the 1970s/80s, and (iv) macro and micro hydraulic infrastructure developed under the MRP during the late 1990's.

A pronounced feature of the current water infrastructure is the canal network constructed during the MRP. The macro-system affected the peat areas in the northern part of the EMRP and Block C. The micro-network was developed for Block A only, in the Lamunti, Dadahup, and Jenamas development blocks, and consisted of a closed system of secondary, tertiary and quarternary canals with water control structures.

An important issue is that of the uncultivated areas (lahan tidur) in the villages of both spontaneous settlers and ex-transmigrants, and the surrounding (degraded) swamp and peat lands in the EMRP. Interflow of poor quality water from under developed areas occurs even in relative flat areas, and interacts with agriculture. Uncultivated areas are also a source of pests, and canals are not maintained, limiting the effectiveness of the overall hydraulic infrastructure. From a land and water management perspective it is considered best that these areas will be developed, for food crops, industrial crops, as community forest or otherwise.

Operation and maintenance of the canal systems in the EMRP has been neglected, especially after the crisis of 1997. O&M picked up again in 2005, when more budget became available. This translated into rehabilitation and improved O&M of existing networks, but not yet in re-designs and upgrading. In general, and this is also the case in the EMRP, agencies lack (skilled) field staff, e.g. O&M staff and agricultural extension workers. Due to recent re-organizations, re-distribution of responsibilities, and staff-shortages, there is a lack of design capacity within the responsible agencies. Given that many of the schemes in the EMRP need a far reaching design review and upgrading, staff shortages should be urgently resolved.

2.5.1 Traditional Water Management

The first water management systems in the EMRP area appeared during the early 20th century along the banks in the downstream regions of the Barito, Kapuas and Kahayan rivers. These simple traditional canal systems, or handils, were developed by spontaneous settlers from Banjarese origin, and consist of 2 to 4 km long canals perpendicular to the river. Dayak communities copied this model in the upstream areas. Many of the handil systems and villages have a mixed population currently.

Box 5 - Dayak Land and Water Management

Pilang village in Block C (Kahayan river) and Katunjung village in Block A/B (Kapuas river) are representative of Dayak land and water management practices. The villages are located along semi-tidal rivers, on a narrow strip of mineral soils and shallow peat, extending into deep peat lands. The canal water levels are much influenced by the run-off from the peat areas. The local handil canals are used both for drainage and transportation. Flooding typically lasts for up to one month and can damage rubber stands and village road infrastructure. Maintaining the tradition of local fisheries is considered important, even though acidity from newly reclaimed and bordering peat lands has greatly reduced production. Acidity in the fields is traditionally neutralized with ashes from burning, a practice that is currently prohibited, which greatly limits the land use options for the local population. Village areas extend up to 5 to 7 km from the river into the (degraded) peat forest areas, but only a small part is under cultivation.

The Trans Kalimantan highway crosses the village lands of Pilang and cuts off drainage from the upstream fields. Farmers have invested in a new canal into the peat lands to extend the area under rubber. In Katunjung the farmers make use of the new PLG canal infrastructure along which they grow banana's and other crops. The communities report a lack of technology and the finances to improve their situation and request assistance to improve the land and water management and flood protection.

Dayak Land and Water Management - Dayak livelihoods in the EMRP area involve fisheries, tree crops, collection of forest products and agriculture, often in peat areas, see Box 5. Dayak communities incorporated the Banjar drainage design, i.e. relative short drainage canals perpendicular to the river, mainly for the cultivation of rubber along the riverbanks. These systems are found in the upstream, often non-tidal stretches of the rivers, where flooding may occur, either from the river or from adjacent peat domes. Canals may extend into deep peat areas and so influence these peat lands.

Banjar Land and Water Management - The Banjarese settled along the tidal rivers in the coastal and near-coastal zone, i.e. southern part of the EMRP, see Box 6. Banjarese are not merely agriculturists, but fishermen and traders as well and known to maintain extensive networks with coastal settlements elsewhere. The Banjar drainage design consists of simple canals (*handil*) perpendicular to the tidal river. These canals are generally 2 to 4 km long, depending on the tidal influence and land quality. Basically the canals aim at creating drainage and (tidal) irrigation conditions for the cultivation of wetland rice and coconut on and near the riverbanks.

Box 6 - Banjar Land and Water Management

Bahaur Hilir village is located in the full tidal zone in Block C, along the Kahayan River. Coconut is grown on the right bank of the Kahayan River, near to the peat lands, and (tidal irrigated) rice on the left bank. The daily tides penetrate deeply into the canal systems allowing for good drainage. However, shallow tidal flooding and wave action leads to some scouring of riverbanks, damage to village roads and erosion in the fields. Salinity intrusion occurs from June until September and is reported to neutralize acidity from the PLG infrastructure and newly opened fields. However, suitable drinking water is not available during this period and needs to be collected from Mintin, located 50 km from the village. As the canals are used for transport, water control structures are not an option. The larger part of the village area is not under cultivation (*lahan tidur*). The community requests assistance with flood protection, canal rehabilitation and extension of the agricultural area.

2.5.2 Transmigration Settlements

Earliest transmigration - The first government-supported settlement took place on a modest scale in the 1930s and 1950s along the Anjir canals (river connecting canals) in Pulang Pisau and Pulau Petak. Anjir Basarang and Anjir Kelampan in Block D, and Anjir Talaran, Anjir Serapat and Anjir Tamban in Pulau Petak, provides Palangkaraya with an inland water connection to Banjarmasin. These anjirs were the starting point for the first systematic swamp reclamation for agricultural development.

Large-scale transmigration - During the 1970s and 80s large-scale government-sponsored transmigration and tidal land reclamation started by opening up the swamp interior along the downstream parts of the Kahayan and Kapuas Rivers in Blocks C and D, as the riverbanks were already occupied, see Box 7. Reclamation of the swamp interior is more complicated than is the case along the tidal rivers, because of poor drainage and associated stagnant water and acidity problems. Transmigrants, mainly of Javanese origin, did not have prior experience in the management of tidal lands, (potential) acid sulphate soils and organic soils. The lay-out of these schemes, i.e. with dead-ended, forked, main canals, and kolams, is now considered inadequate for land and water management requirements (drainage) in tidal lands.

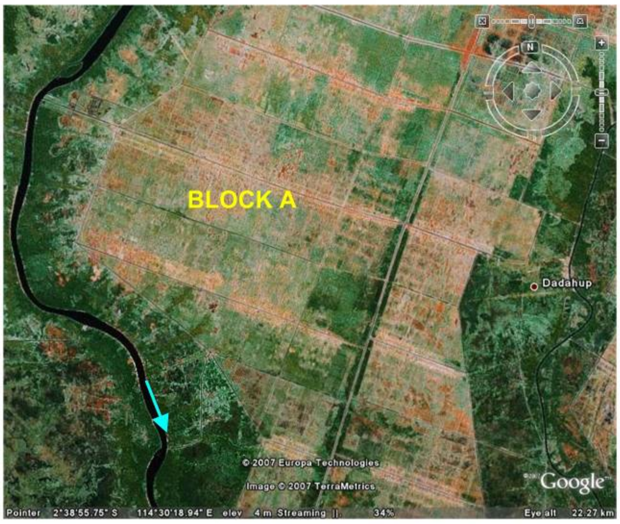
Figure 6 – Water Management Systems in the EMRP

Spontaneous settlement in coastal- and near-coastal areas. Mainly Banjarese settlements with wetland rice and coconut plantings along the tidal river-banks at Bahaur and Terusan Jaya, Kahayan River, Blocks C and D, South

Note the EMRP primary canal running North-South through Block C. The schemes on the right-bank are adjacent to deep peat areas

Government sponsored ex-transmigration sites of the 1970s and 1980s. Dead-ended canals and kolam. Mixed cropping and 'lahan tidur'. Beyond the riverbanks at Pangkuh, Kahayan River, Block C and D.

Note the EMRP primary canal running North-South through Block D. The schemes on the right-bank are constructed well into deep peat areas



Government sponsored transmigration sites of the 1990s, the EMRP area in Block A, Lamunti, left-bank Kapuas River. Double-connected canal system, but incomplete. Scheme is sparsely settled. Borders on deep peat area in the North.

Note the traditional Dayak settlements on the river banks, i.e. the dark green belt along the Kapuas River.

Box 7 - Transmigration Villages from the 1970s and 1980s

Gandang A village is located in the Maliku-Pangkoh V older transmigration scheme in Block C, on the right bank of the Kahayan River, which is fully tidal here. Soils are mainly (potentially acid) mineral soils and shallow peat. The original dead-ended forked canal system is now connected to the PLG macro-infrastructure in the deep peat lands, and partly with the PLG canal near the river. Gandang B and C villages, along the same canal but located on deeper peat areas, were abandoned and transmigrants re-settled, partly in Block A of the EMRP area. The tidal influence is limited and tidal irrigation is not possible due to the canal conditions and relative higher land elevation. The soil and water conditions are poor, acid, and drainage and water circulation is insufficient. Poor quality drainage water from the bordering peat lands enters the scheme. Only few water control structures are in place, and on-farm water management is not developed. Existing culverts hamper drainage as the elevation is too high following subsidence of the land. Public Works has taken up maintenance since 2005 and O&M staff, *pengamat* and *juru* are active. Water user associations (P3A) were formed but are not active.

Only where the river influence is improved, i.e. where the old canal infrastructure is linked to new PLG canals near the Kahayan river, is soil and water quality better and rice production far higher. Otherwise, mainly dryland and tree crops are grown in combination with cattle raising. The larger part of the village area is not cultivated (*lahan tidur*). Farmers request improved hydraulic infrastructure, water control, on-farm water management and better maintenance. The situation in Block D is somewhat different as there is only limited peat land. Instead, the centre of the Block consists of (acid) degraded lowland swamps. Soil and water quality is still poor in the traditional dead-ended canal systems where there is little water circulation, a lack of water control, and no on-farm water management. Only in limited areas near Terusan Raya, tidal irrigation results in better soil and water conditions. Farmers along the Anjir canals increasingly grow rubber instead of rice.

MRP transmigration - The hydraulic design of the MRP transmigration sites in Block A, established in 1996, is based on improved concepts of drainage, leaching and flushing, and includes double connected canals and structures to improve the circulation of water, see Box 8. The primary canals are very long with limited connections to the rivers. The early design also assumed supply from upstream areas but this concept was flawed as the supply canals were crossing elevated peat domes and the schemes are located in a complex hydrological environment between the non-tidal Barito and the (semi) tidal Kapuas Rivers. Construction of the water management systems was never completed

2.5.3 Private Sector Development

Private sector - Several private sector (oil palm) plantations have already started operations. These plantations are often located in deep peat areas, where drainage in principle will have a negative effect on the peat. Inherent to drainage of deep peat lands for tree crops is that the drainage systems needs adjustment with increased subsidence, and that the final scenario always will be that the peat will disappear or become un-drainable. Many more plantation permits have been given out in the EMRP, many in sensitive peat lands and fringe areas.

Box 8 - MRP Transmigration Villages

The Manggala Permai (Block G5) and Rantau Jaya villages are located in the Lamunti scheme. Many farmers left soon after initial settlement. Remaining farmers grow rice, palawija and vegetables, sometimes outside the project area, where conditions are found to be better. Two-thirds of the village area is not cultivated (*lahan tidur*). Soils are mainly mineral with only shallow peat. Acidity is a major problem due to lack of drainage, unfamiliarity of farmers with reclamation techniques, and poor land preparation. There is limited tidal influence in the secondary and tertiary canals but the fields cannot be irrigated. No flooding from the river is reported but shallow and short-term ponding occurs during high rainfall due to a lack of on-farm drainage in combination with obstructions in the main canal system.

Water control structures in the main canal system are not functional and there are as yet no structures in the tertiary system and no on-farm drainage infrastructure. Canals are not maintained in the unpopulated areas, reducing the function of the overall infrastructure. Government is assisting with canal rehabilitation and maintenance but has not fielded *pengamat* or *juru pengairan*. The Water User Association is inactive due to lack of support.

Farmers request completion and improvement of hydraulic infrastructure including on-farm water management, re-population of the area, agricultural and water management support (mechanization), and O&M staff. GoI is currently improving the flood protection in the Dadahup scheme. From several sources (Gandang A, and Banjar villages) it is reported that outside settlers are moving into the Lamunti and Dadahup areas. The GoI is supporting further development of kerbau rawa in the Jenamas area.

2.5.4 Land Use

Land utilisation types are based on bio-physical and socio-cultural characteristics, e.g. land use/land cover, hydrology, climate, socio-economic, ethnic and cultural aspects, farming systems, soil and water management, e.g. degraded peat lands, ex-transmigration in swamp interior, traditional settlers along tidal rivers, see Table 2 and Figure 7.

There are only limited areas left with (peat) forest, mainly in Block E. In the coastal zone of Block D a stretch of mangrove is still found, whereas in the southern part of Block C the mangrove has been replaced by large fishery and tambak systems. Most forests have been subjected to (excessive) logging, and subsequent fires destroyed most of the remaining forest. Degraded forests make up the larger part of the non-cultivated area and are a main source of (illegal) fires and carbon emissions.

The (deep) peat areas are increasingly targeted for private sector plantation development (oil palm, rubber, pulp), in spite of regulations that would prohibit development in these zones. Though a number of plantation permits were issued, most firms have not started development and/or production yet. The (deep) peat areas are to a lesser scale also used by the local Dayak population, who for their existence have depended for ages on sustainable forest exploitation.

Agricultural development is found especially in Block D, and in the downstream part of Block C along the right-bank of the Kahayan river. More recent development started in the Block A, but infrastructure is not complete, and schemes are only partially settled.

Traditional communities are settled along the rivers, the Dayaks on the river banks in the more upstream areas bordering peat lands, and the Banjar along tidal rivers in the coastal and near-coastal zone. These communities each have well established traditions and rights, and share common land use and livelihood goals.

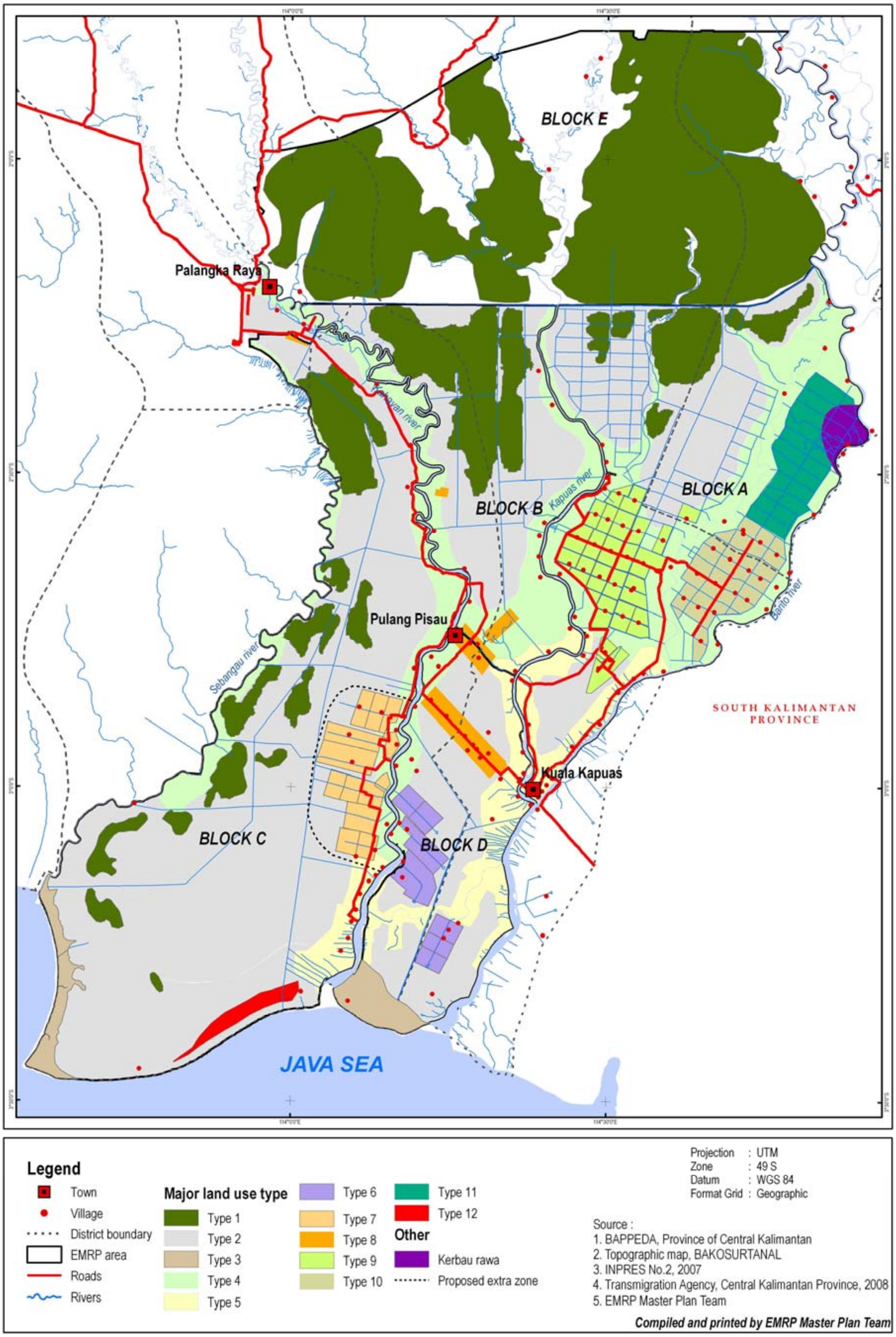


Figure 7 – Land utilization types in the ERMP. (See Table 2 for details of types)

Table 2 - Land Utilisation Types in the EMRP

Type	Description	Remarks
1	Existing forest / eco-systems, including greenbelts.	Livelihood activities in this area include fishing and collection of forest products
2	Degraded forest / eco-systems, including greenbelts	
3	Mangrove Forest	
4	Traditional Dayak / mixed settlements along rivers, including greenbelts	Dryland rice and tree crops (rubber), fishing, rattan collection, livestock and off-farm employment in upstream semi- to non tidal zone, small scale hydraulic infrastructure (handils)
5	Traditional Banjar / mixed settlements along rivers, including greenbelts	Wetland rice and tree crops (coconut), vegetables, fishing, off-farm employment, in downstream tidal to semi-tidal zone, medium-scale hydraulic infrastructure (handils)
6	Older transmigration sites in downstream tidal zone, swamp interior	Mixed, mainly wetland rice agriculture, fallow lands (lahan tidur), off-farm employment, large-scale hydraulic infrastructure with dead ended canals and kolam systems, acidity
7	Older transmigration sites in upstream semi- to non-tidal zone, swamp interior (along anjirs)	
8	Ex-PLG transmigration schemes in upstream semi-tidal zone, swamp interior (Lamunti)	Mixed dryland agriculture, incomplete design and settlement, some flooding
9	Ex-PLG transmigration schemes in upstream semi- to non-tidal zone, swamp interior (Dadahup)	Mainly wetland ride, incomplete design and settlement, flooding constraint
10	Ex-PLG transmigration schemes in upstream non-tidal zone, swamp interior (Jenamas)	Severe flooding in wet season, deserted, kerbau rawa
11	Private sector plantation	Often in peat areas, independent hydraulic infrastructure
12	Tambaks	Coastal zone, fishponds in former mangrove

Traditional (Banjar) farming systems focus on wetland rice and coconut cultivation, next to fisheries and trade, along the tidal rivers, while the Dayak population in the upstream areas focus on the cultivation of rubber, fisheries, forestry and gathering.

Transmigration communities are far more heterogeneous. Large-scale transmigration sites are usually located in the swamp interior, where far more complex conditions exist, with some very old development located along the Anjir canals. A distinction is made between different transmigration sites, based on age of settlement, socio-economic issues, hydrological boundary conditions, and scheme design and lay-out.

During the large-scale 1970s government sponsored transmigration program, new areas were opened up in the swamp interior of Blocks C and D, initially aiming at wetland rice cultivation. Due to poor site selection, e.g. in (deep) peat, and shortcomings in main system design, these schemes are not very successful, and livelihoods now focus more on crop diversification and off-farm employment.

In Block A, under the EMRP, areas were opened up in 1996 and prepared to receive new transmigration. The hydraulic infrastructure was only partly completed, and, after the government abandoned the EMRP, many transmigrants left the area. Most of the area is currently not cultivated. Those farmers still active focus on the diversification of wetland and dryland farming, in- and outside the project area.

Plantations are found in the deep peat areas as well as in the lowland areas, though most have not started operations or are not formally acknowledged yet. Tambaks are found in the coastal zone between the Kahayan and Sebangau.

2.6 Institutional Aspects

Land and water management for agricultural development has mostly been the domain of the Public Works (research, O&M, extension), Agriculture (research, demonstrations, extension), and the farmers. More recently the private sector increasingly became engaged in agricultural development in the peat and lowlands.

During the 1980s the O&M of swamp schemes was mostly the responsibility of the central level Public Works agencies, i.e. Directorate of Swamps, assisted through Projects in the provinces. O&M organizations were set up and some of those were already transferred to local government. The Directorate of Swamps was abolished in the late 1990s, and its responsibilities transferred to regional sub-directorates within the Ministry. This resulted in loss of valuable expertise and management capability. In 2004 the Directorate of Swamps was re-established, and is increasingly active again in the lowland schemes.

Since the crisis and political turmoil in 1998, and the fall-out from the PLG, there was far less budget available for O&M in the lowlands. Under decentralization, O&M responsibilities for all schemes were suddenly transferred to local governments, who were not equipped, had insufficient manpower or budget, and last but not least, lacked expertise and understanding of land and water management processes in the (tidal) lowlands. This resulted in an almost total collapse of O&M services, which was particularly harsh on the (tidal) lowlands, where reclamation and agricultural development hinges on the functioning of drainage canals. Soil and water conditions deteriorated and yields declined. The 'decade of neglect'[6] occurred in in lowlands on

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[6] Euroconsult (2008)

a national scale. One of the results is that Public Works is no longer in the 'driving-seat' and that many more actors are involved in lowland management.

There are many (new) regulations that are concerned with the planning and management of peat and lowlands. The following regulations are of importance to the situation in the lowlands from the perspective of water resources management and O&M, see Box 9.

Box 9 - Regulations concerning O&M and water management in the lowlands

- Law No 7/2004 on Water Resources – framework law
- PP 20/2006 on Irrigation
- PP 42/2008 on Water Resources Management
- PP 43/2008 on Ground Water
- PP 27/1991 on Swamps, to be replaced by new PP under preparation
- PP 35/1991 on Rivers and Lakes to be replaced by new PP under preparation

Law No 7/2004 on Water Resources stipulates that schemes > 3000 ha are the responsibility of **central level**, schemes 1000 – 3000 ha that of the **province**, and schemes < 1000 ha that of the **district** (except in cross-boundary situations where responsibility is relocated to the higher management levels). In the EMRP and elsewhere this implies that most (ex-) transmigration schemes fall under central government and most traditional schemes under local government. The responsibility for the O&M of the central government schemes > 3,000 ha is delegated to the Balai Wilaya Sungai (Balai WS), or River Basin Authorities.

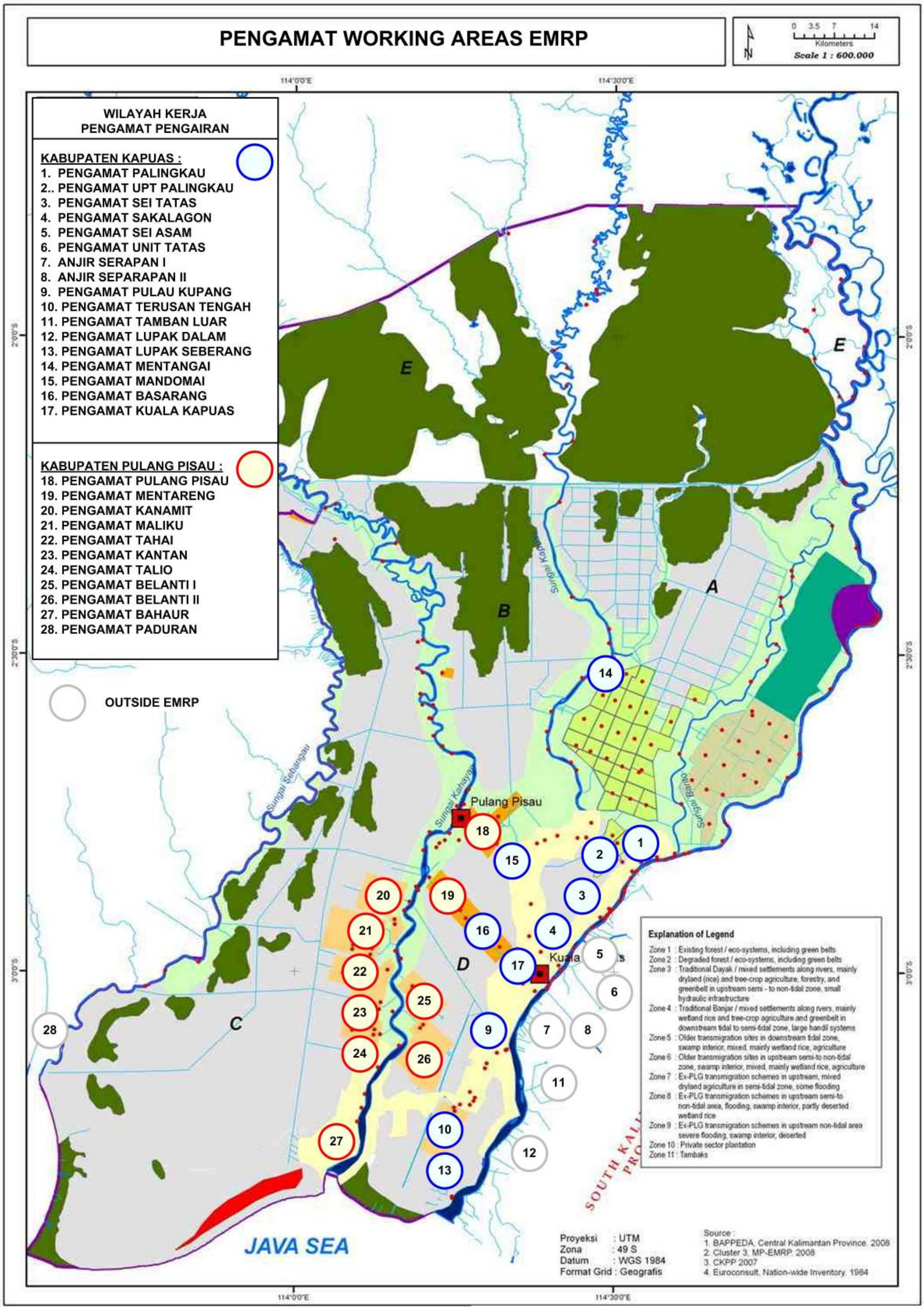
Government Regulation PP 42/2008 on Water Resources Management describes the management of water resources along river basin boundaries, i.e. 'one basin – one management'. River basin management authorities (Balai WS) were set up, answering to the Director General of Water Resources of Public Works, who are responsible for development of the river basin Pola (strategy) and Water Resources Management (WRM) Plan. The Pola and WRM Plan will have a life-time of 20 years, but will be adjusted every 5 years. Several other regulations are under preparation, notably the regulation peat land management. As of yet, there is no overall regulatory or institutional frame work for integrated lowland development.

The Balai WS is responsible, not only for the development of river basin strategies and plans, but also the O&M in larger schemes under the responsibility of central level. Next to the vertical division of O&M responsibilities, lowlands are part of administrative units who are responsible for a.o. spatial planning (Province, District), but also part of the river basin, where separate river basin management (WRM) plans will be produced. An assessment[7] of regulations shows that the integration of spatial planning and WRM planning is not yet clear.

Lowlands have unique characteristics, physically, socially and economically, that sets these aside from traditional irrigated or dry land agriculture. Lowland development is a complicated and highly dynamic process, where first of all an integrated approach is required. Current institutional and legal arrangements do not reflect these basic lowland management requirements.

[7] Euroconsult (2008)

Figure 8 – O&M set-up in the EMRP



2.6.1 Operation and Maintenance (O&M)

The field O&M organizations in the EMRP are situated in the Kapuas and Pulang Pisau districts, where most of the agricultural development takes place, see Figure 8. There are no other drainage schemes in the EMRP, other than those of the two districts. Annex 3 provides information on O&M staff and condition of hydraulic infrastructure in the EMRP.

Large schemes (> 3,000 ha) in the EMRP fall under the responsibility of the Balai WS Kalimantan II, with main offices in Banjarmasin (South Kalimantan), and Kapuas (Central Kalimantan), and a sub-office in Palangkaraya (Central Kalimantan). The Balai WS was established in 2007 and faces serious staff shortages. The Balai WS indicated that it eventually plans to delegate regular swamp O&M to local administrative levels, i.e. province and/or district, under the Assistance Concept (personal communication 2007). Currently the Balai is involved in rehabilitation of the larger schemes, both in South and Central Kalimantan, design and flood studies in the EMRP, and the implementation of Inpres 2/2007 works. Funding is provided by Jakarta through the APBN budget.

The Water Management Section of the Public Works Agency (*Sub-Dinas Pengairan*) at provincial level is responsible for the O&M in schemes 1,000 – 3,000 ha. Funding is provided through the provincial APBD. The Sub-dinas Pengairan in Pulang Pisau was established in 2003, and also faces serious capacity shortages. The Sub-dinas in Pulang Pisau and in Kapuas are responsible for schemes < 1,000 ha, which are mainly the small and simple, traditional, drainage systems. Funding is provided from district APBD, and the Special Allocation Fund (DAK).

The O&M organization at field level consists of Pengamats (overseers), and Juru Pengairan (gate operators).The Pengamats, earlier engaged by the Subdinas Pengairan in the District, are now partly working for the Balai in schemes over 3,000 ha, though apparently still employed by the District. The Pengamats play an important role in assisting the farmers, as their knowledge and expertise is usually well appreciated (in contrast to the agricultural extension workers, PPLs, who often have limited experience). As can be seen in Annex 3, Pengamats are usually responsible for several schemes, and, depending on size, the O&M in the working area of one Pengamat may be the responsibility of different levels of Government. In the Lamunti and Dadahup schemes no O&M organizations are set up yet, the reason being that these are still UPTs (technical units) under the Ministry of Transmigration. While that may be so, it does not make the demand for O&M services anything less important.

P3As (water user organizations) were set up in most of the schemes in the EMRP, but usually these are not functional, as there is a lack of water control and water management, and since the existing farmer's organizations are usually far more active and involved in (on-farm) water management. While, according to the Sub-dinas Pengairan in Pulang Pisau, the P3As may be involved in swakelola (self-management by the Sub-dinas rather than contracted) maintenance works, as yet there are no provisions to engage the P3As otherwise in maintenance, e.g. under KSO (community participation in contracts), mechanisms, or as small contractor (requires registration at the law office). P3As and farmer organisations, preferably integrated, are to play an important role in the revitalisation of the agriculture in the EMRP.

O&M starts with data collection and mapping. The scheme inventory, i.e. description of hydraulic infrastructure, designs, condition, etc, is one of the pillars for O&M and the annual planning. Such information is largely missing in the EMRP, as much of it was lost during re-organizations and the transfer of O&M responsibilities, but also at the closure of the ex-PLG project. In general the information available at the various agencies is far from complete. O&M manuals are not available in the EMRP, and the Buku Catatan Pemeliharaan (Maintenance Record Book) is also not used consistently by the field staff.

Needs Based Budgets for the O&M in the schemes have yet to be developed. Current funding levels are often not sufficient, or are prioritised for rehabilitation rather than routine O&M. While the maintenance condition of schemes is gradually improving since 2004, soil and water management conditions are still very poor, and this is, apart from the neglect of maintenance earlier, also the result of poor or incomplete design. O&M and rehabilitation should go hand-in-hand with a re-design of the infrastructure.

The Governor of Central Kalimantan provided in 2007 instructions for the preparation of an Irrigation Committee, with stakeholder representation including the water user organizations, as stipulated in Law No. 7/2004. The law and underlying irrigation regulation does not describe the conditions and requirements for the lowlands. In fact, the Draft Regulation on Swamps will propose to set up an Swamp Committee along the same line, but adapted to the specific and unique conditions of the lowlands.

2.6.2 River Basin Management

The EMRP is located in the downstream parts of the Kahayan and the Barito-Kapuas river basins. The Balai Kalimantan II is currently developing the Pola (strategy) and Water Resources management Plan for both river basins.

The boundary between the two river basins runs along the centre of Block D, and the peat domes in Blocks B and E, see Figure 9. It follows that a single peat dome, which is a separate hydrological unit, is managed under different plans, i.e. based on river hydrology, rather than the land and water management requirements for peat lands.

In the peat and lowlands the hydrology of units between rivers is closely related, as is the hydraulic, and not, as in uplands, separated by a clear watershed divide. This will complicate the management of peat lands and agricultural development areas as hydrological independent units.

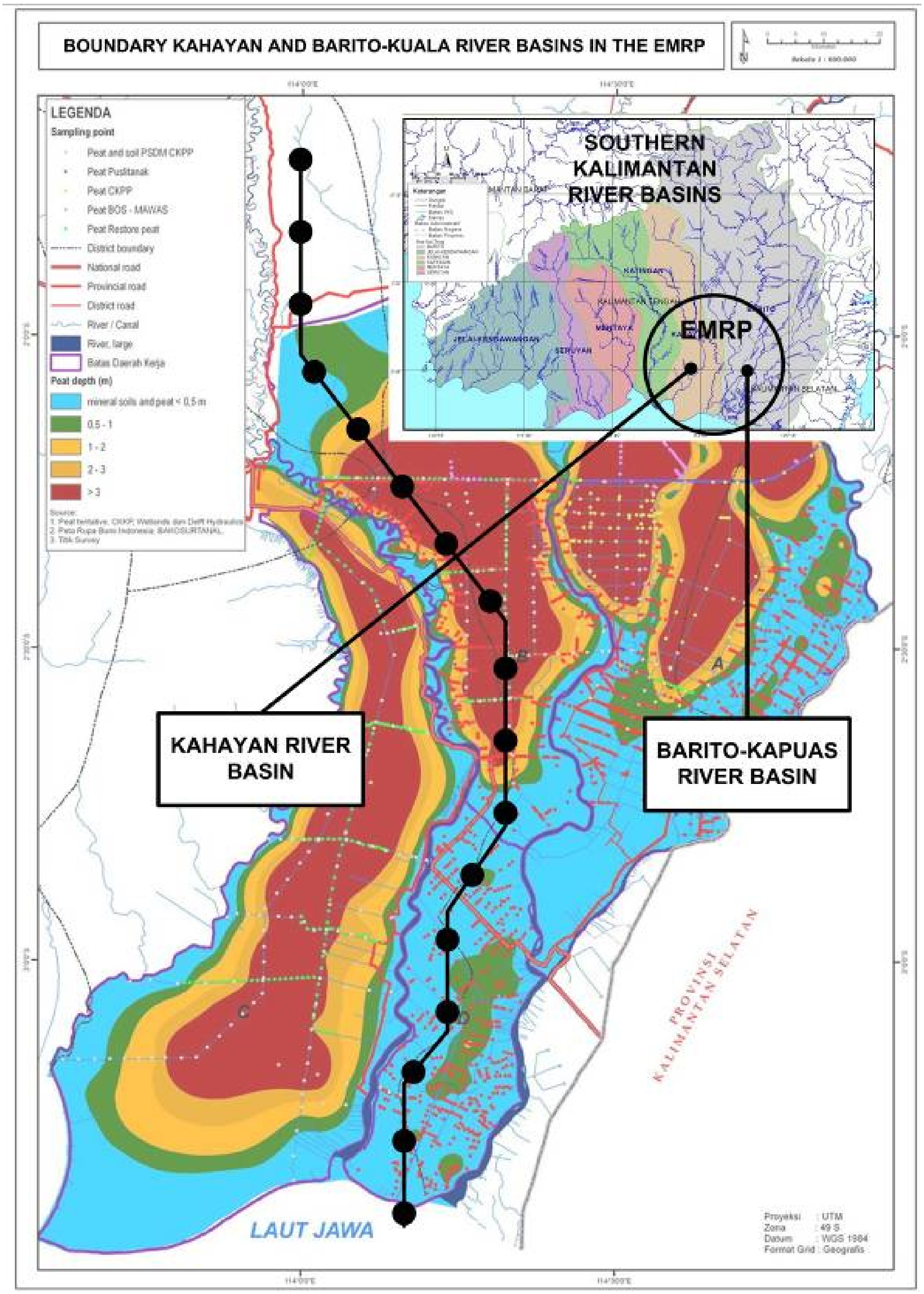


Figure 9 – EMRP boundary Kahayan and Barito-Kapuas river basins

Chapter 3 Land and Water Management Approach

The water management strategy for conservation is obviously based on the rehabilitation or restoration of the hydrology and minimizing impact of drainage, but should also take into account requirements of existing developments and local communities. If the deep peat boundary is taken as a guide for conservation, a careful water management planning is needed for the bordering (peat) areas. A main issue will be to practice drainage and water management that will minimize the impact on the environment, but also provide adequate opportunity to settlers and the local population.

Successful reclamation and agricultural development in the tidal lowlands hinges on the effectiveness of water management. Water management for development aims at (i) creating optimal conditions for settlement and crop production, (ii) accelerating soil ripening processes, and (iii) leaching and flushing of acids and toxins resulting from the soil reclamation process. Water management objectives are typically conflicting, especially during the early development stages, and aggravated by the micro-diversity at field level.

Water management for conservation and development is a closely-related process. Whereas the drainage systems of agricultural schemes bordering on peat areas will further add to degradation of conservation areas, these conservation areas in turn may also negatively influence surrounding agriculture, e.g. through interflow of poor quality acid water and flooding from run-off from higher peat lands.

Similarly, in development areas water management solutions to resolve hydraulic and soil and water quality issues need to be addressed at landscape –delta – level rather than scheme level. Furthermore, development should also be seen in a regional context, and be all inclusive with respect to settlements of different origin, and cultural and ethnic backgrounds.

The land and water management approach for the EMRP area describes:

- Water management zoning on the basis of eco-hydrological criteria
- Options for land and water management in peat conservation zones
- Options for land and water management in development zones

3.1 Management Zoning

An important first step of the land and water management approach in the EMRP is the mapping of land and water management units based on a separation of conservation and agricultural development using eco-hydrological landscape characteristics. Macro-zoning in independent hydrological units aims to ensure that water management and drainage associated with lowland agriculture will not affect sensitive peat and other valuable eco-systems.

Within the macro-zones, separate management units are distinguished, based on bio-physical and socio-cultural characteristics, i.e. land utilisation types, and unique hydrological and/or socio-economic relations. A management unit is the smallest unit for integrated lowland management with a focus on a combined land and water management, socio-economic, environmental, and agricultural development strategy. Land and water management development should be considered firstly at the level of the management units, due to the interaction of hydrology and land use between developed and non developed areas, and the connection of the hydraulic infrastructure of the different schemes[8].

Table 3 - Zoning Framework Integrated Lowland Management

Step I: Macro Planning Zones		Step II: Integrated Management Units	
Peat Land Protection & Conservation Zone	Deep peat areas, (degraded) forests, and areas of bio-diversity value	Hydrological independent units (landscape unit-delta) comprising of conservation and adaptive management areas, e.g. the peat dome & buffer zone	*Policy objective:* Eco-system conservation and rehabilitation *Integrated approach:* Conservation and restoration measures, restrictions on plantation development and operations, livelihood strategies for indigenous communities and transmigration settlers involving minimal drainage
Adaptive Management Zone	Areas between conservation zone & hydrological boundary with development zones, land use restrictions		
Development Zone	Zone where drainage has no impact on conservation areas, no deep peat, mainly mineral soils, no land use restrictions	Hydrological independent units (landscape unit-delta) with different physical, socio-economic and cultural characteristics	*Policy objective:* Development and optimization of agricultural production systems *Integrated approach:* Optimizing land and water management at delta level, small-holder agriculture and private sector plantations, livelihood strategies for indigenous communities and transmigration settlers
Coastal Zone	Coastal zone, (degraded) mangrove and tambak, land use restrictions	Separate management unit based on overriding policy objectives	*Policy objective:* Restoration of protection functions, mitigation of climate change impact *Integrated approach:* Restoration and protection of mangrove forests, restrictions on tambak development and operations, livelihood strategies local communities

1. Macro-zoning

Macro-zones are characterised by overriding policy objectives, i.e. conservation, coastal zone management, or agricultural development. The first step in delineating the macro-zoning in the EMRP area is the identification of the peat dome areas and

[8] The study found that many handil canals along the rivers have become connected to the large-scale ex-transmigration and / or PLG macro-infrastructure

the hydrological units in which these are located. A boundary can thus be drawn along the line: Kahayan River – Anjir Kelampan - Kapuas River - Block A PLG canal - Mengkatip River, which divides the EMRP into a (deep peat) conservation and a development zone, see Figures 10 and 11 and Table 3. Between the legal deep peat areas (> 3 m) and the hydrological conservation boundary, a zone is distinguished where development is adapted to the conservation of the peat dome.

The EMRP-area is thus divided in 3 macro- zones, i.e.

- Peat conservation zone (deep peat > 3.0 m)
- Adapted management zone (deep peat line - hydrological boundary)
- Development zone (no deep peat, independent hydrology)

2. Land Utilisation Types

Land utilisation types are based on bio-physical and socio-cultural characteristics, e.g. land use/land cover, hydrology, climate, socio-economic, ethnic and cultural aspects, farming systems, soil and water management, e.g. degraded peat lands, ex-transmigration in swamp interior, traditional settlers along tidal rivers, see Figure 7 and Table 2.

3. Integrated Management Units

The overlay of the macro-zones and land utilisation types allows for a sub-division of the conservation and development zones into relatively independent management units, where there are unique relations between the different land utilisation types on the basis of socio-economic and landscape (delta) characteristics. Table 4 and Figure 10 show the Integrated Management Units identified in the EMRP area. Table 3 shows the relationship between the macro-zones and management units.

Table 4 - Integrated Management Units in the EMRP

Unit	Location	Description
Peatland Protection and Conservation / Adapted Management Zones		
I	Block A/E	Peat area between Kapuas, Mengkatip and Barito rivers, with indigenous communities settled along river banks, PLG transmigration Block A
II	Block B/E	Peat area between Kahayan and Kapuas rivers, with indigenous communities along river banks, older transmigration Block B
III	Block C	Peat dome between Sebanggau and Kahayan rivers, with indigenous and Banjar communities along river banks, older transmigration
Coastal Management Zone		
IV	Coastal Zone Block C/D	Coastal zone between Sebanggau and Kapuas rivers, villages and tambak
Development Management Zone		
V	Jenamas Block A	Ex-PLG area, uninhabited, with indigenous communities along river banks, kerbau rawa
VI	Dadahup Block A	Ex-PLG area, partly developed with indigenous communities along river banks
VII	Lamunti Block A	Ex-PLG area, partly developed, with indigenous communities along river banks
VIII	Handil Block A	Banjar communities along river banks, lowland swamp interior
IX	Block B/D	Banjar communities along river banks, older transmigration areas and lowland swamp

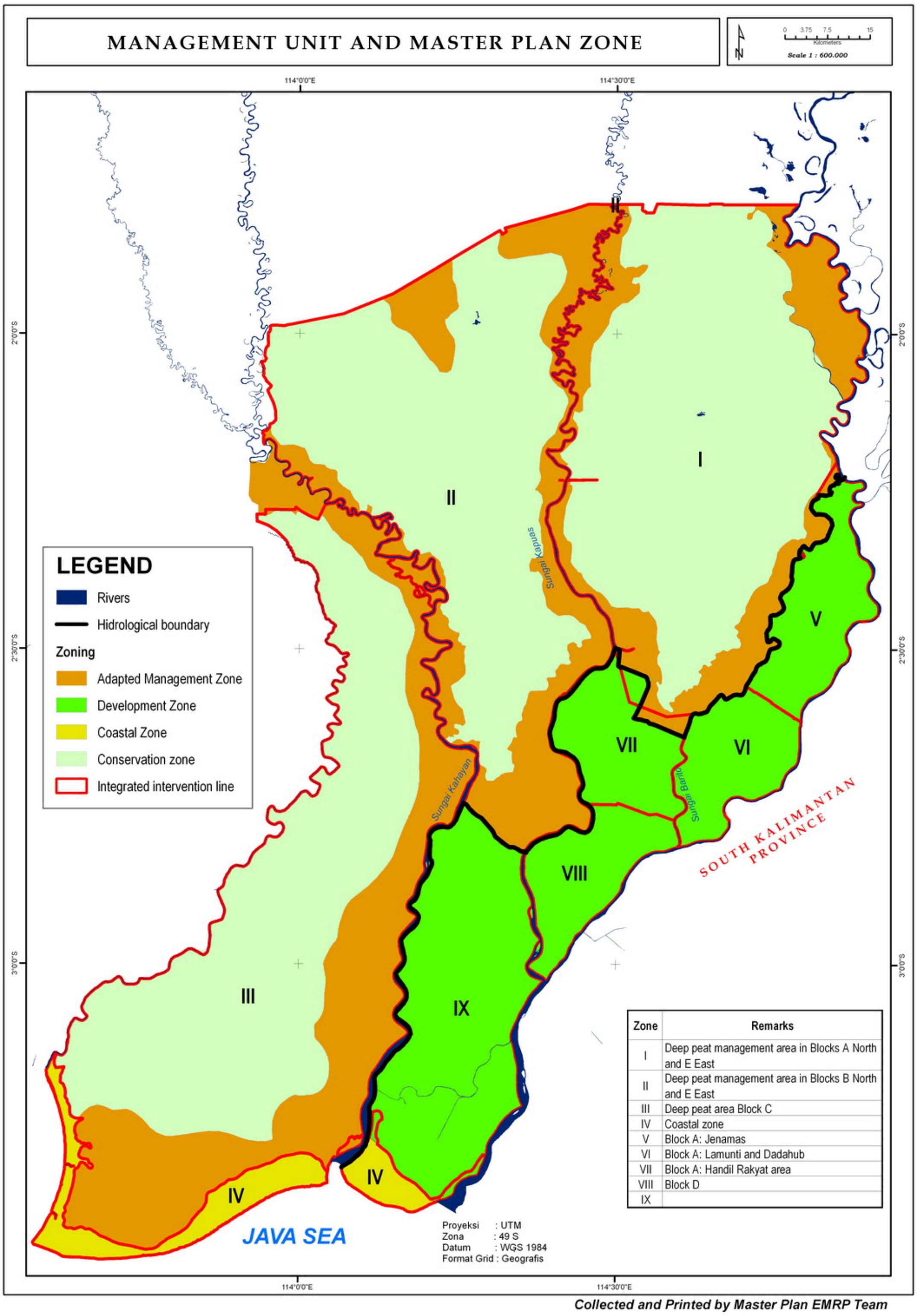
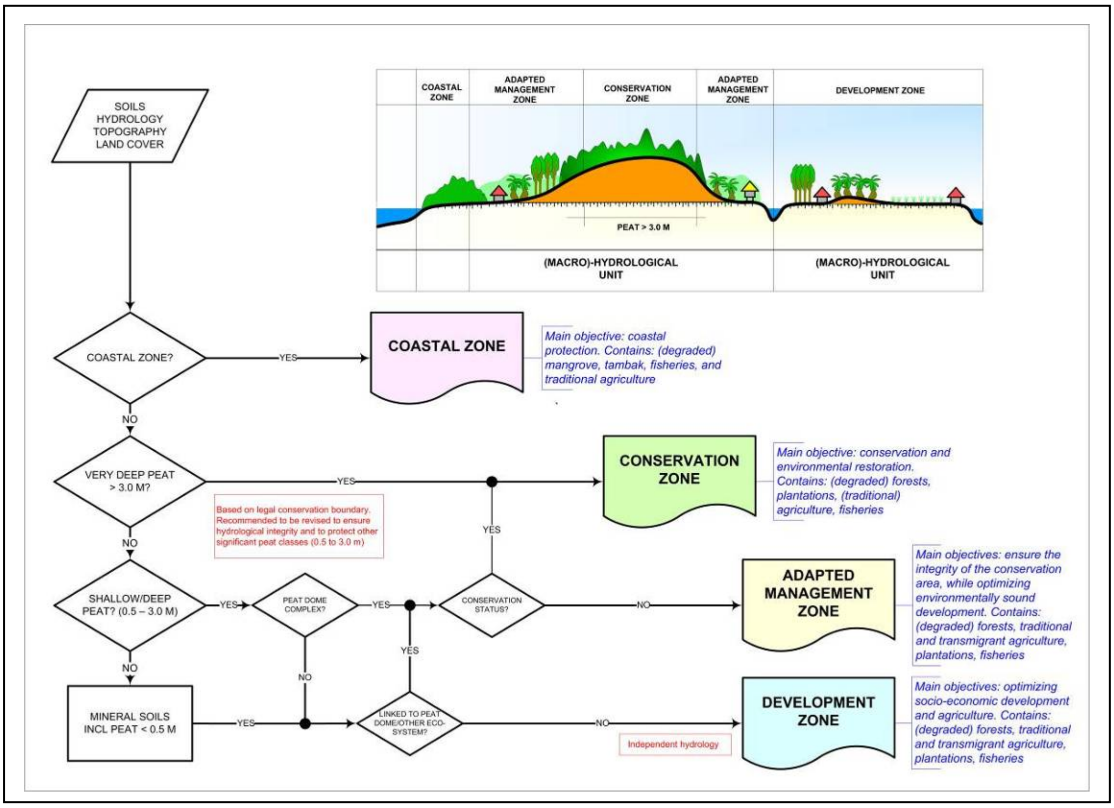


Figure 10 – Macro-zones and Management Units in the EMRP

Figure 11 – Steps in macro-zoning EMRP



3.2 Conservation Areas

This section discusses typical and closely-related water management strategies for the peat conservation areas and adapted management zones. Water management development in both zones is a dynamic process with the ultimate goal, to restore the natural hydrology in as far possible and/or to develop a water management system that can control the water table within close limits, to minimize the impact of drainage on the peat lands.

For forest on peat land, water management options will focus on the rehabilitation of the hydrology by blocking canals in the degraded forest areas

For agriculture on peat land, water management options will focus on (ii) shallow-rooting crops for horticulture, and; (ii) deep-rooting crops like oil palm, rubber and commercial tree plantations.

3.2.1 Forest on Peat Land

To develop water management interventions for the peat conservation areas the following characteristics have to be taken in consideration: (i) the dome shape of the peatland; (ii) hydrology, and (iii) soil characteristics.

Dome shape - Usually the peat bodies are lens-shaped, with a domed surface (Figure 12). Because of the coastal and alluvial geomorphology, they are often elongated and irregular rather than having the 'ideal' round shape that is characteristic of peat bogs. Surface slopes vary between 1 and 2m/km at the sides of such domes near the adjacent rivers. Near the centre of the domes, however, the slope is often less than 0.5 m/km.

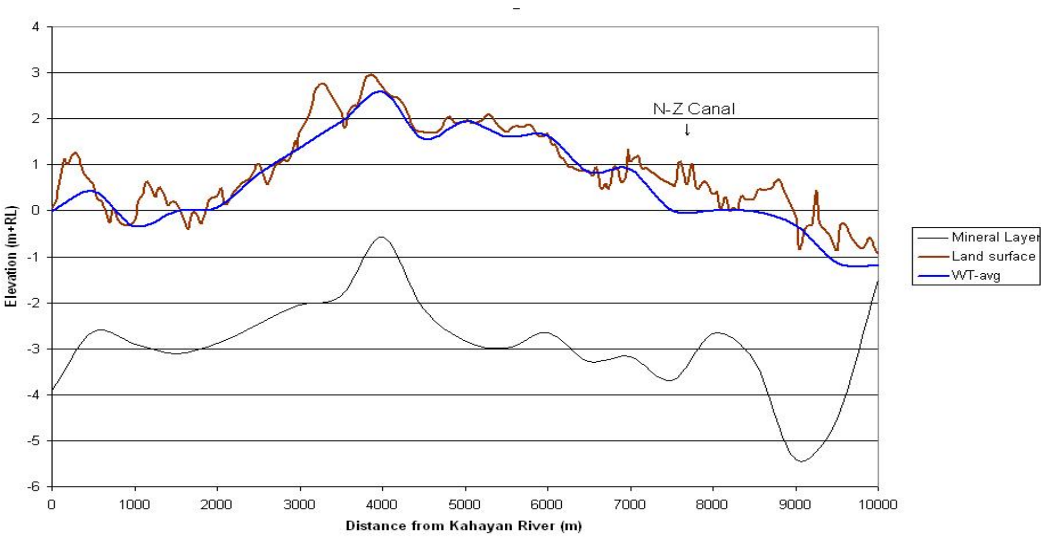


Figure 12 - Cross section of the peat dome at the north site of Block C near Kalanpangan (data CIMTROP)

Hydrology - The peat domes swamps are exclusively rain-fed. Although the water balance of peat swamps seems rather simple, in that it can be expressed in terms of rainfall, evapo-transpiration, storage and outflow, its hydrology is not. Rainfall is not evenly distributed over the year (see Figure 21). The wettest months are November to April. In this season water levels are generally above the ground surface. During the period July to September, evaporation is normally more than average rainfall and droughts can last up to 4 months. Under natural conditions, the excess rainfall is mainly evacuated as surface runoff and subsurface flow in the top layer. This flow appears to be radial and diffuse (i.e. sheet flow rather than channel flow). Due to the convex character of the peat domes, water flows in various directions. A peat dome therefore can be divided into several catchment areas, whereby the boundaries of these catchments change over time as the elevation of the peat surface changes due to accumulation of organic matter or because of subsidence caused by oxidation.

Soil characteristics - The bulk density of the degraded peat in the EMRP area is around 0.2 g/cm^3 with a low hydraulic conductivity, i.e. on average around 1 m/d (see Technical Report 2 – Hydrology). The bearing capacity is low and linear related to the depth of the water table (Salmah, 1992).

Water management interventions - The construction of the canals in the peat lands of the EMRP has resulted in uncontrollable and excessive drainage as these lands are dome-shaped and no control structures were installed. This excessive drainage, in combination with the high permeability of the peat, has lowered the water levels adjacent to the canals. These low water levels have initiated a process of subsidence.

In degraded forest lands on the deep peat areas (> 3.0 m) water management activities will focus on blocking the canals in order to restore the hydrology and the forest cover. Re-forestation criteria, i.e. maximum and minimum water levels, and

> It is **important** to realize that it will be impossible to maintain high water levels during the dry season as even in the natural forest water levels in this season drop as low as 1 m below ground surface. For the same reasons, hydrological interventions cannot truly 'reconnect' peat land units that are now separated by large canals (e.g. the SPI canal in Block E).

maximum allowable flooding period for the various tree species, will be important criteria to the design of a hydrological rehabilitation strategy.

The subsidence rate is assumed linear related to the depth of the (ground) water level.

subsidence rate (cm per year) = 0.1 * depth of the water table (cm)

A consequence of this relation is that, because the groundwater levels are deeper closer to the canal (Table 5), the canal is "eating" itself into the peat dome (Figure 13). If the water levels are not maintained at a higher level, this process will continue till the canal has reached the level of the mineral subsoil (DID & LAWOO 1996)

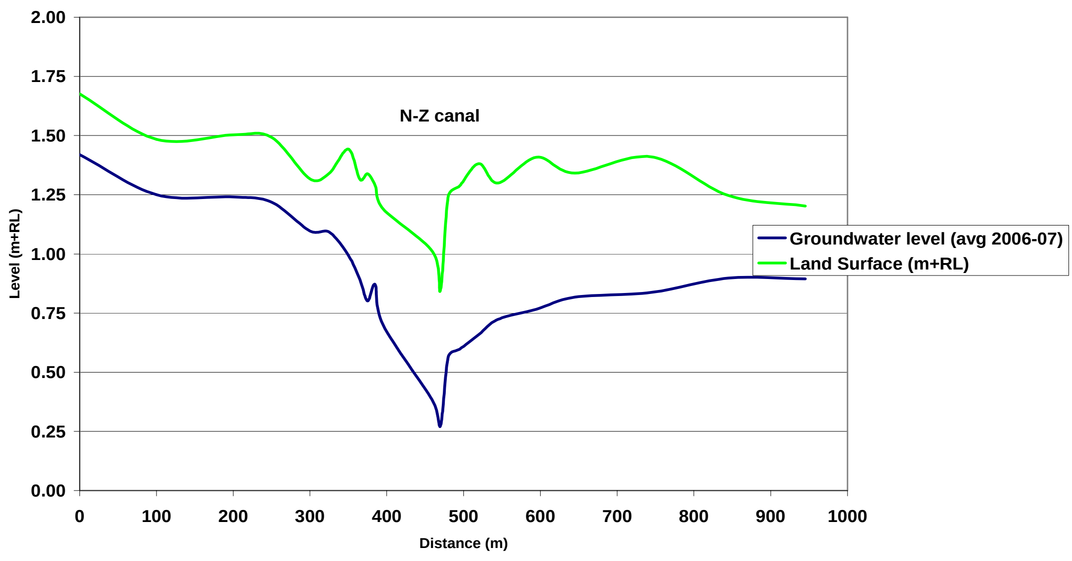


Figure 13 - The elevation of the peat land perpendicular to the NZ-Canal at Kalampangan at the North part of Block C: close to the canal the land has subsided more than further away from the drain (data provided by CIMTROP).

To conserve the deep peat areas natural water levels and drainage patterns have to be restored. To achieve this, water levels in the canals have to be raised. This can only be done if drainage through these canals is stopped or reduced by blocking the canals. How this is best done depends on the type of canal, topography, hydrology, and peat characteristics.

Table 5 – Ground water levels in natural and degraded peat domes

Season	(Ground)water level below land surface (m)				
	Natural Forest (Sebangau)[a]	Degraded forest [b]			
		Distance from canal			
		0 m	100 m	400m	1000m
Dry season (Jul-Oct)	-0.40 (average year) to -1.0 (dry year)	-0.88	-0.54	-0.35	-0.33
Rainy season (Nov-Apr)	+ 0.0 to + 0.20	-0.50	-0.13	-0.05	-0.06
Average	between -0.20 and +0.20	-0.56	-0.24	-0.12	-0.15

[a](Takashi *et al* 2002), [b] data CIMTROP

Types of canals - Three types of canals are distinguished in the peat lands of the EMRP:

1. Canals parallel to the contour lines mainly on top of the peat dome, running in North-South direction. These canals are the most harmful, as they have large cross-sections and directly drain the top of the peat domes. To restore the natural conditions they should be blocked and (ideally) be re-filled to the level of the adjacent land

2. Canals perpendicular to the contour lines, connecting the rivers. These canals also function as drainage canals and because there are no control structures, their drainage capacity is increasing with time (as they further subside into the peat dome).

3. Illegal logging canals. These canals are relatively small (up to 1-2 m wide and 1-2 m deep) but can extend several kilometres into the peat dome. Once the illegal logging has stopped these canals loose their function for transport, but are continue to slowly drain the peat dome. To restore the hydrology these canals also have to be blocked, especially in those areas still under forest. Such canals are mainly found on the Sebangau site of Block C, and in the Block E and Mawas areas.

Canal blocking strategies - It must be realized that canal blocking is part of an overall strategy for the rehabilitation of the hydrology and re-greening of the peat lands (for further details, see Technical Guideline No. 4 on Canal Blocking Design). This is a long-term objective and much of the science required to support implementation needs further development. Canal blocking does not automatically result in hydrological restoration and thus to re-greening. An important element of a broader strategy must be to consider and test a wide range of integrated solutions leading to the overall objective.

Hydrological assessments (Deltares, Wageningen UR 2008) show that the short term effect of canal blocking on water depths, and therefore on associated parameters (subsidence rates, fire risk, forest regeneration conditions), is limited in the EMRP area, due to peat morphology and characteristics in the area. The importance of canal blocks is to halt further subsidence and erosion, and a lowering of the drainage base. Once a new equilibrium of peat morphology and hydrology is established, the function of the canal blocks will extend to larger areas.

The changed morphology with depressions and mini-domes as a result from subsidence along the canals, will effect the design requirements and functionality of the structures. On one hand the design of canal blocks must take into account dry season objectives, i.e. to maintain the highest possible water levels, while on the other hand, the structure must be designed to evacuate and withstand the high peak discharges in the wet season.

Population density and the aspirations of local communities should also be considered. Dams not only block water but also access, and can provide valuable building materials that will be removed if communities are not involved in protection and maintenance. Ultimately, the approach to canal blocking will need to respond to the local conditions and use of canals in specific areas and proposed interventions should be negotiated with communities in advance. Not all canal blocks can be handled through community involvement, given the scale of the degraded lands in the EMRP area, especially in Blocks A and C, or the design requirements. For different situations, different solutions will be required.

The expected life-time of the current structures (5-10 years) is less than the time-frame involved in the restoration of the hydrology and the re-greening (25 years or more). The blocking of canals results in slowing the flows of water, allowing for sedimentation and re-growth, i.e. that after several years a more stable, 'natural' situation develops, with the structure as a temporary trigger. However, the sediment mainly consists of peat particles, which are easily washed out during high flows in the wet season, and are also susceptible to oxidation in the dry season. Re-growth may take place from the canal slopes, but is unlikely to occur rapidly on silted up canal floors. In other words, structures need to be rebuilt several times before a new equilibrium has been established and 'nature' has taken over.

Typical canal block structures should include a mix of the traditional gelam structures as currently build by CIMTROP and WI-IP, and larger overflow structures, designed to withstand the higher peak flows. It is recommended to start canal blockings from the centre of the peat dome, with smaller discharges, to gradually increase water control.

- **Canals on top of the peat dome.** These canals run parallel to the contour lines and consequently have a very gentle slope, e.g. the main NS-canal in Block C has a slope varying from -0.6 to + 0.4 m/km (Jaya, 2005). Thus flows and velocities are small compared to the flows in the canals that connect the rivers. On the other hand, the slope of the peat land is perpendicular to the canal in the direction of one of the rivers. The main purpose of blocking this type of canals is to raise the upstream water level so that the water is diverted away from the canal and flows to the river as overland or subsurface flow

- **Canals connecting the rivers.** These canals run perpendicular to the contour lines, thus the gradient, flows and velocities are high, especially during the rainy season. Furthermore, because the canal elevation is low (and gets lower all the time by the subsidence), water is directed back to the canal. In this situation, the purpose of a structure is not only to raise the upstream water level, but also to evacuate excess flow away over the structure (or bypass) in to the downstream section.

- **Illegal logging canals.** The length and dimensions of these canals are generally unknown, flows are relatively small and blocking itself is not so problematic, but more the unknown number and locations.

Challenges - The main challenges that have to be tackled are**:**

- Low bearing capacity: structures should not create much head difference (= difference between upstream and downstream water level).
- High permeability: structures cannot store much water, will mainly act as an extra barrier to flow (= increase flow resistance).
- Irregular rainfall, average yearly rainfall varies between 1000 to 3500 mm. Large variation in discharge thus options are (a) overtopping of (part of) the structure should be possible without causing damage (=structures should be designed as weirs) or (b) dam crests should be high with bypasses for peak flows.
- Canals are also used for navigation/transport: alternative transport facilities should be considered to avoid that local people will damage and/or surpass the structures.
- Blocking canals will affect the livelihood of the local people. Their involvement in the design (location) and construction (to generate alternative income) is of utmost important.

Towards solutions - Canal blocking strategies thus depend on the type of canal that has to be blocked and the above mentioned challenges. There are, of course, many options, they should be based on the following principles:

- Avoid too much head difference: built cascades of dams or weirs
- Avoid too high discharges: start blocking the drainage canal at the upstream end
- Avoid too much load/weight: use, whenever possible indigenous materials
- Avoid expensive foundations: design “floating” structures
- Avoid excessive maintenance: lets nature take over in time
- Avoid local opposition: involve local people in the planning, design and construction.

3.2.2 Agriculture on Peat Land

The lowland peat swamps of Central Kalimantan are purely rain-fed and waterlogged most times of the year. In the shallow peat areas where local communities practice agriculture, the Master Plan defines a limited (adaptive) development zone. In this zone, drainage is needed to make these waterlogged lands suitable for agriculture or other land uses. It should be realised that because of the dome-shape topography, peat domes cannot be irrigated by gravity from the surrounding rivers. The only source of water is rainfall. The rainfall is not distributed evenly over the year (Ritzema and Wösten, 2002). The average dry season (monthly rainfall <100 mm) can last for 3 to 4 months.

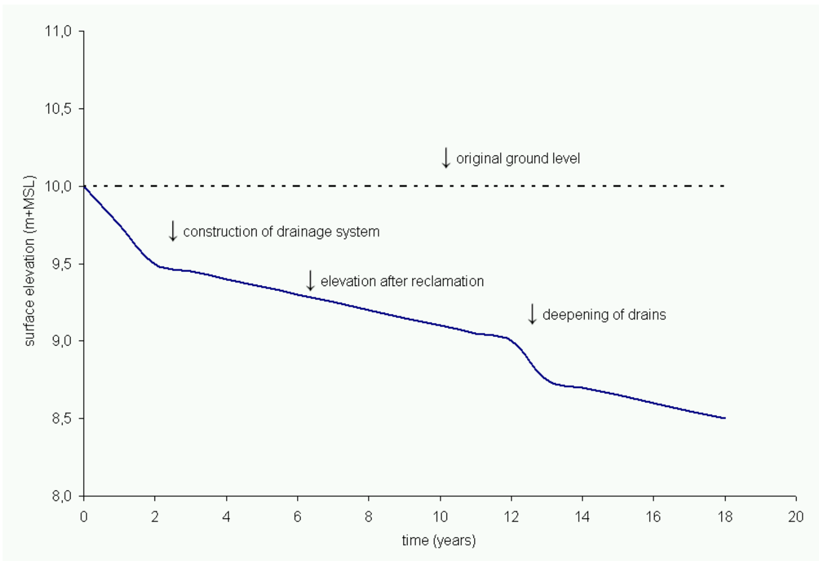


Figure 14 - The everlasting subsidence results in a continuously lowering of the land surface (After Eggelsman, 1982).

Under these conditions the water table depth can fall to one metre or more below the peat surface (Takahashi *et al.*, 2002). Without water conservation, this can lead to severe and persistent moisture deficits in the surface peat layer and thus to increased oxidation and risk of fire. Compared to mineral soils, peat has a much higher infiltration capacity, drainable pore space and hydraulic conductivity, but a lower capillary rise, bulk density and plant-available water (Wösten *et al.*, 2003).

Another major difference is the subsidence behaviour of peat; it is partly caused by oxidation and is never-ending. Oxidation leads to CO_2 emission, which under the prevailing conditions in Central Kalimantan conditions, is estimated to be in the order of 25-100 tonnes CO_2 per hectare per year.

In addition to the loss of peat by oxidation, the excessive subsidence rates result in a pronounced drop in the elevation of the land reducing the efficiency of the drainage system. To avoid flooding and waterlogging problems during the monsoon season, frequent deepening of the system is required (Figure 14).

The resulting progressive lowering of water levels triggers off increased subsidence and so on. In Western Johore, Peninsular Malaysia, for example, it is estimated that the low water levels in the drainage system, caused by uncontrolled drainage, increase the overall subsidence by approximately 30 per cent (DID and LAWOO, 1996).

The mineral substratum under peat soils is often sulphidic. Once the peat has disappeared, the mineral subsoil, which are often sulphidic, will surface. The available pyrite will oxidise and acid sulphate soils with very low pH values will form (Kselik *et al*., 1993). This continual subsidence process threatens the sustainable use of peat areas (Rieley *et al.*, 2002). To sustain the use of lowland peat swamps water management, based on the specific characteristics of peatland hydrology, is a prerequisite.

Crop water management requirements - The Master Plan takes a farming system approach to agriculture in the region. In this approach, the dominant crop is linked to farm management (Table 6). The crop water management requirements for these crops are presented in Table 7.

Table 6 - Farm Systems in the EMRP

Farming system	Dominant crop	Principal livelihoods
Rice based	Lowland rice	Rice; upland crop (peanut, maize, cassava), vegetables; horticulture (banana, citrus)
	Upland rice	Rice and secondary crop: maize, vegetables
Tree crop based	Rubber	Rubber, pineapple, rottan, fishing
	Coconut	Coconut rice
	Oil palm	Oil palm
Livestock-based		Cattle –vegetable, horticulture
Fisheries		

Table 7 - Water management requirements for dominant crops in peat[9] (DID, 2001)

Crop	Water Management Requirements			Main constraints to yields or productivity[a]
	Optimum range of the water table (m)		Maximum period of flooding (days)	
	Minimum	Maximum		
Oil palm	0.60	0.75	3	▪ Low fertility ▪ Susceptible to termites ▪ Poor anchorage ▪ Drought stress
Cassava/Tapioca	0.30	0.60	nil[b]	▪ Mechanisation
Sago	0.20	0.40		
Horticultural crops	0.30	0.60	nil	▪ Mechanisation
Aquaculture				▪ Water quality ▪ Construction of ponds ▪ Water control in ponds
Paddy	-0.10	0.0		▪ Water control in individual plots ▪ Plant nutritional problems ▪ Mechanisation
Pineapple	0.75	0.90	1	▪ Mechanisation
Rubber	0.75	1.0		▪ Poor anchorage
Acacia crassicarpa	0.70	0.80		▪ Poor anchorage

[a] Criteria for transportation (e.g. access) apply to all crops. Not mentioned here.
[b] Very low tolerance, not to be planted in flood-prone areas

Peat lands have a low pH (as low as 2). This low pH not only restrict the agriculture use, but and the water drained from peat lands can be serious repercussions on the downstream land and water bodies. The high permeability makes it hard to regulate drained of the peat lands.

The design of the drain spacing should be based on the agricultural criterion that during the growing season the water table will fluctuate in the range that is required for optimum crop growth (Table 8). This criterion combines the agricultural requirements (represented by the required depth of the water table) with the climatic conditions (represented by the corresponding discharge during the considered period). The criterion depends on economic considerations.

It is possible to calculate the design drain spacing for the wet season (November–March), for the three wettest months (December–February), for the single wettest month (January) or even for a 30-day rainfall period with a certain frequency (e.g. two-year or five-year).

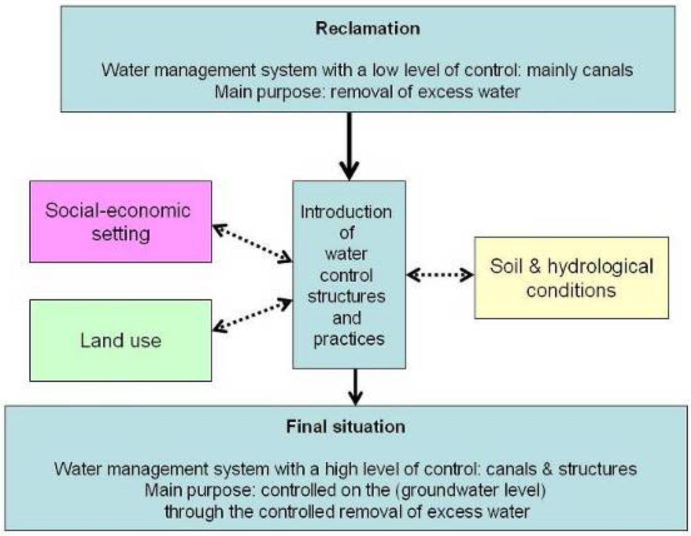
[9] DID 2001

Table 8 - Water table depths for optimum growth of various crops on peat.

Crop	Depth of the water table (m)		Maximum flooding period (hours)
	Minimum	Maximum	
Vegetables	0.30	0.60	Nil*
Tapioca	0.30	0.60	Nil
Pineapple	0.75	0.90	24
Rubber	0.75	1.00	
Oil palm	0.60	0.75	72
Acacia	0.70	0.80	

* Very low tolerance, planting in flood-prone areas strongly discouraged

Figure 15 - Gradual introduction water management control



In peat areas, the initial subsidence after reclamation can be 1 m or more and produce a considerable change in the (micro) relief. Thus only in course of time, water management can be optimized. And, because subsidence is a never-ending process, the water management systems have to be upgraded at a regular interval. The interval depends on the land use: deep water tables cause more subsidence and thus require a more frequent upgrading. Thus the development of the water management infrastructure is a dynamic process: in the first years after reclamation not much control can be achieved, only gradually more control can be introduced (Figure 15).

This process is mainly driven by the farmers: they have to adapt their farming practices to the micro-relief and can indicate when and where the water management system can be improved. Thus the development of a water management infrastructure requires an adaptive approach based on three sets of inputs: the specific soil & hydrological conditions (land suitability), the existing and future land use and the socio-economic setting.

The strategy for water management is based on the principle that peat is a precious resource that should be handled with care to prolong its life. This can only be achieved if there is a shift from the concept of unrestricted removal of excess water to controlled drainage. This integrated water management principle combines drainage, irrigation and water conservation. Water management aspects of the major land-use options on peat lands are discussed in Annex 4.

Drainage is needed during the monsoon season to control the water table and to remove excess surface and subsurface water from the land. Irrigation, which in this case is called sub-irrigation or inverse drainage, is needed to supply water through capillary flow during dry spells. And water conservation is needed to control the water table at a higher level throughout the year to avoid excessive subsidence and to reduce the risk of fire.

Thus a water management system in peat land has three functions, i.e.:

- Removal of excess (surface and subsurface) water during the monsoon season
- Control of the (ground)water table, and
- Conservation of the water during dry periods.

These functions are somewhat conflicting: on the one hand removal of excess water requires unrestricted outflow conditions and on the other hand the control of the water table and water conservation can only be achieved by restricting the outflow. The water management requirements also vary within a year. Water table control is required the whole year around, with removal of excess water only during periods with excess rainfall, whilst water conservation is essential during prolonged dry periods.

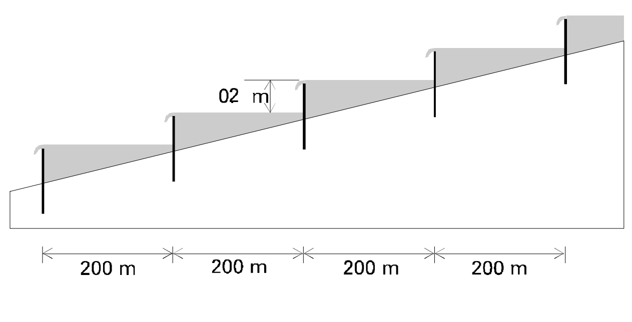
The EMRP project area has two seasons: in the dry season, rainfall is lower or equal to evaporation and water conservation is required. In the wet or monsoon season, rainfall exceeds evaporation and drainage is needed to remove the excess rainfall. On top of this, there are short periods of extreme rainfall requiring an extra drainage capacity. To fulfill these conflicting needs, controlled drainage is required.

Two conditions have to be considered:

- To maintain the water table at a level that is low enough to enhance the agricultural use and, at the same time, high enough to sustain the peat. This water table criterion will determine the spacing of the drains. It should be based on the drainage requirement during an average wet season.
- To remove excess rainfall during extreme events. This discharge criterion will determine the capacity of the drains (dimensions) and should be based on an extreme (e.g. one-in-5 year rainstorm) rainfall event.

The design should also take into account the specific soil hydraulic characteristics of peat, i.e. the very high infiltration rate, storage capacity and permeability. Because of these characteristics, excess rainfall is not removed as surface runoff but mainly as interflow and (to a smaller extent) groundwater runoff. The change from surface to interflow and groundwater runoff has a significant effect on the discharge: model simulations for a similar peat area in Western Johore, Peninsular Malaysia, showed a reduction of the peak discharge by more than 100% (Ritzema *et al.*, 1998). For conditions in Borneo, with its humid climate and prolonged periods of rather uniform rainfall, the steady-state approach (e.g. the Hooghoudt Equation, see for example (Ritzema, 2006) can be used to calculate drain spacing. The simplicity and the limited requirement of input data of this approach make it very suitable.

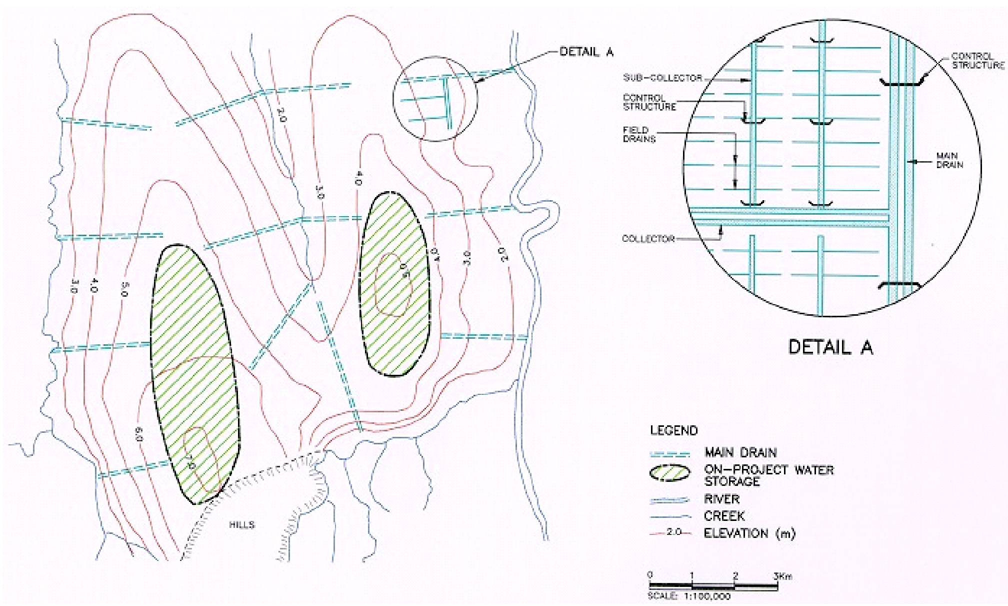
Figure 16 - Cascade of control structures



Structures are needed to control the drainage. Because peat is so permeable, structures with small head differences are recommended. The dynamic storage capacity in the drainage system is small compared to the recharge by excess rainfall and the corresponding discharge. Therefore it is possible to use the steady-state approach for the design (Beekman, 2006). Structures act as barriers to prevent the flow but water cannot be stored for long periods as it will seep away through the surrounding peat. Computer simulations show that a cascade of closely spaced dams is most effective for water control (Figure 16).

The distance between the structures depends on the gradient of the peat dome (Beekman, 2006). In the central part of the dome, the slope is often less than 0.5 m km^{-1}, increasing to more than 2 m km^{-1} near the edges. Consequently, the distance between structures in the central part of the dome can be as far apart as 1 to 2 km, but this must be much less towards the edges. As the structures are intended as water control rather than water impoundment structures, they do not have to be watertight and their construction can be relatively simple. Structures have to be adapted to the specific characteristics of tropical peat, in particular its very high hydraulic conductivity (Wösten and Ritzema, 2001) and low load bearing capacity (Salmah, 1992).

Figure 17 - Typical layout of a drainage system in which the centre of the peat-dome can be used to store water

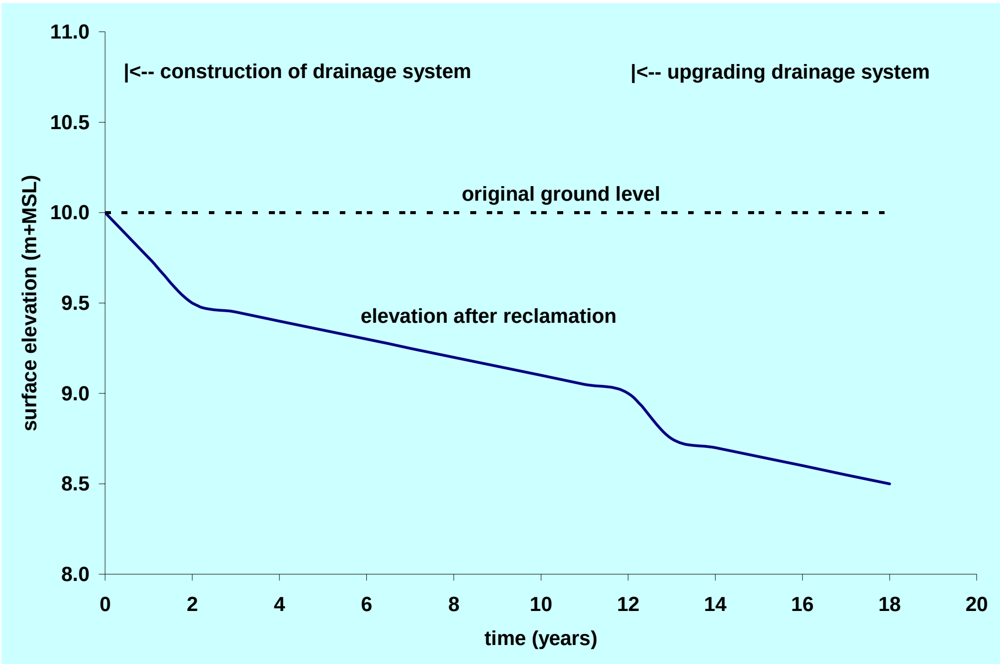


The above considerations result in a water management system with narrowly spaced drains in combination with an intensive network of control structures. A consequence of this high intensity system is that the percentage of the area occupied by the water management system is high: between 15 and 20% compared to less than 5% in mineral soil areas. The layout of the water management system should also make use of the dome-shaped topography of the peat lands (DID, 2001). Field drains should be located parallel to the contour lines and collector drains perpendicular to these. The best location for water storage, needed to replenish the groundwater during prolonged dry periods, is in the centre of the peat dome (Figure 17).

Design Procedure - A detailed topographic survey is the key to designing a water management system whose purpose is to control the water table within close limits. In peat areas, the initial subsidence after reclamation can be 1 m or more and produce a considerable change in the (micro) relief. Thus a detailed topographic survey can be made only after this initial subsidence has taken place. To minimise the effects of rapid peat subsidence, we recommend a phased approach to developing a drainage project:

- Phase 1 Development involves constructing the peripheral infrastructure to allow for initial drainage of the project area. Main components include perimeter bunds and drains, tidal structures, the main and collector drainage system, internal water control structures and bridge crossings.
- Phase 2 Development involves constructing the additional drainage network that consists of collectors and sub-collectors and check and drop structures. Another important activity is the upgrading of main internal bunds to farm access roads. Construction of the field drainage system can start at the same time.

Figure 18 - Continuous process of subsidence in peat soils



There should be a time delay of 1–2 years between the two phases. It should be noted, however, that the continuous subsidence will require the upgrading of the system every 5–10 years (Figure 18). Consequently, the procedure for designing and implementing a drainage system in peat swamps will differ from the normal procedure for mineral soils and should include (but need not be limited to) the following steps.

The design includes the following steps:

- Pre-drainage/reconnaissance survey
- Preliminary conceptual layout
- Detailed design and construction of main drainage system
- Design of the field drainage system
- Construction of the field drainage system
- Adjusting the on-farm drainage

Issues:

- Investment costs in peat areas are in general much higher than those in mineral soil areas.
- After drainage, irreversible drying of surface peat will occur, producing hard granules that are sterile and non-productive.
- Without controlled drainage, groundwater levels will drop below 1 m, resulting in subsidence rates of 5 to 10 cm/year (Figure 19).

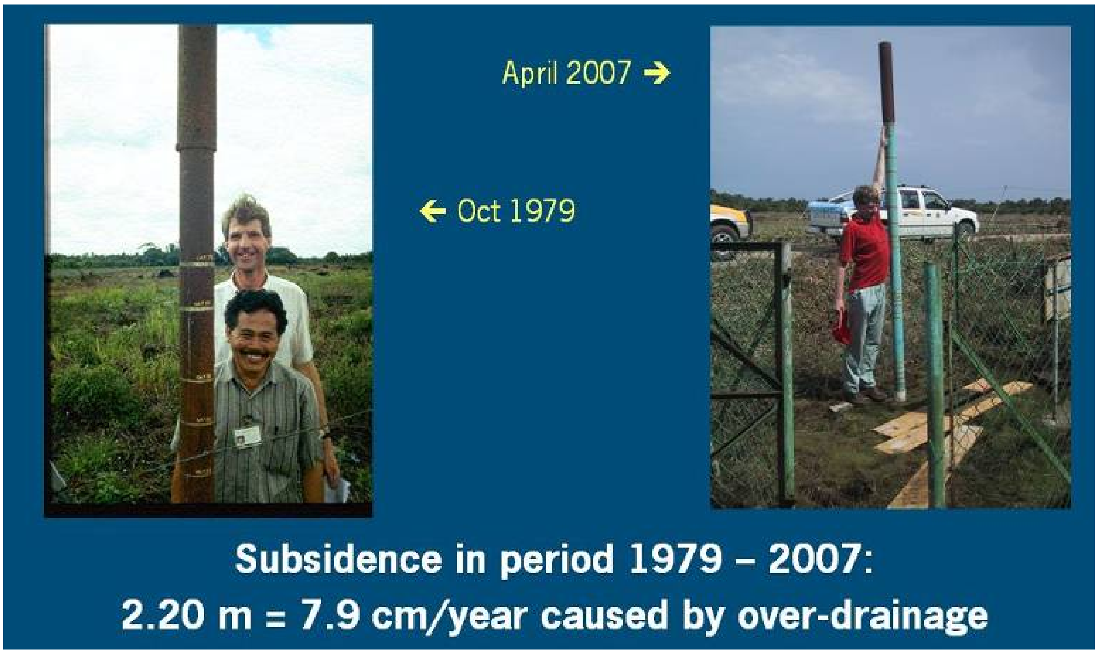
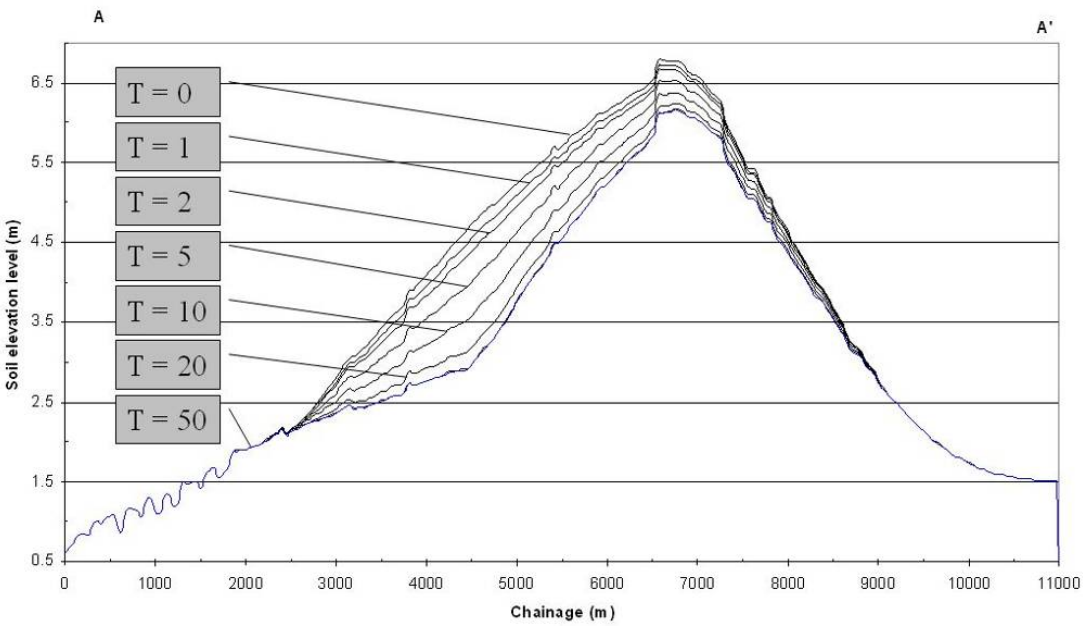


Figure 19 - Uncontrolled drainage will cause excessive subsidence - Example Western Johore, Malaysia: more than 2 meters of subsidence in 20 years

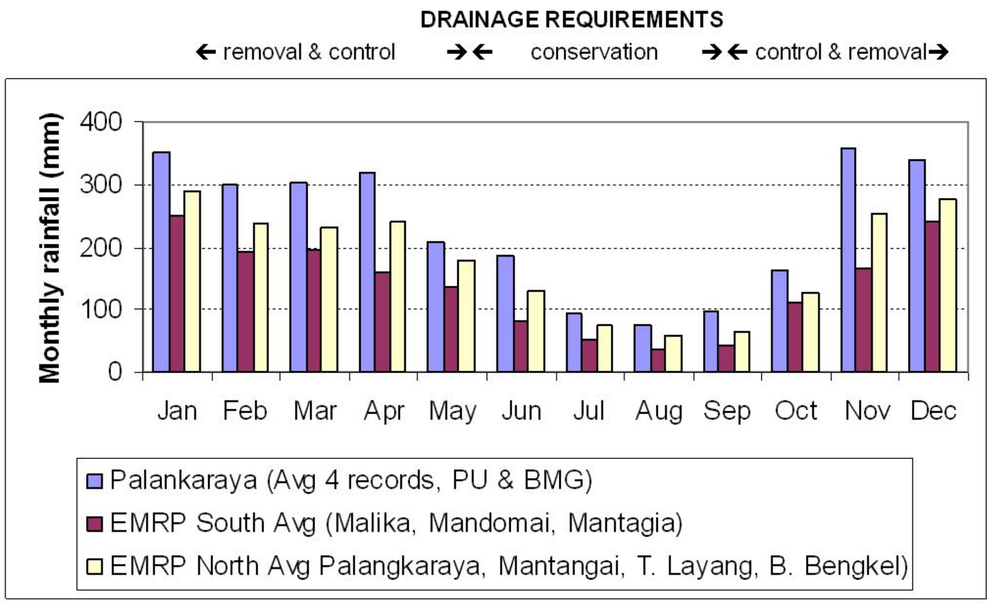
Figure 20 - Even with controlled drainage, subsidence rates will be 5 to 10 cm/yr – model simulation of the subsidence in a peat dome (Example Balingian, Sarawak, Malaysia)



- Subsidence and loss of peat by oxidation can be reduced by controlled drainage and an eco-hydrological (catchment) approach.

- It should be remembered that, even with improved water management, subsidence cannot be arrested (Figure 20). Ultimately the peat will disappear. Depending on the thickness of the peat layer, this can be from 10 to 100 years for peat depths up to 3m (Figure 14).
- On deep peat, initial subsidence after reclamation can be 1 m or more and produce a considerable change in the (micro) relief. Thus only in course of time, water management can be optimized. And, because subsidence is a never-ending process, water management systems have to be upgraded a regular interval. The interval depends on the land use: deep water tables cause more subsidence and thus require a more frequent upgrading.
- Water stress will occur during prolonged dry periods: during the monsoon season, a lower level will have to be maintained to increase the discharge capacity and during the dry season a higher level will have to be maintained to conserve water. Due to the permeability of the peat, controlled drainage, however, will not prevented water stress during prolonged dry period (Figure 21).

Figure 21 - Control is needed to store water in the dry period



- Water management has direct engineering implications for the selection of on-farm vehicles and for design, construction and maintenance of infrastructure, because the bearing capacity of shallowly drained peat is very low compared to deeply drained peat.
- Sustainable solutions for on-farm transport on peat soil should be based on the principle that the ground pressure of vehicles should not exceed the bearing capacity of the soil (for loads of relatively short duration).
- The challenge for operation and maintenance is to control water levels in a continuously changing environment that is the result of ongoing subsidence. Operational aspects have to be addressed at two levels: catchment and property or project level. Real sustainability can be achieved only if the two levels integrate properly in a system-based approach.

3.3 Development zone

3.3.1 Outline of the Strategy

The overall objectives of water management in the development areas are twofold:

- Land reclamation, i.e. soil ripening
- Agricultural development, i.e. crop water requirements

The development zone is the area identified as being hydrological independent from the peat domes and peripheral areas. Drainage in the development zone (Block A South and Block D) will not affect the conservation[10] areas, and can be fully optimised for agricultural development, i.e. the revitalisation of agricultural development.

Water management improvement in support of agricultural development starts with addressing the shortcomings of the original and existing main system designs, which are rather serious, to create proper conditions for on-farm water management.

Tidal lands are not so generally suited for wetland rice as was once considered, and under different settings, different land and water management strategies are called for. Crop diversification is an essential part of the socio-economic development approach.

Due to rainfall patterns in Indonesia, acidity in the tidal lands is normally not a constraint, but poor soil and water management is. Favorable conditions for wetland rice in the tidal lands include supply with fresh (tidal) water to avoid stagnant water conditions and to leach and flush out acidity and toxicities formed during the dry season. Options for leaching and flushing are more limited in the swamp interior, away from the tidal river, due to the reduced tidal influence. Stagnant water is one of the major constraints in the majority of the tidal lands. Water management for the areas without access to tidal irrigation, and with less ripe and/or pyritic soils must aim at drainage, and that dry land crops best suit these conditions.

Water management systems designed or operated on minimal drainage and water retention, such as the older transmigration schemes in the EMRP, with their dead-ended fork layout, can not evacuate acidities and toxicities. This results in accumulation of acids and toxics, low yields, and stagnating agriculture. Other short-comings of the hydraulic infrastructure include rigid canal grids which do not take the natural drainage lay-out into account, poor condition of structural works, and a lack of canal maintenance, hampering water management and agricultural development.

Solutions for land and water management, in the development areas of the EMRP must start at the management unit – delta – level, because:

- Hydraulic infrastructure needs to be double-connected to rivers
- Ex-transmigration and traditional handil schemes have become connected, and development of the two can not be separated
- Fallow lands (lahan tidur) in and around the schemes are a source for interflow of acids and toxics into the agricultural lands as the hydrology is closely linked
- In Block D, the ex-PLG main canal system can probably be utilized

[10] Apart from the land border of Lamunti and the Block A North peat dome, where special measures are required to limit the impact of drainage. Further study and modelling required.

- In Lamunti and Dadahup a re-design is required that addresses land and water management at unit level (e.g. floods)
- Socio-economic development is a regional process.

Design of the hydraulic infrastructure and water management is influenced by:
- Physical conditions, i.e. soil aspects, hydrology and topography
- Crop requirements, i.e. wetland rice, dry land or tree crops
- Socio-economic aspects

These factors also show a considerable degree of spatial variation, at macro- and at micro-level, and over time. Land development results in changing physical characteristics, while cropping patterns are decided as much by field characteristics, as by socio-economic aspects.

The objectives are also often conflicting, e.g. water retention versus drainage. Most soils in reclaimed swamp lands are not yet fully ripe, and require a specific water management. Land reclamation is a long-term process, that will take even longer when infrastructure is not properly designed, operated, or maintained.

Land and water management in the (tidal) lowlands requires a dynamic, process-like approach. The land and water management strategy for the EMRP must be flexible. This ‘adaptiveness’ should be build into the design of hydraulic infrastructure, water management, and operations. Land and water management development in the EMRP will further require an integrated approach, with participation of the farmers, who often learned the hard way how to best manage their fields.

A short-term approach is required to address the more urgent issues, such as completing the data base and inventory of the EMRP, the re-design of hydraulic infrastructure that is now a major limiting factor for agricultural development, and the study and design of hydraulic measures to separate development from conservation. Rehabilitation of existing canal networks and routine O&M, especially in the traditional schemes also needs to be stepped up.

A long-term approach is essential to deal with the diversity and processes at field level. Site-specific measures are required that are best developed together with the farmers. Trials and demonstrations at field level, as well as monitoring of the soil and water conditions should commence as soon as possible. The role of extension workers should be enhanced, and preferably linked to the trials and demonstrations. Field schools cum training centers will be needed to integrate the efforts of the different agencies, research institutes, and knowledgeable farmers.

The land and water management strategy for development in the EMRP involves:
- Macro-level: hydraulic design and upgrading at management unit/ scheme level
- Micro-level: long-term on-farm development
- Monitoring, trials and demonstrations
- Institutional support, including training

3.3.2 Water Management Options

As part of the farming systems approach in the EMRP Master Plan, the following typical land and water management options are identified, see Table 9.

Special reference is made to the Technical Guidelines on Swamp Development, Volume V: Water Management (Euroconsult 1996b), as this is the most comprehensive guideline available on water management in the tidal lowlands.

Table 9 – Water management options in tidal lowlands[11]

Crop	Tidal Irrigated Areas	Rainfed Areas (no tidal irrigation)		
		Pyritic and muck soils	Non-pyritic soils	Peat soils (See Section 2.2)
Wetland Rice	Pyritic and muck soils, non-pyritic soils S1 - Recommended land use for non-saline areas (during cropping season). Drainage 0.30 m. S3/N for saline areas (during cropping season) Tidal water supply sufficient to suppress and mitigate acidity and toxicities. Only possible in fields directly connected to the tidal rivers and minor, scattered areas in the swamp interior, as very high head loss in canals is limiting factor. N – Peat soils	S3/N – Drainage, leaching, flushing essential to maintain soil and water quality and to support soil ripening. Water retention **NOT** recommended. Opt for Dryland Rice water management. S3 for salinity in canals (during cropping season) S2 for pumped irrigation. Drainage 0.30 m. S3/N for salinity in canals (during cropping season)	S2 – Land and water management as in upland areas. S2 for salinity in canals (during cropping season) S1 – Pumped irrigation. S3/N for salinity in canals (during cropping season)	N
Dryland Rice	Not applicable	S2 – Minimal drainage requirement 0.30 m. Leaching and flushing through shallow drainage, **NOT** water retention. S3 for salinity in canals (during cropping season)	S1 – Land and water management as in upland areas. S2 for salinity in canals (during cropping season)	N
Palawija	As for rainfed. Grown on raised beds to ensure drainability	S2 – if drainage > 0.60 m S3 – if drainage < 0.60 m. Minimal drainage requirement: 0.30-0.60 m Grown on raised beds S3 – for salinity in canals (during cropping season)	S1 – if drainage > 0.60 m S2/S3 – if drainage < 0.60 m. Minimal drainage requirement: 0.30-0.60 m Grown on raised beds S3 – for salinity in canals (during cropping season)	S3/N
Tree crops, homeyards	As for rainfed. Grown on raised beds and mounds to ensure drainability	S2 – if drainage > 0.60 m S3 – if drainage < 0.60 m. Grown on raised beds and mounds to ensure drainability S3 – for salinity in canals	S1 – if drainage > 0.60 m S2/S3 – if drainage < 0.60 m. Grown on raised beds and mounds to ensure drainability S3 – for salinity in canals	S2/S3 – Raised beds and mounds recommended to ensure drainability.

Note: S1-Well suitable; S2-Moderately suitable; S3-Marginally suitable, N-Not suitable

[11] Adapted from Euroconsult, 1996a, p. 3-22

Table 9 does not differentiate between small-holder and private sector driven agriculture (or a combination thereof), though the different management approaches are very relevant for land and water management. Problematic areas are perhaps more suitable for development by the private sector, rather than small-holders, as far better management control can exercised. It should thus be considered to involve the private sector in scheme development in close cooperation with the farmers, e.g. the revitalisation of Dadahup / Lamunti.

Box 10 - Water management for agriculture in Adapted Management Zone

For agriculture in adapted management zones, especially Block C, the drainage objectives are more complicated than those for the development areas:

- Maintain high water tables to minimize drainage of surrounding peat lands
- Evacuation of excess surface run-off from higher peat lands
- Evacuation of surface run-off/interflow of poor quality water from higher peat lands
- Drainage for land reclamation and soil ripening
- Drainage for settlement and sustainable crop development

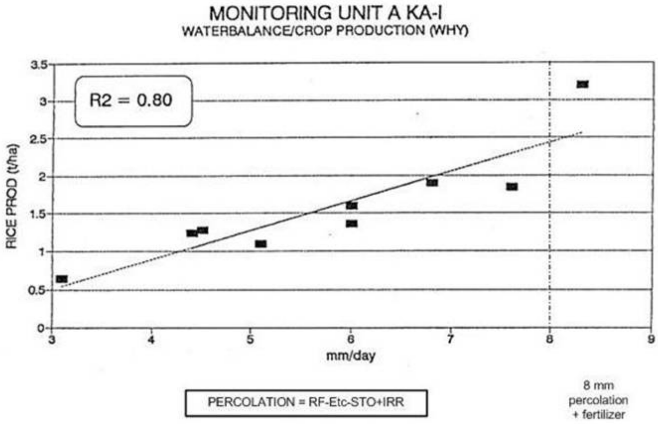
There is already an obvious conflict where wetland rice is grown in unripe and organic (muck) soils and where there is no access to tidal irrigation, i.e. water retention versus shallow drainage. Maintaining high water tables to minimize drainage of peat lands involving water retention will certainly increase stagnant water and acid and toxic conditions, delay the soil ripening process, and further depress the already marginal (rice) yields. Dryland crops including tree crops require deeper drainage, and this also may conflict with the water management requirements for peat lands.

Optimisation of land and water management for agriculture in the adapted zones will involve the following measures:

- Intercept and/or block off drainage flows from (higher) peat lands
- Increase water circulation and influence from tidal river (proximity to the river)
- Add water control to regulate flows, while maintaining a shallow drainage base.
- Grow dry land/tree crops on raised beds and mounds, also in the higher topographical classes so that water tables can stay as close to natural ground level as possible
- Grow crops that will sustain high water levels and are not sensitive too acids and toxics
- Alternative land uses, i.e. community forestry, cattle, fisheries, etc. etc
- Strengthening of GoI and farmers institutions (O&M, agricultural extension etc)
- Raising awareness

Figure 22 – Water management and rice yields in tidal lands South Sumatera

KARANG AGUNG I
SOUTH SUMATERA
1988-1991



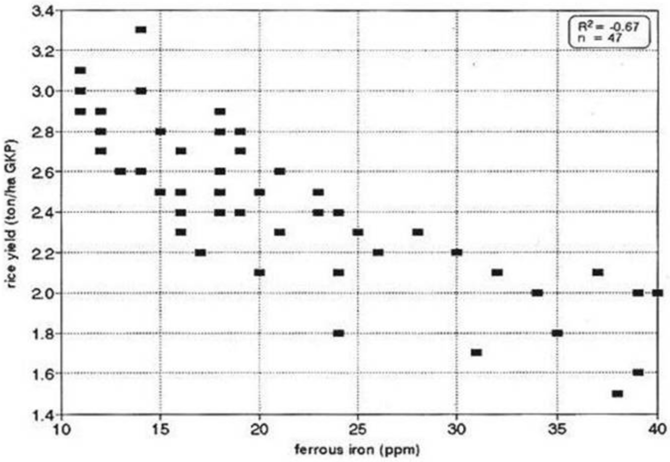
From Dry Season 1989 up till the Wet Season of 1990/91, on average 3 cropping seasons (dry and wet) water management conditions were monitored in 8 rice fields in Karang Agung I, South Sumatera.

From field observations and water balance calculations, the 'percolation' or ' 'leaching' could be approximated. It was found that there was a sharp correlation between the 'percolation' component of the water balance and yields in the wet fields. In the dry fields this relation was not evident.

It was concluded that, in wet rice fields, a percolation rate of 8 mm/day is required to achieve higher yields, and for fertilizer applications to become effective.

Euroconsult 1991

TELANG I
SOUTH SUMATERA
1993-1997



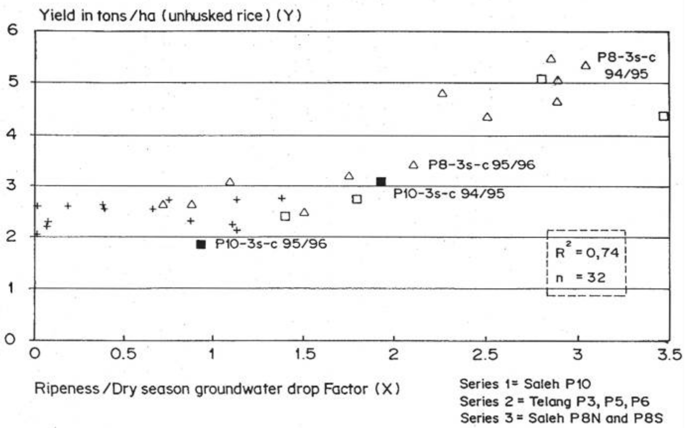
Water management monitoring was conducted during 4 years in the Telang I and the Delta Saleh schemes in South Sumatera. Rehabilitation of the Telang I scheme was ongoing. Soils were stil very unripe due to prior poor drainage conditions. Delta Saleh was already rehabilitated during the 1980s, is located in higher hydro-topographical classes, and soil ripening is more advanced.

A comparison of Fe2+ levels with rice yields in Telang I showed a correlation at iron levels that are normally not considered toxic for rice.

Soil and water quality relations in the tidal lands are complex, and unripe soils appear to be sensitive to even lower levels of toxicity.

Euroconsult, 1997a

TELANG I + DELTA SALEH
SOUTH SUMATERA
1993-1997



During the same study, a comparison was made between rice yields in both Telang I and Delta Saleh, and a function for soil development, i.e. ripeness and ground water drop in the dry season.

It was found that the riper soils, in combination with drainage during the dry season preceding the cropping season up to 0.60 m below ground level, resulted in the higher yields, it must be noted that Saleh is rather acid, but due to its relative higher position and intensive drainage system, obtains quite high yields.

Water management principles in the adapted zone are not different from the development zone, but far more attention must be given to the impact of drainage on the surrounding peat lands, for which additional measure and a higher level of water control is required, see Box 10.

3.3.3 Soils and Water Management

There is ample evidence and experience, in South Sumatera, South Kalimantan and elsewhere, to support the approach that land and water management should be geared towards soil development, and that, with the exception of the tidal irrigated areas, the larger part of the tidal lowlands are dependent on drainage to maintain a soil and water quality that will sustain the cultivation of crops.

The main soil issues in tidal lands concern:
- Soil ripening
- Acid sulphate soils and muck soils
- Peat soils

Soil ripening

Upon reclamation, soils of the tidal swamp lands are subject to a process of physical and chemical ripening. Soil ripening involves a reduction of the water content and soil pore volume (in other words an increase of the bulk density), a reduction of the organic matter content, and changes in soil structure and exchangeable cations. Experience in Indonesia and elsewhere shows that rice yields on unripe swamp soils are much lower than those on ripe soils[12]. Reasons for lower yields on unripe soils include the formation of toxic organic compounds in anaerobic conditions as a consequence of the high water content. A relation has also been found in unripe soils between ferrous (Fe^{2+}) content and yields, at Fe^{2+} levels which normally are not considered toxic to plants (below 50 ppm), see Figure 22.

The high permeability of unripe soils makes it difficult to maintain a standing water layer while also proper puddling of the soil is not possible. Prolonged drainage of the soils will promote soil ripening, will prevent anaerobic conditions, and will stimulate oxidation of organic material. Based on examples from Saleh in South Sumatera, it is suggested that maintaining groundwater levels at 0.60 m below field levels during the dry season, in combination with better drainage and riper soils will result in higher rice yields.

Soil ripening is important and should be promoted by providing sufficient drainage:
- Shallow (0.20-0.30 m deep) field drains, at a spacing of 8 to 12 m
- During the fallow season a lowering of groundwater tables by controlled drainage (e.g. at 0.60 m depth), even if this leads to oxidation of some pyritic soil material
- Flushing of the canals during periods of high (spring) tide
- Leaching of acid and toxic elements with infiltration from rainwater, especially in the beginning of the wet season, and for which a lowering of water tables is required

[12] Euroconsult (1997a)

Rice on unripe swamp soils should not be grown as a traditional wetland rice, with standing water on the field, but instead with groundwater tables at 10 to 20 cm below field level and a sufficient head difference between groundwater and canal water-level to enable leaching. In this way, the soils will become more productive and can, upon ripening, ultimately be treated as ‘normal’ clay soils.

Tidal irrigated areas

The main advantage of tidal irrigated areas is the absence of toxicity hazards by pyrite oxidation. Acids formed by the oxidation of pyrite, as well as organic acids, are quickly leached from the root zone by the large amounts of fresh water supply. A disadvantage is that soils are often not yet ripe, which may reduce yields, and also hampers the introduction of mechanization. Apart from the topography, the extent of tidal irrigated area is often limited by the canal dimensions, which in a very short time should convey a large flow onto the fields. Wetland rice is obviously the most suitable crop for the tidal irrigated lands.

A dense network of shallow field drains is important to quickly spread the tidal water. During spring-tide the gate operation should allow maximum tidal influence, supplying water to the fields at high tide and removing any acidities or toxicities at low tide. During neap-tide, when the water cannot flood the land, water retention becomes important in periods with low rainfall, otherwise the same water management as during spring-tide can be followed. During land preparation a soaked, water saturated soil is preferred and it may then be necessary to keep all water as much as possible within the system (water retention, maximum water supply). In periods with strong salinity intrusion, the inflow of water needs to be blocked.

Acid sulphate soils

Most soils in tidal swamps contain acid-sulphate soil material at some depth below the surface. As long as this pyritic material remains submerged it poses no hazard to plants, and the soil is classified as a potential acid sulphate soil. Upon reclamation and drainage, the pyritic material starts to oxidize. The potential acid sulphate soil (PASS) may then turn into an actual acid sulphate soil in which the farmers are faced with the complex problems of low pH and high Fe^{2+} and Al^{3+} toxicities.

While under tidal irrigation, there is sufficient water supply to provide flushing and leaching to maintain a good soil and water quality. Under rain-fed conditions, water retention is often practiced, but this often leads to stagnant water conditions. The preferred water management then involves shallow, controlled drainage. System designs should be adapted to leaching and flushing requirements, i.e. aiming at water circulation and refreshing from the tidal rivers.

Sometimes a one-way ground water flow system is recommended. By maintaining high and low water levels in alternating tertiary canals, it is assumed that a ground water flow is created from one canal to the other that in the process will leach out acids and toxics into the canal with the lower water level. Apart from difficulties to exercise such a high level of water control, long-term monitoring[13] showed that in practice no such ground water flow will occur, as water levels in the canals are never higher than those in the fields. In lower, tidal irrigated areas this may be an option, but here it is probably not relevant, as soil and water quality is a far lesser problem here.

[13] Euroconsult 1997a

Muck soils

Pyritic or muck soils with hydro-topography B/C, C and D, are by far the most common areas in tidal lands. Tidal irrigation is not possible, and acidities and toxicities from pyrite and organic matter have to be removed by leaching with rain water only. Muck soils require a similar water management as acid sulphate soils. In surveys and mapping the muck soils are usually identified as 'acid sulphate soils'.

Non-pyritic soils

This includes pyritic soils where the upper pyrite boundary is well below the rootzone (> 1 m below the soil surface). The absence of toxicity hazards makes that water management can be similar to 'normal' rainfed crop growing in upland areas, and will focus on drainage during periods of high rainfall and water retention and, if possible, water supply to the canal during periods of low rainfall.

Peat soils

The main constraint of peat soils is their very low fertility, see also Section 3.2. Unless the organic layer is shallow (less than 50 cm) and/or mixed with mineral soil material (so called muck soils), peat soils are less suitable for arable cropping, but better suitable for tree crops, depending on the depth of the peat. Besides the chemical fertility, physical properties of peat soils are poor as well: a low bearing capacity, a very high permeability making it difficult to maintain a water layer for rice cultivation, susceptible to subsidence upon reclamation, and a low thermal conductivity which causes great temperature variations at the soil surface.

3.3.4 Crops and Water Management

Different water management strategies are required for the different crops in the the tidal lands. These strategies are very much dependent on the physical conditions which may vary considerably between locations, and even from field-to-field.

Water management options in the tidal lowlands discussed here are those for:
- Rice, tidal irrigation and rainfed
- Palawija (dryland) crops
- Treecrops

Annex 5 provides a more detailed description of the land preparation and water management requirements for these crops under different soil and hydrological conditions.

Rice

<u>Wetland rice</u> is recommended for the tidal irrigated areas, in both pyritic and non-pyritic soils, and in rain-fed areas only for the non-pyritic soils (with pumping as an additional option).

<u>Dryland rice</u> is recommended for pyritic and muck soils which are not irrigated by the tides, with water management involving shallow controlled drainage to avoid stagnant water conditions. In non-pyritic soils rice can be grown as a true wetland crop.

Whether or not a water layer can be maintained on the field depends on the rainfall, the ripening degree of the soil, and on the possibilities for supplemental water supply, e.g. by pumping.

In principle, the following types of water management apply to rice cultivation in tidal lands:

- Water retention
- Drainage and leaching of the soil
- Tidal irrigation and pump irrigation

<u>Water retention</u> aims at creating a water layer on rice fields to suppress weeds, to create a proper environment for nutrient uptake, and to serve as a buffer for the rice plants in case of drought. Without irrigation, the only source of water is rainfall. Water retention may result in development of toxic substances in the soil under stagnant water (anaerobic) conditions. Acidity resulting from the oxidation of pyrite and organic matter, e.g. formed during the dry season, can not be removed during water retention. With a poor soil and water quality, water retention is not recommended, as instead drainage and leaching of the soil is required.

<u>Drainage</u> is required (i) after heavy rainfall, (ii) before fertilizer applications, and (iii) when the quality of the soil and water deteriorates. To avoid the development of acid and toxic conditions in soils with a relative high organic matter content, controlled drainage is more important and should be preferred over water retention.

<u>Tidal irrigation</u> with good-quality water ensures water supply to the rice plants but also greatly improves the soil and water conditions. Oxidation of pyrite as well as conditions of stagnant water are avoided, and any toxic elements already present or formed during the fallow periods can be leached from the soil by gravity drainage during low tide. Other important advantages of tidal irrigations are that high yielding varieties can be grown in stead of local varieties, and that planting can start earlier which in turn increases the possibilities to grow a second crop.

<u>Pumped irrigation</u> - Although at present irrigation by pumping water from the canals is practiced on a very limited scale only, it is expected to become more important in the future, especially after soil ripening will allow for better water control at field level and higher yields. The risks of pumped irrigation for wetland rice cultivation includes that also water retention is practiced, possibly resulting in stagnant water conditions.

Palawija

Water management for palawija (dryland) crops focuses on drainage and maintaining a groundwater level at a depth of 0.40 to 0.60 cm below the surface. Palawija can be grown in the lower hydro-topographical categories following the wet-season rice crop when groundwater levels are still high. The crop then needs to be grown on 0.20 to 0.40 m high ridges to assure drainage of the root zone and to quickly evacuate excess rain through furrows in between the ridges. Canal water management aims at maintaining water levels in the tertiaries at some 0.50 to 0.70 m below field (ridge) level.

Tree crops

Water management for tree crops focuses on drainage and maintaining a stable groundwater table. The optimal depth of the groundwater table is 0.60 to 1.0 m below ground level. Water-levels in the tertiary canals should then be kept at 0.80 to 1.0 m below field level. In low areas, this will require drainage structures at quaternary, tertiary and perhaps also secondary level. In soils with shallow pyrite, the allowable drainage depth may be limited to avoid oxidation of the pyrite. Tree crops may have to be grown on mounds or raised beds if the groundwater table cannot be sufficiently lowered, e.g. in case adjacent areas are under rice or palawija. Water management for larger areas under tree crops on pyritic soils is similar to the water management for tree crops on non-pyritic soils.

3.3.5 Macro-level Hydraulic Infrastructure

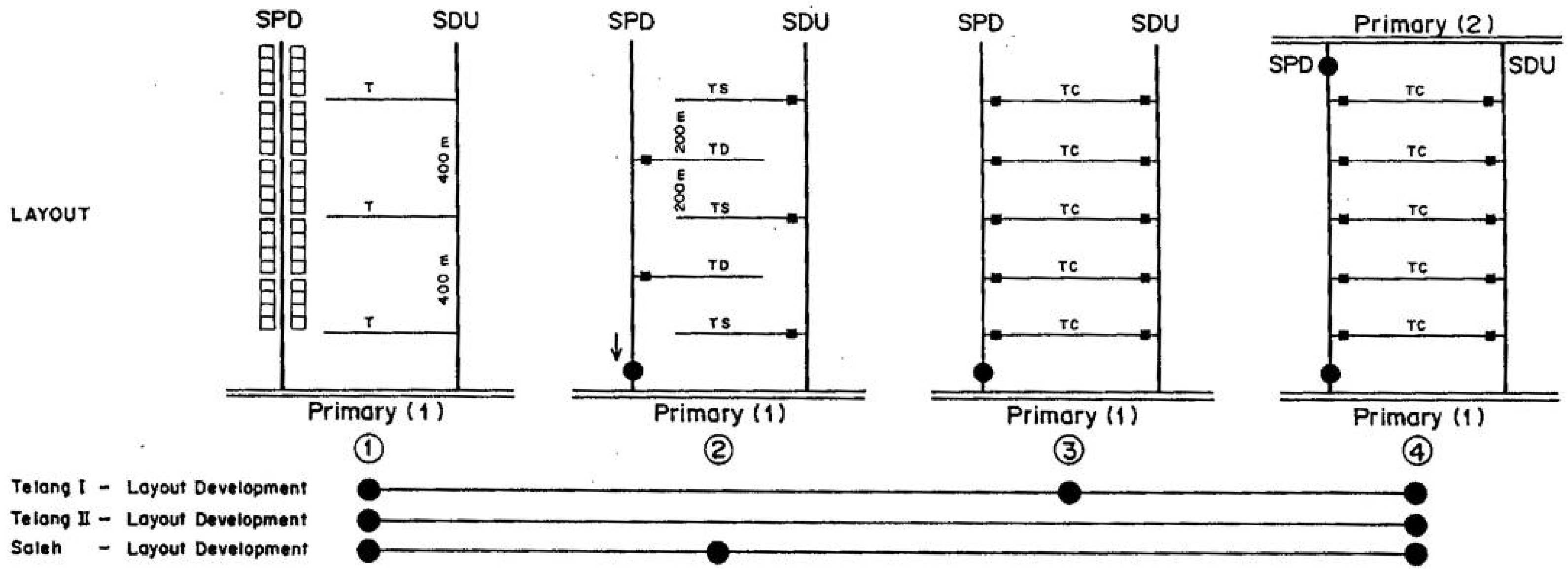
The development of hydraulic infrastructure of the large-scale ex-transmigration schemes in the tidal lowlands during the 1970/80s was designed in phases:

- First stage: low-cost simple open infrastructure adapted to the initial reclamation needs and wetland rice cultivation (designed on minimal drainage principles)
- Second stage: improved water control, crop diversification, socio-economic development
- Third / fourth stages: full fledged polders and water control in the estuary

The schemes in the EMRP are still mainly in the first stage, i.e. designed for minimal drainage. Second stage development was introduced in selected schemes in South Sumatera, Jambi, Riau and West Kalimantan. South Sumatera is the best example, with average rice yields up to around 3 to 4 ton/ha, and under controlled circumstances in water management pilots up to 6 to 8 ton. It will be important to draw on the lessons learnt from second stage development elsewhere (a.o. World Bank 2001).

Figure 23 shows, as an example, the development over the years of a main canal system in South Sumatera (Euroconsult 1997a) to better suit requirements for flushing and leaching, and crop diversification. Such an ‘evolution’ did not occur in the ex-transmigration schemes in the EMRP, which are still stuck with the outdated designs of the early 1980s.

DESIGN	ORIGINAL DESIGN ± 1978 ITB / IPB	SPECIAL MAINTENANCE 1988 – 1991 P3S – SUMSEL	TELANG-SALEH PHASE I 1992 – 1997 EC / BINTEK	TELANG-SALEH PHASE II PROPOSED EC / BINTEK



Main Concept	Minimal Drainage	One-way GW flow Shallow Drainage	Flushing Shallow Drainage	Flushing Shallow Drainage
Cropping Pattern	Rice	Rice	Low = Rice, High = Diverse	Low = Rice, High = Diverse
Tertiary Layout	Single	Single	Double	Double
Secondary Layout	Single	Single	Single	Double
SPD Operation	Open	Controlled Drainage (HY)	Controlled Drainage (HY)	Controlled Drainage (HY)
SDU Operation	Open	Open	Open	Open
Tertiary Operation	Open	One-way flow : TS = High TD = Low	Flexible	Flexible
Operation	No Operation	Water Management Plan	Water Management Plan	Water Management Plan

Figure 23 - Development of main system. Example of Telang-Saleh South Sumatra

Main system improvements will require re-designs on the basis of accurate topographical, hydrological and land suitability assessments (see also Table 10 and Technical Guideline No.6 on Redesign of Hydraulic Infrastructure). The upgrading of the hydraulic infrastructure in the EMRP should focus on flood control and improving the soil and water quality, i.e. shallow controlled but intensive drainage, water circulation, leaching and flushing. The upgrading of the existing hydraulic infrastructure is a pre-condition for on-farm land and water management development and the revitalisation of the agriculture.

Table 10 – Hydrological parameters for LWM[14]

Parameters		Period	Purpose
River	▪ Maximum HWL	WS	▪ Flood risks
	▪ 25 % HWL	WS/DS	▪ Tidal irrigation options
	▪ Average HWL ▪ Average MWL ▪ Average LWL	WS/DS	▪ Drainage options
	▪ Minimum LWL	DS	▪ Navigation options
	▪ Discharges	WS/DS	▪ Non-tidal irrigation
	▪ Cross sections		▪ Drainage/navigation
Canal	▪ Damping of HWL	WS/DS	▪ Tidal irrigation options
	▪ Damping of LWL	WS/DS	▪ Drainage options
	▪ Discharges	WS/DS	▪ Non-tidal irrigation
	▪ Cross sections		▪ Drainage/navigation
Flooding ▪ River flooding ▪ Tidal flooding ▪ Rainfall ponding ▪ Adjacent areas	▪ Extent ▪ Depth ▪ Frequency ▪ Duration	WS/DS	▪ Flood protection design ▪ Macro-drainage design ▪ Water management design/ operation ▪ Cropping patterns
Salinity intrusion	▪ > 1000 ppm more than 2 consecutive months yearly	WS/DS	▪ Drinking water ▪ (Tidal) irrigation options ▪ Cropping patterns

Note: WS = Wet season; DS = Dry season

Solutions to improve the soil and water quality will involve interventions at delta level rather than scheme level, e.g. river-connecting canals. Schemes are often interconnected, or are influenced by the hydrology of the surroundings, e.g. through surface run-off or interflow.

Uncultivated land in and around agricultural areas are a source for acidity, fires and pests, affecting agricultural development. Consideration must be given to revitalise the undeveloped areas (lahan tidur), in- and outside the schemes, to minimize impact on existing agriculture. Apart from the technical considerations, socio-economic development and the revitalisation of agriculture requires a regional approach, and there should be no differentiation between type of scheme or ethnic background The recommendation therefore is to focus on the delta (management unit) in its entirety as the unit for development.

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[14] Adapted from Euroconsult, 2000a

The following steps are thus involved in the hydraulic re-design of the Management Unit:

- A hydrological 'plan' indicating irrigation, supply and drainage potentials
- A 'mini master plan' for the development and re-vitalisation of the Management Unit
- System planning followed by the hydraulic re-design

Table 11 shows a summary of steps and data required for the improvement of the land and water management in the development areas of the EMRP.

Table 11 –Water management development in the Management Unit

Steps	Actions	Remarks
Hydrological plan	▪ Assessment of hydrological boundary conditions for the management unit	*See also Annex 1:* ▪ Daily tidal fluctuations ▪ Seasonal fluctuations ▪ Water quality
	▪ Assessment of land and water management potentials in the management unit	*See also Annex 2:* ▪ Hydro-topography ▪ Drainage classes ▪ Irrigation classes ▪ Flood classes (non-tidal)
	▪ Assessment of integrated land and water management aspects in the management unit	▪ Conservation, development, and adapted management zones ▪ Separation conservation and agricultural development ▪ Lahan tidur
	▪ Options for system improvement in the management unit	▪ Management unit ▪ Villages and schemes
Development plan	▪ 'Mini'-master plan ▪ Socio-economic planning ▪ Land use planning ▪ New development areas ▪ Time frame	▪ Management unit ▪ Villages and schemes
System planning	▪ System lay out ▪ Land use options	▪ Including developed and non-developed areas incl lahan tidur
Re-design	▪ Drainage modules ▪ Supply modules	▪ Percolation, leaching and flushing requirements ▪ Tidal irrigation and flushing requirements ▪ Navigation criteria
Upgrading and rehabilitation	▪ Short term: macro-system ▪ Long-term: on-farm development, TAM, etc	▪ Macro-system improvement necessary to support on-farm development
O&M	▪ Set up and strengthening of O&M field organization	▪ Resolve capacity shortage and knowledge gap at field and regional level

Design objectives

Designs for the macro-level hydraulic infrastructure must fulfil the following requirements:

Drainage, flushing and leaching – Acidity and toxicities is considered a major cause for the low agricultural productivity in the EMRP area. The hydraulic infrastructure in the EMRP is normally not designed for water circulation, flushing and leaching. Double-connecting canals are required, preferably from river-to-river, rather than the current dead ended systems, see Figure 24. The length of the drainage path should be reduced by adding more canals and more connections to the tidal rivers. The distance between drainage canals needs to reduced, e.g. the maximum tertiary drainage distance should be no more than 200 m.

Tidal irrigation– In practice there is a limited area that can potentially be irrigated by the tides since the majority of the tidal lands in the EMRP is located in hydro-topographical Class C, situated above high tidal water levels. It must also be realized that tidal (gravity-based) irrigation can only occur during 2-4 days at the peak of the spring tide cycle, and than only during 2-4 hours per day. This will result in high peak flows with high head losses. Still, for those areas that are potentially suitable for tidal irrigation, e.g. along Terusan Jaya, the macro-level design should include these peak supply flows. Tidal inflow is also required for flushing and to restore water levels in the canal systems. Irrigation and supply modules must take into account recommended percolation requirements of 8 mm/day.

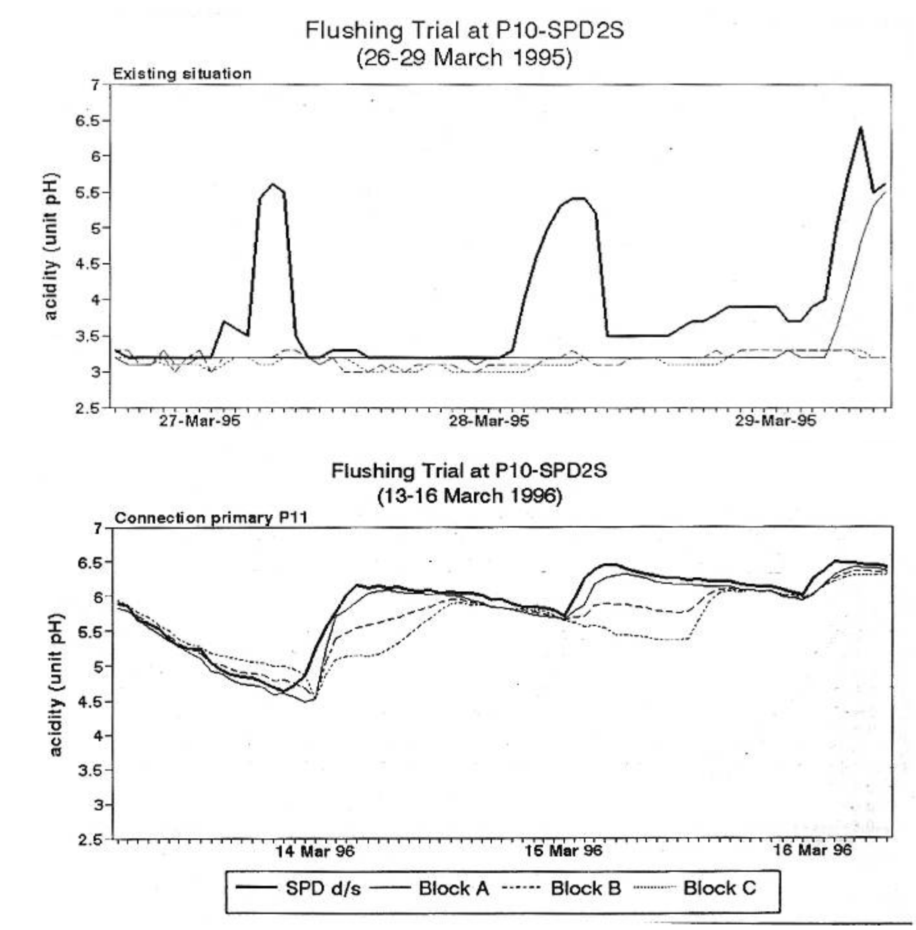


Figure 24 – Improvement of water quality in 4,000 m long dead-ended secondary canal after double-connecting to a new (river to river) primary canal. P11 Saleh, South Sumatera (Euroconsult 1997a)

Crop diversification - Crop diversification is an essential part of agricultural development, and it also fits the diverse and dynamic conditions in the lowlands. Dry land and tree crops may be preferred, not only from an economical perspective, but also to avoid the acidity and toxicities associated with the high water tables for wetland rice. In practice, the tidal lands are highly diverse, and crop decisions are taken mostly at field – household - level. Not all tidal lands are equally suitable for wetland rice, and/or dry land and tree crops, but maximum flexibility is required in main system design, to allow farmers to make individual choices. Main system design should therefore include drainage modules for tree crops in the hydro-topographical Classes B-D (tree crops on mounds in Class B). Canal bottom levels should be designed such that the required drainage depth for tree crops can be achieved.

Navigation – Some larger, open, canals, especially when these are connected on both sides to a river, may have an important navigation function. The hydraulic design should take into account criteria for navigation, usually based on 24 hr navigation during the dry season, resulting in a canal depth of 1 m below lowest tidal water levels, while the width of the canal should take into account that during the design situation, two boats should be able to pass.

Flooding **-** In the tidal areas in the southern part of the EMRP, short-duration and shallow flooding occurs in lower areas during high daily tides. Such floods are usually limited to spring tide and considered beneficial for wet land rice (i.e. tidal irrigation). Flood prone low-lying tidal areas may require minor flood protection measures. Long-term, deep, flooding occurs in semi- and non-tidal areas in the northern part of the EMRP. Larger flood protection works are required here. In general, the non-tidal areas require a very different land and water management approach from the tidal areas.

Special reference is made to the Technical Guidelines on Swamp Development, Volume II: Surveys, Investigations and Design, Euroconsult (2000a), as this is the most comprehensive guideline available on hydraulic design in the tidal lowlands.

System design

Main system improvements will require re-designs on the basis of accurate topographical, hydrological and land suitability assessments. The upgrading should focus on flood control and drainage management, water circulation, leaching and flushing, and will entail reducing the length of canals and drainage intervals by adding new canals, the double-connection of dead-ended canals, and adding water control structures. The following table provides a summary for design considerations for the upgrading of hydraulic infrastructure.

Table 12 – Design considerations hydraulic infrastructure in the EMRP

Condition	Issues to be Considered	Infrastructure requirements
All swamplands	Drainage of excess rainfall	Drain spacing at 200 m
	(Ground) water level control	Water control at farm level
River/canal tidal in dry and wet season, daily LW > 1 m below NGL	Potential for tidal irrigation	Wide open canals
	Protection against tidal flooding	Low embankments
River/canal tidal in dry and wet season, daily LW < 1 m below NGL during part of the year	Improved drainage	Drainage structures at tert/sec level
	Protection against tidal flooding	Low embankments
River/canal tidal in dry season only	Flood protection	High embankments
	Improved drainage	Drainage structures primary level, pumping
	Alternative drainage outlets	Long drainage diversion canals parallel to river and connecting downstream
River/canal outside tidal range	Same	Same
Deep peat and conservation areas	Prevent drainage	Physical separation of development and conservation areas
	Hydrological restoration	Block existing canals, physical separation of development and conservation areas
Deep peat, tree crops	Minimize drainage	Structures in canals
	Subsidence and future drainability	No or only few permanent structures
Shallow peat	Minimize drainage	Structures in canals
	Subsidence and future drainability	No or only few permanent structures
Adapted management zone along conservation	Minimize drainage	Structures in canals
Acidity	Water circulation	Double-connected canals at all levels
	Canal flushing/one-way flow	Flap-gate structures tert/sec level
	Soil leaching	Tata Air Mikro (TAM)
Salinity	Need to prevent salinity intrusion	Flapgate structures at tert/sec level

The macro-and main hydraulic infrastructure should be designed to provide farmers with maximum flexibility to the selection of their crops. For this it is required that the drainage designs of the main canal systems is based on the following land use[15]:

[15] This coincides with current discussions in the framework of the draft law on the preservation of lands for food crop production, i.e. the RUU Lahan Abadi, by the Ministry of Agriculture. Personal communication with staff of the Directorate of Swamps, Ministry of Public Works, 2009.

- Hydro-topography Class A: Wetland rice
- Hydro-topography Class B: Tree crops on mounds/wetland rice
- Hydro-topography Class C/D: Tree crops

Because of the daily tidal water level fluctuations, and with appropriate water control in the fields and the tertiary canals, the farmers have thus maximum flexibility in adopting the crop of their choice.

Improved designs were used in the ex-PLG design of the Lamunti and Dadahup schemes, but these were never completed, and furthermore, the hydrology is so complex in these partly non-tidal areas, that further investigations and modelling is required.

The focus of macro-level re-design and upgrading in the development zone is on:
- Overhaul of the dead-ended canal networks in Block D, including additional river-connecting main canals and connections to the ex-PLG main canals
- New development in fallow areas in Block D
- Completion and upgrading of the Dadahup / Lamunti schemes, requiring a re-design on the basis of precise flood predictions and assessments

Drainage modules

Drainage modules for agricultural use are usually designed on the basis of a 1-in-5 year maximum storm drainage. During such periods it can not be avoided that the fields will become saturated and even flooded, and it will depend on crop characteristics as to what the return period to normal water levels will be.

Rice: 1-in-5 year maximum 3-day rainfall, reduced with an increase in field storage volume of 50 mm, to be evacuated in 3 days

Palawija: 1-in-5 year maximum 4-day rainfall, to be evacuated in 4 days: the first 2 days as surface run-off, the second two days as ground water discharge

Tree crops: 1-in-5 year maximum 6-day rainfall, to be evacuated in 6 days: the first 3 days as surface run-off, the second 3 days as ground water discharge.

Drainage from greenbelts is calculated for a 6 day period, to be evacuated as surface run-off in 6 days. Home yards and public areas have the same drainage requirements as tree-crops.

The consultants involved during 2007 in the Surveys, Investigations and Design (SID) in Block A, Mintin, Menaren, and Terusan Jaya, all used for the calculation of drainage modules the rainfall data from Menaren station, 1995-2006. While based on the same time-series, different outcomes were reported for the design storm rainfall, and the drainage modules.

The Table 13 shows, for indicative purposes, drainage modules used for second stage designs in South Sumatera (Euroconsult 1997a). It is expected that these will not be far different from those in the EMRP area. It is however urgently required to design similar modules for the EMRP area, based on a proper assessment of rainfall frequency-duration curves, as the basis for the hydraulic designs.

Supply modules

Supply calculations must take into account percolation requirements to maintain a proper soil and water quality. As high tidal water levels are only for short periods above the field level, tidal (gravity) irrigations occur only during a few hours per day and then mostly only during several days around the springtide period. Large quantities of water thus need to be conveyed to the fields in a short time, as irrigation rotation is hardly an option here.

This requires also very large primary and secondary canals, and a dense system of tertiary, quaternary, and field canals. Head losses are high during peak supply flows, and this puts a practical limitation on the areas that can be irrigated in large-scale canal systems. This situation is different from traditional fields, which are often flooded directly from the river.

Table 13- Drainage modules based forSouth Sumatera second stage design

	Greenbelts		Wetland rice		Palawija and Homeyards		Tree crops	
Day	1-6	-	1-3	-	1-2	3-4	1-3	3-6
Surface Run Off (SRO) in l/sec/ha	3.0		4.9		6.3		4.9	
Ground Water Discharge (GWD) in l/sec/ha		-		-		4.9		4.5
Infiltration in mm/day	-	-	-	-	25	-	25	-
Storage change in mm	+50	-	+50	-	+50	-50	+50	-0.50
Design field water level (mGL)	+0.25	-	+0.25	-	-0.50		-0.50	
Design tertiary canal water level (mGL)	-0.10	-	-0.10	-	-0.10	-0.60	-0.10	-0.60
Design storm rainfall:			**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**
6 day period, 1 per 5 year, in mm)			130	27	19	14	10	7

Source: Euroconsult 2000a

For second stage hydraulic designs in South Sumatera (Euroconsult 1997a), the following experimental design criteria were introduced to quantify actual (tidal) water supply requirements. These criteria should be further reviewed and tested in the field.

(Tidal) supply is required to:
- Compensate for the crop water balance deficit
- Restore canal and field water levels after drainage for flushing
- Limit a deep drop of ground water tables in extreme dry periods

<u>Crop water balance</u> - The crop water balance is calculated for a 1-in-5 year or 80% dry year. For *wetland rice*, the water requirement for land preparation is set at 100+50 mm. For the duration of the crop an average percolation rate of 8 mm/day is recommended to maintain a proper soil and water quality. For *palawija*, the water requirement for land preparation is set at 50 mm, while a percolation rate of 2

mm/day is assumed for leaching and flushing under condition of a 2-weekly replenishment of the canal and field water tables. The driest months are selected for the wet season crop and the secondary crop for the irrigation and supply designs.

A similar calculation can be done for periods of no rainfall, i.e. representing conditions of an extreme dry year (El Nino year), whereby supply should be maximized in an attempt to avoid a deep fall of ground water tables, as this will lead to the production of large amounts of acidity and toxicities that can remain in the system for years after.

<u>Tidal irrigation</u> – Based on the crop water balance, maximum supply requirements for a wet season and a secondary dry season crop can be calculated. Tidal irrigations take only place during a narrow period during spring tides, when the water levels are high enough to inundate the fields, and then only for about 3 hours per day due to the daily tidal fluctuation. For the boundary conditions, the *25 % exceeded high tidal water level* for the wet season and the dry season respectively in the river is taken, representing the water level at which tidal irrigation will take place for 4 days per spring tide cycle, i.e. a total of 12 hours per 2-weekly spring tide cycle.

<u>Pumped irrigation</u> – Pumped irrigation from the tertiary canals will extend the supply period and reduce peak flows. In many schemes the soil and water quality (acidity, salinity) limits the use of pumps. In the higher areas, where most of the pumped irrigation will be required, the high canal bottom levels relative to the tidal water levels, is another limiting factor. It is estimated that pumped irrigation can take place on average for 6 days during spring tide, for 8 hours daily, i.e. or a total of 48 hrs per 2-weekly spring tide cycle.

The following table shows, as example, calculated supply modules for South Sumatera:

Table 14 – Calculated supply design modules

HT class	Crop	Season	1 per 5 year (80 %) dry year			No rainfall		
			Monthly deficit	Tidal IRR	Pump IRR	Monthly deficit	Tidal IRR	Pump IRR
			mm	l/sec/ha	l/sec/ha	mm	l/sec/ha	l/sec/ha
A	Wet	Wet	124	14.4	3.6	124	14.4	3.6
B	Wet	Wet	124	14.4	3.6	124	14.4	3.6
C	Dry	Wet	38*	4.4	1.1	180	20.8	5.2
A	Wet	Dry	158	18.3	4.6	158	18.3	4.6
B	Dry	Dry	52	6.0	1.5	171	19.8	4.9
C	Dry	Dry	52	6.0	1.5	171	19.8	4.9

HT is hydro-topography (class); IRR = irrigation
* In South Sumatera, February is a relative dry month which explains the small difference between wet and dry season deficit

Design methodology

Based on the above design conditions and criteria, stationary design formulas can be used to approximate the design requirements, cross sections and bottom levels of canals and structures. The overriding drainage or supply situation must be taken for the final design. Once the design is complete, the assumptions should be tested in a non-stationary hydraulic model. The models will also allow for the analysys of the effect of water control structures. It is not recommended to use the model as basis for the hydraulic design, as these models are often too sensitive for the dense and small canal systems in the tidal lands schemes.

3.3.6 On-farm Water Management

Annex 5 describes the most common combinations of crops and water management in the tidal lands. By necessity, on-farm water management is a long-term process, as it directly deals with all the variables and changing conditions in lowland development. A field-to-field approach is required, but over time, the water management should also be coordinated at the level of the water control structure at tertiary and / or the secondary level.

On-farm water management, as in the example of South Sumatera[16], involves the following:

- Development of the on-farm water management system[17]
- Improvement of the tertiary water management system
- Development of operation rules water control structures at field and tertiary level
- Organization and management, i.e. water user associations and farmer groups
- Agricultural development: farm inputs, mechanized land preparation, post-harvest processing (as it is here where most losses occur)

Water management, land preparation and agricultural development are closely integrated processes, and while the South Sumatera example is specifically designed for the increase of wetland rice production in areas that have a reasonable to good macro-level hydraulic infrastructure, the concept can be applied to other areas and cropping systems as well. This approach is strongly recommended for the development areas in the EMRP, see Figure 25.

An important step ahead was the resurrection of Water Users Associations (P3A), which were formed from federations of Farmer Groups (Gabungan KT). In this manner the relationship between on-farm water management and agricultural development was strengthened, while it is also true that the Farmer Groups are traditionally the more active and viable organizations.

Apart from the successes of this approach, it was also clear that, even in the relative sophisticated hydraulic infrastructure of South Sumatera, almost none of the tertiary and secondary structures were operational, and it took considerable effort and time to replace some tertiary structures for sake of the trials. So also here, water control is as yet not possible in most of the hydraulic infrastructure. One of the reasons is that government response is divided over several layers, and that, more often than not, solutions are ad hoc. Another limiting factor is that government response to

[16] RWS-IHE *et al*, 2007

[17] Usually under the Tata Air Mikro or TAM program, the on farm-water management program by the Directorate-General of Land and Water Management, Ministry of Agriculture

conditions in the field is governed by the annual planning framework, so that works often start at least a year after the initial request.

3.3.7 Operation

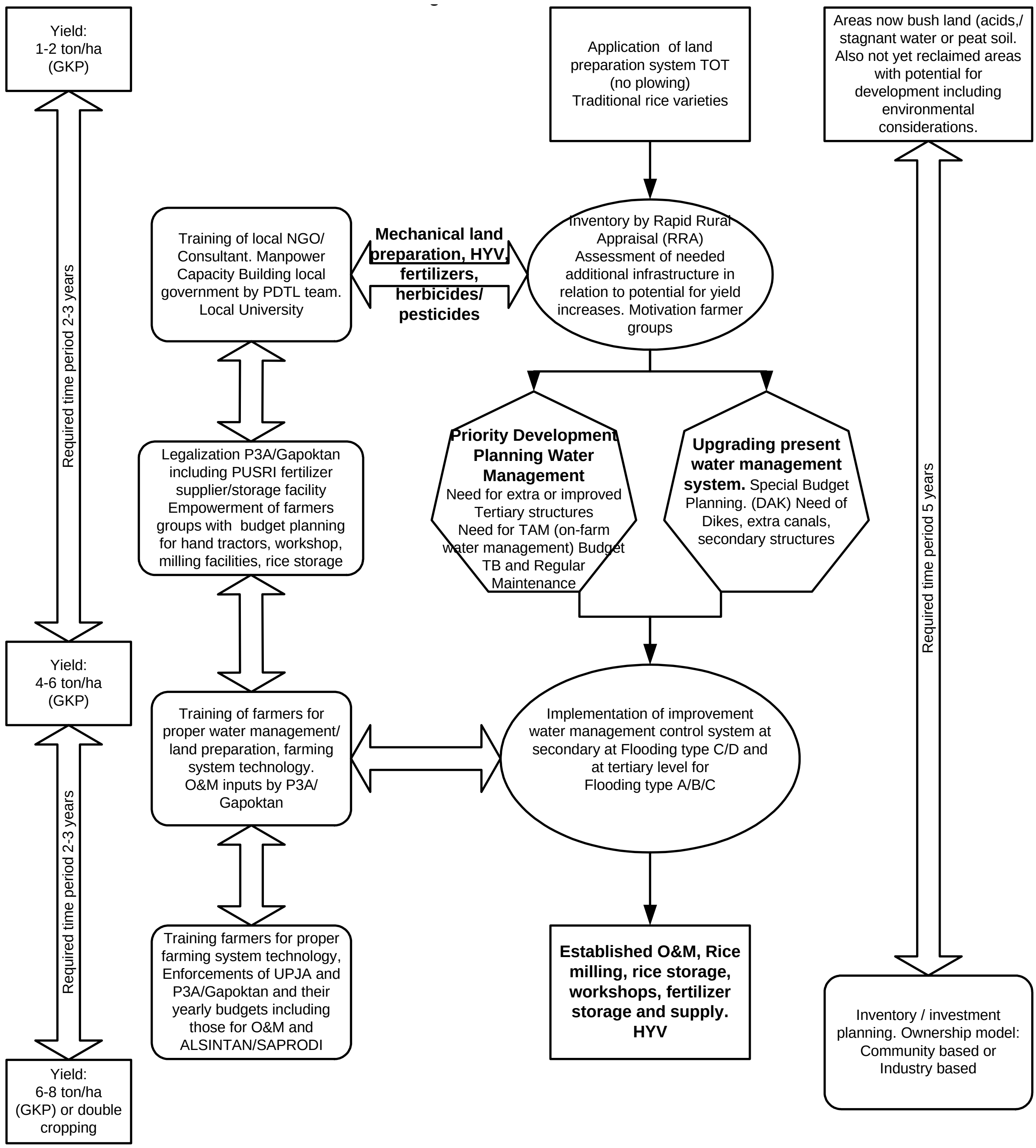
The water management for shallow controlled drainage, leaching and flushing requires water control and the operation of structures, first of all at field and tertiary level. Secondary level water control is very much recommended, but structures at this level make only sense when these are operated, hence, when there is demand, for which organization is required.

Operations are very much decided by the 2-weekly tidal cycle (spring tide – neap tide – spring tide), with drainage, flushing and tidal supply usually taking place during the short (e.g. four days) spring tide period, and water control / retention during the neap tide period. Table 15 shows the structure operations, typical for the water management in the tidal lowlands.

Secondary structures are often in disrepair, operated only by a few powerful farmers near the structure, to the detriment of other farmers, or are not operated at all. Secondary canals are also often used for (illegal) transport of logs, or, in case of the traditional canal systems, to provide access to the hinterland, or to float coconuts from the fields to a point near the river where these will be processed. What is clear though is that if structures do not have the fullest support of communities, they will be vandalized and become non-functional.

The level that water control can be exercised will gradually increase, but during the development stage, when soils are unripe and permeable, maintaining stable water levels will be difficult, let alone maintaining water layers on the field, being one of the reasons that a rice farmer tends to focus on water retention, in turn creating stagnant water conditions. What is often perceived as over-drainage is in fact mostly a lack of (controlled) drainage.

Figure 25 - Model for on-farm development for wetland rice [18]



[18] RWS-IHE *et al*, 2007

Table 15 - General structure operation modes in tidal lands[19]

Operation mode	Gate position		Objective
	Low tide	High tide	
Maximum drainage	open	closed	▪ Increase drainage capacity of the system
Controlled drainage	partly open	closed	Stabilize canal water-levels: ▪ for subsurface drainage ▪ for soil leaching
Maximum water supply	closed	open	▪ Tidal irrigation ▪ Canal re-fill ▪ Subsurface water supply
Water retention	closed	closed	▪ Keep rice fields inundated
Flood, salinity control	open or closed	closed	▪ Keep flood or saline waters out
Maximum tidal influence	open	open	▪ Tidal irrigation at high tide, drainage, leaching at low tide
Flushing - 1 or more days max. drainage - 1 or more days max. supply	 open closed	 closed open	▪ Improve water quality in dead-ended canals
One-way canal flow - structure at supply end - structure at drainage end	 closed open	 open closed	▪ Improve water quality in double connected canals

The operation of water control structures requires a flexible (adaptive) approach. The larger the area under water control, the larger the (micro-) diversity. Apart from that, the physical conditions, e.g. land levels, but also the degree of ripening of the soil, will change over time and water management needs to be adjusted accordingly.

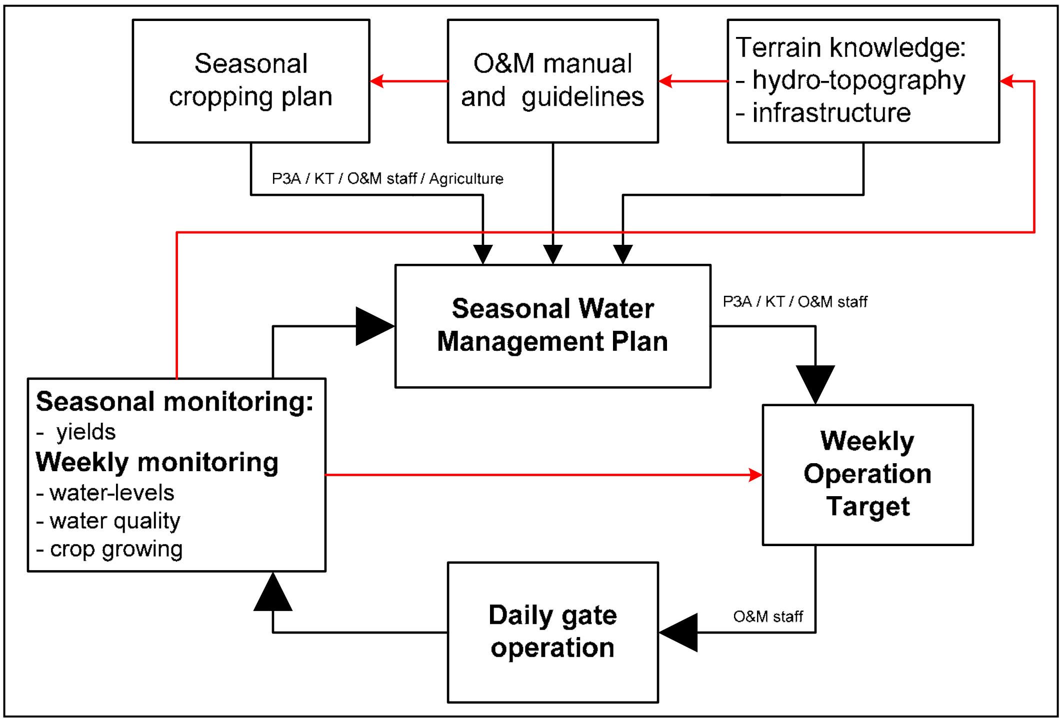
It can not be assumed that the operation of structures is fixed from the onset. It will take a long period to develop operation rules that will suit the variable conditions in the water management unit. Practical experience, combined with monitoring of field conditions will over time lead to a better understanding of the soil and water management in the unit.

There is little use in providing strict operation rules in an environment where there is often not sufficient terrain knowledge, where proper water management strategies need further testing, and where physical conditions are subject to change. It is then far more important to provide a framework for adjustment of operations based on developing insight, and which also ensures representation of all farmers affected by these structure operations. Recommendations on structure settings in O&M manuals and guidelines should thus be seen as the starting point only to fine-tune operations to actual field conditions in each of the water management units.

[19] Euroconsult 1996c

Figure 29 shows the process of structure operations in relation to cropping plans and water management planning, and the development of operation procedures. Essential in the approach is the feed-back into the daily gate operations on the basis of actual field conditions, and into the seasonal planning, on the basis of increased terrain knowledge. These tasks are the domain of the O&M organization, the water user associations (P3A) / farmer groups, and the agricultural extension services, preferably assisted by community facilitators with the support of research institutions and NGOs, and - at start up - professional consultants.

Figure 29 – Adaptive approach to structure operations[20]



3.3.8 Maintenance

As discussed in previous sections, canal maintenance is very important for soil and water management in the tidal lands schemes, not only to achieve certain design water levels, but especially to maintain a proper soil and water quality, which sets the tidal lands apart from the conditions and water management requirements elsewhere.

Based on the Government Regulation on Swamps No. 27/1991[21], the larger canals, i.e. navigation, primary and secondary canals are under the responsibility of the government, including the first 50 m of the tertiary canals including the structure,

[20] Euroconsult 1996c

[21] The PP No.27/1991 on Rawa is still effective where the regulation is not in conflict with the new water resources law of 2004. A PP Rawa is being drafted to supersede the 1991 regulation.

while the tertiary canals are the responsibility of the farmers, i.e. the water user association.

Main issues in maintenance include:

- After the initial rehabilitation and upgrading of hydraulic infrastructure, routine maintenance should take over, and budgets should reflect the actual requirements, i.e. needs. Such Needs Based Budgets need to be developed as part of improved O&M
- Navigation canals fulfil a regional transport function, and their maintenance should be shifted to the Ministry of Transportation, and costs should not be part of the Needs Based Budgets (NBB) for the O&M of the development schemes(i.e. as linked to agriculture)
- Routine maintenance by the government per definition follows the government planning and budget cycle. Budget is not available year-round, and most often so during the second half of the wet season crop, i.e. at the start of the new fiscal year. Routine maintenance should preferably be implemented on a 12-month basis, but, in absence of that, at least during the cropping season
- The division in responsibilities between the central, provincial and district level government based on scheme-size[22] is in its current form not practical in the lowland environment, where socio-economic development has a regional character, and schemes are often linked physically. The way this division works out in the lowlands, and in the EMRP area, is that the large-scale ex-transmigration schemes are under central level responsibility, and that, as a result, the traditional communities feel once again neglected (Euroconsult 2008). is highly recommended that central level develops partnerships and takes up the role to support the local O&M agencies, rather than operate autonomously from decentralized processes.
- The nomenclature of the canal infrastructure is often not clear, and this has consequences for the budgeting for routine maintenance, and the responsibilities of government *viz a viz* the farmers. In addition, it is also recommended to sub-divide the tertiary canal system on the basis of dimensions in the field. Size is often a handicap for community maintenance. Larger tertiary canals (i.e. > 2 m width) could be renamed into sub-secondary canals (Euroconsult 2000a), which then fall under the responsibility of the government
- Farmer's participation in canal maintenance is of course essential for on-farm development. However, this requires organization (water user associations) and incentives, especially in areas where a large part of the farm holdings remain fallow. It is also well possible to engage water user associations in government financed maintenance works, see also the MP EMRP Guideline for Re-design of the Hydraulic Infrastructure which describes the various mechanisms for community involvement in government contracts. The advantage of the latter approach is that Water User Associations not only will develop a sense of belonging regarding the hydraulic infrastructure at tertiary and secondary level, but will also generate income that will facilitate the organization to invest, e.g. in hand tractors or pumps, which then can be rented out to the farmers.
- It is also clear that farmer's willingness to share in O&M responsibilities is very much decided by the condition and effectiveness of the higher order hydraulic infrastructure under the responsibility of the government. In other words, the government should take the first step in rehabilitating and maintaining the

[22] District responsible for schemes < 1000 ha, province responsible for schemes 1000-3000 ha, central level (through Balai WS Kalimantan II) responsible for schemes > 3000 ha.

hydraulic infrastructure, as starting point for participatory approaches with the involvement of the farmers.

- Government response to conditions in the field is decided by the annual planning framework, so that works often start at least a year after the initial request, which is far too rigid for developments in the field, where daily new lessons are learnt

3.3.9 Monitoring, Trials and Demonstrations

The recent NLDS study (Euroconsult MottMacDonald 2008) concludes that data needed to design and support interventions in lowland development are often incomplete or lacking, and the impact of interventions is largely known from scattered surveys and studies. The lack of data time series compromises the review of lowland development. There is also little historical information on the 'wise-use' of peat lands and restoration of tropical peat lands, as these are relatively new concepts in Indonesia. This certainly describes the situation in the EMRP area.

Swamp development processes are complex and dynamic, and results are not always immediately visible in the field because of the gradual effect of drainage improvement on soil potential. Adaptive management responses involve regular updates of development strategies prompted by monitoring of interventions, process reviews, and new scientific insights. Similarly, the annual development planning process needs to be supported with monitoring of actual field conditions. Education curricula should be kept updated on the basis of process assessments and new insights, for which monitoring is essential.

While monitoring will be conducted by different agencies, this process should be supervised to ensure that the proper standards and procedures are followed, and that data are reliable, complete and accessible to all. It is recommended to establish national and regional lowland management knowledge centres, responsible for data management. Table 16 provides a summary of basic options for the improvement of a national and regional system for lowland monitoring and database management. It is recommended that monitoring in the EMRP area feed into a national data base management framework and information-sharing approach.

Table 16 - Options for Lowland Monitoring & Database Management

Lowland Monitoring and Database Management Framework	
Monitoring	▪ Routine monitoring nationwide of conditions in peat lands and lowland production areas, e.g. forest cover and land use changes, fires, hydrology and topography (hydro-topography) and soil parameters, agricultural production, and socio-economic processes, ▪ Detailed monitoring in selected sites, probably in combination with pilot activities, academic research, demonstrations, and farmer-led field schools, ▪ Record keeping of projects, studies, research, etc
Database Management	▪ A central level information and database centre, linked to planning and development agencies and academic institutions, ▪ Regional information and database centres, linked to the central level centre, and regional planning and development agencies and academic institutions, ▪ Improvement of the district and village data base, to strengthen local ownership and participation in the development planning process.

At field level, monitoring is required to regulate the water management in the fields and the water management units (i.e. the area served by a water control structure), and to develop a insight into the potentials and constraints of the particular water management unit. Each water user association, in cooperation with O&M field staff, should keep record of basic soil and water management indicators in the fields, i.e. rainfall, acidity, toxicities, ripeness of the topsoil, the water levels that maintained in relation to the cropping pattern, flooding and drought incidents, and yields, see also the section on structure operations. This information should be consolidated at scheme and at delta – management unit – level, for further analysis. It is important for farmers to receive feed-back from agencies on the data they provide.

Agricultural development and land and water management requires more research and testing. Trials and demonstrations as well as research are often the responsibility of different government departments and agencies. A major challenge is to establish water management at secondary level, with which little experience is available, as (agricultural) research and demonstrations often focuses on field or tertiary level. Apart from that, farmers have developed considerable hands-on knowledge over the years, which should be of interest to researchers and decision-makers alike. Rather than having separate research plots and demonstration units, it is recommended to combine these efforts, and re-instate the concept of integrated test-farms in a cooperation between Public Works and Agriculture that was so useful during the 1970s. The concept should be adapted and include more participants, i.e. agencies involved in tree crops but also research institutes, including that of government agencies, but also that of regional and national universities, and last but not least the farmers.'

Integration of research and demonstrations, hand-in-hand with the farmers, appears to be the only practical way forward to enhance the knowledge on land and water management and agricultural development in the tidal lands, not only in general, but in practical, site-specific terms, i.e. as close as possible to the real conditions faced by the farmers.

3.3.10 Capacity Building

There is a serious staff shortage developing in the water resources sector in Indonesia (DHV & UNESCO-IHE 2008), and this crisis may have an effect on the revitalisation of the agriculture in EMRP area. Staff shortages are felt just as well at the central level and the Balai Kalimantan II, as the provincial and district levels, and at field level. Apart from these staff shortages, there is also a lack of staff specifically skilled in land and water management and agriculture in the tidal lands.

Of immediate importance for the land and water management development in the EMRP area will be the strengthening of the survey, investigation and design capacity of agencies, and the improvement of O&M and agricultural extension services. It is felt that the knowledge centres proposed at field and regional levels, can also facilitate training of O&M staff, extension services, water user associations, facilitators and NGOs. This would ensure an integrated approach and a better understanding of staff of processes that require multi-sector responses.

The field school approach, as advocated by the Ministry of Agriculture, may well be the proper formal framework, perhaps with some amendments, under which to manage the research-demonstration-training approach based on the integrated test-farm concept of the 1970s, as recommended for the EMRP and elsewhere.

Of utmost importance is to support and strengthen local capacity, i.e. at science institutes, NGOs etc. to carry the future peat and lowland development process in the EMRP, and also to ensure that decisions sufficiently reflect local aspirations.

3.3.11 Integrated Land and Water Management Approach

Processes in lowland development are diverse and mostly closely related. Technical interventions can not be seen separate from each other or from socio-cultural processes. In addition, the typical dynamics of the lowland environment involves changing soil and water and socio-economic conditions, both in the conservation and development areas

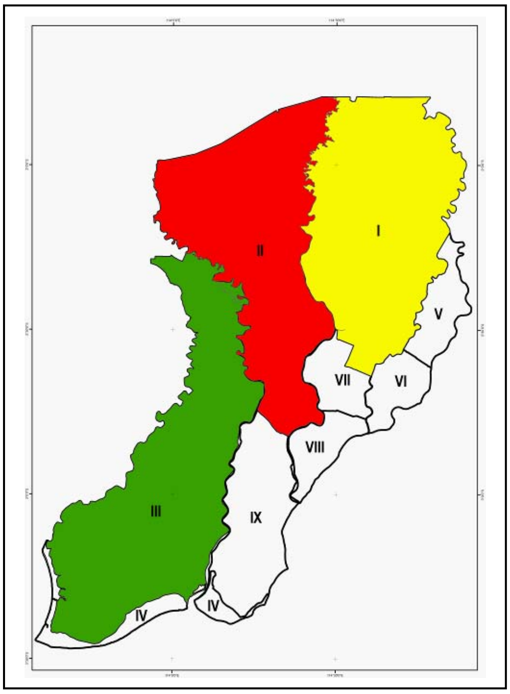
Development strategies and interventions can only be designed properly if based on actual suitabilities, and when addressing all aspects of the development process, i.e. (i) physical characteristics, (ii) land use, and (iii) socio-cultural and socio-economic conditions. Hydraulic design and land and water management should not be approached in isolation and must be firmly embedded into a broader - multi-disciplinary - strategy.

There are currently no standard procedures for the integrated evaluation of lowland areas in Indonesia, in part because the science is not complete, e.g. the hydrological restoration of peat lands, in part because the criteria and methodology is not developed or available, but also because this requires a multi-sector approach. Development of integrated evaluation criteria, linked to a progressive scientific understanding, and embedding these procedures in the sector agencies should be high on the agenda of the lowland development approach.

Chapter 4 Land and Water Management of the EMRP Management Units

The land and water management in the Management Units of the EMRP area is governed by the overall policy objectives of the macro-zones in which these units are located, i.e. with a focus on conservation, coastal zone management, or agricultural development. A Management Unit requires a unique approach to land and water management development, based on physical characteristics, requirements and interaction of each of the land use options, and in the context of the overall policy objectives.

4.1 Conservation Management Units



The three (3) Conservation Management Units in the EMRP are largely made up by very deep peat domes, with shallow to medium deep peat and mineral soils in a band along the rivers, West of the line: Kahayan River – Anjir Kelampan - Kapuas River - Block A PLG canal - Mengkatip River, and therefore hydrologically independent from the Development Areas East of the line.

The lower areas are influenced by the hydrology of the rivers. In Block E, and along the Sebanggau, the rivers are non-tidal, which may result in deep, long duration flooding during the wet season. In the southern parts of Block A,B, and C, the rivers are tidal, and floods are shallow, frequent, and of usually short duration.

The deep peat areas in the centre of the Management Units are part of the conservation zone in the EMRP. Similarly, the transition from the conservation zone towards the rivers is part of the adapted management zone of the EMRP.

Development is located along the rivers. Indigenous Dayak are found in the northern parts of the EMRP, including parts of Block C. In the southern part, especially along the Kahayan river in Block C, traditional settlers are mostly of Banjarese origine. Transmigration took place in the 1970/80s on the right bank of the Kahayan in Block C and small parts of Block B.

Deep peat areas are increasingly targeted by the private sector. The peat forests of Block A, B and C are severely damaged by logging, drainage, and fires. In Block E the hydrology is still rather intact and peat forests in a relative good condition. A zone of 5-7 km along the rivers is set aside for indigenous settlers. Beyond that, the land is under government responsibility.

The survival of the peat dome depends very much on conserving the hydrological integrity of the entire Management Unit. An adaptive management approach is required, supported by strict land and water management measures. Land and water management development is closely linked to environmental, agricultural development and socio-economic activities.

As a first step, a development plan should be prepared for the Management Unit on the basis of detailed hydrological assessments, i.e. a hydrological plan, and other land characteristics, socio-economic development criteria, and community aspirations. Table 17 shows the major land and water management characteristics of the conservation Management Units in the EMRP.

Table 17 – Characteristics of Conservation Management Units in the EMRP[23]

Characteristics	Management Unit I	Management Unit II	Management Unit III
	Block A/E	Block B/E	Block C
Macro zone / Policy objective	▪ Conservation ▪ Adapted management	▪ Conservation ▪ Adapted management	▪ Conservation ▪ Adapted management
Area	▪ 361,000 ha	▪ 355,500 ha	▪ 409,000 ha
Land utilisation	▪ Type 1 - Existing forest / eco-systems, greenbelts ▪ Type 2 - Degraded forest / eco-systems, greenbelts ▪ Type 3 -Traditional Dayak / mixed settlements	▪ Type 1 - Existing forest / eco-systems, greenbelts ▪ Type 2 - Degraded forest / eco-systems, greenbelts ▪ Type 3 -Traditional Dayak / mixed settlements ▪ Type 6 - Older transmigration	▪ Type 1 - Existing forest / eco-systems, greenbelts ▪ Type 2 - Degraded forest / eco-systems, greenbelts ▪ Type 3 -Traditional Dayak / mixed settlements ▪ Type 4 - Traditional Banjar / mixed settlements ▪ Type 5 - Older transmigration
Farming systems	▪ Tree crop based	▪ Tree crrop based	▪ Rice based ▪ Tree crop based ▪ Livestock based
Boundary condition of rivers	▪ Zone I: tidal ▪ Zone II: reduced tidal ▪ Zone III: non-tidal WS ▪ Zone IV: non-tidal ▪ Non-saline	▪ Zone I: tidal ▪ Zone II: reduced tidal ▪ Zone III: non-tidal WS ▪ Zone IV: non-tidal ▪ Non-saline	▪ Zone I: tidal ▪ Zone II: reduced tidal ▪ Zone III: non-tidal WS ▪ Saline - Non-saline
Flood classes	▪ Block E: non-tidal ▪ Block A-South: full tidal	▪ Block E: non-tidal ▪ Block B-South: full tidal	▪ Sebanggau-N:non-tidal ▪ Kahayan-N: Reduced tidal ▪ Block C-South: Tidal
Hydro-topography	▪ Non-tidal	▪ Non-tidal ▪ Class B-C	▪ Non-tidal ▪ Class B-C (North) ▪ Class A-B (South)
Soils	▪ Deep peat ▪ Shallow to medium peat ▪ Mineral soils ▪ Quarts sands	▪ Deep peat ▪ Shallow to medium peat ▪ Mineral soils ▪ Quarts sands	▪ Deep peat ▪ Shallow to medium peat ▪ Mineral soils
Hydraulic infrastructure	▪ Handil (Dayak) ▪ Ex-PLG 1990s	▪ Handil (Dayak) ▪ Ex-transmigration 1930s ▪ Ex-transmigration 1970/80s ▪ Ex-PLG 1990s	▪ Handil (Dayak, Banjar) ▪ Ex-transmigration 1970/80s ▪ Ex-PLG 1990s
O&M	▪ No O&M organization	▪ No O&M organization	▪ Pengamat

Note: WS = only during wet season; no indication implies both wet and dry season

[23] Based on currently available information. Additional surveys and modelling required

4.1.1 Management Unit I - Deep peat Block A / E

Management Unit I is located in the north-eastern part of the EMRP, see Figure 10. The unit borders on the Kapuas, Mengkatip and Barito rivers in the East and West, the Palangkaraya - Buntok road in the North, and the Lamunti scheme in the South. Administratively the area falls under the jurisdiction of the Barito Selatan and Kapuas districts.

Current Land and Water Management

The unit is defined by the hydrological landscape associated with the deep peat area in the northern part of Block A and the eastern part of Block E, see Figure 5. The peat overlies partly thick white quartz sand formations, often referred to as the Giant Podsol.

The river hydrology is complex as the unit is located in the transition from the non-tidal to the tidal zone, see also Figure 2. Upstream of the ex-PLG SPI canal, the Kapuas and Barito rivers are largely non-tidal, with flood plains consisting of levees (pematang), back swamps, and old river courses (oxbow lakes). The rivers at the southern border with Lamunti in Block A are fully tidal year-round.

Block E was not included in the PLG design, and therefore remained relatively undisturbed, even though the area has been logged and logging tracts and canals are still present. The peat land forests of Block E are home to important orang-utan populations.

The East-West oriented ex-PLG SPI canal is the divide between Block E and Block A. Little is known yet on the actual hydrology of the SPI canal and the impact on the peat areas in Block E (upstream) and Block A (downstream). Since the area will be sloping towards the coast, it is expected that the SPI canal, apart from providing access, functions as an interceptor drain for the peat lands in Block E. The impact of the SPI canal on the peat lands in Block A is, besides access, the cut off from ground water and overland flows from Block E.

In Block A, a dense canal network of canals was constructed under the PLG, and, while settlement did not take place, most peat forests are severely degraded by logging, drainage and fires. The ex-PLG drainage infrastructure in Block A caused the formation of local mini-domes, which now govern the local peat hydrology[24], and affecting canal blocking efforts.

Wetlands International (CKPP) was till 2008 involved in canal blocking in Block A. Due to the topography, with canals at the lowest point in the landscape, canal blocks have a limited effect on raising the water levels of relative higher peat lands. Hydrological rehabilitation will thus require a broader approach, and additional studies and trials are needed. The benefit of canal blockings is on the stabilization of current water levels and drainage base to limit further degradation, rather than restoration of the natural hydrology.

Traditional Dayak settlements along the river banks, with simple open canal systems, *handils*, border on the deep peat areas. Local communities also make increasingly use of the ex-PLG infrastructure for access into the peat lands and cultivation along the drainage canals.

[24] Deltares, WUR (2008)

Apart from few indigenous settlements along the rivers, there is little other development in the area. In the northern part of Block E, quarts sand mining takes place to supply factories in Banjarmasin. Mining was observed in rivers near Buntok. Oil palm operations are about to start or have already started in or near the peat lands in the southern part of Block A.

Main Land and Water Management Issues

Due to the deep peat area with only a narrow zone along the rivers suitable for settlement and agriculture, the impact of drainage on peat, and the traditional rights of indigenous Dayak communities, the carrying capacity of the unit is considered minimal, and the unit is not considered suitable for new development and transmigration.

Dayak communities make increasingly use of the access into the peat lands provided by the PLG infrastructure. Conservation of the peat lands, canal blocking and water management must go hand-in-hand with livelihood improvement of these communities.

Other aspects that will have an impact on the land and water management are:

- Drainage of Lamunti (agricultural revitalisation) and the effect on bordering peat areas
- The start of an oilpalm plantation at the border with Lamunti
- Increased access from Lamunti to the peat areas in Block A by the construction of a bridge at Mentangai and the upgrading of the road to Katunjung, left bank of the Kapuas
- (River) mining and quarts sand quarries in the northern part of Block E

The Barito Selatan and Kapuas districts need to coordinate, as the management of the unit is based on eco-hydrological landscape requirements for peat land management.

(i) Peat land conservation

In Block E, especially the Mawas area with its reasonably preserved forests, the first priority is on the prevention of logging and the blocking of old logging canals. In Block A, with its degraded forests, the first priority is on fire prevention, as well as canal blocking.

Canal blocking in itself will not result in the hydrological restoration of the peat lands, but must be implemented as part of a broader strategy for rehabilitation and re-greening. Further trials and research is required to support the design of an overall strategy.

Of equal high priority is the hydrology of the SPI canal and the impact of the canal on the drainage of the peat lands, which is expected to be considerable. Mitigation will require water control, and access should be restricted to discourage illegal loggers.

Another priority is the physical separation of the conservation units and the development units e.g. the at the border with the Lamunti scheme, to minimize the impact of drainage from development on the peat lands, and for which hydraulic modelling should provide guidance.

The oil palm plantation on the peat lands in Block A should be reviewed, but it should also be encouraged that, in general, adequate standards for the wise use of peat lands are implemented in the unit. Exit strategies should be designed for plantations and other developments.

(ii) Agricultural development

The Dayak communities in the Management Unit expect to benefit from the improvement of the *handil* canals to provide better drainage, and better access to the fields. A design review of the canal system is required, in combination with measures to minimize the impact of drainage on the peat lands. As the farmers are engaged in activities in the peat lands and use the canals for access, community involvement in canal blocking is essential.

Key information gaps

The following data need to be collected and /or finalized:

- Extent and depth of peat lands the north of the SPI canal
- Topography of ground levels, peat layers, and underlying mineral soil stratum
- Hydrology of rivers, peat, and transition zones
- Hydrology of the SPI canal and interaction with upstream and downstream peat lands
- Comprehensive strategy for the hydrological rehabilitation of peat lands
- Hydrological separation of cultivation and peat areas
- Land suitability

Recommendations

Table 18 summarizes the main recommendations for land and water management interventions in the Management Unit.

Table 18 - LWM approach Management Unit I – Block A / E

Objective	Intervention		
	Urgent	Short-term	Medium to long-term
Planning	▪ Hydrological Plan: boundary conditions ▪ Development Plan: conservation, agriculture in adapted management zone ▪ System planning and re-design		
Conservation	▪ Data collection ▪ Logging / fire prevention ▪ Canal blocking Block A ▪ Canal blocking Block E ▪ Oil palm Block A review ▪ Modelling of SPI canal ▪ No new development	▪ Block A: review access ▪ Block E: review mining ▪ Water control SPI canal ▪ Research and field trials ▪ Monitoring water levels and soil and water quality ▪ Design restoration strategy	▪ Hydrological restoration and re-greening of degraded peat lands ▪ Wise use of peat lands
Limited agricultural development	▪ Data collection ▪ Modelling separation development / conservation: oilpalm, handil, transmigration: Lamunti / Block A peat ▪ No new development	▪ Separation of development from conservation ▪ Monitoring water levels and soil and water quality ▪ Land and water management strategy for Dayak settlements ▪ Improvement of handil systems, access to fields	▪ Socio-economic development in conservation and adapted management zones

4.1.2 Management unit II - Deep peat Block B / E

Management Unit II is located in the north-western part of the EMRP, see Figure 10. The unit borders on the Kapuas and Kahayan rivers in the East and West, the Palangkaraya - Buntok road in the North, and Anjir Kelampan in the South. Administratively the area falls under the jurisdiction of Palangkaraya, Pulang Pisau and Kapuas districts.

Current Land and Water Management

The unit is defined by the hydrological landscape associated with the deep peat area in the northern part of Block B and the western part of Block E, see Figure 5. As in Management Unit I, the peat overlies thick white quartz sand formations.

The river hydrology of this unit is similarly complex to that in the Management I, as it is located in the transition from non-tidal to tidal, see Figure 2. The ex-PLG SPI canal is the divide between Blocks B and E. The impact of the canal on surrounding peat lands needs further study and modelling, but is considered considerable.

In Block B, a start was made during the PLG with the construction of main and lower order canals, but construction was halted, and the canal grid is thus less dense than in Block A. Forests have been logged, but dense forest is still to be found in Block E and in the western part of Block B. Fires and deforestation occurs mainly along the ex-PLG main canals. A large area along the SPI canal seems to have already been affected by fires.

Apart from the Dayak settlements along the river banks, with their traditional handil canals, Dayak and Banjar communities also settled along Anjir Kelapan already in the 1950s. Two small ex-transmigration sites are located along the Anjir and the left bank of the Kahayan. Large-scale oil palm plantations in the eastern part of Block B appear to have become operational as of 2007. In the northern part of Block E, quarts sand mining takes place.

Main Land and Water Management Issues

Because of the deep peat, the limited potential of the area, and the indigenous Dayak settlements along the river, the carrying capacity of the unit is minimal, which is thus considered not suitable for new development and transmigration.

Dayak communities make increasingly use of the access into the peat lands provided by the PLG infrastructure. Conservation of the peat lands, canal blocking and water management must go hand-in-hand with livelihood improvement of these communities.

Oil palm plantations in the medium to deep peat areas of Block B will increase drainage of the peat lands. Expansion of oil palm areas in the peat lands will also result in the degradation of the few remaining peat land forests in the area.

Other aspects that will have an impact on the land and water management are:

- Newly planned transmigration in Block B (Inpres 2/2007)
- Improved access to Block B from the Mentengai-Katujung road in Block A
- Quarts sand quarries in the northern part of Block E

The Palangkaraya, Pulang Pisau and Kapuas districts need to coordinate, as the management of the unit is based on eco-hydrological landscape requirements for peat land management.

(i) Peat land conservation

The most urgent intervention in Block E, which is still largely covered by forests in a relative good condition, is to prevent illegal logging and to close (logging) canals.

In Block B of the unit, which is only partly covered by forests, fire prevention is first priority, next to the blocking of canals. As in Management Unit I – Block A /E, study is required into the hydrology of the SPI canal and better water control to reduce drainage of Block E.

The oil palm permits on the deep peat lands in Block B should be reviewed, but it should in general be encouraged that adequate standards for the wise use of peat lands are implemented.

Another priority is the physical separation of the conservation and the agricultural development areas e.g. the settlements along the Anjir Kelapan and the oil palm plantations, to minimize the impact of drainage from development on the peat lands.

(ii) Agricultural development

The Dayak communities in the unit expect to benefit from the improvement of the *handil* canals to provide better drainage, and better access to the fields. A design review of the canal system is required, in combination with measures to minimize the impact of drainage on the peat lands. As the farmers are engaged in activities in the peat lands and use the canals for access, community involvement in canal blocking and restoration is essential.

Under the Inpres 2 2007, new transmigration is planned along the Kahayan River. Plantation licenses overlap with the designated conservation and adaptive management zones, and at least one plantation is active in the medium deep and very deep peat zone

Key information gaps

The following data need to be collected and /or finalized:

- Extent and depth of peat lands the north of the SPI canal
- Topography of ground levels, peat layers, and underlying mineral soil stratum
- Hydrology of rivers, peat and transition zones
- Hydrology of the SPI canal and interaction with upstream and downstream peat lands
- Comprehensive techniques for the hydrological storation of peat lands
- Hydrological separation of cultivation and peat areas
- Land suitability

Recommendations

Table 19 summarizes main recommendations on proposed land and water management actions in the conservation in the unit:

Table 19 - LWM approach Management Unit II – Block B / E

Objective	Intervention		
	Urgent	Short-term	Medium to long-term
Planning	▪ Hydrological Plan: boundary conditions ▪ Development Plan: conservation, agriculture in adapted management zone ▪ System planning and re-design		
Conservation	▪ Data collection ▪ Logging / fire prevention ▪ Canal blocking Block B ▪ Canal blocking Block E ▪ Oil palm Block B review ▪ Modelling of SPI canal ▪ No new development	▪ Block B: access review ▪ Block E: mining review ▪ Water control SPI canal ▪ Research and field trials ▪ Monitoring water levels and soil and water quality ▪ Design restoration strategy	▪ Hydrological restoration and re-greening of degraded peat lands ▪ Wise use of peat lands
Limited agricultural development	▪ Data collection ▪ Modelling separation development / conservation: oilpalm, handil, transmigration ▪ No new development	▪ Separation of development from conservation ▪ Monitoring water levels and soil and water quality ▪ Design land and water management strategy for settlements ▪ Improvement of drainage systems, access to fields	▪ Socio-economic development in conservation and adapted management zones

4.1.3 Management Unit III - Deep peat Block C

Management Unit III is located in the western part of the EMRP, see Figure 10. The unit borders on the Kahayan and Sebanggau rivers in the East and West, and the coastal zone in the South. The area falls under the jurisdiction of Palangkaraya and Pulang Pisau districts.

The main road Palangkaraya – Kuala Kapuas runs along the Kahayan river till Pulang Pisau, and new houses are being constructed in Block C in the peat areas along that road.

Current Land and Water Management

The unit is defined by the hydrological landscape associated with the deep peat area South of Palangkaraya in Block C, see Figure 5. The Sebanggau river is non-tidal upstream. The Kahayan river has a reduced tidal regime during the wet season near Palangkaraya, but is otherwise fully tidal, see also Figure 2.

Primary canals were constructed during the PLG, which cross the peat dome in North-South and East-West direction, aggravating an already dire condition of the peat land and peat forests. This is by far the most degraded unit of the 3 conservation units, due to access, development along the Kahayan river, and proximity to Palangkaraya and Banjarmasin.

Small and scattered pockets of peat forest remain along the Sebangau river and in a more sizeable patch in Block C North. The PLG canals created better access to

Sebangau, and further development of the Block C would unavoidably have a negative impact on the park.

Development is mostly located in the Limited Development (Adapted Management) Zone along the Kahayan river, and to some extend into the deep peat areas of the Conservation Zone. Increasingly new development is started in the peat lands, including large-scale plantations for oil palm.

CIMTROP - In the northern part of the unit, CIMTROP has been active in blocking of the PLG canals, and recently started trials with fish ponds in deep peat soils.

Dayak settlements - Traditional Dayak settlements located along the rivers in the northern part of Block C. These communities are extending their canal systems into the deep peat areas, usually to grow rubber, contributing to drainage of the peat lands. Wet season flooding of low areas along the Kahayan river is reported for periods of several days during reduced tidal conditions in the wet season. New fire policies forbid burning of the fields, but farmers can often not afford alternative land preparation and occasionally give up on (rice) farming.

Ex-transmigration - The southern part of Block C has along the Kahayan river a number of transmigration schemes constructed in the 1970/80s. The schemes extend into the deep peat areas. Due to the drainage and tidal supply limitations of the dead-ended fork system, the soil and water quality is poor, resulting in very low (rice) yields. During a field visit to Maliku it was observed that where older infrastructure is connected to the North-South main PLG canal, an additional flow of acid water from the peat dome will enter the scheme. Whereas when the scheme is connected to the East-West oriented PLG canals (linked to the Kahayan), soil and water quality improves dramatically as do rice yields, due to improved drainage and water circulation. Shallow tidal flooding occurs in a small zone directly along the Kahayan river.

Banjar settlements - Banjarese villages and their traditional handil systems are located near the coast along the Kahayan river in the most southern part of Block C. Their canals are also often linked to the ex-PLG canals. Mostly coconut is grown here, while the communities have rice fields along the left bank of the Kahayan river, in Block D. Tidal flooding occurs directly along the Kahayan river, and lower areas more inland. It was observed in the field that tidal flooding here leads to scouring of canals and erosion of the fields.

Oil palm - Large scale oil palm development has started in the deep peat areas West of Maliku, where the PLG main canal system connects to the ex-transmigration schemes.

Main Land and Water Management Issues

Due to the deep peat area with a relative narrow strip of other soils along the rivers, and the presence and rights of indigenous Dayak, traditional Banjar and ex-transmigration settlements, Block C is not suitable for large scale development and transmigration.

The impact of canal blockings needs to be further investigated, but land and water management in the severely degraded peat areas should urgently focus on fire control and fire prevention, while a more comprehensive strategy for the hydrological rehabilitation and re-greening is being considered. Peat land rehabilitation in Block C needs a different approach than in the other Management Units, due to the scale of area and interventions required. Strictly guided plantation development should be considered as one of the options, as this leads to better fire management, water control, and tree cover.

Improvement of conditions in the existing agricultural areas, including those of the older transmigration settlements need to take into account that improved drainage, being the key to higher agricultural productivity, will have a serious impact on the hydrology of the peat dome. One of the major land and water management objectives in this unit is the hydrological separation of peat lands from agricultural development.

Under the Inpres 2 2007, new transmigration is planned along the Kahayan river and in the deep peat along the Sebanggau river. Plantation licenses overlap with the designated conservation and adaptive management zones, and at least one plantation is active in the medium deep to very deep peat zone

The Palangkaraya, Pulang Pisau and Kapuas districts need to coordinate, as the management of the unit is based on eco-hydrological landscape requirements for peat land management.

(i) Peat land conservation

Most of Block C is severely deforested and fire-prone, and the unit is also the most developed of the three peat land units. The prevention of fires and logging should have first priority. Canal blockings may be helpful to prevent further degradation and lowering of the drainage base, especially in the somewhat more densely drained and populated areas around the CIMTROP area in the North and around the Pankoh scheme in the South, but further research and testing is required before large scale duplication of canal blocks is recommended.

Measures for water control in the larger North-South PLG canal should be combined with the separation of the cultivation areas from the peat lands, and the hydraulic infrastructure for oil palm, and should be part of the overall hydrological plan for the management unit.

Research and testing is also required for the hydrological separation of development from the peat land conservation areas, especially around the ex-transmigration schemes near Pangkoh, to minimize the impact of drainage from development on the peat lands, but also drainage poor quality water into the agricultural areas.

The oil palm permits in the medium to deep peat lands of Block C should be reviewed, and, in general, it is encouraged that criteria for the wise use of peat lands are implemented.

(ii) Agricultural development

The hydraulic infrastructure of the ex-transmigration schemes requires a major re-design, to improve flushing and leaching for the improvement of the soil and water quality. Measures are also required to minimize the influence of drainage on the peat dome, and the inflow of poor quality water from the main PLG canal.

Banjar and Dayak canal infrastructure will require minor improvements as the system usually already suits local conditions. The construction of new canals into the peat dome should be avoided and properly regulated. Along the Kahayan river flood protection is required, for which further study is needed of the hydrological boundary conditions in relation to the topography. Salinity intrusion is not considered a constraint, but severely affects drinking water quality, especially in the Banjar areas.

Key information gaps

The following data need to be collected and /or finalized:

- Topography of ground levels, peat layers, and underlying mineral soil stratum
- Hydrology of rivers, peat, large canals, and transition zones
- Comprehensive strategy for the hydrological rehabilitation of peat lands
- Comprehensive strategy for large scale peat land rehabilitation
- Hydrological separation of cultivation and peat areas near Pangkoh / Maliku
- Scheme re-designs, water management, and land use for adapted management
- Land suitability

Recommendations

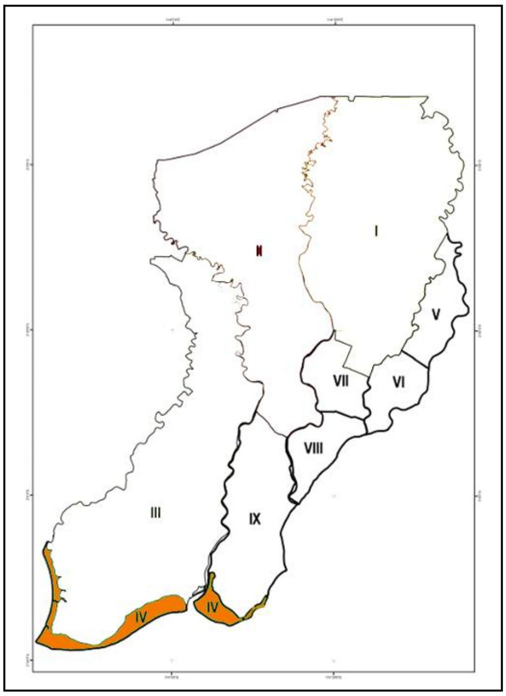
Table 20 summarizes main recommendations on proposed land and water management actions in the conservation Management Unit III – Block C.

Table 20 - Approach Management Unit III – Block C

Objective	Intervention		
	Urgent	Short-term	Medium to long-term
Planning	▪ Hydrological Plan: boundary conditions ▪ Development Plan: conservation, agriculture in adapted management zone ▪ System planning and re-design		
Conservation	▪ Data collection ▪ Logging / fire prevention ▪ Canal blocking Block C North and Block C South ▪ Oil palm Block C South No new development	▪ Block B: access review ▪ Block E: mining review ▪ Water control SPI canal ▪ Research and field trials ▪ Monitoring water levels and soil and water quality ▪ Design restoration strategy	▪ Hydrological restoration and re-greening of degraded peat lands ▪ Wise use of peat lands
Limited agricultural development	▪ Data collection ▪ Modelling separation development/conservation: handil, oilpalm, transmigration ▪ No new development	▪ Separation of development from conservation ▪ Monitoring water levels and soil and water quality ▪ Design land and water management strategy for settlements ▪ Improvement of drainage systems, access to fields	▪ Socio-economic development in conservation and adapted management zones

4.2 Coastal Management Unit

The Coastal Zone Management Unit forms the coastal area between the Sebanggau, Kahayan and Kapuas rivers, in the most southern part of the EMRP. The hydrology is first all determined by the sea, and partly by the hinterland.



The coastal area is treated as a separate zone due to its characteristics, and overriding importance for protection of the hinterlands. This is all the more relevant in view of climate change and a predicted sea level rise. The coastal zone is the first line of defence.

As a first step, a development plan should be prepared for the Management Unit on the basis of detailed hydrological assessments, i.e. a hydrological plan, and other land characteristics, socio-economic development criteria, and community aspirations.

Table 21shows the major land and water management characteristics of the conservation Management Units in the EMRP:

Table 21 – Characteristics of the Coastal Zone Management Units in the EMRP[25]

Characteristics	Management Unit IV Coastal Zone
Macro zone / Policy objective	▪ Conservation ▪ Adapted management
Area	▪ 40,000 ha
Land use	▪ Type 1 - Existing forest / eco-systems, greenbelts ▪ Type 2 - Degraded forest / eco-systems, greenbelts ▪ Type 11 – Tambak
Farming systems	▪ Tambaks / fisheries
Boundary condition of rivers	▪ Zone I: Tidal ▪ Saline > 2 months
Flood classes	▪ Tidal
Hydro-topography	▪ Class A-C
Soils	▪ Mineral ▪ Sandy beach ridges
Hydraulic infrastructure	▪ Community fisheries and private sector tambak
O&M	▪ No O&M organization

[25] Based on currently available information. Additional surveys required

4.2.1 Management Unit IV – Coastal zone – Block C / D

Management Unit IV forms the coastal area between the Sebangau, Kahayan Rivers and Kapuas rivers in the most southern part of the EMRP. Administratively the area falls under the jurisdiction of the Pulang Pisau and Kapuas districts.

Current land and water management

The coastal zone is characterized by mangrove and sand ridges, and deep flooded areas beyond the zone due to impeded drainage. Between the Sebanggau and Kahayan rivers, the mangrove is very much degraded and large parts have been transformed into tambak. Between the Kahayan and the Kapuas the mangrove is still in good condition.

Main land and water management issues

The area West of the Kahayan river consists of largely degraded mangrove and tambak systems. The area East of the Kahayan river is targeted for tambak development, even though this contains the last stretch of relatively unspoilt mangrove forest in the EMRP. Development will further degrade the protective function of the coast line, something that eventually will threaten the agricultural development in the EMRP.

Key information gaps

The following data need to be collected and /or finalized:

- Status of mangrove forests
- Hydrology and lay-out of tambak systems

Recommendations

Management of the coastal zone should take into account the effects of climate change, where a sea level rise and more intense storm systems are predicted, which will increase erosion of the coast line. Measures are to be taken to restore the protective function of the coast line.

The forested mangrove areas between the Kapuas and Kahayan rivers need protection, and further development (i.e. road construction and tambaks) should be halted. Degarde mangrove should be rehabilitated and the coastal protective function should be restored.

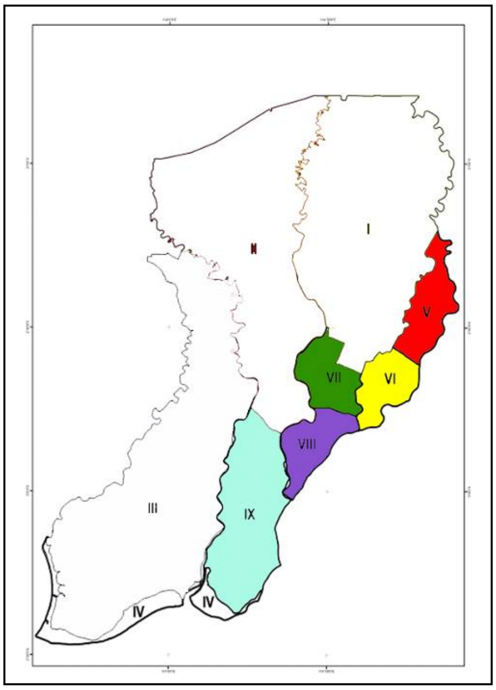
The area is only suitable for very limited tambak development, and no new development should be allowed. Development should thus only be allowed for tambak systems that are already located in the area, that are not a direct threat to the hydrological and protective function of the coastal zone, operate successfully, and have a proper water management system in place. Other tambak systems should where possible be returned to nature, as part of the conservation and restoration strategy.

Table 22 summarizes main recommendations on proposed land and water management actions in the conservation Management Unit IV – Block C / D.

Table 22 - Approach Management Unit IV – Block C / D

Objective	Intervention		
	Urgent	**Short-term**	**Medium to long-term**
Planning	▪ Hydrological Plan: boundary conditions, coastal protection function ▪ Development Plan: conservation, limited agricultural development		
Conservation	▪ Data collection ▪ Review of tambak systems ▪ No new development	▪ Design restoration strategy	▪ Restoration and re-greening of degraded mangrove areas ▪ Restore coastal protection function
Limited agricultural development	▪ Data collection ▪ Review of tambak systems ▪ No new development	▪ Design land and water management strategy for tambaks to minimize impact on coastal zone	▪ Socio-economic development

4.3 Development Management Units



The five (5) Development Management Units in the EMRP are the mineral soil and shallow peat areas located East of the line Kahayan River – Anjir Kelampan - Kapuas River - Block A PLG canal - Mengkatip River, and therefore hydrological independent from the peat land areas. The units cover the southern part of Block A and all of Block D.

In Block A the Barito and Mengkatip rivers are semi to non-tidal, which results in deep, long duration flooding (up to 6 months) during the wet season. The rivers are fully tidal in Block D, where are shallow, frequent, and of usually short duration. Salinity intrusion during the dry season may reach up to the northern par of Block D.

With the exception of the ex-PLG sites in Block A, this area has been largely developed for over a century, being part of the influence sphere of Banjarmasin, with which it is connected from a socio-economic point of view, but also through the river-to-river transportation canals, already constructed during the Dutch-Indies government.

Traditional *handil* settlements are located along the rivers, with mainly indigenous Dayak in the northern parts of the EMRP, especially along the Kapuas and Mengkatip rivers in Block A and mainly Banjar in the southern parts up until the coast line. origine. Transmigration took place in the 1930/50s, along the Anjir Kelampan, during the 1970/80s in the centre of Block D, and during the 1990s in Block A.

As a first step, a development plan should be prepared for the Management Units on the basis of detailed hydrological assessments, i.e. a hydrological plan, other land characteristics, socio-economic development criteria, and community aspirations.

Table 23 – Characteristics of the Development Management Units in the EMRP[26]

Characteristics	Management Unit V Jenamas	Management Unit VI Dadahup	Management Unit VII Lamunti
Macro zone / Policy objective	▪ Development	▪ Development	▪ Development
Area	▪ 46,000 ha	▪ 39,500 ha	▪ 41,500 ha
Land utilisation	▪ Type 3 -Traditional Dayak / mixed settlements ▪ Type 9 - Ex-PLG transmigration schemes ▪ Kerbau rawa	▪ Type 3 -Traditional Dayak / mixed settlements ▪ Type 8 - Ex-PLG transmigration schemes	▪ Type 3 -Traditional Dayak / mixed settlements ▪ Type 7 - Ex-PLG transmigration schemes
Boundary conditions	▪ Zone III: non-tidal WS ▪ Zone IV: non-tidal WS/DS ▪ Non-saline	▪ Zone II: reduced tidal WS ▪ Zone III: non-tidal WS ▪ Non-saline	▪ Zone II: reduced tidal WS ▪ Non-saline
Flood class	▪ Non-tidal ▪ Tidal DS	▪ Non-tidal ▪ Tidal WS/DS	▪ Non-tidal ▪ Tidal WS/DS
Hydro-topography	▪ Non-tidal	▪ Non-tidal ▪ Class B-C	▪ Non-tidal ▪ Class C-D
Soils	▪ Mineral ▪ Shallow peat	▪ Mineral ▪ Shallow peat	▪ Mineral ▪ Shallow peat
Hydraulic infrastructure	▪ Ex-PLG 1990s	▪ Handil ▪ Ex-PLG 1990s	▪ Handil ▪ Ex-PLG 1990s
O&M	▪ No O&M organization	▪ No O&M organization	▪ No O&M organization
Land and water management issues	▪ Non-tidal flooding, severe ▪ Traditional land use ▪ Kerbau rawa ▪ No settlements ▪ O&M staff shortages	▪ Non-tidal flooding ▪ Lahan tidur ▪ Partly settled / developed ▪ Incomplete ex-PLG infrastructure, poor drainage ▪ Inter-connected schemes ▪ Interflow ▪ Poor soil and water quality ▪ Poor land preparation ▪ O&M staff shortages	▪ Non-tidal flooding, limited ▪ Lahan tidur ▪ Incomplete ex-PLG infrastructure, poor drainage ▪ Partly settled / developed ▪ Inter-connected schemes ▪ Interflow ▪ Poor soil and water quality ▪ Poor land preparation ▪ O&M staff shortages

[26] Additional surveys and modelling required

Table 24 – Characteristics of the Development Management Units in the EMRP[27]

Characteristics	Management Unit VIII Handil Rakyat	Management Unit IX Block D	
Macro zone / Policy objective	▪ Development	▪ Development	
Area	▪ 41,000 ha	▪ 125,500 ha	
Land utilisation	▪ Type 2 - Degraded forest / eco-systems, greenbelts ▪ Type 4 - Traditional Banjar / mixed settlements ▪ Type 5 - Older transmigration sites	▪ Type 2 - Degraded forest / eco-systems, greenbelts ▪ Type 3 -Traditional Dayak / mixed settlements ▪ Type 4 - Traditional Banjar / mixed settlements ▪ Type 5 - Older transmigration sites ▪ Type 6 - Older transmigration sites ▪	
Boundary conditions	▪ Zone I: tidal WS/DS ▪ Non-saline ▪ Saline > 2 months	▪ Zone I: tidal WS/DS ▪ Saline > 2 months	
Flood class	▪ Tidal WS/DS ▪ Non-tidal WS	▪ Tidal WS/DS	
Hydro-topography	▪ Class B-C	▪ Class A-B (South) ▪ Class B-C (North)	
Soils	▪ Mineral ▪ Shallow peat	▪ Mineral ▪ Shallow peat	
Hydraulic infrastructure	▪ Handil ▪ Ex-transmigration 1970/80s	▪ Handil ▪ Ex-transmigration 1930s ▪ Ex-transmigration 1970/80s	
O&M	▪ Pengamat	▪ Pengamat	
Water management issues	▪ Non-tidal flooding, limited ▪ Poor soil and water quality ▪ Poor drainage ▪ Poor hydraulic design ▪ Poor land preparation ▪ Lahan tidur ▪ Inter-connected schemes ▪ O&M staff shortages	▪ Tidal flooding, limited ▪ Lahan tidur ▪ Poor hydraulic design ▪ Inter-connected schemes ▪ Interflow ▪ Poor soil and water quality ▪ Salinity intrusion ▪ Poor land preparation ▪ O&M staff shortages	

4.3.1 Management Unit V – Block A Jenamas

Management Unit V is located in the north-western part of the PLG area, South of Block E, see Figure 10. The unit borders on the Barito river in the North and East and the Mengkatip river in the West. The scheme borders in the South on the Dadahup scheme, with which it shares the main hydraulic infrastructure. Administratively the unit falls under the jurisdiction of the Barito Selatan district.

[27] Additional surveys and modelling required

Current Land and Water Management

The hydrology is complex as the unit is located in the transition from the non-tidal to the tidal zone, see also Figure 2. The area is basically a non-tidal floodplain (rawa lebak). Severe and prolongued flooding (up to 6 months) occurs in the larger part of Jenamas, to some extend from the Mengkatip river, but mostly from the Barito, which is non-tidal in the wet season here. The eastern part of the unit, along the Barito river, a large back swamp system, is the habitat for kerbau rawa. The area was part of the ex-PLG project, and most of the main hydraulic infrastructure was completed before the cancellation of the project. However, the area was not settled by transmigrants. Traditional settlements are located along the Mengkatip and Barito rivers, with some traditional *handil* canals along the Mengkatip river.

According to the SID consultants (PT Bina Karya 2007), only very shallow peat layers (<0.50 m) are present, while the depth to acid-sulphate layers is mostly > 1.50 m, with areas of more shallow (0.50-1.00 m) acid-sulphate layers in the centre of the unit. Land use consists mainly of (degraded) gelam forests, some mixed tree crops, fisheries and kerbau rawa. The government of Barito Selatan is currently promoting the extension of kerbau rawa activities in the area, which results in an influx from outside communities.

The Barito Selatan administration is currently supporting the expansion of the kerbau rawa activities in the area. Canal embankments are used for sheltering the kerbau rawa. The Barito Selatan administration decided in 2008 that the area should not be targeted for transmigration, but instead for development and support of local communities.

Main Land and Water Management Issues

Prolonged, deep flooding makes this area unsuitable for large-scale agriculture settlement, unless very high investments for flood protection and drainage requirements (e.g. pumped drainage) are considered. The area is targeted for new transmigration under the Inpres 2/2007. Transforming the area and improving conditions for transmigration and agriculture is very costly with a low probability of success.

Key Information Gaps

The following data need to be collected and /or finalized:

- Topography
- Hydrology of rivers and back swamps
- Modelling of hydraulic infrastructure, water control
- Comprehensive strategy for community-based development
- Hydrological separation of Jenamas and Dadhup (floods)
- Land suitability

Recommendations

Rehabilitation and protection of the greenbelt areas is required to protect the inland areas from river floods. This is all the more important regarding the predicted effects of climate change.

Traditional land use options are preferred over large-scale new settlement, i.e. those closest related to current land use by the communities, such as beje fisheries, kerbau rawa, and forestry. Steps towards improving the local livelihoods can concentrate on the improvement of the fishery system and tree crop systems on the higher areas (levees).

Beje fisheries can be intensified and extensified, for which parts of the existing hydraulic infrastructure can be utilized, a.o. to maintain a proper water quality, which would involve the regulation of water flows from the Barito river through the scheme and into Dadahup. The water quality of the Mengkatip river is considered less suitable.

Further study is required as to what extent the existing and defunct hydraulic ex-PLG infrastructure can play a part in the development of traditional fisheries. This should be done in close coordination with the development of the Dadahup area.

Table 25 summarizes the main recommendations for land and water management interventions in the Management Unit.

Table 25 - Approach Management Unit V – Block A Jenamas

Objective	Intervention		
	Urgent	Short-term	Medium to long-term
Planning	▪ Hydrological Plan: boundary conditions ▪ Development Plan: conservation, agriculture ▪ System planning and re-design		
Conservation	▪ Data collection	▪ Greenbelt ▪ Kebau rawa habitat	▪ Not applicable
Agricultural development	▪ Data collection ▪ No new transmigration	▪ Modelling flooding ▪ Modelling hydraulic infrastructure (fisheries) ▪ Monitoring water levels and soil and water quality ▪ Design land and water management strategy for local communities	▪ Socio-economic development of traditional communities

4.3.2 Management Unit VI – Block A Dadahup

Management Unit VI is located in the north-eastern part of the PLG area, South of Block E, see Figure 10. The unit borders on the Barito and Kapuas Murung rivers in the South and East, and the Mengkatip river in the West. The scheme borders in the North on the Jenamas area., with which it shares the main hydraulic infrastructure. Administratively the unit falls under the jurisdiction of the Barito Selatan and Kapuas districts.

Current Land and Water Management

The hydrology is complex as the unit is located in the transition from the non-tidal to the tidal zone, see also Figure 2. Severe flooding occurs in the northern part of Dadahup and along the Barito river. The area is also considered to have a lower topography. The area was part of the ex-PLG project, and, while most of the main canals were constructed, the infrastructure, including flood protection, was never completed. Public Works is currently addressing the flood problems in Dadahup, as part of the agricultural revitalisation of the EMRP.

The wetter conditions make this area more suitable for wetland rice, which is the major crop crop in the ex-PLG scheme. In demonstration units yields of up to 5 ton/ha are achieved. In farmer's fields the yields (of local rice varieties) are in the range of 1 to 2 ton/ha. Extension towards farmers is limited and no on-farm research is done. Experiments at the field station do not link to the needs of the local community. No O&M organizations are active in the area, but farmers were paid since 2005/2006 to maintain part of the tertiary canals.

The area was settled by transmigrants from Javanese and local origine, of which a considerable number again left (up to 40-50 %). This is related to the initial hardship, not uncommon for early swamp reclamation phases (and in this case aggravated by the unregulated flooding), but also to the background of local transmigrant settlers, who are often not familiar with wetland rice-based cropping systems.

It was reported from other parts of the EMRP, a.o. the Maliku area, that transmigrants, who failed in the deep peat areas of Block C, were re-settled in the Dadahup-Lamunti schemes. It was also reported that settlers of Banjarese origin were spontaneously moving into the area.

According to the SID consultants (PT Bina Karya 2007), only very shallow peat layers (<0.50 m) are present, while the depth to acid-sulphate layers is mostly > 1.50 m, with a limited area with more shallow (0.50 – 1.00 m) acid-sulphate layers in the centre of the unit. Land use consists of sawah and fallow lands in the transmigration areas of the swamp interior, with greenbelts and traditional cultivation along the river banks.

Main Land and Water Management Issues

Flooding from the Mengkatip and Barito river is the most serious limiting factor to agricultural development in this unit. Under (temporary) non-tidal conditions in the river in the wet season there will also be periods that drainage is restricted.

While measures are taken to mitigate flooding and improve the drainage, there is in fact not sufficient information (hydrology and topography) available yet to prepare a system planning or detailed design. Sorting out the hydrology of the unit is the first step that is required to revitalise the unit. On-farm water management, including TAM, land preparation and mechanization, is not developed, for which it is required that the main hydraulic infrastructure is completed and flood control is in place.

The limited number of farmers is a constraint for the agricultural development in this area, as a compact approach is required to overcome soil and water quality issues associated with land reclamation and soil ripening, and to achieve an effective water control and pest management. The large area of fallow land (lahan tidur) is a source for acidity, toxics and pests.

Since the area is still under the responsibility of the Department of Transmigration, no O&M organization has been set up yet, even though this is essential for support to the farmers, extension, and the build up of knowledge networks.

During settlement conflicts with local communities ensued, often regarding land rights. When settlers left the project area they either used the land certificate as collateral to borrow money from local villagers for the return trip, or simply took the land certificate with them. In any case, new development in Dadahup can start only when the land rights issues are settled.

The Barito Selatan and Kapuas districts need to coordinate, as the socio-economic and hydrological relations in the management unit are closely related.

Key Information Gaps

The following data need to be collected and /or finalized:

- Topography
- Hydrology of rivers
- Modelling of hydraulic infrastructure, flood and water control
- Comprehensive development approach for local and transmigration communities
- Hydrological separation of Jenamas and Dadahup (floods)
- Alternatively a connection with Jenamas for fisheries and flushing / irrigation
- Land right status
- Land suitability

Recommendations

Rehabilitation and protection of the greenbelt areas is required to protect the inland areas from river floods. This is all the more important regarding the predicted effects of climate change.

The hydrology of the Dadahup unit, must be assessed in detail, and modelled carefully, in relation to the topography before providing recommendations for detailed design of flood protection, drainage infrastructure and land and water management.

An urgent system planning and re-design of Dadahup is required. On-farm water management should be promoted once the main system is completed, but for this the involvement of O&M organizations and other extension workers is essential, preferably in combination with test-farms, field schools and training facilities with participation of the farmers. It is this strongly recommend to set up the O&M organizations and position staff and facilities in the field.

Another high priority is to resolve outstanding land right issues with local communities before a refill with new transmigrants will start, as considered necessary to re-start the agricultural development in the unit. A combined socio-economic development strategy for both the local and transmigrant communities is required to avoid socio-ethnic issues to re-occur.

Table 26 summarizes the main recommendations for land and water management interventions in the Management Unit.

Table 26 - Approach Management Unit VI – Block A Dadahup

<table>
<tr><th rowspan="2">Objective</th><th colspan="3">Intervention</th></tr>
<tr><th>Urgent</th><th>Short-term</th><th>Medium to long-term</th></tr>
<tr><td>Planning</td><td colspan="3">▪ Hydrological Plan: boundary conditions
▪ Development Plan: conservation, agriculture
▪ System planning and re-design</td></tr>
<tr><td>Conservation</td><td>▪ Data collection</td><td>▪ Greenbelt</td><td>▪ Not applicable</td></tr>
<tr><td>Agricultural development</td><td>▪ Data collection
▪ Land right issues</td><td>▪ Modelling flooding
▪ Modelling hydraulic infrastructure
▪ Re-design of hydraulic infrastructure incl flood protection measures
▪ Monitoring water levels and soil and water quality
▪ Design land and water management strategy for transmigrant and local communities
▪ Trials, demonstations, field schools, farm research
▪ Set up O&M organization
▪ On-farm development
▪ New settlement (re-fill)</td><td>▪ Socio-economic development
▪ Optimisation of agricultural development</td></tr>
</table>

4.3.3 Management Unit VII – Lamunti

Management Unit VII is located in the north-western part of the PLG area, South of Block E, see Figure 10. The unit borders on the Kapuas and Mentengai rivers in the West, and the Mengkatip river in the East. The scheme borders in the North on the Block A / E deep. Administratively the unit falls under the jurisdiction of the Kapuas district.

Current Land and Water Management

Traditional Dayak handil systems (rubber) are located along the river banks. The area was also part of the ex-PLG project, and, while most of the main canals were constructed, the infrastructure, including flood protection, was never completed. Water control structures are mostly non-operational or have been demolished. The small-scale handil systems and the large-scale hydraulic network of the ex-PLG site have become connected over the years.

The area was settled by transmigrants from Javanese and local origine, of which a considerable number again left (up to 40-50 %). This is related to the initial hardship, not uncommon for early swamp reclamation phases, but also to the background of local transmigrant settlers, who are often not familiar with wetland rice-based cropping systems. Oil palm licenses cover a large part of the Lamunti scheme, while at least one firm is active in the border area with the Block A / E deep peat lands.

The area is considered to have a higher topography than Dadahup, and also has a more favourable hydrology, as the Kapuas is largely tidal. Some flooding from the Mengkatip river is reported in the north-eastern part of Lamunti. The area is suitable for dry land and tree crops including padi gunung (dry land rice) with appropriate land and water management. The agricultural research station moved its focus to other crops i.e. vegetables, maize and soya. No O&M organizations are active in the area.

During initial land clearing, many tree trunks were levelled into the surface, causing irregular field levels and problems with land preparation, Ash and lime are used by the farmers to counter the acidity in the area due to lack of drainage and water circulation. New regulations on burning have repercussions for these farmers as they lack other means for land preparation. Many farmers grow rice in plots outside the scheme, nearer to the river, where land and water management conditions are more favourable, and grow fruit trees near the homesteads

According to the SID consultants (PT Bina Karya 2007), only very shallow peat layers (<0.50 m) are present, while the depth to acid-sulphate layers is mostly > 1.50 m, with a limited area with more shallow (0.50 – 1.00 m) acid-sulphate layers in the centre of the unit. Land use consists of sawah and fallow lands in the transmigration areas of the swamp interior, with greenbelts and traditional cultivation along the river banks.

Main Land and Water Management issues

Lack of water control, tertiary drainage systems and links to the tidal river, land rights and social-ethnic issues, as well as a scarce population are limiting factors for agricultural development in this unit. Land preparation and mechanization are other factors to be considered.

There is not sufficient information (hydrology and topography) available yet to prepare a system planning or detailed design. Sorting out the hydrology of the unit is the first step that is required to revitalise the unit. Improvement of the drainage and water circulation should have priority in the re-designs. On-farm water management is not developed, for which it is required that the main hydraulic infrastructure is completed, and O&M organizations set up.

The limited number of farmers is a constraint for the agricultural development in this area, as a compact approach is required to overcome soil and water quality issues associated with land reclamation and soil ripening, and to achieve an effective water control and pest management. The large area of fallow land (lahan tidur) is a source for acidity, toxics and pests.

Since the area is still under the responsibility of the Department of Transmigration, no O&M organization has been set up yet, even though this is essential for support to the farmers, extension, and the build up of knowledge networks.

During settlement conflicts with local communities ensued, often regarding land rights. When settlers left the project area they either used the land certificate as collateral to borrow money from local villagers for the return trip, or simply took the land certificate with them. In any case, new development in Lamunti can start only when the land rights issues are settled.

Key information Gaps

The following data need to be collected and /or finalized:

- Topography
- Hydrology of rivers
- Modelling of hydraulic infrastructure, flood and water control
- Comprehensive development approach for local and transmigration communities
- Land right status
- Land suitability

Recommendations

Rehabilitation and protection of the greenbelt areas is required to protect the inland areas from river floods. This is all the more important regarding the predicted effects of climate change.

The hydrology of the Dadahup unit, must be assessed in detail, and modelled carefully, in relation to the topography before providing recommendations for detailed design of drainage infrastructure and land and water management.

An urgent system planning and re-design of Lamunti is required. On-farm water management should be promoted once the main system is completed, but for this the involvement of O&M organizations and other extension workers is essential, preferably in combination with test-farms, field schools and training facilities with participation of the farmers. It is thus strongly recommend to set up the O&M organizations and position staff and facilities in the field.

Another high priority is to resolve outstanding land right issues with local communities before a refill with new transmigrants will start, as considered necessary to re-start the agricultural development in the unit. A combined socio-economic development strategy for both the local and transmigrant communities is required to avoid socio-ethnic issues to re-occur.

Table 27 summarizes the main recommendations for land and water management interventions in the Management Unit.

Table 27 - Approach Management Unit VII– Block A Lamunti

<table>
<tr><th rowspan="2">Objective</th><th colspan="3">Intervention</th></tr>
<tr><th>Urgent</th><th>Short-term</th><th>Medium to long-term</th></tr>
<tr><td>Planning</td><td colspan="3">▪ Hydrological Plan: boundary conditions
▪ Development Plan: conservation, agriculture
▪ System planning and re-design</td></tr>
<tr><td>Conservation</td><td>▪ Data collection</td><td>▪ Greenbelt</td><td>▪ Not applicable</td></tr>
<tr><td>Agricultural development</td><td>▪ Data collection
▪ Land right issues</td><td>▪ Modelling drainage
▪ Modelling hydraulic infrastructure
▪ Re-design of hydraulic infrastructure incl flood protection measures
▪ Monitoring water levels and soil and water quality
▪ Design land and water management strategy for transmigrant and local communities
▪ Trials, demonstations, field schools, farm research
▪ Set up O&M organization
▪ On-farm development
▪ New settlement (re-fill)</td><td>▪ Socio-economic development
▪ Optimisation of agricultural development</td></tr>
</table>

4.3.4 Management Unit VIII - Handil Rakyat area

Management Unit VIII is located in the southern most part of Block A., see Figure 10. The unit borders on the Kapuas river in the West, the Kapuas Murung river in the East, and the Lamunti scheme in the North. Administratively the unit falls under the jurisdiction of the Kapuas district.

.Current Land and Water Management

Canal systems consist of the traditional dead-ended handil canals into the swamp interior. The land and water management system requires minor improvements. Over land access to agricultural fields is important to reduce crop loss and is also required for mechanization.

Main Land and Water Management Issues

There are no overriding land and water management issues. Further study is required into the social development and revitalisation.

Key Information Gaps

The following data need to be collected and /or finalized:
- Topography
- Hydrology of rivers
- Possible flooding
- Land suitability

Recommendations

Rehabilitation and protection of the greenbelt areas is required to protect the inland areas from river floods. This is all the more important regarding the predicted effects of climate change.

An integrated socio-economic development strategy is required, on the basis of which measures for the upgrading of the agriculture and the water management can be formulated.

Table 28 - Approach Management Unit VIII – Handil Rakyat

Objective	Intervention		
	Urgent	Short-term	Medium to long-term
Planning	▪ Hydrological Plan: boundary conditions ▪ Development Plan: conservation, agriculture ▪ System planning and re-design		
Conservation	▪ Data collection	▪ Greenbelt	▪ Not applicable
Agricultural development	▪ Data collection	▪ Monitoring water levels and soil and water quality ▪ Design land and water management strategy for local communities ▪ Trials, demonstrations, field schools, farm research ▪ Strengthening of O&M	▪ Socio-economic development ▪ Optimisation of agricultural development

4.3.5 Management Unit IX - Block D

Management Unit IX is located in the south-eastern part of the EMRP area, see Figure 10. The unit borders on the Kahayan river in the West, the Kapuas river in the East, the Anjir Kelampan in the North, and the coastal zone in the South. Administratively the unit falls under the jurisdiction of the Pulang Pisau and Kapuas district.

Current Land and Water Management

The area consists of handil systems (mainly Banjar) areas along the rivers, and older transmigration sites in the swamp interior and along the anjir canals. Gelam-purun associations in the swamp centre are designated as protection area. The block is located in the full tidal zone. It is a fairly low-lying area, especially nearer to the coast. Tidal irrigation is utilized in the traditional Banjar areas in the South, and areas near Terusan Jaya.

The area is crossed by a large anjir canal that connects the Kapuas and Kahayan rivers, that is part of the inland water way connection between Palangkaraya and Banjarmasin. During the 1990s a large North-South canal was constructed under the PLG, that is now connected to the sea. This canal connects in the North to both the Kahayan and Kapuas rivers.

The main crop in the southern part is wetland rice. Tidal irrigation is possible in some of the areas near Terusan Jaya. Salinity intrusion (> 3 months in the southern areas) is a limiting factor for double cropping. Other areas are developed for mixed agriculture, including rubber, along the Anjir Kelampan in the North. Oil palm plantations are operational in the Terusan Jaya area, with licenses covering other parts.

Although the area is suitable for high yielding varieties, the majority of farmers grow local rice varieties. High yielding varieties require proper water control and a good soil and water quality, not available yet. High inputs and labour requirements needed for the high yielding variety and the low returns are other main criteria to stick to the local varieties.

Drainability will depend on the tidal range and the topographical relation, and the design and condition of the hydraulic infrastructure. The design of the transmigration schemes follows the forked kolam system. A dead-ended system that is known to be inadequate for the leaching and flushing needed for the management of acid sulphate soils. Poor soil and water quality is one of the major limitations for agriculture in this unit.

Surveys in the northern area of Block D, i.e. Mintin and Mentaren, showed that the soils are a complex of pyrtitic and muck soils, often covered with a shallow to medium deep peat layer (PT Transka Dharma Konsultan 2007 and others).

According to the SID consultants (PT Sarana Bhuana Jaya 2007), who surveyed an area of 6,000 ha south of Terusan Jaya, only very shallow peat layers (<0.50 m) are present, while the depth to acid-sulphate layers is in some 60 % of the area between 0.50 to 1.00 m. While the area may be potentially suitable for tidal irrigation, the large peak flows involved will reduce the area that can practically be irrigated. Tidal flooding, now and in the future, salinity intrusion, and acidity are other factors to consider in this area.

Main Land and Water Management Issues

Even though the soils are mainly mineral, subsidence is likely to occur due to the continuing soil ripening processes. In view of the lower topography, in combination with a predicted sea level rise, future drainability and flood risk will be important criteria for the assessment of the agricultural suitability.

Lack of water control, poor drainage and water circulation and associated acidity and toxicities are important limiting factors for agricultural development in this unit. Land preparation and mechanization, i.e. on-farm land and water management are other factors to consider.

There is not sufficient information (hydrology and topography) available yet to prepare a system planning or detailed design. Sorting out the hydrology of the unit is the first step that is required to revitalise the unit. Improvement of the drainage and water circulation should have priority in the re-designs.

Key Information Gaps

The following data need to be collected and /or finalized:

- Topography
- Hydrology of rivers
- Drainability
- Modelling of hydraulic infrastructure (incl macro-level and ex-PLG canals
- Comprehensive development approach for local and transmigration communities
- Land suitability

Recommendations

Rehabilitation and protection of the greenbelt areas is required to protect the inland areas from river floods. This is all the more important regarding the predicted effects of climate change.

The unit should be developed in its entirety, and become the prime focus for revitalisation of the agriculture proposed under the Inpres 2/2007. This will only be successful when addressing the major soil and water management and socio-economic development issues at the delta (management unit) level. A combined development strategy for both the local and transmigrant communities is required, and new settlement is part of this strategy.

The macro-level hydrology of Block D, must be assessed in detail, and modelled carefully, in relation to the topography before providing recommendations for detailed design of drainage infrastructure and land and water management. It is expected that the PLG macro canals in the swamp interior can be used to improve the land and water management.

On-farm water management should be promoted, which will require the strengthening of O&M organizations and other extension workers, and the development of test-farms, field schools and training facilities with participation of the farmers.

Table 29 summarizes the main recommendations for land and water management interventions in the Management Unit.

Table 29 - Approach Management Unit IX– Block D

Objective	Intervention		
	Urgent	Short-term	Medium to long-term
Planning	▪ Hydrological Plan: boundary conditions ▪ Development Plan: conservation, agriculture ▪ System planning and re-design		
Conservation	▪ Data collection	▪ Greenbelt	▪ Rehabiliation and conservation
Agricultural development	▪ Data collection	▪ Modelling hydraulic infrastructure ▪ Re-design of hydraulic infrastructure ▪ Monitoring water levels and soil and water quality ▪ Design land and water management strategy for transmigrant and local communities ▪ Trials, demonstations, field schools, farm research ▪ Strengthening of O&M ▪ On-farm development	▪ Optimisation of agricultural development

Chapter 5 Conclusions and Recommendations

5.1 General

The reclamation and agricultural development of peat and (tidal) lowlands in Indonesia has shown successes and failures. The lessons learned, especially the success stories, must be taken into account into the land and water management strategy for the EMRP. It must be understood that the reclamation of tidal lands takes time, and that interventions need to be adapted to actual changing conditions, and developments. The same holds for the hydrological rehabilitation and restoration of the tropical peat lands.

Climate change is expected to result in longer dry seasons, adding to drought problems facing degraded peat areas, and a sea level rise that will affect tidal river water levels, hampering future drainage and increasing flooding risks. A long term view is required on the suitability of drainage interventions, and potential drainability and flooding.

> Land and water management in peat lands and lowlands is characterised by a changing environment and dynamic processes, for which a long-term commitment and a flexible, 'adaptive' management approach is essential.

Drainage of peat lands will unavoidably result in subsidence and loss of peat. Drainage of (unripe) mineral soils will also cause subsidence. With the lowering of the land surface, drainage may become impeded. The (future) topographical relation with the hydrology of the rivers will determine whether gravity drainage remains possible in the long run.

Drainage of peat lands and acid-sulphate soils also involves the evacuation of acids and toxins (iron and aluminium compounds), which is known to effect downstream agriculture and fisheries[28]. Drainage of agricultural areas bordering on peat lands will affect water tables of the peat domes, which is why peat domes should be managed at the hydrological landscape scale. It is therefore important to physically separate development from conservation areas.

> Drainage management is key to the sustainable development of the EMRP. However, drainage will also bring about irreversible changes. Whether such changes are acceptable depends on development objectives in relation to current and future bio-physical conditions. A physical separation of conservation and agricultural development is required to minimize impact of drainage on peat lands. An eco-hydrological landscape – delta – based zoning is recommended for water management planning and implementation.

[28] 'Downstream' refers to various scales, e.g. peat dome versus bordering areas, higher versus lower areas, areas draining into canals and rivers, acid transport into downstream rivers

The morphology of peat lands is influenced by subsidence along the canals, which appears to have a dominant impact on the effectiveness of canal blocks. Canal blockings will have a direct effect on raising water levels in the immediate vicinity of the canal, but this effect is far less clear on the elevated peat areas at a distance from the canal. The function of canal blocks is now seen as to avoid further erosion and maintain a stable drainage base, rather restoring the water tables in peat dome. Canal blockings will thus not in themselves create conditions for a hydrological restoration and re-greening, for which additional measures should be taken.

Canal blockings should be seen as part of a broader and longer-term strategy for the hydrological rehabilitation and restoration and re-greening of the peat lands.

An essential feature of land and water management in (tidal) lowlands is the capability of the water management infrastructure to maintain a proper soil and water quality through controlled drainage, flushing and leaching. In Indonesia, acidity as such is normally not a main constraint, but poor water management and stagnant water conditions are.

The Banjarese were very selective in the development of their water management systems, along the tidal rivers. The handil canals perpendicular to the river in the tidal zone follow the boundary of the tidal propagation into the swamp interior, i.e. allowing for drainage of tree crops during low-tide, and tidal irrigation during high spring tide. The water management in these areas does not need to be changed drastically. This is to a lesser extent the case with the more upstream Dayak handil areas that have a more complex hydrology and morphology.

The ex-transmigrants in the EMRP are settled in the swamp interior, where land and water management conditions and options are less favourable. Only in a small part of the swamp interior will tidal fed irrigation be possible, not in continuous blocks, but along minor depressions, adding to the micro-diversity of bio-physical conditions. Soil and water quality management in the transmigration schemes is largely dependent on rainfall and controlled drainage. The existing hydraulic infrastructure and water management practices are inadequate to create optimal land and water management conditions for agriculture.

Designs and water management practices in the EMRP area are either not complete, or not adapted to principles of controlled drainage, leaching and flushing, poor soil and water quality being a major cause for low production and stagnating agriculture.

Whereas the broad outline of land and water management interventions in the EMRP is clear, it will be essential to closely monitor and study the effects of land and water management improvements, and adapt proposed measures as needed.

Basic challenges to land and water management development in the EMRP include:

- Lack on information on hydrology, topography, and soils
- Peat conservation and land reclamation being long-term, dynamic processes
- Eco-hydrological landscape – delta- approach
- Separation of conservation and development areas
- The hydrological restoration of peat lands
- Designs must take future drainage, flooding, and weather patterns into account
- Re-design of macro-level hydraulic infrastructure
- Long-term support to on-farm development and mechanization
- Study, monitoring, trials and demonstrations

- Flexible and adaptive management, and strengthening of institutions

Until major technical and social constraints in the existing traditional and ex-transmigration schemes are resolved, new development is discouraged. No new development should take place in areas bordering peat lands.

5.2 Approach

Table 30 provides a summary of the land and water management approach in the conservation, adapted management and development zones at different levels in the EMRP.

Table 30 - Land and water management approach EMRP

Level	Conservation zone	Adapted management zone	Development zone
Overall Inpres objectives	▪ Peat land and bio-diversity conservation and restoration		▪ Revitalisation of agriculture
Specific objectives	▪ Conservation & restoration	▪ Socio-economic development ▪ Conservation & restoration ▪ LWM: conditional ▪ Agriculture: conditional ▪ Alternative livelihoods	▪ Socio-economic development ▪ Optimisation LWM ▪ Optimisation agriculture
Landscape - manageme nt unit	▪ Conservation planning ▪ Restoration planning ▪ Development planning ▪ Hydrological planning ▪ System planning ▪ Data base development		▪ Development planning ▪ Hydrological planning ▪ System planning ▪ Macro drainage infrastructure ▪ Data base development
Scheme	▪ Exit strategy plantations and transmigration sites ▪ Hydrological restoration ▪ Re-greening / forestry	▪ Exit strategy plantations and transmigration sites ▪ Hydrological restoration ▪ Re-greening / forestry ▪ Rehabilitation & upgrading ▪ Crop diversification ▪ Routine O&M ▪ Water user associations ▪ Extension services ▪ Field schools	▪ Refill of transmigration sites ▪ Development of lahan tidur ▪ Rehabilitation & upgrading ▪ Crop diversification ▪ Double connected canals ▪ Shortening of canal length ▪ Drainage width = or < 200m ▪ Routine O&M ▪ Water user associations ▪ Extension services ▪ Field schools
Field	▪ Awareness ▪ Community participation ▪ Canal blocks ▪ Research ▪ Trials and demonstrations ▪ Monitoring & evaluation	▪ Awareness ▪ Community participation ▪ Canal blocks ▪ On-farm water management ▪ Farmer groups ▪ Field to field approach ▪ Applied research ▪ Trials and demonstrations ▪ Monitoring & evaluation	▪ On-farm water management ▪ Farmer groups ▪ Field to field approach ▪ Research ▪ Trials and demonstrations ▪ Monitoring & evaluation

Interventions are proposed at the macro –delta – level of management units, village and scheme level, and on-farm. Land and water management must be considered together with agricultural development and socio-economic issues. Land and water management requires furthermore both technical and non-technical activities and support.

5.3 Data collection

The lack of (reliable) information on the most basic conditions in the EMRP, such as hydrology, topography, and soil conditions, is frustrating the design of strategies for peat land conservation, agricultural development, land and water management, and the rehabilitation and upgrading of hydraulic infrastructure.

Completion of the information on basic conditions in the EMRP area should be given first priority to support conservation, agricultural and land and water management strategies, and deserves the fullest attention of decision-makers in the EMRP.

The SID studies conducted in 2007 illustrated the lack and reliability of information and a standard for the design rainfall in the EMRP, even though this is a major boundary condition for land and water management and hydraulic design. Rainfall duration-frequency curves, based on the analysis of long term rainfall records, are required for the assessment of flood and run-off characteristics, and the design of drainage and irrigation modules. The hydrological database assembled by the Master Plan team can be used for this purpose.

Hydrological information on boundary conditions for land and water management and hydraulic design, e.g. tidal and non-tidal characteristics, maximum, minimum, and mean river water levels, flood levels, salinity intrusion, etc. is not yet available for the EMRP.

Hydrological information can also not be linked to a common datum, usually mean sea level, and the existing land levels, due to the inaccuracy of the available DEM and subsequent field checks. This is particularly critical for the assessment of land and water management in the development areas in the tidal zone, and in the hydrological complex environment of Block A, located in the transition from tidal to non-tidal rivers.

Hydrological studies and topographical surveys must take into account the land and water management relations in the (tidal) lowlands, where minor differences (< 0.25 m) in the relation of the hydrology and topography have a very large impact on land use and water management options and hydraulic design. Similar detailed information should be available in support of the hydrological restoration of the peat lands.

Soil information collected under the CKPP basically involved the mapping of peat depths, but not the soils in the mineral categories. This provided useful information for the EMRP macro-zoning in conservation, adapted and development zones, but not for an assessment of soil conditions in developed areas. In any case, some parts of the peat lands in the EMRP, especially Block E and the southern part of Block C, were not sufficiently covered by CKPP.

There is also a serious lack on scheme information, e.g. original design and dimensions of the existing hydraulic infrastructure, and the O&M inventory[29]. Reliable scheme maps are absent, and nomenclature of the hydraulic infrastructure is not clear.

> As a matter of high priority, the following information should be finalized and/or completed in support of land and water management development:
>
> - Statistical rainfall analysis, including storm drainage and design modules
> - Hydrological boundary conditions in rivers, e.g. tidal and non-tidal characteristics
> - Topographical surveys, i.e. closed loop traverses or Lidar, for the EMRP, in MSL
> - (Semi-detailed) soil mapping
> - Scheme inventories, O&M data base, nomenclature

5.4 Conservation Areas

The land and water management focus is currently on the blocking of canals, to halt further lowering of the drainage base. For the hydrological restoration of peat lands a more comprehensive and long-term approach is required, of which the canal blocking strategy is only a part. It follows that for large-scale re-greening, additional options and measures should be considered and tested. Canal blocking is urgently required to limit further damage to the peat lands, but the strategy should go hand-in-hand with the testing of other techniques such as creation of small lakes and other standing water in depressions near the top of peat domes or in areas such as along the SPI canal.

Given the current, dire conditions of the peat lands in the EMRP, especially in Block C, it must be realized that private sector plantations can play a role in restoring some of the functions of the (deep) peat lands. In combination with appropriate guidelines on crops and water management, private sector involvement may well be part of a ‘quick fix’ to reduce further degradation, fires, and carbon emissions through providing soil cover and water control. Where plantations are not considered a long-term objective, exit strategies must be in place, which could include a transition towards a more natural vegetation cover.

Agricultural development and associated drainage infrastructure along and into peat lands has a detrimental impact on the hydrology of the domes. Run-off from peat domes may on the other hand have a negative impact on the agricultural areas, e.g. causing flooding or interflow of poor quality (acid and toxic) water. Measures are required to physically separate agriculture from conservation.

[29] Scheme inventories (canal length, dimensions, structures, etc.) are normally part of O&M Manuals and form the basis for (annual) maintenance planning

In general, land and water management in conservation areas concerns:

(i) Development of peat land conservation zones

- Canal blocking to halt further lowering of drainage base
- Physical separation of conservation from development
- Review of plantation permits and transmigration planning
- Implementation of technical measures related to wise-use of peat lands
- Exit strategy for existing developments, including plantations
- Trials and research into hydrological rehabilitation strategy (incl. modelling)
- Trials and research into re-greening strategy

(ii) Development of adapted management zones

- Review of existing development and impact on conservation (incl. modelling)
- Re-design of hydraulic infrastructure to minimize impact on environment
- Careful selection of new development sites

5.5 Development Areas

The land and water management focus is on optimisation of the agriculture. As these areas are hydrological independent from the peat areas, drainage will not affect these. A landscape –delta - approach, rather than a project or scheme approach is required to solve the major hydraulic, soil and water quality and socio-economic development issues.

The following steps required for the hydraulic re-design of the Management Unit:

- A hydrological ‘plan’ indicating irrigation, supply and drainage potentials
- A ‘mini master plan’ for the development and re-vitalisation of the Management Unit
- System planning followed by the hydraulic re-design

5.5.1 Macro-level Designs

To support the revitalization of agriculture in the EMRP a re-design of the hydraulic infrastructure is required to remove stagnant water conditions (acidity and toxicities), to promote the soil ripening process, to support crop diversification, and to mitigate flooding. The upgrading of the existing hydraulic infrastructure is a pre-condition for on-farm land and water management development and the agricultural development. Further details of approaches are provided in Technical Guideline No. 6 on the Redesign of Hydraulic Infrastructure in the EMRP Area.

This requires not only a ‘macro’ approach, but also an adjustment of the older designs that should include reducing the length and density of canals by adding new canals, the double-connection of dead-ended canals, and water control structures. Drainage and supply design modules must reflect requirements for percolation, leaching and flushing, see also Chapter 3. The main canal systems should also provide sufficient flexibility to grow a variety of crops, based on conditions which may vary from field-to-field and over time.

Uncultivated land (lahan tidur) in and around agricultural areas are a source for acidity, fires and pests in the EMRP, effecting agricultural development. Water management systems are only partly functional in these uncultivated lands, limiting the effectiveness of the overall infrastructure. Consideration must be given to revitalise and develop these areas (lahan tidur), both in and outside the schemes.

The re-design of the macro-hydraulic infrastructure should include:

- Delta level: hydrology, soil and water quality and socio-economic considerations
- Criteria for system planning based on water circulation and flushing, i.e. double-connected canals, shorter drain lengths and drainage intervals
- Criteria for leaching and flushing, shallow controlled drainage and crop diversification, i.e. proper drainage and design modules
- Flexibility with regard to cropping patterns i.e. wetland, dry land and tree crops

5.5.2 Hydraulic Modelling

Typical land and water management cases in the EMRP were identified for hydraulic modelling, e.g. design of measures to separate agriculture from conservation, Block D macro-infrastructure development, and Block A flood and hydraulic design. These models are urgently required to support the land and water management strategy, but can only be finalized when more detailed information on hydrology and topography is available,

5.5.3 On-farm Water Management

Development of the land and water management at tertiary and on-farm level requires a different and long-term approach, dealing with micro-variations of soil and water conditions and potentials, and the limited capacity of farmers and government institutions.

Land and water management development must be site-specific and is closely linked to agricultural and socio-economic development. An important on-farm aspect is mechanized land preparation, as this will further ripen the soil, but is also needed to reduce labour requirements. Mechanization is only possible when the soil has reached a certain level of ripening, for which regular drainage is required.

An example is the STLD project in South Sumatera (RWS-IHE-Euroconsult MottMacDonald 2007), where long term support to water management and agriculture has demonstrated a field-to-field approach that should also be applied in the EMRP area.

Research, demonstrations and trials

Research, demonstrations and trials are required to support the dynamic process of agricultural development in the lowland areas. It is recommended that field schools are established, where trials and demonstrations, as well as research is combined with training, e.g of O&M field staff, extension workers, with the fullest participation of the farmers, i.e. rather similar to the integrated test farm concept of the early 1980s.

5.5.4 Institutional Strengthening

The institutions for land and water management are just as important as the technique involved and the technical measures implemented. Institutional strengthening can not limit itself to the EMRP area as many issues also have a national dimension.

The management of the Management Unit is to be addressed, if a truly integrated approach is adapted.

Data base, monitoring and evaluation

A soil and water monitoring network is required to measure the effectiveness of the hydraulic infrastructure and adjust the land and water management approach as needed. Soil and water quality indicators (pH, $Fe2^{+}$, ripening etc) as well as rainfall, water levels in the rivers, canals and fields, and flooding are aspects that should be measured on a regular base, and in a format that is accessible for all involved.

The NLDS study (Euroconsult 2008) concludes that data needed to design and support interventions in lowland development are often incomplete or lacking, and the impact of interventions is largely known from scattered surveys and studies. The lack of data time series compromises the review of lowland development. There is also little historical information on the 'wise-use' of peatlands and restoration of tropical peatlands, as these are relatively new concepts in Indonesia. This certainly describes the situation in the EMRP area. It is important to develop networks and data sharing mechanisms (regional, national, international).

Capacity building

The strategy should involve development of local capacity, i.e. at science institutes, NGOs etc. to carry the future peat and lowland development process in the EMRP, and also to ensure that decisions sufficiently reflect local aspirations.

There is a serious staff shortage developing in the water resources sector in general (DHV & UNESCO-IHE 2008), and this will have an effect on the EMRP. Staff shortages, at the Balai Kalimantan II, and provincial, district and field levels, should be urgently resolved.

Training of O&M staff, extension services, P3As and NGOs is best combined with the establishment of field schools cum training centres.

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ANNEXES

Annex 1 – Hydraulic boundary conditions
Annex 2 – Hydro-topography and water management
Annex 3 – O&M in the EMRP
Annex 4 – Crops and water management in peat lands
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Annex 6 – Modeling of typical land and water management cases

Annex 1 - Hydraulic boundary conditions[30]

The following hydrological boundary conditions (in relation to land levels) are relevant for land and water management options and potentials in the EMRP:

I. Daily tidal fluctuations

a. Daily high water-levels: Determine the possibilities for:

Tidal irrigation	Tidal irrigation requires flooding of the land on at least 4 or 5 days in an average spring/neap-tide cycle (additional percolation requirement of 8 mm/day). Taking into account unavoidable head losses in the canals between the river and the fields, tidal irrigation requires the spring high waters in the river to be well above the land levels.
Water supply	Even if no flooding of the land can take place, water supply to canals is important for groundwater recharge and to avoid severe desiccation of the lands, as well as for domestic water supply. This requires bottom levels of the canals to be well below the (dry-season) tidal high water-levels.
Flood protection	The highest high water-level determines the required elevation of flood protection embankments.

b. Daily tidal low and mean water-levels: Determine the possibilities for:

Drainage	Theoretically, the ultimate drainage base for gravity is the tidal low water-level in the river. However, the available drainage time at low water becomes very short. In practice, the lowest possible drainage level is somewhere between low tide and mean tide. For initial estimates of drainability, mostly the mean tidal level is assumed to be the drainage base, with an effective drainage time of 12 hours per day. Drainage below this level requires either very careful structure operation (draining only a few hours per day at low tide) or pumping.
Navigation	Depending on the bottom level of the canal in relation to the water-levels, the low tide limits the time available for navigation.

c. Tidal range (HWL_{daily} - LWL_{daily}): Determines the possibilities for:

Drainage	With land elevation mostly around tidal high water, the larger the range, the larger the difference between land elevations and tidal low and mean water levels, hence the better the drainage possibilities.
Canal flushing	The larger the range, the higher the potential flow velocities in the canals, the better the possibilities for flushing. High flow velocities

[30]Euroconsult (2000a)

on the other hand may cause erosion of the canals and embankments.

II. Seasonal fluctuations

In the fully tidal river stretch seasonal fluctuations are small, with the dry-season tide levels normally a few dm lower than wet-season levels. Nevertheless, these fluctuations cause important differences between wet and dry season in possibilities for tidal irrigation, flushing, water supply, and navigation.

Further upstream, in the transition zone from tidal to non-tidal water regime, the seasonal variations become more pronounced. Especially the low water-levels are raised and increasingly restrict the possibilities for drainage.

In the non-tidal river stretch, or at least no tidal influence in the wet season, the seasonal fluctuation are large and drainage of lowlands becomes severely impeded or impossible during high river stages. River floods may cause deep inundations, calling for high flood protection embankments which in turn may lead to even higher flood levels in the river.

III. Water quality:

Salinity intrusion limits the possibilities for tidal irrigation and drinking water use. Water with a salinity >5 mS/cm should not be used for irrigation (only in exceptional cases more saline water may be used, e.g. to replace strongly acid water in the fields). Except for areas directly bordering on the coast, salinity intrusion is limited to the dry season, and rarely influences the groundwater. Brackish water can be used for the flushing of canals. Water with a salinity of over 1 mS/cm is unfit for human consumption.

The water quality of main rivers traversing the lowlands is usually sufficient for agricultural use. The water of smaller rivers, with their catchments mainly within the swamp lands, is often polluted, i.e. low pH, high organic matter content, and typical black colouring. This limits its usefulness for canal flushing and renders the water unsuitable for domestic supply.

Annex 2 – Hydro-topography and water management[31]

The hydro-topographical classification is the moist commonly used water management classification in the tidal lands of Indonesia. Both Public Works, Agriculture, and farmers are familiar with the hydro-topography. Definitions have changed over time, with progressing insight in the land and water management requirements of the tidal lowlands.

Class A: Tidal irrigated areas

The fields can be flooded on at least 4 to 5 days around spring-tide in both the wet and the dry season. These are mostly low areas along fully tidal rivers and major canals, or former natural drainage depressions. The lower part of so-called sorjans may also fall in this category.

Additional tidal water supply is sufficient to make up for both the dry season rainfall deficit, and the high percolation and leaching requirements to maintain a proper soil and water quality for wetland rice, set at 8 mm per day (Euroconsult 1988, AARD 1991). Double cropping of wetland rice is in principle possible. HYV rice could be grown provided water-levels can be controlled to prevent flooding and to ensure adequate drainage. Near the coast, salinity intrusion may prohibit irrigation, especially in the dry season. In that case, the wet season rice crop could be followed by a dry season palawija crop, if drainage is adequate. As dryland crops in the low-lying Class A often require raised beds, the annual conversion from paddy field to dryland crops is likely far too labour intensive however. As the larger tidal range will allow good drainage, these areas are (conditionally) also suitable for tree crops. Traditional settlers (Buginese/Banjar) developed these areas for wetland rice – coconuts.

During tidal irrigations, water control structures should be fully open to let the high tide enter far into the fields with a minimum loss of high water-levels. In some areas however, gate operations are required to avoid deep flooding of low areas and housing and village areas along the supply canals, and/or to avoid saline water intrusion. Tidal flooding in combination with organic and soft, unripe soil conditions may cause severe erosion of canals and fields, especially in the open systems of both traditional and ex-transmigration areas. Structures and flood protection may be required here to better control the supply flows.

On-farm water management is geared towards water retention and drainage of excess rainfall during neap tides, alternated with tidal water supply for leaching and to restore the water layer on the fields during the spring tides. Alternate irrigation and drainage provides ample leaching of acid and toxic elements, and soil and water quality remains generally good.

Class B: Periodically tidal irrigated areas

The fields can be flooded on at least 4 to 5 days around spring-tide, but only in the wet season. Double cropping with rice will not be very successful because the water supply in the dry season is not sufficient to meet the high percolation and leaching requirements to maintain a good soil and water quality for wetland rice. In addition to the dry season water balance deficit, it will be more difficult than in Class A to

[31] Adapted from Euroconsult (1996b)

maintain water layers on the fields due to the relative higher elevation and associated percolation losses.

It is recommended that a wet season rice crop is followed by a dry season palawija crop, or that palawija crops are grown year round, depending on labour requirements for the conversion of the fields. It will require proper structure operation and raised beds to grow palawija during the wet season, and possibly also during the dry season (though less so than in Class A). Ground-water levels should not fall below upper boundaries of pyritic layers during the cropping season to avoid actual acidity through oxidation of these layers. Though less than in Category A, flood protection may be required to avoid too deep inundations.

In the wet season, on-farm water management of wetland rice is similar to that in Category A. Alternate irrigation and drainage will provide leaching of acid and toxic elements, though not as effectively as in Category A. A more intensive refreshing of water layers in the fields, and flushing of canals is therefore recommended.

During the dry season water management focuses on drainage and water retention to maintain the desired groundwater depth. Regular leaching of the soil is needed to remove acids and toxicities formed in drier periods. After leaching, the canals should be re-filled at high tide with good quality water, to prevent a large drop of the groundwater table.

Class C: Areas just above the tidal levels

These fields cannot be regularly flooded by the tides, even not in the wet season. Groundwater tables may still be influenced by tidal fluctuations, but water-levels in the canals are usually too low to prevent high seepage losses from paddy fields, and, due to the permeability of the unripe soils, no water layer can effectively be maintained on the fields.

The natural response of farmers in rice growing areas is to focus the water management on maximum water retention and minimal drainage. However, in the pyritic and organic muck soils in the tidal lands, acids and toxicities are unavoidably formed during dry periods, and will accumulate in the ground water, which during water retention operations in drier periods will reach the root zone. Shallow and controlled drainage is recommended, which better fits a dryland water management regime for upland rice, palawija, and tree crops.

Water management during the wet season concerns mainly drainage of excess rainfall and leaching of the rootzone. During the dry season upland crops are often more harmed by wet soil conditions than by drought. Monitoring of groundwater levels is needed to determine how long drainage is needed, and when to shift to water conservation. The optimum groundwater depth varies with type of crop, growing stage of the crop and the soil and water quality.

Care should be taken to limit drainage of pyritic layers and the formation and mitigation of acids and related toxicities. Leaching and flushing should be practiced when and where possible. Land preparation, including ploughing and sun-drying, are essential for soil development and the improvement of soil conditions in the root zone. Drainage is required for the ripening of the soils to create conditions for mechanization[32].

Class D: Areas well above the tidal levels

The fields are well above high tide. Upland rice, palawija, and tree crops are better suited to these areas than wetland rice. If the soils are not acid and have no organic material, water management will be similar to that of rainfed agriculture in upland areas, otherwise it will be similar to that for Category C. As groundwater levels will drop deeper below the surface than in Category C, water conservation during the dry season becomes more important. However, it will be difficult to supply (tidal) water to the tertiary canals in the dry season.

[32] Labour requirements in lowland development are high. Due to labour shortages, mechanized land preparation is essential for the development and revitalization of the agriculture.

Annex 3 – O&M in the EMRP

Table A.3.1 – O&M organization in the EMRP – Kapuas

NO	KECAMATAN	WILAYAH PENGAMAT	Daerah Rawa	PENGAMAT	STAFF PENGAMAT	JURU PENGAIRAN	P3A	REMARKS
1	Kapuas Murung	Palingkau (3.440 Ha)	Palingkau I (910 Ha) Palingkai II (950 Ha) Palingkau III (980 Ha) Palingkau IV (600 Ha)	1. Pattah NIP. 110049958	1. Mahrianto NIP. 530022537	1. Wanson NIP. 530022326. 2. Maranti NIP. 530022339.	18 P3A (5.446 Ha)	District
		Unit Palingkau (1.265 Ha)	UPT Palingkau I (265 Ha) UPT Palingkau II (1.000 Ha)	1. Pattah NIP. 110049958	1. Syamsudin Nor NIP.	1. Fernandus NIP. 530022500 2. Bobby Patin	9 P3A (3.200 Ha)	District / Province
2	Pulau Petak	Sei Tatas (3.313 Ha)	Sei Tatas I (982 Ha) Sei Tatas II (900 Ha) Sei Tatas III (950 Ha) Sei Tatas IV (481 Ha)	1. Harry NIP. 530008990	1. Hertalena Tambunan NIP. 530022524	1. Antariksa Sembiring NIP. 530022336	7 P3A (2.130 Ha)	District
		Sakalagon (3.366 Ha)	Sakalagon I (975 Ha) Sakalagon II (386 Ha) Sakalagon III (925 Ha) Sakalagon IV (900 Ha)	1. Yanto NIP. 110048260	1. Marta Paulina NIP. 530022526	1. Zainuddin NIP. 110040208	5 P3A (2.494 Ha)	District
3	Kapuas Hilir	Sei Asam (1.285 Ha)	Sungai Asem I (650 Ha) Sungai Asem II (635 Ha)	1. Poltak Pangaribuan NIP. 110049189	1. Didik Sulistyawan NIP. 530022532	1. Muliadi NIP. 530022327	9 P3A (3.202 Ha)	District (non-EMRP)
		Unit Tatas (2.907 Ha)	Unit Tatas I (950 Ha) Unit Tatas II (980 Ha) Unit Tatas III (977 Ha)	1. Kadir NIP. 110046144	1. Emiyati NIP. 530022525	1. Rusman Hutapea NIP. 530022206	4 P3A (790 Ha)	District (non-EMRP)
4	Kapuas Timur	Anjir Serapan I (4.081 Ha)	Anjir Serapan I (3.121 Ha) Anjir Serapan IA (960 Ha)	1. Syaiful Akhmadi NIP. 110041325	1. Muses NIP. 530022601	1. Abdul Kholik NIP. 110052977	7 P3A (1.645 Ha)	District / Balai (non-EMRP)
		Anjir Serapan II (3.471 Ha)	Anjir Serapan II (3.471 Ha)	1. Syamsul Bachri NIP. 110051512	1. M. Armansyah NIP. 530022554	1. Idai Iriyanto NIP. 11008984	7 P3A (3.185 Ha)	Balai (non-EMRP)
5	Selat	Pulau Kupang (4.071 Ha)	Pulau kupang I (999 Ha) Pulau Kupang II (990 Ha) Pulau Kupang III (637 Ha)	1. Olie Penyang NIP. 110052404	1. Hendy Prasetya H. NIP. 530022555	1. Sutrisno	6 P3A (2.114 Ha)	District
		Terusan Tengah (3.504 Ha)	Terusan I (950 Ha) Terusan II (3.121 Ha)	1. Gubrek Hariono NIP. 110041328	1. Maryono	1. Darmiko	10 P3A (3.866 Ha)	District
		Kota K. Kapuas (340 Ha)	Kota K. Kapuas (340 Ha)	1. Nayan NIP. 110051734	1. Wastur NIP. 530022325	1.	-	District
6	Kapuas Kuala	Tamban Luar (3.884 Ha)	Tamban Luar I (950 Ha) Tamban Luar II (975 Ha) Tamban Luar III (965 Ha) Tamban Luar IV (994 Ha)	1. Uberson, Amd NIP. 530008986	1.	1. Burhan C.S NIP. 110050574	8 P3A (2.346 Ha)	District (non-EMRP)
		Lupak Dalam (6.740 Ha)	Lupak Dalam I (5.790 Ha) Lupak Dalam II (950 Ha)	1. Arsani NIP. 530009214	1. Sulkani	1.	8 P3A (1.899 Ha)	District / Balai (non-EMRP)
		Lupak Seberang (8.135 Ha)	Lupak Seberang I (7185 Ha) Lupak Seberang II (950 Ha)	1. Jamali NIP. 110040532	1. Suhaimi	1. Slamet NIP. 110041326	13 P3A (3.430 Ha)	District / Balai
7	Kapuas Barat	Mandomai (2.213 Ha)	Mandomai I (750 Ha) Mandomai II (600 Ha) Mandomai III (863 Ha)	1. Jainuri NIP. 110050115	1. Mahriandi NIP. 530022535	1. Bachtiar NIP. 110050921 2. Daniel NIP. 530008988	6 P3A (1.350 Ha)	District
8	Mentangai	Mentangai (1.466 Ha)	Mentangai I (466 Ha) Mentangai II (1.000 Ha)	1. Mawan Pasaribu NIP. 110049662	1. Jahriansyah NIP. 530022499	1. Hantrong NIP. 530022337 2. Hoidi NIP.530022341	6 P3A (2.208 Ha)	District / Province
9	Basarang	Basarang (865 Ha)	Basarang (865 Ha)	1. Riadi Dwikora NIP. 530007787	1. Wayan Slamet NIP. 530022499	1. Abdul Kimin NIP. 110052441 2. Simjon Sinabang NIP.530022340	5 P3A (2.202 Ha)	District
10	Kapuas Murung Mentangai Kapuas Barat	Lamunti - Dadahup	Lamunti Dadahup } (33.000 Ha)	Belum ada	Belum ada	Belum ada	-	Balai

Sumber : Sub Dinas Pengairan Kabupaten Kapuas, Tahun 2008

Table A.3.2 - O&M organization in the EMRP – Pulang Pisau

NO	KECAMATAN	PENGAMAT	Daerah Rawa	PENGAMAT	STAFF PENGAMAT	JURU PENGAIRAN	P3A	REMARKS
1	Kahayan Hilir	Pulang Pisau (7.940 Ha)	- Kalawa I - Gohong - Anjir Kelampan - Kelawa II	1. Bangun Situmorang NIP. Pendidikan STM	1. Leonard Pendidikan SMA	1. Karlie 2. Ronie Karunia	12 P3A (2.775 Ha)	Distr / Prov
2	Jabiren Raya	Mentaren (5.785 Ha)	- Mentaren I - Mentaren II - Pulang Pisau - Mintin	1. Marming NIP. 110050573 Pendidikan SMA	1. ………………	1. Supriyadi 2. Surdiar	3 P3A (534 Ha)	Distr / Prov
2	Maliku	Kanamit (9.300Ha)	- Kanamit - Pangkoh IX - Pangkoh X	1. Sukardi NIP. 110024206 Pendidikan STM	1. Wasiran Pendidikan SMA	1. Alamsyah W. 2. Ahmadi	6 P3A (4.010 Ha)	Balai WS Kal II
		Maliku (11.115 Ha)	- Maliku - Pangkoh V,VI,XI - Maliku Baru	1. Manahara S. NIP. 110048034 Pendidikan STM	1. Rosita Pendidikan SMA	1. Buliher P. 2. Jimmi Nadi 3. Marhani	18 P3A (10.979 Ha)	Balai WS Kal II
		Tahai (3.740 Ha)	- Tahai - Pangkoh IV	1. Budiono NIP. 110038248 Pendidikan STM	1. Darmaji Pendidikan SMA	1. Wartoyo NIP. 530017..... 2. Sumarto	5 P3A (925 Ha)	Balai WS Kal II
3	Pandih Batu	Kantan (10.194 Ha)	- Kantan - Pangkoh II, III	1. Slamet Budiyono NIP. 530009210 Pendidikan STM	1. Tambang Pendidikan STM	1. Adno 2. Akhmad Arif	12 P3A (3.407 Ha)	Balai WS Kal II
		Talio (6.930 Ha)	- Talio - Pangkoh I	1. Haris Muhtadi NIP. 110049654 Pendidikan SMA	1. Paimin Hutapea Pendidikan SMA	1. Anton 2. Margono	10 P3A (3.800 Ha)	Balai WS Kal II
		Belanti I (3.800Ha)	- Belanti I - Pangkoh VII	1. Lubis NIP. 110052397 Pendidikan SMEA	1. Kalim Budianto Pendidikan SMEA	1. Tasriffin 2. Sumarno	3 P3A (3.087 Ha)	Balai WS Kal II
		Belanti II (4.500Ha)	Belanti II Pangkoh VIII	1. Joni NIP. Pendidikan STM	1. Susanti Pendidikan SMA	1. Ampar	8 P3A (2.800 Ha)	Balai WS Kal II
4	Kahayan Kuala	Bahaur (14.950 Ha)	- Bahaur Hilir - Bahaur Tengah - Bahaur Hulu	1. Irianto C. Sato NIP. 530008999 Pendidikan SMA	1. Relegius Pendidikan STM	1. Akhdiat	12 P3A (2.218 Ha)	District
5	Sebangau Kuala	Paduran (8.846 Ha)	- Panduran I - Panduran II - Panduran III	1. Sudirman S. NIP Pendidikan SMA	1.	1. Sinar Budianto 2. Istikari	3 P3A (1.324 Ha)	Balai WS Kal II

Sumber : Sub Dinas Pengairan Kabupaten Pulang Pisau, Tahun 2008

Table A.3.3 –Condition of hydraulic infrastructure in Kapuas

No	Pengamat	Service Area (ha)			Condition of canals												Condition water control structures								Remarks
					Primary				Secondary				Tertiary				Concrete				Ulin wood				
		ha	Potensial	Fungsi	km	B	RR	RB	km	B	RR	RB	L	B	RR	RB	nos	B	RR	RB	nos	B	RR	RB	
I	**Kec. Kapuas murung**																								
	1. Palingkau	**6,550**	4,774	4,464	**-**	-	-	-	**146.0**	51.1	21.9	73.0	**74.0**	10.0	4.0	60	**22**	16	4	3	**40**	20	10	10	District
	2. UPT Palingkau	**7,422**	7,078	1,265	**57.0**	34.2	17.1	5.7	**290.0**	101.5	43.5	145.0	**-**	-	-	-	**94**	87	4	2	**30**	15	8	7	Prov / Distr
II	**Kec. Pulau Petak**																								
	3. Sei Tatas	**10,524**	6,052	5,150	**-**	-	-	-	**240.0**	90.0	36.0	114.0	**12.7**	2.0	0.7	10	**13**	6	3	4	**28**	14	8	4	District
	4. Sakalagon	**9,570**	7,825	4,800	**30.0**	18.0	8.0	3.0	**202.0**	89.7	30.3	82.0	**53.4**	40.0	13.4	-	**12**	6	3	3	**3**	20	6	4	District
III	**Kec. Kapuas Hilir**																								
	5. Sei Asam	**5,710**	4,000	810	**-**	-	-	-	**94.0**	36.6	14.4	43.0	**-**	-	-	-	**19**	10	4	5	**9**	5	2	2	District
	6. Unit Tatas	**9,450**	8,715	2,413	**19.0**	11.4	5.7	1.9	**179.0**	77.6	26.9	74.5	**25.5**	4.0	1.5	20	**2**	1	-	1	**-**	-	-	-	District
IV	**Kapuas Timur**																								
	7. Anjir Serapan I	**9,925**	8,313	6,065	**-**	-	-	-	**165.0**	54.3	23.2	87.5	**30.7**	8.0	2.7	20	**21**	10	5	6	**12**	6	3	3	Distr / Balai
	8. Anjir Serapan II	**9,380**	8,620	5,354	**-**	-	-	-	**182.0**	70.2	25.8	86.0	**55.0**	12.0	3.0	40	**16**	8	4	4	**32**	12	10	2	Balai
V	**Kec. Selat**																								
	9. Pulau Kupang	**12,580**	9,709	7,105	**-**	-	-	-	**294.0**	179.2	26.5	88.3	**-**	-	-	-	**25**	12	7	6	**13**	6	6	4	District
	10. Terusan Tengah	**10,655**	8,560	4,274	**15.0**	9.0	4.5	1.5	**220.0**	77.0	33.0	110.0	**-**	-	-	-	**2**	2	-	-	**65**	30	20	3	Distr / Balai
	11. Kota K. Kapuas	**1,900**	990	500	**-**	-	-	-	**55.0**	10.5	4.5	40.0	**-**	-	-	-	**-**	-	-	-	**-**	-	-	-	District
VI	**Kec.Kapuas Kuala**																								
	12. Tamban Luar	**6,479**	5,830	5,786	**26.0**	15.6	7.8	2.6	**126.0**	43.7	18.7	63.6	**-**	-	-	-	**38**	19	8	11	**-**	-	-	-	District
	13. Lupak Dalam	**10,695**	9,022	8,474	**10.0**	6.0	3.0	2.0	**216.0**	83.6	32.4	100.0	**-**	-	-	-	**25**	12	7	6	**-**	-	-	-	Distr / Balai
	14. Lupak Seberang	**15,505**	14,333	9,058	**12.0**	7.2	3.6	1.2	**234.0**	100.4	35.1	98.5	**-**	-	-	-	**-**	-	-	-	**-**	-	-	-	Distr / Balai
VII	**Kec. Mentangai**																								
	15. Mentangai	**23,400**	14,530	11,230	**-**	-	-	-	**150.0**	77.5	16.7	55.8	**15.0**	3.0	1.0	11	**-**	-	-	-	**-**	-	-	-	Distr / Prov
VII	**Kec. Kapuas Barat**																								
	16. Mandomai	**18,815**	17,975	2,548	**-**	-	-	-	**320.0**	138.0	42.0	140.0	**-**	-	-	-	**9**	4	3	2	**7**	7	-	-	District
VIII	**Kec. Basarang**																								
	17. Basarang	**16,036**	13,410	2,710	**-**	-	-	-	**160.0**	127.8	-	32.2	**-**	-	-	-	**20**	10	5	5	**7**	7	-	-	Kab
	Jumlah	**184,596**	**149,736**	**82,006**	**169.0**	**101.4**	**49.7**	**17.9**	**3,273.0**	**1,408.7**	**430.9**	**1,433.4**	**266.3**	**79.0**	**26.3**	**161.0**	**318**	**203**	**57**	**58**	**246**	**142**	**73**	**39**	

Sumber : Sub Dinas Pengairan Kabupaten Kapuas, Tahun 2008

Note: B = Baik (good); RR = Rusak Ringan (minor damage); RB = Rusak Berat (major damage)

Table A.3.4 – Condition of hydraulic infrastructure in Pulang Pisau

No	Pengamat	Service Area (ha)			Condition of canals - Primary				Condition of canals - Secondary				Condition of canals - Tertiary				Condition water control structures - Concrete				Condition water control structures - Ulin wood				Remarks
		ha	Potensi	Fungsi	km	B	RR	RB	km	B	RR	RB	L	B	RR	RB	nos	B	RR	RB	nos	B	RR	RB	
I	Kec. Jabiren Raya																								
	18. Pulang Pisau	**5,199**	4,583	1,113	**11**				**91**								**7**			4					Distr / Prov
II	Kec. Kahayan Hilir																								
	19. Mentaren	**7,815**	6,740	670	**8.2**				**173**								**3**								Distr / Prov
III	Kec. Maliku																								
	20. Kanamit	**4,800**	4,342	1,415	**17**				**238**								**3**								Balai
	21. Maliku	**9,610**	9,224	1,270	**27**				**363**				**47**				**18**								Balai
	22. Tahai	**3,740**	3,733	891	**10**				**180**								**33**								Balai
IV	Kec. Pandih Batu																								
	23. Kantan	**10,561**	9,734	2,135					**29**				**476**												Balai
	24. Talio	**8,838**	6,981	381	**24**				**301**				**21**				**2**								Balai
	25. Belanti I	**3,600**	3,429	757	**11**				**100**								**36**								Balai
	26. Belanti II	**4,489**	4,300	524	**9**				**213**								**9**		1						Balai
V	Kec. Kahayan Kuala																								
	27. Bahaur	**11,003**	8,653	3,333					**166**				**84**				**7**								District
VI	Kec. Sebangau Kuala																								
	28. Paduran	**8,633**	6,677	770	**29**				**193**				**48**				**15**								Balai
Jumlah		**78,288**	**68,396**	**13,259**	**146**	**0**	**0**	**0**	**2,046**	**0**	**0**	**0**	**676**	**0**	**0**	**0**	**133**	**0**	**1**	**4**	**0**	**0**	**0**	**0**	

Sumber : Sub Dinas Pengairan Kabupaten Pulang Pisau, Tahun 2008, data incomplete

Annex 4 - Crops and water management in peat lands[33]

Oil palm (Elaeis guineensis) **–** Oil palm is one of the most important vegetable oil crops in the world. It is a typical crop for the Tropics. It requires frequent year-round rainfall and abundant sunshine. Among all the promising crops that perform satisfactorily on peat soils, oil palm is the only one that has been grown profitably on a large commercial scale in especially Malaysia and Indonesia.

Although they require higher production costs, well-managed oil palms growing on peat soils often yield better than those cultivated on mineral/hill soils. The success of planting oil palm depends to a large extent on sufficient fertiliser inputs. In particular, heavy dressings of potassium are required, and micro-nutrients such as copper, zinc and boron are fundamental to healthy palm growth on peat soils. Due to poor anchorage, oil palm on peat soils tends to lodge as it grows taller. Practices such as compacting the planting row prior to planting and using the 'hole-in-a-hole' method of planting helps to minimise this problem. Only the top layer above the water table can be compacted. Compaction does not cause a loss in material, but it does contribute substantially to the initial subsidence.

Leguminous cover crops are not normally planted. The natural 'soft' weeds are allowed to grow in the inter-rows to provide the ground cover. This prevents a direct exposure of the ground surface to sunlight and thus helps to prevent the excessive drying of the surface soil.

To cultivate oil palm on organic soils, it is best to maintain the water table at a depth of 0.60–0.75 m below the soil's surface. For the purpose of drainage design, the maximum allowed saturation period is three days (72 hours). Although oil palm can survive up to two weeks of flooding in running water, stagnant water will cause a serious decrease in yield.

On the other hand, over-drainage should be avoided to minimise subsidence and prevent the formation of an irreversibly dried surface. Oil palm is sensitive to drought. Yields in areas with a moisture deficit of 400 mm have been reported to be only half of yields obtained in zero-deficit areas such as Sarawak. Because of the low-to-zero capillary rise in most peat soils, dry spells lasting longer than 10 days will result in significant yield reductions. Controlled water management to prevent over-drainage is, therefore, important.

The planting density will have some influence on the spacing of the field drains. With 8.5 m triangular planting, the field drains are usually spaced 8 rows apart, though with the higher rainfall in Sarawak, drain spacing at 4-row intervals has sometimes been adopted, especially where the micro-relief is irregular with many depressions.

Sago (Metroxylon spp.) **-** Plantation of sago has been identified as a promising land-use option for peat because the sago palms can tolerate a relatively high water table, which will reduce drainage intensity and peat subsidence. Sago requires less labour and is less fertiliser-intensive than oil palm. Sago in Sarawak, however, remains largely a smallholder crop, although efforts have been made to grow this crop on a commercial plantation basis since the last decade.

Sago palms growing on organic soils take 12 years to mature as compared to 9 years on mineral soils. Starch yields per palm are, however, comparable on peat and

[33]Adapted from DID (2001)

poorly-drained mineral soils. Apart from some occasional slashing, smallholder sago farmers do very little maintenance and they apply no fertiliser.

There is a general consensus that completely stagnant water is not favourable for sago growing on deep peat, and that a certain amount of drainage is required. The amount of drainage required, however, is a point of contention. Some feel that a drainage (and fertiliser) regime similar to that of oil palm is required, but at similar levels of input use, most people would rather grow oil palm instead of sago.

During the wet season, the water table might be allowed near to the surface. Despite sub-optimal yields, the less costly infrastructure requirement and the more environmentally friendly practices would provide adequate trade-offs. Although the drainage issue needs to be rigorously field-tested, the present indications are that the water table should be maintained in the range of 0.20 – 0.50 m for better growth of sago palm.

Pineapple (Ananas comosus) **-** Pineapple, both for canning and the fresh-fruit market, grows well on peat. To cultivate pineapple on organic soils, it is best to maintain the water table at a depth of 0.75–0.90 m below the soil's surface. The design of the drainage system must take into account that the allowed saturation period is one day (24 hours). Harvesting can usually take place 12–15 months after planting.

Horticultural and some annual crops - Both leafy and fruit vegetables, and some other horticultural and annual crops such as ginger, groundnut, watermelon, soybean, sweet potato and papaya can be grown successfully on drained peat soils.

Moreover, unlike oil palm, horticultural crops (vegetables in particular) may be an interesting land-use option from the point of view of nutrition and food security. Thus, vegetables and other horticultural crops deserve consideration for planting.

Mechanisation problems are a serious constraint to growing vegetables and annual and semi-perennial crops including groundnut, watermelon, soybean, sweet potato and papaya. For papaya, poor anchorage also poses another serious problem. To cultivate vegetables on peat soils, it is necessary to maintain the water table at a depth of about 0.30–0.60 m below the soil's surface. Vegetables have a very low flood tolerance, so they should not be planted in flood-prone areas. The design of the drainage system should take into account that the saturation period is less than one day (24 hours).

Tapioca (Manihot utilissima) **-** Tapioca or cassava (Manihot utilissima) is an annual crop that can perform well on peat soils. It is able to take advantage of the excellent physical conditions of drained peat. Currently, no large-scale planting of tapioca on peat soil is practised in Sarawak. Mechanisation problems are a serious constraint to growing tapioca. To cultivate tapioca on peat soils, it is necessary to maintain the water table at a depth of 0.30–0.60 m below the soil's surface. Tapioca has a very low flood tolerance; it should not be planted in flood-prone areas. The design of the drainage system should take into account that the allowed saturation period is less than one day (24 hours).

Rubber (Hevea brasiliensis) **-** In Borneo, there is a long tradition of rubber cultivation on drained peat soils. Over the years, drastic subsidence has exposed the roots of the rubber trees, making rubber-tapping an arduous task. Most of the rubber stands are leaning at extreme angles. There are no records of how well the rubber trees grew in the peat swamp environment. The main reasons for not growing rubber trees on peat are their relatively lower latex yield, their longer maturity period, and their shorter economic life. In recent years, however, interest in rubber trees for timber has grown tremendously thanks to the popular use of rubber wood or ‘hevea wood’, particularly in the furniture industry. Rubber trees produce a pale-coloured, light hardwood that is easy to work. Apart from furniture, it is also widely used in the manufacture of parquet flooring, stairs, doors, turnery items, and plywood. The growing of rubber for timber, however, has never been field-tested on deep peat.

Paddy - The prospects for growing wet paddy on peat soils would seem to be promising because paddy’s normal growth conditions are similar to the natural conditions in peat soils. Nevertheless, satisfactory paddy growth seems to be restricted to shallow peat soils and deep peat soils with a high mineral or ash content on the surface. Peat soils, especially deep peat soils, are not entirely suitable for intensive, irrigated, and commercialised wet paddy cultivation. Their low bearing capacity and their woody composition limit the extent of mechanisation. Water management in paddy fields on peat soils is difficult because of the soil’s high permeability. Puddling is not effective, making it difficult to retain the water in one field, especially if the adjacent fields are drained for one reason or another. Paddy yield on shallow peat soils is generally 20–40% lower than paddy yield on clayey, poorly drained mineral soils under similar management. At the present stage of development, large-scale commercial wet paddy cultivation on deep peat soils is not recommended.

Forestry - Peat swamps have been of prime importance for the timber production. The most valuable peat swamp timber species include “ramin” (Gonystylus bancanus), “meranti” (Shorea spp.) and “jongkong” (Dactylocladus stenostachys). From the studies on natural regeneration and experimental planting of Shorea albida in Sarawak, it is evident that there is a potential to establish forest plantations with indigenous swamp species in peat areas.

Under planted conditions, light, moisture and nutrient requirements can be controlled and optimised. In a well-managed plantation, a much better survival rate and higher performance can be expected. Selection of high quality planting stock or clones will also ensure a more uniform performance. One advantage of plantation over natural forest is the choice of fast-growing and high-value species to achieve maximum productivity. Experiences in Sumatra, for example, show that Acacia crassicarpa can be planted in lowland peat areas.

In newly developed areas with high water table, anchorage can be a problem because the anchorage is merely provided by a few lateral roots that remain confined to the top layer above the water table. The root system can only extend downwards in more deeply drained peat. In the Sumatran example (Henk Ritzema: Wong C. Y., personal communication), secondary drains of about 1.0 m wide and 1.0 m deep are dug at 400-500 m apart. There are practically no tertiary drains, and the primary or main drains with a width of up to 3.0 m and a depth of up to 2.0 m are only dug when several secondary drains need to be linked by a common outlet to an adjacent river.

From these descriptions, it is obvious that the drainage requirements of acacias have not been precisely worked out as in oil palm. However, it can be seen that although the drainage issue needs to be rigorously field-tested, indications are that the water table should be maintained in the range of 0.70– 0.80m.

Aquaculture - Deep peat soils are not recommended for commercial aquaculture in any form. The waters emanating from peat swamps are highly acidic, have low dissolved oxygen, and are relatively high in tannins and organic acids. Moreover, the characteristics of the soils make it very difficult to construct aquaculture ponds. The peat materials are too porous to retain water, they are unstable, and any embankments constructed will collapse easily.

Annex 5 - Crops and water management in tidal lands[34]

Different water management strategies are required for the different crops in the the tidal lands. These strategies are very much dependent on the physical conditions which may vary considerably between locations, and even from field-to-field.

A.5.1 Water management for rice (Figures A.5.1, A.5.2, A.5.5)

To maintain a good soil and water quality, leaching is required in tidal lowlands. Water requirements of wetland rice are therefore high and cannot be met by rainfall alone in years with average rainfall, let alone in drier years. If no additional water supply is available (tidal or pumped irrigation), it is recommended under acid and toxic conditions to grow the rice as a dry land rice, thus avoiding the negative consequences of stagnant water in the field.

In principle, the following types of water management apply to rice cultivation in tidal lands:

- Water retention
- Drainage and leaching of the soil
- Tidal irrigation and pump irrigation

Water retention – Water retention aims at creating a water layer on rice fields to suppress weeds, to create a proper environment for nutrient uptake, and to serve as a buffer storage for the rice plants in case of drought. Without irrigation, the only source of water is rainfall.

Water retention in tidal swamp lands is however associated with the development of toxic substances in the soil under continuing, stagnant water (anaerobic) and water conditions, especially during the initial stages of reclamation. Also, acidity resulting from the oxidation of pyrite and organic matter, e.g. formed during the dry season, can not be removed during water retention. With a poor soil and water quality, water retention for prolonged periods is not recommended, as instead drainage and leaching of the soil is required.

Maintaining water layers on the (rain-fed) fields in the tidal lands is often difficult because of the high permeability of the top soils, the difficulty to puddle these soils, and the distinct micro-relief. Land levelling is important as well as soil ripening and water control.

Drainage and leaching of the (top) soil - Drainage is required (i) after heavy rainfall, (ii) before fertilizer applications, and (iii) when the quality of the soil and water deteriorates.

To avoid the development of toxic conditions in soils with high organic matter content, shallow, controlled drainage is more important than water retention. Measurements suggest that percolation rates of 8 mm/day are required in organic unripe swamp soils, to obtain higher yields [35]. The same study suggests that at lower percolation rates, fertilizer applications are ineffective. The rice is grown during part of the season on non-inundated fields, with a groundwater table at 0.30 m below the surface (minimal required potential drainage for wetland rice). The lowering of the

[34] Adapted from Euroconsult (1996b)
[35] Euroconsult (1991)

water table is also required for rainwater to infiltrate the soil, rather than being drained away as surface run-off. Extensive research in South Sumatra and South Kalimantan, has shown that alternating shallow controlled drainage and water retention is the recommended water management for these areas.

On-farm drainage for wetland rice requires quaternary ditches, 70 cm deep, and spaced at 50 to 100 m intervals, small pipes through the field bunds, and low water-levels in the drains. Leaching of the soil takes place by seepage of (rain) water through the soil to the drains. The tertiary drain interval should be not more than 200 m.

Deep drainage should be avoided. It not only causes water stress for the plants, but also risks the oxidation of pyrite in the subsoil. Therefore, depending on rainfall and depth of the pyritic layer, water-levels in the drains should be maintained at controlled levels below the surface.

However, even when taking precautions, it can never be avoided that the groundwater table will drop below upper pyritic layers in (potentially) acid sulphate soils, especially during the long dry season in ENSO years. Acids should be leached from the soil, starting with the first rains of the wet season requiring drainage and a lowering of ground water table. Interflow from relative higher fields and ‘lahan tidur’ adds to the accumulation of acids and development of toxic conditions in lower areas, and the drainage system should adapt to this.

Tidal irrigation - Where tidal irrigation with good-quality water is possible, this not only assures a sufficient water supply to the rice plants but also greatly improves the soil and water conditions. Oxidation of pyrite as well as conditions of stagnant water are avoided, and any toxic elements already present or formed during the fallow periods can be leached from the soil by gravity drainage during low tide. Other important advantages of tidal irrigations are that high yielding varieties can be grown in stead of local varieties, and that planting can start earlier which in turn increases the possibilities to grow a second crop.

Supply calculations must take into account percolation requirements to maintain a proper soil and water quality. As high tidal water levels are only for short periods above the field level, tidal (gravity) irrigations occur only during a few hours per day and then mostly only during several days around the springtide period. Large quantities of water thus need to be conveyed to the fields in a short time, as irrigation rotation is hardly an option here.

This requires very large primary and secondary canals, and a dense system of tertiary, quaternary, and field canals. Head losses are high during peak supply flows, and this puts a practical limitation on the areas that can be irrigated in large-scale canal systems. This situation is different from traditional fields, which are often flooded directly from the river.

Pump irrigation - With no tidal irrigation, but with good-quality water available in the canals, pumped irrigation may help to overcome critical dry periods. An advantage is that pumping is not restricted to the spring tide high water level periods and use can be made of storage provided by the canal system. The quantities of water involved will normally be smaller than the large in- and outflows of tidal irrigation, and farmers will tend to save on pumping costs by retaining all water as much as possible on the field, with all the associated risks of stagnant water and a poor soil and water quality.

Pest control - Regulation of water-levels in rice fields can help to control certain pests. Black bugs favour moist conditions while mole crickets favour dry conditions. Flooding or drainage of the fields kills the insects or causes them to migrate to other areas.

A.5.2 Water management for palawija (Figure A.5.3)

Water management for palawija focuses on drainage and maintaining a groundwater level at a depth of 0.40 to 0.60 cm below the surface. Quaternary canals in between the tertiary canals are required with a spacing not exceeding 100 m, with a tertiary canal spacing of 200 m.

Palawija can be grown in the lower hydro-topographical categories following the wet-season rice crop when groundwater levels are still high. The crop then needs to be grown on 0.20 to 0.40 m high ridges to assure adequate drainage of the root zone and to quickly evacuate excess rain through furrows in between the ridges. This requires high labour inputs however, and palawija as a second crop is not practised on a large scale. Palawija can also be grown as main crop year-round in fields with a somewhat higher hydro-topography.

Canal water management will aim at maintaining water levels in the tertiaries at some 0.50 to 0.70 m below field (ridge) level. In the dry season, when groundwater levels may drop below design levels, recharge of groundwater should be attempted by water supply from the canals. In the higher hydro-topographical categories, especially during extended dry periods, canal water levels cannot be maintained above the bottom-levels of most (tertiary) canals. Regular flushing of the canals with fresh tidal water is important to replace acid and polluted drainage water. If good quality water is available, pump irrigation should be considered.

Sorjans - The construction of sorjans involves lowering part of the soil surface to improve the possibilities for tidal irrigation, and creating raised beds with the excavated soil where palawija or tree crops could benefit from improved drainage. The basins are typically 4 to 10 m wide, the beds 2 to 4 m wide and 0.40 to 0.80 m high. It is an attempt to improve the conditions for rice growing while at the same time diversifying the cropping plan. Sorjans are not recommended in the tidal lands due to the unripe and organic soil conditions, presence of (potentially) acid-sulphate soils, and poor soil and water quality.

A.5.3 Water management for tree crops (Figures A.5.4, A.5.6)

As for palawija crops, water management for tree crops focuses on drainage and maintaining a stable groundwater table. The preferred depth of the groundwater table is 0.60 to 1.0 m. Quaternaries in between the tertiaries (200 m interval) are very important, as the drain spacing should not exceed 25 to 50 m. Water-levels in the tertiary canals should be kept at 0.80 to 1.0 m below field level. In low areas, this will require drainage structures at quaternary or tertiary level. In soils with shallow pyrite, the allowable drainage depth may be limited to avoid oxidation of the pyrite. In that case, as well in other areas where the groundwater can not be sufficiently lowered, trees may be grown on raised mounds.

During the initial years, when canopies of the trees are not yet fully developed, intercropping may well be considered. For intercropping with rice, the trees will need to be grown on mounds of at least 0.50 m high. Coconuts might also be intercropped with perennial crops such as coffee, fruit trees, etc. Tree crops are not recommended for the lower hydro-topographical categories because of drainage constraints, but are a good alternative in the higher categories that make up the majority of the tidal lowlands

A.5.4 Water management during fallow periods

Drainage stimulates soil ripening and the removal of (potential) acidity. Soil ripening is an essential process to achieve higher productivity. Poor soil and water conditions also prevent cultivation of HYV rice varieties, as these are more susceptible to (lack of) water control and acidity and toxicities, being one of the reasons why farmers opt for long duration local rice, with lower yields (other reasons being labour shortages and off-farm employment).

Ripening will also improve the soil bearing capacity which is important for land preparation (ploughing, levelling, puddling), and mechanization. Land preparation has little to no effect in unripe soils and soils with high organic matter content. Active water management, i.e. drainage up to 0.60 m, during fallow dry season periods is recommended to accelerate the soil reclamation process. Mechanized land preparation is one of the major requirements for the agricultural revitalisation in the tidal lands of the EMRP.

Figure A.5.1 - On-farm Water Management for Tidal Irrigated Rice

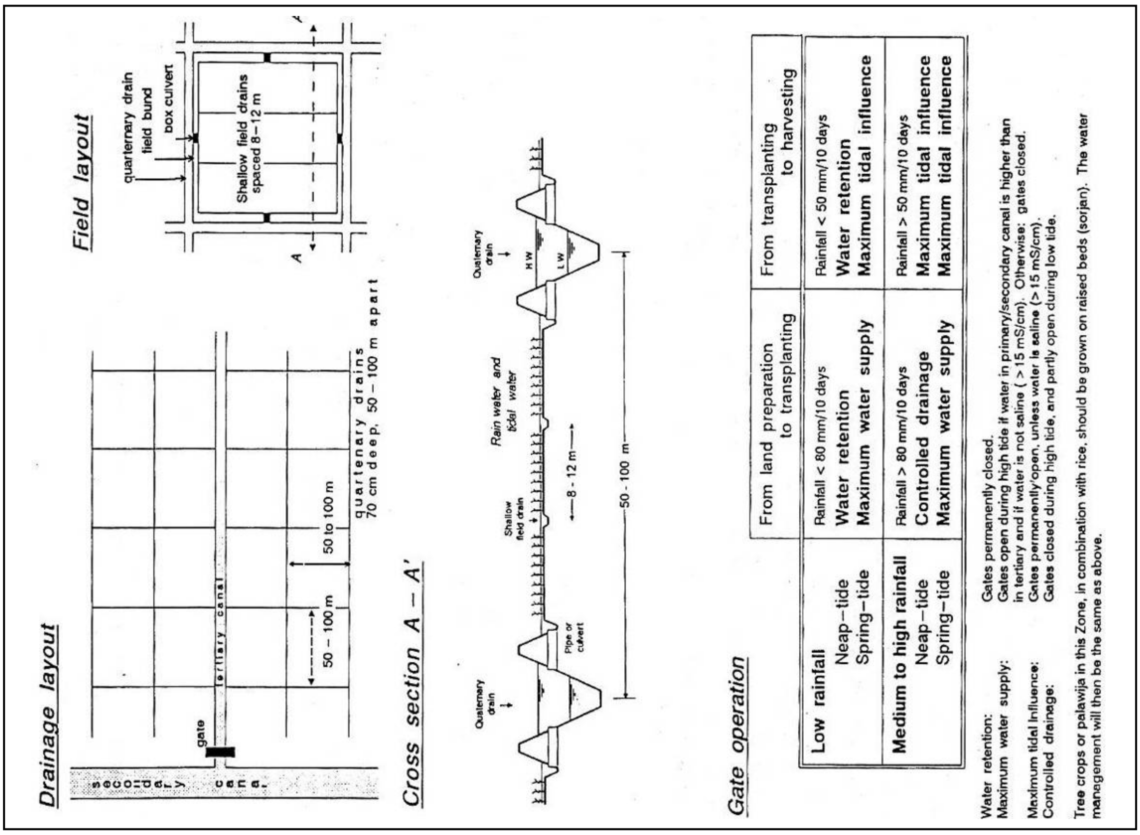


Figure A.5.2 – On-farm Water Management for Rice on Pyritic and Muck Soils

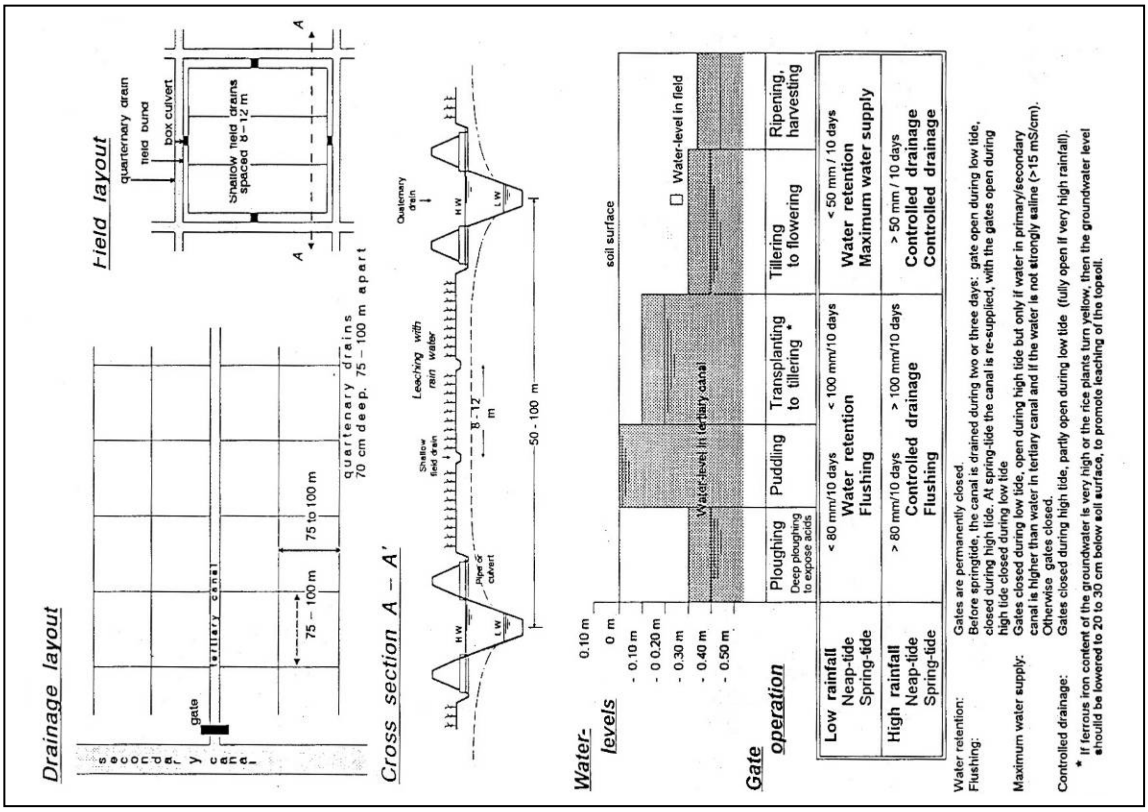


Figure A.5.3 - On-farm Water Management for Palawija on Pyritic and Muck Soils

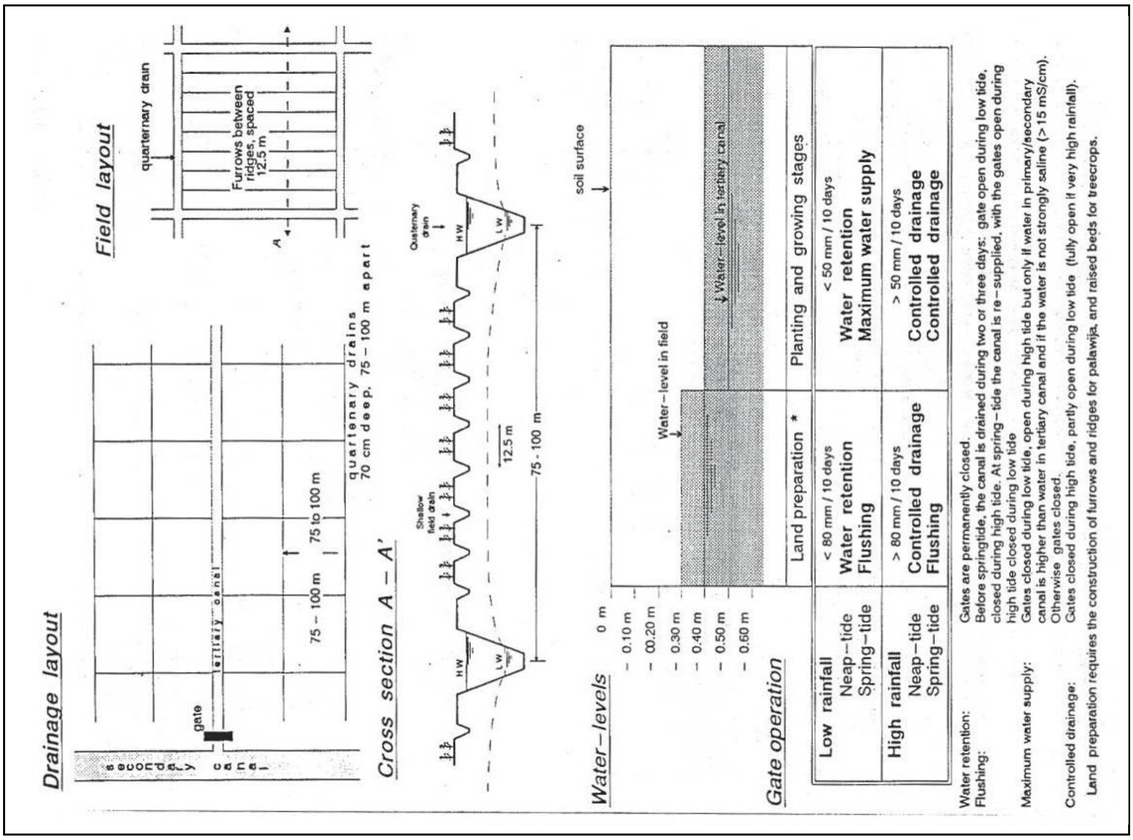


Figure A.5.4 - On-farm Water Management Tree Crops, Pyritic and Non-Pyritic Soils

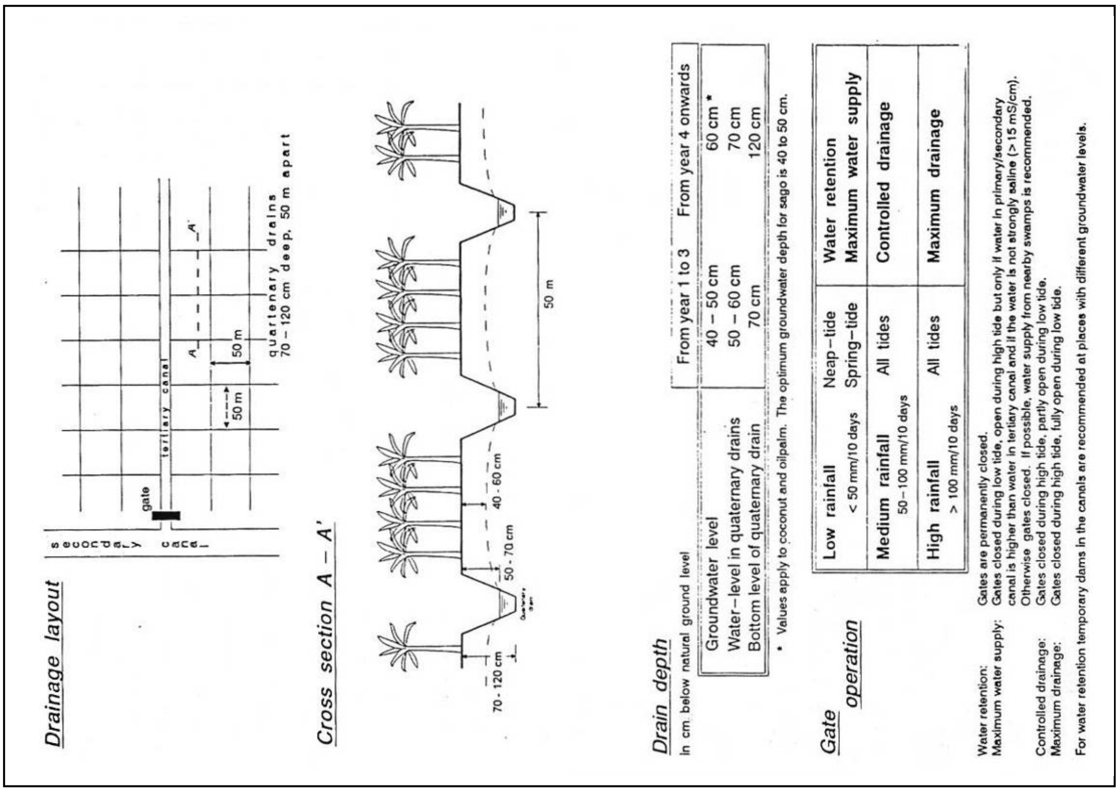


Figure A.5.5 – On-farm Water Management for Rice on Non-Pyritic Soils

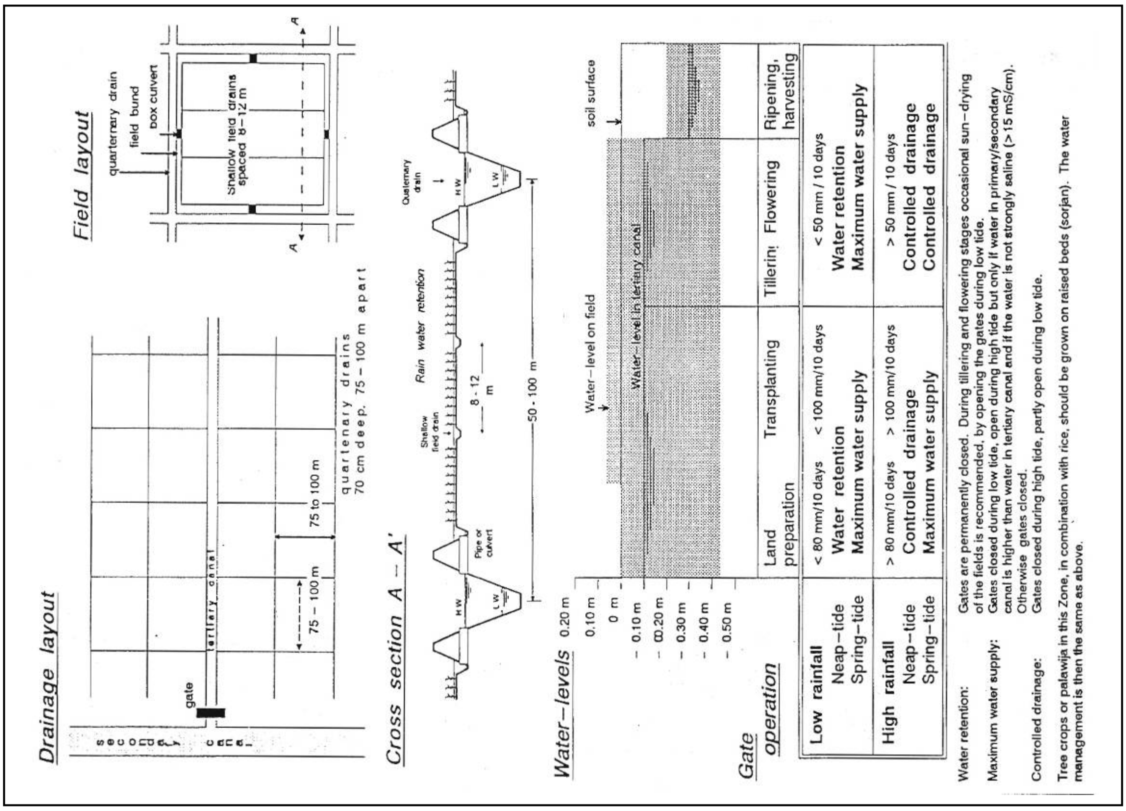
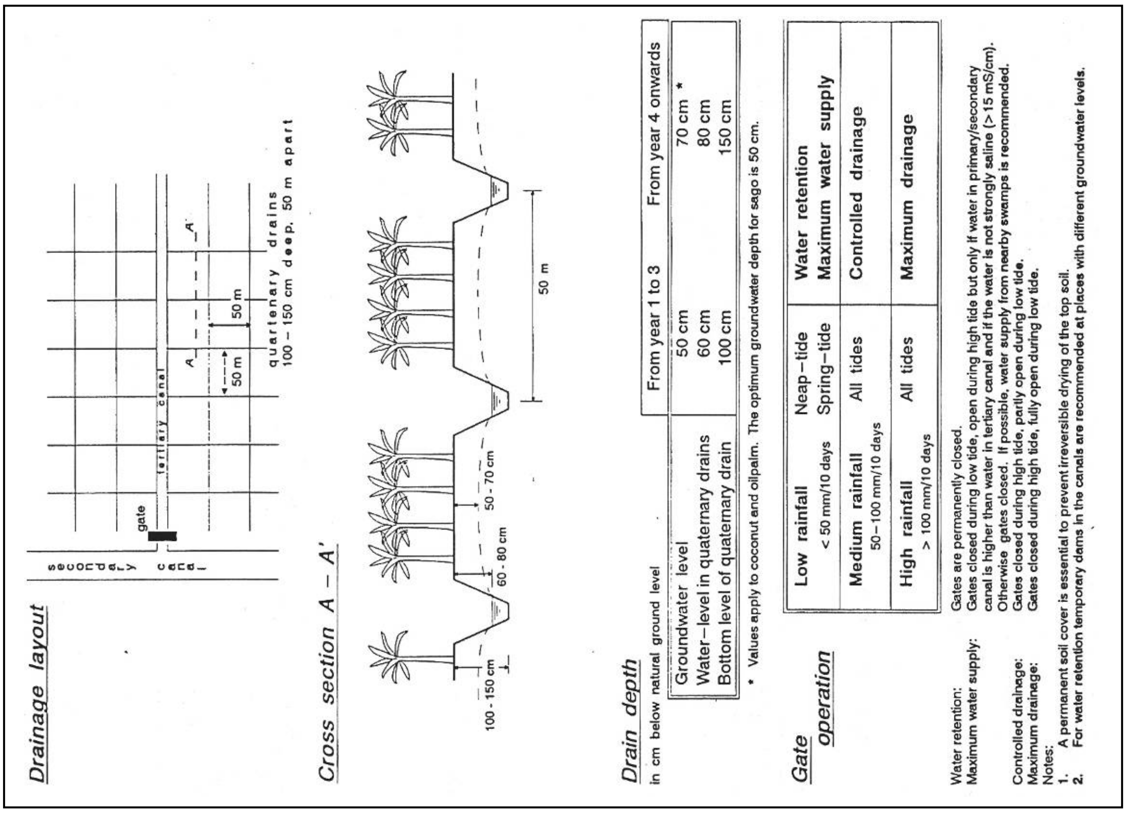


Figure A.5.6 – On-farm Water Management for Tree Crops on Peat Soils



Annex 6 - Modeling of typical land and water management cases

During the master planning study, the following typical cases and hydraulic models were identified, to support the design of a land and water management strategy. These cases focus on specific land and water management situations in the adapted management zone (3), and the development areas (4), see Table A.6.1 and Figure A.6.1.

Table A.6.1 – Hydraulic modeling of typical LWM cases

Location	Model	Main objective
North-West Block A	A-2 Adapted Management Zone	Effect on adjacent conservation area of Lamunti scheme
	A-3a Development Zone	Appropriate system layout for Lamunti scheme, main system
	A-3b Development Zone	Main system + flood mitigation Dadahup scheme, main system
	A-4 Development Zone	Appropriate system layout for Lamunti scheme, secondary/tertiary system
North Block C	Cn-2 Adapted Management Zone	Effect on adjacent conservation area of traditional farmer-made canal system
South Block C	Cs-2 Adapted Management Zone	Effect on adjacent conservation area of Govenrment scheme, Kahayan R bank
Block D	D-1 Development Zone	Effect of PLG main N-S canal

<u>North-west Block A</u>

Model A-2: Adapted Management Zone

Objectives

- Determine capacity of canal system for drainage within the zone
- Determine potential for tidal irrigation and need for flood protection
- Determine effect of subsidence on drainability and flood hazards within the zone
- Determine the effect on (ground-)water levels and subsidence in the adjacent peat conservation area in case of:
    - water management in AMZ for shallow-rooting crops
    - water management in AMZ for deep-rooting crops
- Determine required minimum width of drainage impact on peat lands

Evaluation criteria

- Groundwater depth inside zone during normal rainfall and during a 1 in 5 year maximum rain storm
- Height and duration (per day, per month) of canal water-level above land level inside the zone, at present and after X years of subsidence.
- Groundwater depth in wet and dry season in the conservation area at various distances from the boundary with the Adapted Management Zone.
- Others, to be determined

Boundary

Kapuas, Mentangai, and Mengkatib rivers.

Water management requirements

- Drainage requirements to be determined based on impact on peat conservation (as in model A-1), and/or agricultural requirements (as in model A-3).
- Others, to be determined

Comments

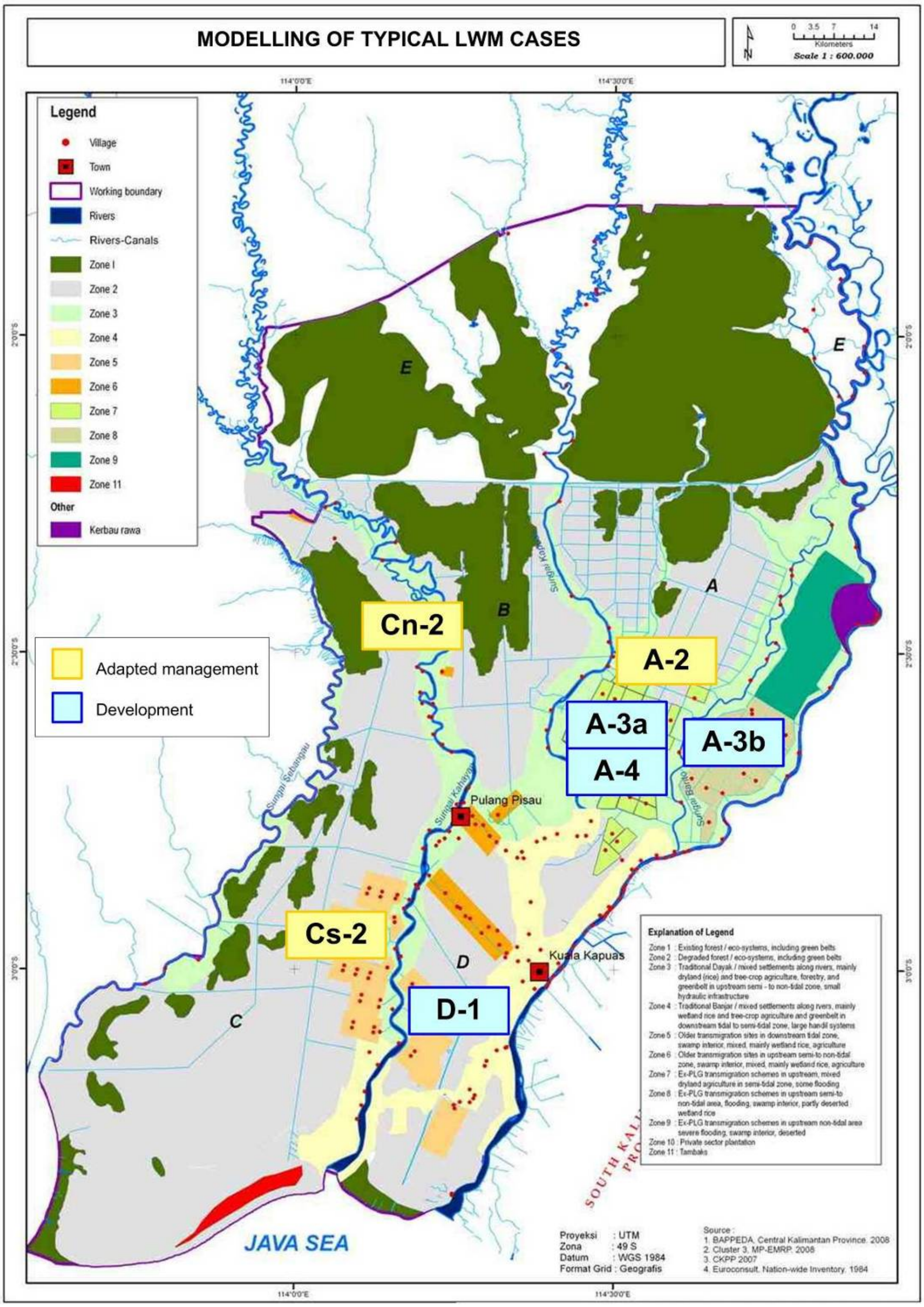
The legal boundary between Peat Conservation Zone and Adapted Management Zone is currently fixed at 3 m peat depth. This is an arbitrary boundary, and it is recommended instead that eco-hydrological landscape criteria, and/or that a stricter peat depth criteria, e.g. the 1 m peat depth line, is used.

Model A-3a: Main canal system of Lamunti scheme

Objectives

- Determine capacity of existing primary canal system for drainage
- Determine potential for tidal irrigation and need for flood protection
- Determine effectiveness of canal system in removing acid drainage water
- Determine effect of alternative layouts of primary canals and structures:
    - open versus closed system
    - number and location of river connections
    - various gate operations

Figure A.6.1 – Proposed land and water management modelling



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Evaluation criteria

- Groundwater depth inside scheme during normal rainfall and during a 1 in 5 year maximum rain storm
- Height and duration (per day, per month) of canal water-level above land level.
- Time required to remove 50% of acids released at a certain moment in the area

Boundary

- Kapuas, Mentangai and Mengkatib rivers.
- Adapted Management Zone.

Water management requirements[36]

- Drainage base: average tide in the river during the month of the growing season with the highest river levels.
- In periods with normal rain drainage should be possible till a depth of at least:
  - Wetland rice 30 cm
  - Dryland crops 30 – 60 cm
  - House-lot and village area 30 – 50 cm
  - Tree crops 60 cm
- During a 1-in-5 year maximum rainfall the system should enable:
  - Rice: maximum 3-day rainfall, reduced with an allowable increase in field storage of 50 mm, to be evacuated in 3 days
  - Dryland crops maximum 4-day rainfall to be evacuated in 4 days, with groundwater table back to normal (see above).
  - Tree crops maximum 6-day rainfall to be evacuated in 6 days, with groundwater table back to normal (see above).

Comments

- No peat, hence no subsidence.
- All canals serve the same purpose, no distinction between originally designed drainage and supply canals.

Model A-3b: A similar exercise for the Dadahup area is recommended, where boundary conditions are very different (Barito river floods)

Model A-4: Secondary / tertiary canals in selected part of Lamunti scheme

Objectives

- Determine capacity of existing canal system for drainage
- Determine potential for tidal irrigation and need for flood protection
- Determine effectiveness of canal system in removing acid drainage water
- Determine effect of alternative layouts of tertiary canals and structures

Evaluation criteria:

- Groundwater depth inside area during normal rainfall and during a 1 in 5 year maximum rain storm

[36] Euroconsult (2000a), p. 4-3 to 4-7

- Height and duration (per day, per month) of canal water-level above land level.
- Time required to remove 50% of acids released at a certain moment in the area

Boundary

- Primary canal system
- Kapuas, Mentangai and Mengkatib rivers.
- Adapted Management Zone.

Water management requirements

- Same as for Model A-3.

<u>North Block C</u>

Model Cn-2: Farmer-made canal system

Objectives

- Determine capacity of canal system for drainage
- Determine need for flood protection and potential for tidal irrigation
- Determine effect of canals and their operation on groundwater-levels in adjacent peat dome area

Boundary

Kahayan river levels, N-S PLG canal

Evaluation criteria

- Groundwater depth inside area during normal rainfall and during a 1 in 5 year maximum rain storm, at present and after X years of subsidence.
- Height and duration (per day, per month) of canal water-level above land level inside the zone, at present and after X years of subsidence.
- Groundwater depth in wet and dry season in the conservation area at various distances from the boundary with the Adapted Management Zone.

Water management requirements

- As in Model A-3
- Others

<u>South Block C</u>

Model Cs-2: Government scheme, Kahayan right bank

Objective:

- Determine capacity of existing canal system for drainage
- Determine need for flood protection, potential for tidal irrigation
- Check effect of canals and their operation on groundwater-levels in adjacent peat dome
- Determine effect of alternative system layout and operation modes:
    - open versus closed system

- interconnection of (dead-ended) canals
- function interceptor drain between peat and developed area

Evaluation criteria:

- Groundwater depth inside scheme during normal rainfall and during a 1 in 5 year maximum rain storm, at present and after X years of subsidence.
- Height and duration (per day, per month) of canal water-level above land level inside the zone, at present and after X years of subsidence.
- Groundwater depth in wet and dry season in the conservation area at various distances from the boundary with the Adapted Management Zone.

Boundary:

Kahayan river levels, N-S PLG canal

Water management requirements:

Same as for Model A-3.

Block D

Model D-1: Government schemes, Kahayan left bank

Objective:

- Determine capacity of existing canal systems for drainage
- Determine need for flood protection, potential for tidal irrigation
- Determine influence of major PLG N-S canal on water management in schemes with and without control structures (improve water quality, flushing, increase tidal irrigation possibilities)

Boundary:

Kahayan river levels, PLG canal, and Kapuas river water levels

Evaluation criteria:

- Groundwater depth inside scheme during normal rainfall and during a 1 in 5 year maximum rain storm
- Height and duration (per day, per month) of canal water-level above land level.
- Flow quantities through main canals.

Water management requirements:

Same as for Model A-3.

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