DORAS - DELTA : research report n°8

INCO : Topic 1

Dry-season water allocation and management in the Chao Phraya Delta

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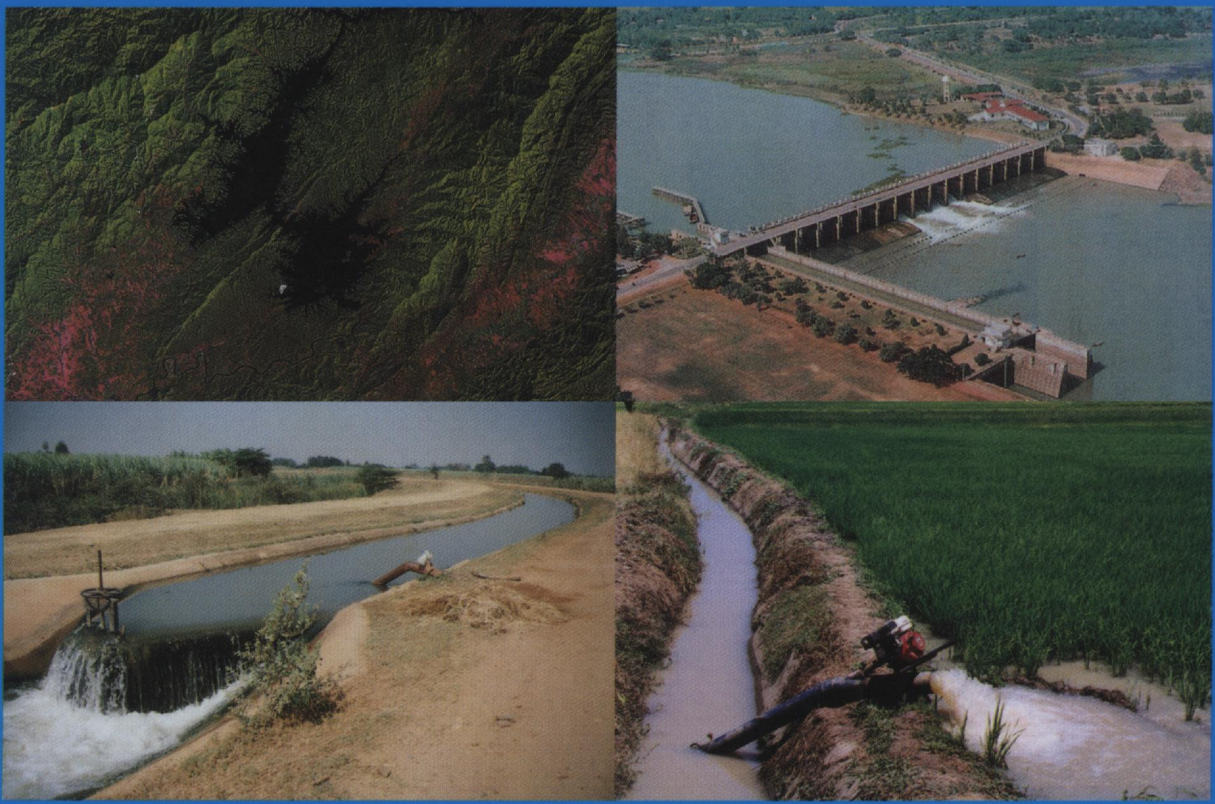

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<u>Cover</u>*: Four successive levels of water management:*
Sirikit Dam; Chai Nat Diversion Dam; Irrigation structure; water use at the plot level

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The authors are greatly indebted to many RID officers for the valuable information they have provided all through this study. This common work has been built on mutual confidence and all the observations made hereafter must be seen as a positive contribution to improving management, efficiency and equity in the Chao Phraya River basin. Although some comments may appear as criticism, it would be fairer to regard them as constructive remarks aimed at calling attention upon points which need to be addressed. The study was carried out with the pervasive impression that the technical maintenance and management of irrigated systems in the Chao Phraya Delta, although widely based on experience, compared very favourably with many other large scale irrigation schemes world wide. In what follows, emphasis is laid on the changes, often recent, which affected the delta and its environment, and on the consequent adjustments and, sometimes, redefinitions needed at the policy and operational levels.

Our gratitude goes to Chaiwat Prechawit and Wirat Khao-Uppatum, advisers to this research project, and to all the RID officers at the Regional and Project levels who have participated to (often long) discussions with the research team. At EGAT, the authors are deeply indebted to Mrs Uamphon Kumnuansilp who lent herself to all kinds of inquiries and provided numerous data used in the analysis. Dr. Chaipant Rukvichai, at Chulalongkorn University, is gratefully thanked for his insightful remarks on an earlier draft of this report.

Report 1:

Dry-season water allocation and management in the Chao Phraya Delta

Annexe report: The impact of the access to irrigation water on the evolution of farming systems: a case study of three villages in the Chao Phraya Delta

Report 2:

Patterns of social interaction and organisation in irrigated agriculture:
the case of the Chao Phraya Delta

Report 3:

Agricultural diversification in the Chao Phraya Delta:
agro-economic and environmental aspects of raised bed systems

These research reports are parts of a comprehensive comparative study between the Red River, Mekong River and Chao Phraya River Deltas. This project addressed three topics: 1) water management along the "water chain"; 2) social and institutional aspects of water resources management; 3) agricultural diversification in raised bed systems. Three companion reports are available for each of the three deltas.

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Executive Summary

The Chao Phraya River Basin (one third of Thailand but 70% of its GDP) is now facing unprecedented challenges regarding the status of its water resources. Existing water storage facilities are insufficient to fully realise the potential for production in the dry-season and new water resource development projects are facing financial and environmental constraints. There is increased awareness that both surface and underground water are not properly monitored and the concerned agencies are not empowered with sufficient technical, human and legal means to control these different uses. This translates into high externalities (shortages, pollution and land subsidence) and patterns of distribution characterised by uncertainty and low levels of equity. Despite the temporary respite brought about by the 1997 economic crisis, projections for the mid-term show dramatic consequences and confirm that drastic measures are needed. In other words, what is at stake is the proper management of the transition from a status of common-pool resources in sparsely populated agricultural areas to one of a collective management of more complex and closed river basins, respectful of basic equity and efficiency standards.

This report first analyses the current situation regarding water allocation in the dry-season and attempts to understand evolutions and to identify bottlenecks.

☑ **Water accounting in the dry season for the Chao Phraya Delta** shows that very little unproductive water is lost out of the system. This includes evaporation in waterways and evapotranspiration in fallow lands, and the amount of water which flows to the sea in excess of what is necessary to control pollution and saline intrusions. Infiltrations to shallow aquifers are re-used by tube wells, while those to deep aquifers are tapped by deep wells in Bangkok Metropolitan Area (BMA). Most drains are gated or supply downstream areas. Altogether, it is estimated that only 12% of controlled supply (dam releases, transfer from Mae Klong Basin and underground water) is lost, pointing to an *overall macro efficiency of 88%*. If evaporation losses in the two storage dams are computed, this rate decreases to 83%. This situation is typical of 'closed systems', where demand exceeds supply and reuse of water is high.

☑ **A prospective analysis of the supply and demand in the basin** indicates that the amount of water available for dry-season agriculture is bound to decline drastically over the next two decades. This far-reaching trend results from both the decline of the inflow in the Bhumipol and Sirikit Dams (due to growing abstraction and climatic change in the upper basin) and from the growth of urban areas, particularly BMA. This forecasted evolution will materialise more rapidly if the growth rate of BMA is high, but it is shown that in all instances the decline is likely to be much higher than any gain or savings which could be made by improving the current situation. In other words, there remains little doubt that however desirable these improvements may be, supply will have to be augmented in the mid-run. Projections show that with a growth of non-agricultural water use (principally BMA) at 5% per year, the average available water for agriculture in the dry-season will decline from 4.6 billion m^3 in 2000 to under 3.0 billion m^3 (Bm3) in 2015 (all other parameters being constant).

☑ Dry-season cropping had significantly changed in many respects over the last quarter of century. It increased in magnitude and expanded in both the middle basin (lower Ping, lower Nan) and the delta. *The total **<u>cropping intensity</u>** over the 1977-99 period was estimated at 1.45 but was as high as 1.63 in the last 5 years*. Several historical constraints have been removed to allow the growth of DS cropping:

1) some canals were dredged or recalibrated, allowing larger flows;
2) farmers offset the difficulty of having gravity inflow into their canal or ditch by acquiring impressive individual and mobile pumping capacities;
3) secondary water sources were developed or tapped (wells, ponds, drains);
4) shorter rice varieties (as short as 90 days) have become common;
5) transplanting, and its constraints in timing and scheduling, gave way to a more flexible technique (wet broadcasting); harvesting is now widely mechanised, easing calendars and labour force constraints;
6) on-farm development gradually expanded (farmers' investments);
7) calendars were de-regulated to adapt to fluctuating conditions of supply (western upper delta) and of the flood regime (west bank).

An average value of the cropping area in the dry season is 3 million *rai* (of rice-equivalent) with 60% in the lower delta and 40% in the upper delta. In the last 5 years records have been beaten, with a high of 4.9 million rai in 1998. This corresponded to a surge of **<u>triple cropping</u>**, recorded at 1 million rai.

☑ But **<u>spatial patterns of allocation</u>** *show a significant inequity between the western and the eastern parts of the upper delta, and more generally between Projects*.

The average cropping intensity by Project, taking into account only the area with on-farm conditions allowing the cultivation of High Yield Varieties in the dry-season, was found to vary widely (from 1.07 to 1.88). The lower delta (conservation area) is at an advantage because canal water is available to farmers with little possible control by RID. In the upper delta, the western region is found to enjoy higher cropping intensities, partly because of political interventions, partly because of tube wells (upper area), and land consolidation (preferential allocation, formerly justified by the fact that the farmers concerned had to pay back part of the costs).

☑ *The analysis of the year 1998 showed a very **<u>complex spatial pattern</u>** in the spread of cropping areas*. In contrast with the official dry-season calendar starting in February, it could be seen that the western part of the upper delta started cropping as early as November. More generally the de-regulation of cropping calendars was analysed and understood as a strategy to save water and to gain access to water, in particular by forcing RID to supply already established crops with irrigation water. In the dry-season 1998, only 23% of the upper-delta did not grow a second rice crop, against 44% with double-cropping, 9% with triple cropping (7% with non rice-crops, and 15% of non-agricultural areas).

A striking observation was that a *significant part of the flood-prone area* (planted with traditional varieties in the wet season), initially disregarded by planners and managers, *could achieve dry-season cropping*. This was allowed by an endogenous development of on-farm facilities.

☑ The current **method of water allocation** was investigated and appeared as supply-driven, guided by experience rather than by clear-cut technical parameters, somewhat flexible rather than rigidly pre-determined. It focuses on the allocation at the macro level, with little control on the day-to-day fluctuations experienced at the lower levels but with a concern not to stray too much from the weekly planning, as a way to ensure that the total water released at the end of June does not differ from the overall target by, say, more than15%. Adjustments in the planned schedule are sometimes necessary to respond to sharp imbalances between the planned and effective crop progress, to climatic events or political interventions.

The main point under consideration was how the targets (volume released and cropping areas) were defined, based on the available water volume at the beginning of the dry-season. Insufficient security carry-over stocks at the end of the dry season make the system vulnerable to exceptionally dry wet-seasons, when the net gain in stored water can be as low as 1.5 Bm3. *The 1980, 1994 and 1999 crises were analysed* and it was shown that they resulted from the inability to cut dry-season water supply in-line with security standards. *Attributing the responsibility of water shortage to poor efficiency is the most widespread and misleading misconception*. Should irrigation gain 10% in efficiency, this would not diffuse any crisis but only raise, by the same amount, the area that would be irrigated (as supply is to remain far under the overall potential demand). Shortages and crises are not due to an hypothetical low efficiency but to the allocation policy and its impact on dam water stocks when risk has been mis-evaluated. The lack of strong technical criteria in managing dams and in allocating water to irrigation, and the way they are being challenged by political interventions and farmers' uncontrolled planting, are conducive to recurrent shortages and incur escalating risk. This does not dismiss the fact that efficiency gains are desirable, in that they allow the benefits of water use to be spread to a larger number of users, but it draws our attention to the inconsistency of the commonly stated relationship between efficiency and water shortage.

☑ An attempt was made **to estimate the amount of water released by the dams and further lost to the sea** (in excess of what is necessary to control salinity). This is a controversial question as EGAT is often accused of using huge amounts of water only for the sake of energy generation, which depletes the water stocks available for agriculture. The total average yearly loss was found to be quite considerable, amounting to 2.9 Bm3, or 30% of the average inflow in the two dams. However, most of the years with high "losses" were early years in which a significant share of the Thai energy generation system was based on hydroelectricity. In the 1990s, on the other hand, as the Chao Phraya system gradually "closed" and water resources came under stricter scrutiny, such losses were under 1 Bm3/year, with the exception of the year 1996 which stands as a horrendous counter-example and serves to stress that regulative measures are needed in order to avoid such occurrences.

☑ **Extensive farm surveys in three villages with contrasting access to water** in the dry-season were conducted to show *the impact of such an access on the sustainability of farming systems in the delta*. Dramatic differences in cropping intensity and land productivity between the three villages were observed. Despite a relative re-balancing of average incomes thanks to animal breeding and non-agricultural work opportunities, this strengthens the necessity to give due attention to existing allocation imbalances, in particular to give more consideration to those areas which grow deep water rice in the wet season but have adequate on-farm development to also grow a crop in the dry season.

Based on these analyses, several measures and recommendations could be established.

☑ Water scarcity can be partly solved by **tapping additional local water sources**. A brief mention is made of the development of individual tube-wells and public reservoirs in low lands. Shallow aquifers are already intensively exploited where they are accessible and of good quality (the upper delta and Mae Klong area) and there is little scope for expanding farmers pumping capacity. The policy to excavate huge public reservoirs in natural swamps and low lying public land was scrutinised through a case study in Ayutthaya Province. It was shown that it is far from certain that farmers will use these reservoirs, and that many factors must be considered before engaging in such well-intentioned but costly investments.

☑ **Increasing efficiency in the irrigation sector** is a returning 'red herring'. Unqualified insistence on very low efficiency (30%) is both misleading when adopting a basin wide vision and erroneous when applied to the distribution of irrigation water. It can be shown that a *rai* of rice consumes on the average 1,500 m^3/*rai* , for an average plant consumptive use of 980 m^3/*rai*, with 210 m^3/*rai* supplied by rainfall, which gives an overall irrigation efficiency of 60%, a rather high figure as far as gravity irrigation is concerned. The efficiency in the lower delta is significantly higher than this value, but the opposite is true regarding the upper delta.

Rather than focusing on illusory gains at the plot level, gains in efficiency can be obtained by reducing the amount of water effectively consumed by the plant. This can be done either by giving more attention to cropping calendars or by adopting non-rice crops.

It was shown that the evolution of climatic parameters along the year (ET and rainfall), to which must be added the residual soil moisture, significantly impacts on crop water requirements. De-aggregating dry-season cropping calendars and promoting early and late calendars, instead of sticking to the conventional season starting in February, leads to sizeable water savings (up to 10%). This path has been shown by the farmers themselves and must be incorporated in a new definition of cropping calendars by sub-areas.

Diversification out of rice to field crops is a popular refrain at least as far back as the 1960s. As long as the economic environment of field crop production remains unattractive and uncertain, there is little incentive for farmers to adopt such crops and scope to sustain criticism on their growing rice, as many have incurred in losses by growing field crops (either by will or by suggestion from extension services). Inducing shifts in cropping patterns to achieve water saving by means of differential taxes is believed to be unrealistic while such risk remains. In addition, there are several other constraints (agro-ecology: heavy soil with little drainage, not favourable to growing field crops; labour and capital requirements, skill-learning, development of proper marketing channels, etc.), which condition the process of diversification and it is doubtful that, in addition to public policies aimed at fostering it, its pace may be increased much beyond what is already observed. Farmers do not need to have their water priced to shift to other productions. *They will increasingly do so if uncertainty on water supply and prices is lowered.*

☑ **Demand management options and its emphasis on cost recovery and sectorial allocation** was also analysed with regards to the Chao Phraya Basin context. It was shown that the central water allocation system had handled relatively well the issue of allocating water to activities with higher economic return, and that the assumed 'lion share' of agriculture eventually was the (fluctuating) leftover water in the system. With reduced scope for achieving water savings or economic reallocation, concepts of water charge or water markets lose most of their appeal. In addition, their application would be critically constrained by several practical aspects: a high heterogeneity in the access to water, and in the social cohesion of farmers (which precludes strong collective arrangements); the lack of control over water at the basin level, of metering and conveyance facilities; and the presence of numerous small-scale users difficult to identify. Cost recovery also appeared as a questionable objective, when seen in the wider national context of taxation and subsidisation. The alleged 'huge drain' of Operation and Maintenance costs amount to 0.16% of the national income and it would probably not be difficult to identify other larger 'drains' with much less social and economic benefits.

However, the 'virtuous' linkage existing between structural, managerial, institutional and financial approaches is recognised, with the pricing of water considered as a mere element of contractual binding between RID and groups of users. It can be seen as a reinforcing factor in a participatory process in which users would be brought into the decision making process regarding allocation and management. Such a reform was outlined but emphasis was placed on the existing gap between its prerequisites and the current situation. Defining a 'service' or 'a right' is probably both the most important prerequisite and the major difficulty. The actual lack of control over the system (which includes technical, institutional and political aspects) does not allow reliable scheduling and causes widespread heterogeneities in the access to water (in terms of quantity, quality, timing, and water level).

☑ **Energy generation and dam management** must be adapted to changing conditions. With a contribution of Bhumipol and Sirikit Dams, each between 1 and 2% of Thai energy generation, there is no more justification to use dam water for the sole purpose of electricity generation, given the high socio-economic value of water for agriculture and rural livelihood. In addition, peak requirements generation, usually ensured by dams because of the facility of switching turbines on and off, can now be widely ensured by gas turbines and other dams (in Laos, and dams in surplus basins, such as the Mae Klong Basin). This calls for a formalisation of the priority of downstream uses, in order to avoid occasional huge wastes, as in 1996.

The declining importance of dams in energy generation must also be acknowledged and open the way to the possibility of using dam dead storage volumes when necessary. Public awareness campaigns are needed to avoid psychological side effects and to present this situation as normal, even though it must remain exceptional. The dead storage of the Sirikit Dam is more than enough to cover incompressible needs for 2 or 3 months in case of emergency. *No crisis should be allowed to occur with nearly 3 Bm3 of unused water*.

However, even the probability of a crisis period can be (and should be) easily reduced by applying strict standards on carry-over security stocks. *It was a political failure to limit dry-season releases* which generated the crises of the 1990s, not the lack of water *per se*. It can be shown that setting and enforcing target releases to ensure a stock of 2.5 Bm3 on the 1st of July is enough to avert crises.

Other aspects of dam management which require attention are the *setting of the upper-rule curve* according to a criteria of maximisation of water stocks (under constraints of dam safety) and not of maximisation of energy, and the improvement of the responsiveness to hydrological events, principally rainfall in the wet-season.

☑ **The allocation process must be reconsidered** in order to allow more equity and to raise security standards. This includes:

1) De-aggregation of DS cropping-calendars and the formal (and official) recognition of the interest of shifting part (the western part) ahead in time (November);
2) a growing effective concern to incorporate more equity in the total amount allocated to different sub-areas (more to the east);
3) the recognition that a growing part of the flood-prone area is now fit to accommodate HYV in the dry-season and should also be considered,
4) curtailing triple-cropping by stricter scheduling in order to spread the benefit of double-cropping;
5) fixing targets with due consideration to the security stocks to be ensured at the end of each season.

These measures can be taken even within the top-down allocation system but it is recognised that current political and institutional constraints do not allow a *thorough rebalancing (bottom-up re-allocation)*: this could be achieved if a Chao Phraya Basin Organisation was set up to control water allocation in the different parts of the basin, and to initiate a participatory process with concerned stakeholders in order to: 1) define an overall policy of water allocation; 2) to define the plan to be implemented each year; 3) to have concerned users participating in the monitoring of effective deliveries. This is contingent upon a process of identification and empowerment of user representatives and is at the core of a much more complex long-term institutional reform.

Overall, it is clear that efficiency concerns are poorly addressed by and offer little justification to proposals of water pricing or water markets, and that there is limited scope to achieve large water savings. *The different possible measures proposed are not likely to radically revert the current water short status of the Chao Phraya Basin.* As regards to equity considerations, it is not sure that imbalances be sufficient to justify costly and complex institutional reforms which success is not at all ensured. The return of water crises *can be best interpreted as the expression of the refusal by the farming sector to see its share declining*. *The mismatch between supply and demand is at present dealt with by eliciting* *releases – through political channels - beyond what risk standards command*. The current vulnerability of the overall system can only be done away if the growing water scarcity is fully passed on to users. This has strong political implications and it can be hypothesised that a mounting pressure on water would translate in unrest in rural areas, therefore in more political interventions and more support for water resource development.

It is beyond doubt that a sweeping reform of the administrations and of the legislation involved is needed. However, because of the lack of political support to achieve such reforms (as shown by the stalled process of the water law), it was found more adequate to separate recommendations in two scenarios. The first one is a "low" scenario, which produces significant but partial benefits, and does not rest on the prerequisite of a large-scale institutional reform covered by a new water law. It combines structural improvements and innovations in management.

The second scenario, on the contrary, assumes that the current institutional gridlock is overcome and that a proper Chao Phraya Basin Organisation allows for the empowerment of users and their active participation in the main decision processes: allocation of water within the delta and at the different lower levels, including scheduling and maintenance. Water pricing can be introduced as a "virtuous" binding element between users and suppliers, if conditions for defining contractual services, and in the long term, rights, are fulfilled.

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Part I

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Abbreviations, units and terms used

ADB: Asian Development Bank

BMA: Bangkok Metropolitan Area

CPBO: Chao Phraya Basin Organisation

EGAT: Energy Generation Authority of Thailand

DS: dry-season

DEDP: Department of Energy Development and Promotion

HYV: High Yield Varieties

MOAC: Ministry of Agriculture and Co-operative

NWRC : National Water Resources Committee

RID: Royal Irrigation Department

TAO : Tambon Administration Organisation

TV: traditional varieties

WBO : Water Basin Organisation

WS : wet season

WUA : water users association

WUG : water users groups

rai	1 ha = 6.25 rai
thang	1 thang = 10 kg (for paddy rice in the Central Region)
baht	1 US $ = 37 baht (average)
Mm^3, Bm^3	Million m^3 , Billion m^3
cms	m^3/s (discharge)

"*Project*": one of the administrative and hydraulic sub-units of the Royal Irrigation Department within the delta.

Introduction

The context of basin water resources

Although a monsoon tropical country to which the layman would readily associate an image of luxuriant land with plentiful water, Thailand is now coming under the category of countries with problems of water shortage. Hydrological data show that the yearly average rainfall in the country varies between 1,100 mm and 1,600 mm, if we except the southern region, the eastern region, near Cambodia, and a few forest areas along the border (ESCAP, 1991). While a – rather attenuated - monsoon provides water (often) in excess during, say, for the sake of simplification, half of the year, during the other half most users are supplied with water released from 25 main storage dams. After the second World War, Thailand's water resources were by and large untamed and no storage capacity existed to regulate the seasonally contrasting water regime mentioned above. Population did not exceed 18 million people and most of the uplands were still covered with forests. The second half of the century, however, has witnessed dramatic changes in population (62 million inhabitants in 2000), urbanisation (10 million people in the Bangkok Metropolitan Area (BMA)), water resources storage development (28 main dams totaling 66 10^9 m3), cultivated area (52 to 130 million rai) and irrigated area (32 million rai at present, or 25% of the total agricultural land). However, only 15% of the 200 Bm3 annual run-off remains trapped in the dams (ESCAP, 1991).

The Chao Phraya Basin makes up one third of Thailand's territory and encompasses the great majority of irrigated areas. It also includes Bangkok Metropolitan Area. The basin can be conveniently divided in three sections (Figure 1). The *upper basin* (the catchment area of Bhumipol and Sirikit Dams), the *middle basin* (downstream of the dams, down to Nakhon Sawan), and the lower part (or the *delta*). Because of decreasing precipitation (Bancha *et al.*, 1998) and growing water abstraction, the yearly inflow into the two dams has been declining from 11 to 9 Bm3 during the last thirty years. In the middle reach, both medium and large scale RID Projects and group irrigation based on pumping along the river (fostered by the Department of Energy Promotion) can be found. Private irrigation has also developed along the rivers but no data are available on this issue. In the delta, 1 million ha can potentially be irrigated (with a high potential for triple cropping), while BMA's demand rose from 0.46 million m^3/day in 1978 to approximately 7.5 million m^3/day in 2000 (a sixteen fold increase in twenty-two years). In addition, there is a contribution from underground water to BMA of approximately 3 million m^3/day, most of which is used by industries (90% of which rely on the aquifer) (TDRI, 1990).

During the dry season, all water users within the middle and lower reaches of the basin rely, by and large, on water delivered by the Bhumipol and Sirikit Dams. Less and less water is flowing into these dams; concomitantly, the growth of urban and industrial sectors leads to increasing withdrawals within the basin (see Chapter 1). On the demand side, the potential area for irrigation has also increased, not only because of the increment in the gross area provided with irrigation facilities, but also because a larger share of the delta is now in a position to grow rice during the dry-season: this is due to the gradual improvement of the on-farm conditions of plots which formerly grew only deep-water rice varieties and to the fact that individual pumping capacity now allows access to water even if gravity supply is not ensured.

The eventual equation is despairingly simple: water resources for agriculture are both clamored for by more farmers and deemed to decrease substantially, with a drastic impact on the sustainability of farming in the irrigated areas of the basin. A wide range of solutions have been proposed, debated or opposed by the different stakeholders concerned by the issue. These include:

Increase of supply

This is the preferred option of government agencies which have been engaged in water resources development in the past (RID, EGAT,..). The main solutions are the building of additional dams, the transbasin diversion of water from the Salaween and Mekong rivers, and the tapping of more aquifers.

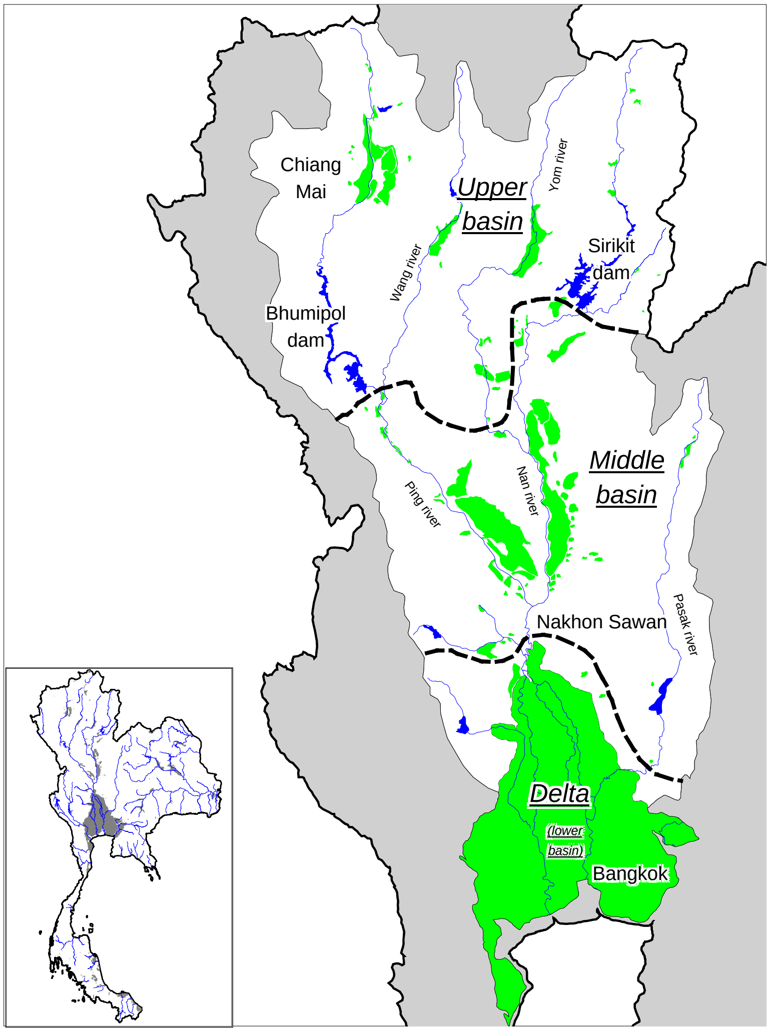
Improvement of overall management

Water in the basin is managed principally by RID, EGAT and PWA (Provincial Water Authorities). Improved knowledge of hydrologic conditions, better co-ordination between agencies, better timing and assessment of water releases, etc. are believed to be potentially conducive to substantial water savings. In other words, the share of (controlled) water released by the dams and flowing to the sea in excess of the discharge needed to control seawater intrusion must be reduced. Institutional and administrative reforms are also needed to create a Basin Agency, or a River Basin Association, which should be responsible for the allocation and monitoring of water supply, for the control of the development of water use, and for enforcing legislation.

Water saving and upgrading efficiency of use

All users may potentially use water in smaller quantities *and* with fewer losses. Irrigators should adopt water saving farm practices and crops with lower water requirements. They should associate in order to adopt patterns of water distribution believed to reduce waste and to increase equity. Loss by infiltration in canals could be cut by lining them. Urban tap water networks should be improved to reduce leakage. Industries should adopt water saving innovations and recycling of the water which has deteriorated in quality to the point that it cannot be used anymore (a sink in the system).

FIGURE 1: LAYOUT OF THE CHAO PHRAYA BASIN AND ITS THREE SUB-DIVISIONS



<u>Economic incentives</u>

In parallel, or as a complement, policies aimed at introducing economic incentives should contribute to water saving ("user-pay principle"), water quality protection ("polluter-pay principle") and to an economically more efficient allocation of water among users (water rights, water markets). Far-reaching administrative and legal reforms are pre-requisite to these incentives.

All these options have pros and cons, contenders and opponents. Engineers are prone to propose hardware or administrative reforms. Macro-economists are concerned with economic incentives and taxation. NGOs and social activists are opposing commoditisation of water, social and environmental costs of new water resource developments, and are worried about the impact on the rural poor. Government agencies favour alternatives giving more power and control to administrative bodies.

The present report is not intended to address all these options and to analyse all these debates. Although it concentrates on the way water is allocated and distributed within the basin in the dry-season, with emphasis on the agricultural sector, it will nevertheless keep a wider basin framework of analysis. As water eventually available for agriculture is contingent upon how and how much water other sectors use, some sections will also address, albeit not in depth, these issues. Given its importance in the present debate on water in Thailand, the question of water pricing will also be considered in some detail[1].

Dry-season cropping

How did irrigated agriculture in the Chao Phraya Basin evolve within the overall context outlined above ? In 1937, 96% of all farmers were growing some rice. This percentage was 90% in 1963, while approximately 70% of farmers grew exclusively rice, once in a year (Molle and Srijantr, 1999). In areas with rather good water control, traditional varieties were grown quite intensively through the use of transplanting. In flood prone areas, agro-ecological conditions imposed the use of dry broadcasting with deep-water or floating rice varieties. Despite the investments made in the infrastructure of the Greater Chao Phraya Irrigation Project, yields first remained unexpectedly low, raising concern on the reasons of such a situation and on the profitability of the investment (FAO, 1968).

In the late 60's the first High Yield Varieties (HYVs) were experimented with but the rate of adoption remained low. Several factors have been cited to explain this slow dissemination, including the depressed rice prices, the high cost of fertiliser, which made the shift unprofitable, and the still inadequate water control at the farm level (Kaida, 1978).

In 1972, the Sirikit Dam was completed and the water deliveries in the dry-season soared. Double-cropping soon appeared as a desirable option and the farmers' demand grew, boosted by governmental policies aimed at encouraging it. Double-cropping and higher rice prices in the 1974-80 period contributed to making HYVs more attractive. Two-wheel tractors, used for land preparation and for powering axial low-lift pumps, rapidly spread, easing labour constraints and improving water control at the farm level.

During the last 25 years, an average of over 500,000 ha of rice has been cultivated in the delta during the dry-season. This increase in cropping intensity appears as a benchmark of agricultural development: it also significantly contributed to the improvement of the economic situation of the farmers who could have access to water and could grow two crops. This benefit, however, was not initially meant to be extended to all farms, because of several main reasons, as appearing in the following table. The present report will provide a thorough reassessment of these constraints and will examine how they have been dealt with during the last 25 years.

It also follows from these constraints and from the overall water balance in the basin that RID was not, and still is not, in a position to deliver water to the whole irrigated area of the Chao

[1] See Molle (2001) for more details on the question of water pricing.

Phraya Delta: *the question of how, when and where to allocate this scarce water is therefore paramount*. It includes technical and socio-political aspects and is faced with the problem of a very high inter-annual variability, as the water stored in the two dams varies greatly from year to year.

In order to cover both the different aspects of dry-season cropping in the Chao Phraya Delta and its linkage with the supply/demand balance of the basin, this report will develop along the following lines:

A first part attempts to identify and describe several relevant issues and aspects of DS cropping:

- Chapter 1 first establishes a detailed water balance of the basin, emphasises the decline of supply and the growth of demand, and investigates the trends to be expected over the next 25 years.

- Chapter 2 provides the general features and an understanding of the physical layout and of cropping systems in the delta, and shows how they constrain dry-season (DS) cropping.

- Chapter 3 analyses water distribution in the DS over the past 22 years. It investigates year to year variability, spatial patterns of allocation and questions the equity of the allocation process. It specifies all the factors which have pushed the DS cropping acreage to unexpected levels.

- Chapter 4 further reveals the complexity of the spatio-temporal progress of DS cropping and zeroes in on the 1997-98 dry season: by comparing the monthly cropping areas under cultivation (as given by both RID data and satellite images) with data on water supplies (canal, well and rainfall), it highlights entangled cropping calendars, extensive conjunctive water use, and establishes standards of water consumption.

- Chapter 5 attempts to describe the formal process of water allocation at the planning stage and compares it to real allocation, looking in particular at the way adjustments are made during the season.

- Chapter 6 analyses the linkages between DS irrigation ("how much water can we use this year for DS cropping") and dam management (including energy generation).

- Chapter 7 summarises findings from a three-village study which shows the impact on cropping intensity on the evolution/differentiation of farming systems along the last 25 years. It draws attention on how crucial DS cropping is for the sustainability of agriculture and on how this point should be incorporated in the planning of water allocation.

A second part investigates several lines of improvement for water allocation and distribution in the dry-season, based on the preceding analyses.

- Chapter 8 investigates whether there is scope for tapping secondary water resources. Tube wells and local storage of water in reservoirs (low lying areas of the floating rice area) are options which are presented and discussed with their respective potential and constraints.

- Chapter 9 analyses whether there is significant water waste in the system and shows that by desegregating the delta and defining more flexible calendars, it is possible to increase the area cultivated in the dry season.

- Chapter 10 and Chapter 11 look at the changes in the energy production systems and provide some proposals on how dam management should be modified accordingly.

- Chapter 12 discusses the issue of water pricing and water markets, the rationale for cost recovery, and the scope for economic regulations in the Chao Phraya Basin;

- Chapter 13 is concerned with the allocation process, the rules to define target volume and target areas and spatial equity.

- Chapter 14 synthesises the main findings and conclusions of the study and propose scenarios of reform.

Part I

Analysis of past and current dry-season water allocation and management

The first part of this report presents an overall perspective on the water balance of the basin, with its consequences on the Chao Phraya, and reviews the main key issues related to dry-season water allocation and management, showing the past evolutions and the present problems faced.

1 Overall basin water balance

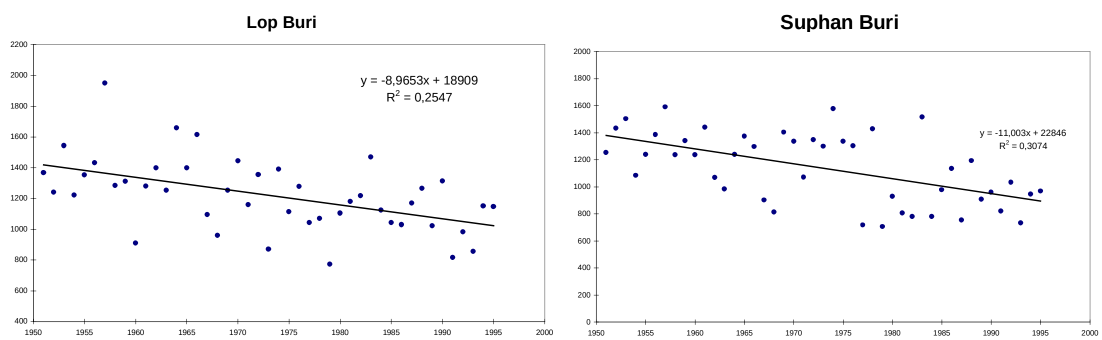
As a preliminary, this chapter characterises the overall water balance at the basin level, stressing the conflict between declining water resources and growing uses.

1.1 Rainfall

The first natural water supply within the basin is rainfall. According to Kwanyuen (2000), there is an evidence of annual rainfall recession in some river basins of the north region especially the Kok, Ping and Nan basins. This recession is relatively strong in Kok basin. This declining trend contributes to reducing the inflow into the two storage dams.

Based on 86 rainfall stations, Kwanyuen *et al.* (1998) reported a decrease of annual rainfall in the central Plain ranging from 2 to 6 mm/year. This trend is particularly obvious in the case of stations such as Lop Buri and Suphan Buri stations (Figure 2), but less acute for other locations, such as Nakhon Sawan. The trends affect both the rainy and dry seasons, therefore impacting on the contribution of rainfall in the dry-season.

FIGURE 2: EXAMPLES OF DECLINING TRENDS OF RAINFALL IN THE CENTRAL PLAIN



1.2 Yearly inflow in the dams

The Bhumipol and Sirikit Dams control approximately 30% of the total basin. The natural inflow into these two storage dams has been steadily declining. Figure 3 plots the decline of the net yearly inflow (i.e the natural inflow – the evaporation loss during the same year). While the overall average is 5.27 Bm^3, the end of the regression line points to a value of 4.2 Bm^3. Similar data for the Sirikit Dam also show a significant decrease, although less dramatic (Figure 4), with an average of 5.23 Bm^3 of net inflow, corrected down to 4.51 Bm^3 by the regression curve for the year 1999. The respective losses by evaporation are also shown on the figures. Bhumipol looses an average of 336 Mm3/year (68% during the dry season), while Sirikit Dam's loss amounts to 291 Mm3 (59% in the dry season).

FIGURE 3: EVOLUTION OF YEARLY NET INFLOW IN BHUMIPOL DAM

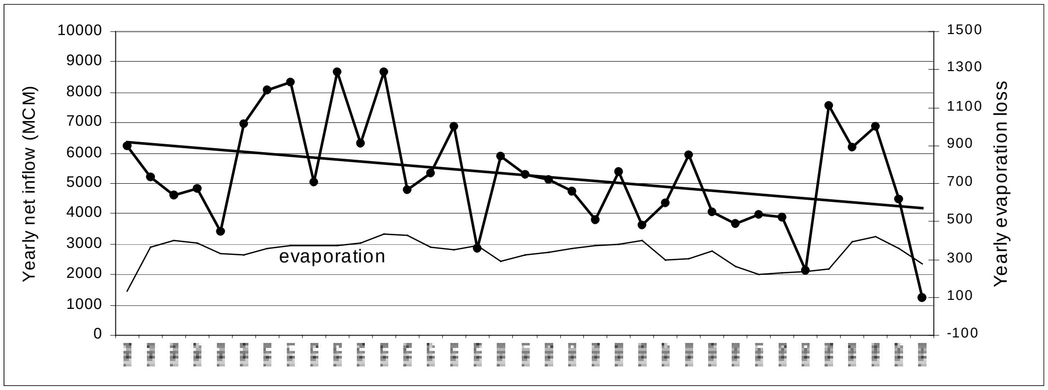


FIGURE 4: EVOLUTION OF YEARLY NET INFLOW IN SIRIKIT DAM

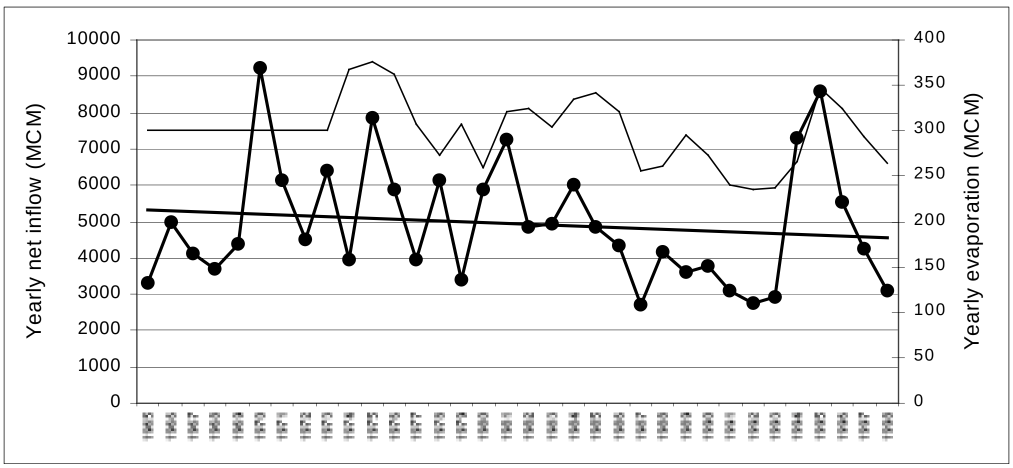
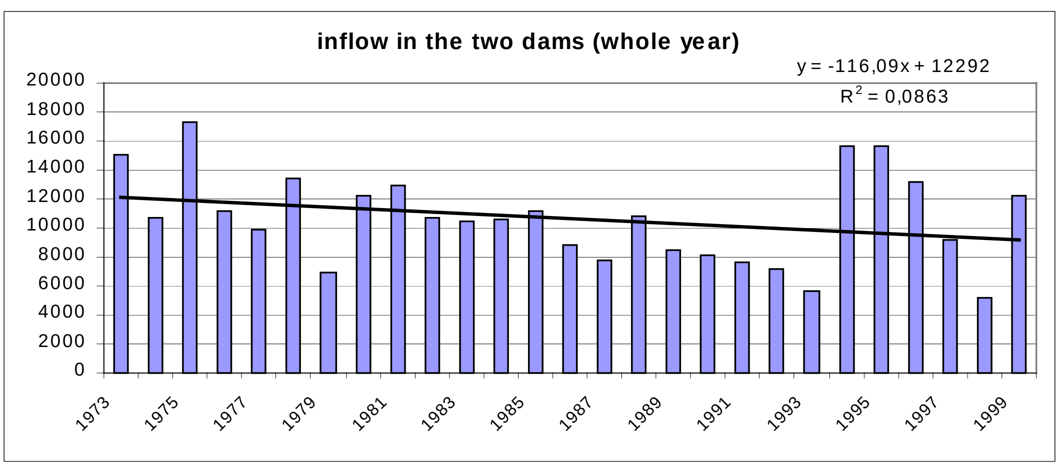


FIGURE 5: YEARLY INFLOW INTO THE TWO DAMS (MM3)

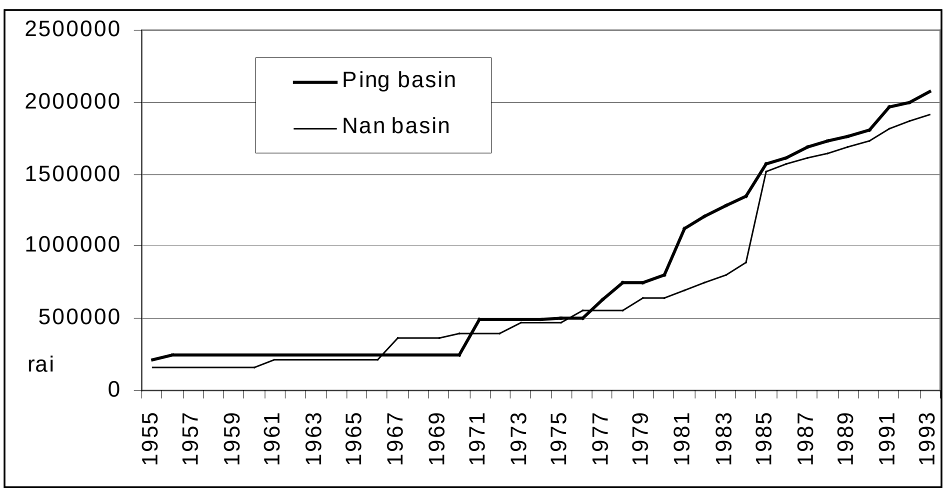


If we now look at the combined inflow in the two dams (Figure 5), we observe a decline from 12 Bm3 down to less than 10 Bm3, from which must be deduced an average loss of 0.6 Bm3 for evaporation/infiltration. Although the linear regression cannot be quantitatively equated to the real declining trend, it is indicative of a drop with a magnitude of 2 Bm3/year, consistent with the changes observed in the upper basin. (We will hereafter consider 10 Bm^3 as a crude but practical (optimistic) estimate of the yearly average net inflow in the two dams).

These changes are driven by climatic change (see above) and by of the increase of water use in the upper reaches of the Ping and Nan Rivers. This phenomena is particularly sharp in the Ping basin because of extensive irrigation infrastructures developed in the Chiang Mai Valley. In the northern region, the irrigated area is reported to have increased 47% between 1980 and 1989 (ESCAP, 1991). Figure 6 shows the steady growth of the irrigated area in the Ping and Nan basins, which now jointly amount to 4 million rai.

According to Pal and Panya (2000), the water demand in the Ping and Nan basins in 1996 was 3.7 Bm3 and 3.0 Bm3 respectively, the greater part of which was coming from the agricultural sector (70%). The order of magnitude of the decline in dam inflow considered earlier (2 Bm3 over 30 years) is consistent with the water demand of 4 million *rai* (not fully doubled cropped).

FIGURE 6: INCREASE OF IRRIGATED AREAS IN THE UPPER BASIN



1.3 Mid and long term water use and strategies

The analysis of these trends must be complemented by a more prospective view on how the pattern of water use is likely to evolve in the near future. All the projections presented below are based on orders of magnitude and average (or median) values; they represent likely trends, and disregard yearly fluctuations.

1.3.1 Supply side

On the supply side, it has been shown above that the absolute increase of water abstraction in the upper part of the basin and the declining rainfall climatic trend do not allow the slightest hope that supply will increase. On the contrary, it is rather likely to decline steadily but there is little agreement on the corresponding rate. Pal and Panya (2000) consider an increase of water use in the Ping and Nan basins from 6.7 Bm3 in 1996 to 9.3 Bm3 in 2016, and a resulting reduction of the inflow at Chai Nat Dam of 1.5 Bm3 over these 20 years. These projections are based on a prospective of domestic and industrial use and on the 'irrigation Project development potential'. They seem to consider a rather optimistic developmental scenario and probably overate the reality to come. JICA (1997) tabulated the expected water demand in the Nan, Yom and Ping basin in 2016, as 11.2 Bm3, against 6.5 Bm3 in 1993. A good part of this increment is due to agriculture (and 0.22 Bm3 to domestic and industrial use), and is also partly provided by natural flows in the wet season.

In sharp contrast to these studies, Binnie & Partners (1997) posit that future demand for irrigation water in the basin will remain constant. This assumption seems to be based on the fact that paddy land is decreased by 1% each year in the delta and on the premonition of a significant shift out of rice to field-crops. This fails to understand that the water demand is governed above all by dynamics in the dry season, in which multiple cropping is possible if the conditions are attractive. In such case and if there is enough water, dry-season cropping will offset by far the decrease in paddy land. In a similar fashion, TDRI (2001), using economic modelling principally based on the World Bank projection of rice world prices, considers that water demand might first rise but later decline in the mid-term. The complexity of agricultural dynamics at the national level, with its linkage to the global economy, together with the high uncertainty regarding rice prices, tend to make such an exercise rather perilous. In any event, a decrease in water use would constitute an interesting precedent, with probably few examples in the world.

These examples suffice to show that there is a somewhat worrying total uncertainty (or at least lack of consensus) on future evolutions. It is estimated here, probably conservatively, that the two dams yearly <u>net</u> inflow (evaporation discounted) has decreased from 11.5 to 9.5 Bm3 in the last 28 years and that it will drop another 0.6 Bm3 in the next 15 years. This corresponds to an intermediate scenario, between full potential development and stagnation.

The increase of water requirements in the BMA is not expected to be fully borne by the Chao Phraya River alone. Water diverted from the Mae Klong basin is already reaching Thon Buri in limited amounts (0.4 Bm3/year) but the discharge is phased to reach 23 cms (m^3/s) in

2010 and a maximum of 45 cms in 2017, in accordance with the gradual development of water purifying units.

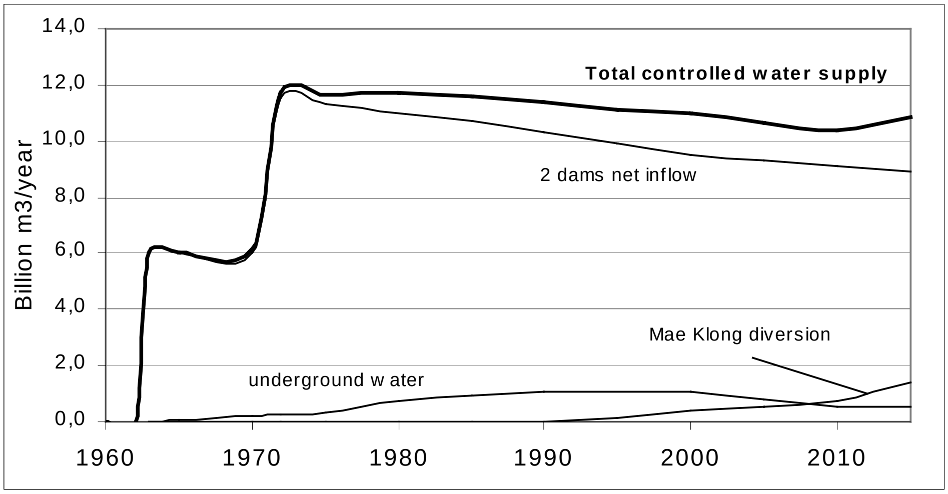
There is no reliable data on the exact volume extracted from the aquifer in the BMA. The Department of Mineral Resources (DMR), for the late 1980s, reports on a total of 9,000 wells extracting 1.3 Mm3/day. Estimates from JICA, based on consumption standards by category of factory, are at 2.9 Mm3/day and TDRI (1990) concluded that they are probably around 3 Mm3/day, appointing to a severe underestimation of underground water by official statistics. A total of 95% of the water used in the manufacture sector is believed to come from underground water (Christensen and Boon-Long, 1994). More recently, the Bangkok Post (1999), citing officers from technical departments, reported that a survey carried out in 1998 found that there were 33,995 factories in Bangkok and surrounding provinces. They were believed to use 1.5 million cubic metres out of 2.5 of water pumped from underground aquifers each year. Given (a) that the price differential between piped water and groundwater has not been bridged in the last ten years; (b) that the industrial sector has dramatically expanded (until 1997), and (c) the admitted unrecorded pumping, there is little likelihood that underground water use may have decreased in the 1990s. Therefore, our calculations are made considering an actual pumping rate of 3 Mm3/day. It is also estimated that the capacity of Bangkok aquifers to supply ground water is about 1 million m3/day, but that water pumped up should be less than capacity to prevent land subsidence (Bangkok Post, 1999)[2].

Figure 7 shows how the net inflow into the dams is declining, under our hypothesises. Underground water use in the BMA is estimated to decrease from its actual level of close to 3 Mm3/day down to 1.5 Mm3/day in the following years (this is a compromise between the ideal abstraction (1 Mm3/day at the most), and the unsustainability of the current rates). Diversion from the Mae Klong will increase from a current 10 cms (m^3/s) to a maximum of 45 cms. Overall, the average total controlled water supply in the basin (from dams, underground water and diversion from the Mae Klong) is going to decrease under 10 Bm3 (with a slight temporary rebound in 2015 due to the full capacity of the diversion from Mae Klong but further decline in the long term). The possible contribution of the Pasak dam is not considered here[3].

[2] According to Kraisoraphong (1995), 0.6 Mm3/day is considered the aquifer's safe yield.

[3] The dam actual contribution of 500 Mm3 will soon be used by 150.000 rai of irrigated area (under construction) (Wirat Khao-uppatum, pers. com.)

FIGURE 7: TRENDS IN TOTAL AVERAGE SUPPLY TO THE CHAO PHRAYA BASIN (MIDDLE AND LOWER BASINS)



1.3.2 Demand side

On the demand side, it is assumed that water uses and dams releases in the wet season will not vary significantly. Agriculture will continue to be supplemented with irrigation at similar rates and the impact of the growth of other uses will be marginal because of their magnitude in front of the contribution of uncontrolled side-flows[4]. The focus is therefore on the water remaining in the dams for dry-season cropping. It must be noted that the production potential of the irrigated agricultural sector will remain largely above the share of water apportioned to it.

A growing and little elastic demand is governed by the growth of cities and industries. Water consumption in the BMA in 1978 was only 460 Mm3 per year, equivalent to a discharge of 15 cms. The inflow from the Chao Phraya River was about 38 cms in 1993 and was targeted at 50 cms for the current year (2000). TDRI's projections in 1990 were based on a growth of 9% per year for residential and 10% for services and gave a total of 1.57 Bm3/year in 2000 (from 750 million in 1989[5]) and a total of 3.5 Bm3 in 2010. Because of the impact of the economic crisis, these projections – somewhat fortunately – proved to be widely overated.

The question of groundwater provides a neat example of mismanagement with dramatic consequences. The first Groundwater Act was issued in 1977 (with a charge of 1 baht/m3) at a time in which excessive pumping was giving way to land subsidence as high as 10 cm/year in the East of Bangkok. With the continuation of the problem, a new Groundwater Act was issued in 1985 which mandated that groundwater pumping in critical areas be substituted by raw superficial water in 1987 and that prices be gradually equated to that of piped water

[4] Disregarding the impact of the growth of non-agricultural requirements on dams release is, in any case, a conservative hypothesis.

[5] This value is unclear as BMA production of water in 1990 was recorded at 1.05 Bm3.

(TDRI, 1990). The use of underground water was – on paper – supposed to be abandoned in… 1998. Prices were raised in 1985 and 1986 by almost 45%. In 1989, the private cost of groundwater abstraction was around 2 baht/m3 (including a one baht tax), whereas piped water charged to industrial plants was around 6 baht/m3. In the late 1990s, the failure to control water abstraction and land subsidence was reaching alarming proportions, with horrendous costs in flood damage and in upgrading flood protection[6]. Although it would be wrong to explain the flood of 1995 by land subsidence, at least a portion of the damage estimated at 2 billion US$ should be attributed to it, therefore to overpumping.

During 1978-88, land in Bangkok sank more than 70 centimetres. The worst affected area was Ramkhamhaeng which sank 85.3 cm and is now 4 cm below mean sea level (Bangkok Post, 1999). It is reported that in less than 50 years the whole of the BMA might be under sea-level, a situation compounded by the rising trend of the latter, estimated to reach between 50 and 100 cm in 100 years (Somboon, 1990). In 2000, the city still sank by an average 2 cm/year (Nation, 2000) and the Ministry of Industry called for a rise from 3.5 to 8.5 baht/m3, while piped water is priced at 21 baht. To crown it all, the Ministry requested a budget of 5 billion baht to build 50 stations designed for recharging aquifers by injection! The seriousness of the situation also led the Provincial Water Authority (PWA) to "urge the DMR to prohibit factories in its service areas from using ground water. But the initiative has run into stiff opposition from the Federation of Thai Industries" (Bangkok Post, 1997).

Not only is the absolute demand growing at appalling rates, but the pressure on superficial water is also likely to increase. The obvious unsustainable nature of groundwater overdraft means that, sooner or later, the water supplied by the aquifer will have to be drawn from superficial water (Sethaputra *et al.* 1990). If we consider that at least half of the estimated 3 Mm3/day underground water contribution will have, willingly or not, to be transferred to superficial supplies. This means that another 0.55 Bm3 must be supplied yearly by the Chao Phraya and Mae Klong river systems. In other words, the Bangkok area is on the way to move from a negligible or secondary user to a main one. Even though, fortunately, a large part of Bangkok needs will be supplied by sideflows in the wet season, the burden on the reservoirs is still estimated at around half of the total need in superficial water[7].

1.3.3 Balancing demand and supply

Assuming that the wet season commands an average dam release of 3.8 Bm3 (as seen from historical series) and that this value will change little in the mid-term (see earlier comment), we may now use the projections on the overall supply to deduce both the amount of water

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[6] In a seminar suggestively entitled "We must rethink about the concept of water before it is too late," held at Chulalongkorn University, academics and conservationists have urged the government to increase water fees to a realistic level to ease a water shortage which is worsening every year (Bangkok Post, 12 Oct. 1997).

[7] During the month of January, abundant water is coming from the drainage of the floodplain. Dams are contributing mostly in the February-June period, and in some periods of the wet season in some years (or at least they should, if releases was attuned to demand). It seems to a common error to compare the total demand in the basin with the inflow in the dams, without considering the part of the requirements which are met with natural sideflows in the wet season.

available in the dry-season and the share remaining for agriculture after other priority uses are satisfied.

The trend in water requirements for BMA (domestic, service, industry) is here estimated for a growth ratio of 5%/year. This demand will be partly met by underground water, Mae Klong diversion and by the Chao Phraya River[8]. Salinity control (water lost to the sea), is attributed a floor value of 0.5 Bm3 for the dry season (RID's norm). The net inflow in the two dams is assumed (probably conservatively) to decline from 9.5 Bm3 to 8.5 Bm3 over the next 25 years, while the increase of supply from the Mae Klong and the decrease by half of underground water (passed over to superficial water[9]) are also taken into account (see details in Annexe 2). *The average controlled water (dams) which will be available for irrigation and other uses in the delta and middle basin in the dry season will undergo a cut of 45% (from 4.6 to 2.8 Bm3) in the next 15 years*. For yearly growth rates of 3% and 7%, these cuts will be 24 and 59% respectively.

The decrease will be extremely sensitive to the growth of non-agricultural use which is now more problematic to assess than before the crisis: using the rates adopted by TDRI in the 1990 study[10], the available water would come under 1 Bm3… An hypothesis of 5% is slightly higher than NESDB's projections for the 9th Plan (2002-2007), with annual growth rates between 5 and 6%, considering that industrial water demand grows by 0.65% for 1% of growth[11] in the industrial sector (Mody, 1997). Projections by MWA for the next 15 years, however, are much more conservative. First, the economic crisis has bent water demand, with BMA's production of tap water for 1998, 1999 and 2000 short of the 1997 level (see Annexe 1). Second, the BMA has planned to invest in maintenance and technology in order to reduce an estimated loss by leakage of 39% down to 30% by 2005 (25% is considered a normal rate). The effective economic growth in the next ten years remains a surmise. The fact that the demand has levelled off with the crisis (see Annexe 1) only shifts the curve by the same token and does not invalidate the trend in the mid-term. In that respect, it becomes clear that the 1997 economic crisis was instrumental in averting a water crisis, or at least in shifting it further in time. With a compound growth of the water demand at 5%, the water supply for agricultural use in the dry-season (again assuming that wet-season cropping is priority and stable) will be almost halved in 15 years, and reduced to less than 1 Bm3 in 25 years (Figure 9). Even with a very reasonable low-hypothesis of a rate at 3%, water supply to DS agriculture is bound to be halved in 25 years.

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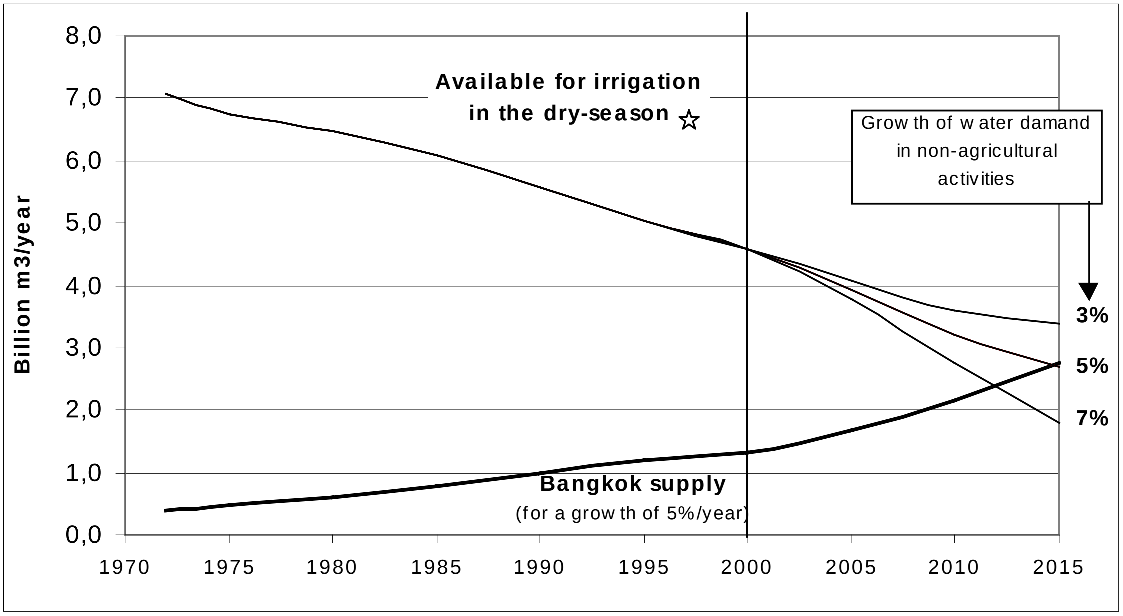
8 There is an agreement that RID should provide BMA with 60 cms in the year 2016. In case of higher growth of BMA demand it is hard to see how this quota will be able to be met.

9 This also means, in passing, that BMA will have to upgrade its capacity to distribute superficial water.

10 "Water demand in Bangkok is projected to grow at 9% per year for residential and 10% for services" (TDRI, 1990). In fact, BMA's production of tap water doubled between 1985 and 1995.

11 Kraisoraphong (1995) refers to TDRI's data which estimate that the elasticity of industrial water demand with respect to industrial output is 0.61 (9% growth gives 5.4% increase).

FIGURE 8: EVOLUTION OF THE AVERAGE TOTAL CONTROLLED WATER SUPPLY IN THE BASIN



* The amount of water available for irrigation will also serve for domestic use of rural communities and will be partly lost by evaporation

The general picture in the 15 years ahead is therefore one of a significant reduction of the water available for the agricultural sector, which will turn drastic if demand growth returns to pre-crisis levels. If we translate this trend into a decline of dry-season cropping acreage, we get in all likelihood a picture of rural decline.

This decline in water resources, however, can be compensated by:

1. improved water management in the wet season; seasonal releases could be lessened by improving the responsiveness to hydrologic events, thus capitalising on rainfall and natural side-flows;
2. a policy of dam water release based on downstream requirements and not energy generation, following the trend already initiated in the last ten years;

   Based on an analysis of losses presented later in section 6.3, we can estimate the maximum theoretical gain which can be brought about by these two measures at 1 Bm3/wet season (the dry season now offers little margin for water savings); more realistically, we can consider a target of 0.5 Bm3 as a possible gain.

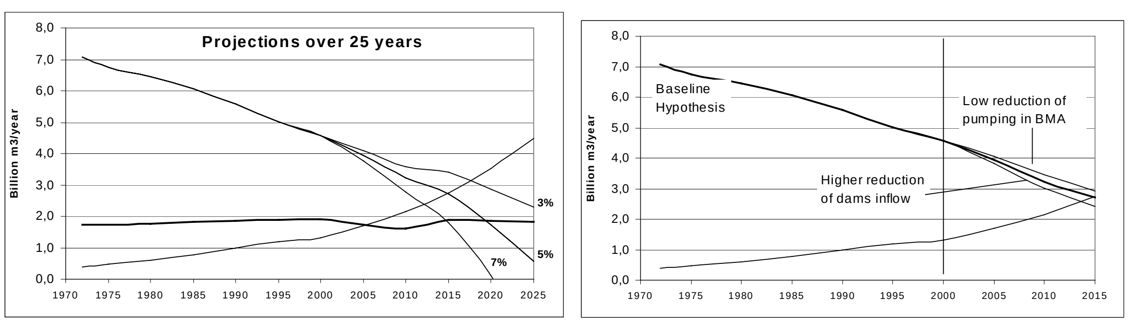
3. a redefinition of cropping calendars, allowing greater use of field wetness after the rainy season and of rainfall;
4. efficiency gains obtained by better water use at the farm level, possibly enforced by economic measures such as water pricing;
5. agricultural diversification, from rice to field crops;

6. it may also be reversed by future transbasin diversion of water[12] or other supply augmenting schemes, including new medium scale dams[13], underground water and water treatment.

Contrary to conventional wisdom, we contend that points 4 and 5 are the least promising. Much can also be attained by regaining control over the basin and designing more rigid allocation policies, but the gains are likely to be in terms of equity rather than in terms of efficiency. The main points for improving water allocation and distribution will be reviewed in Part II. Although measures aimed at augmenting supply (point 6) are not usually favoured at present, it becomes clear from the scenarios presented above that there is no way that such options be discarded in the mid-run: indeed, even considering gains in management (say 1 Bm3/year) and other measures (e.g limit leakage in the BMA), the relief provided by the diversion of 45 cms from the Mae Klong will only be sensible during the next 5 to 10 years. Beyond that, the water available for agriculture will considerably drop, with a speed dictated by the rate of growth of the BMA (and more generally non-agricultural uses), and by the rate of water use in the upper basin.

These scenarios are, of course, rather sensitive to change in parameters and hypothesises[14]. It can be assumed, for example, that instead of decreasing by 1 Bm3 over 25 years, the total dams inflow will be cut by 1.5 Bm3 over 25 years. It can also be assumed that underground water use in BMA will not be halved within 10 years but will decrease only by 15%. The corresponding trends are indicated in Figure 9 (right) and prove not to significantly alter the overall decline. Again, if a respite of *n* years after the crisis (1997) is considered before the growth of demand is back, this only shifts the projections by *n* years along the x axis.

FIGURE 9: PROJECTIONS OVER 25 YEARS AND SENSITIVITY TESTS



[12] For example the Kok-Ing-Nan Project would bring an additional 2 Bm3 inflow to the Sirikit Dam (JICA, 1997), while the Moei-Salawee-Chao Phraya Project would bring 3.5 Bm3 yearly to the Bhumipol Dam.

[13] There are 6 dams with feasibility studies in the Chao Phraya Basin, totalling an active storage of 2.3 Bm3, but 400,000 rai of irrigated areas are also planned (Pal and Panya, 2000).

[14] See for example Molle et al. (2000), in which some scenarios with slightly different assumptions are presented. The present curves are revised versions including finer considerations on the hydrologic regime.

1.4 Water balance in the dry-season

To attempt a yearly or seasonal water balance of the Chao Phraya Delta may appear somewhat risky because all the terms of the balance are extremely unstable and may vary over a wide range. Fluctuations may embody both long term trends and inter-annual variability. The following balance represents a median situation but the terms are chosen in order to mirror the situation observed in the last 5 years. All terms (inflow, consumptive use and outflows) are reviewed below (values are rounded up values expressed in billion m^3 (Bm3), or km3).

1.4.1 Dam releases

Dams releases in the dry season will be scrutinised in a later section but it can be said briefly that, being dependent on the available water stock in the dam, they may vary between 2 and 10 Bm3. 6 Bm3 is an historical average value, while the median value is at 6.5 Bm3. This latter value will be considered for our balance.

1.4.2 Sideflows in the middle basin

Sideflows entering the river system between the two dams and Chai Nat, the apex of the delta, are usually generated by rainfall in May and June. This inflow amounts on the average to 1.3 Bm3 (only 0.1 Bm3 in the January-April period and 1.2 Bm3 during the two remaining months) but the median value is only 1 Bm3. These volumes are incorporated to the inflow at Chai Nat but not always useful because the cropping area at that time is often limited[15]. They are therefore evacuated to the sea through the Chao Phraya River.

1.4.3 Diversion to agricultural areas

Water use in the middle basin has significantly increased in the last 10 years (see § 5.1.8) and now amounts to 25-35 % of the water used in the delta proper. Diversion includes inflow to the Phitsanulok Project but also water diverted by the 5 Projects of the lower reach of the Ping river and by pumping units. A total of 1.2 Bm3 is considered diverted to the middle basin.

The different waterways branching off the Chao Phraya River at Chai Nat receive an average of 4.3 Bm3, or 4.8 Bm3 on a median year. Nine years out of 10, more than 2 Bm3 are diverted, while the historical maximum diversion was 5.9 Bm3. The balance is based on a supply to the delta of 4.4 Bm3.

[15] The dry-season is drawing to its end and the rainy season not yet initiated. However, in some years, abundant rainfall in May and June trigger early wet-season rice cropping. See § 4 on the complexity and variability of cropping calendars.

1.4.4 Sideflows into the delta

Rainfall in the upland bordering the delta may also produce run-off which will flow into the delta. On the western side, there are several natural drains which go through the Makham-Utong canal (siphons), and the Krasiew river. On the eastern side, there are also several intersections with the Chai Nat-Pasak canal and devices allow these flows to be incorporated to the flow of the canal (see Molle *et al.* 1998).

These sideflows are in general negligible but in case of heavy rainfall (May-June) they may bring significant amount of water into the drainage system. Most of the eastern sideflow is not used and flows to the sea. The western sideflow, if any, may partly be incorporated to the hydraulic network but is neglected here.

1.4.5 Water released to the Chao Phraya River at Chai Nat dam

The water not diverted at Chai Nat is released to the Chao Phraya River itself and flows down to Bangkok and to the sea. Over the last 20 years, the average was 2.1 Bm3 but the median value only 1.9 Bm3. Statistics may be confusing because this release incorporates part of the sideflows generated by rainfall in May-June in the middle basin, and also the water which is released in excess of the water demand for the sole purpose of energy generation. Only one third of these releases occur in the first 4 months, against two thirds in the last 2 months. It can be observed that releases in the first 4 months (dry period) have been curtailed in the last ten years to a level close to their minimum values (from 930 to 670 Mm3). Releases in May-June (around 1.2 Bm3) incorporate significant sideflows and dam releases (both estimated[16] at 0.6 Bm3). The median value of <u>1.9 Bm3</u> is retained (which includes approximately 1.3 Bm3 of dam water).

1.4.6 Rainfall

An average precipitation of 340 mm generates an inflow of 5 Bm3, of which 4.4 Bm3 in agricultural areas, with 75% (3.3 Bm3) occurring during the May-June period. As the standing rice cropping area is not likely to exceed 2 million rai, a precipitation of 340 mm contributes effectively to crops requirement by only 0.2 Bm3 in the January-April period and 0.5 Bm3 in the two last months (effective rainfall). Despite much water also getting trapped in fallow land and harvested paddy fields, this suffices to show that there is considerable amounts of water drained to the river system. As there is no measurement to assess these flows from inner runoff occurring downstream of Chai Nat, the shares of the rainfall infiltrating or evaporating on fields and that which flows to the river systems remain a surmise. However, calculating the effective rainfall on fallow land as that of field crops gives values of 0.7 and 1.7 Bm3 for the two sub-periods. Keeping a total value[17] of <u>2.4 Bm3</u> for the first term, the total runoff is estimated as the closing term: <u>1.4 Bm3</u> [0.9 Bm3 + 0.5 Bm3 (80% of rainfall

[16] Derived from the study on potential water saving presented in § 6.3.2

[17] More water may flow out the fallow land but infiltration in drier soils will be higher than in irrigated land.

in non-agricultural areas)]. In any event, these two terms correspond to non-beneficial uses and therefore will not change the overall efficiency.

It may even happen that these precipitations cause flooding, as happened in the 2000 dry-season (RID, 2000). An average of 195 mm fell between the 12th and the 17th of April on the western side of the upper delta, causing flooding and rotting of 17,600 ha of paddy field under harvesting (and significant water pollution in the Tha Chin river).

1.4.7 Return flows

Return flows from the upper delta are channelled to the lower delta and there is normally very little water lost to the rivers. In the upper delta most drains are closed by regulators and/or flow to the Noi and Tha Chin River upstream of a regulator (water is reused). This picture contrasts with that of a "wasteful process" in which 70% of water is supposed to be lost.

Indeed, it can be seen that all the 'exits' of the system are either closed or leading to further downstream areas where water is reused. An exception could be the eastern side of the West Bank, which is the only portion of the lower delta with ungated streams to the river but according to JICA (1992), hydraulic simulation shows that the West Bank receives, albeit very little, water from the Chao Phraya Rivers rather than emptying into it. There is also some limited return flow to the Song Phi Nong river, on the west, but it is incorporated to the flow coming from the Mae Klong fan which is used to support irrigation in the West Bank.

The flow at Phophya regulator, in the Tha Chin River, is used to supply Chao Chet Project and to regulate the discharge at the river mouth (the discharge must remain over 35 cms in order to control salinity).

In summary, return flows from agricultural areas are only significant in the May-June period, in case of heavy rainfall. Their magnitude cannot be measured because there is no flow measurement in the Chao Phraya River downstream of Chai Nat.

1.4.8 Inflow from adjacent rivers

The lower delta receives additional inflow from the eastern side (pumping from Bang Pakong river) and from the western side: water diverted from the Mae Klong system into the Tha Chin River allows the supply of additional water to the West Bank (both through pumping and opening regulators at high tide) and to increase the discharge down to the sea, in order to control saline water intrusion.

These two contributions are taken at <u>0.1 Bm3</u> and <u>0.5 Bm3</u>.

The water diverted from the Mae Klong basin comes through the Tha San Ban Pla and Chorake Samphan drains and amounts to a flow of 70 cms (partly used on the way), or roughly 0.9 Bm3, out of which 0.5 Bm3 goes to the West Bank. The remaining 0.4 Bm3 merge with the 0.3 Bm3 released at Phophya Regulator to control salinity intrusion at the Tha

Chin River mouth (0.6 Bm3) and supply some areas along the river banks (Bang Len, Khlong Chinda, etc) (0.1 Bm3)[18].

It must be noted that a small amount of the Chao Phraya River flow is diverted from its lower reach (near Bangkok) and incorporated into the West Bank. JICA (1992) has estimated this contribution at 0.1 Bm3.

1.4.9 Exchanges with the aquifer

Percolation replenishes shallow aquifers in the upper delta. These aquifers are intensively exploited and tend to be depleted in the dry season and replenished in the wet season. Therefore, they can be considered as temporary reservoirs with a yearly zero balance in the long run. Regarding the sole dry-season, tapping the aquifer leads to a change in storage capacity which must be computed. Such an assessment is highly problematic because the use of tube wells depends on the level of water supply ensured by the irrigation network. Because of higher pumping costs, farmers tend to resort to wells only if water supply is interrupted, or if they want to start establishing their crop early. Considering a gross area of 200,000 ha provided with shallow aquifers, assuming that half of the area can be supplied by a well and that 30% of crop requirements (1,600 m3/rai) comes from the aquifer, we may tentatively estimate the withdrawals of underground water at 0.3 Bm3.

At the same time, paddy fields in the delta are considered to lose 1 mm/day by seepage/percolation. This flow replenishes the superficial aquifers, and is partly transmitted to the drainage system (sub-superficial run-off) or to deep aquifers. It is assumed that 0.1 Bm3 replenishes the shallow aquifers in the area where these are tapped.

Percolation to the three upper deep aquifers is much more limited and estimated at 3.2 % of the yearly rainfall in the delta (AIT, 1982). This gives a recharge of 0.14 Bm3 which adds up to underground flows originating from outside the delta. This percolation rate is tentatively estimated at 0.1 Bm3. This water is not lost but further extracted by deep wells in the Delta.

Water abstraction at present in the BMA is estimated between 1.5 and 3.0 Mm3/day (95% of it being carried out by industries). Considering a rate of 2 Mm3/day, this gives a total of 0.86 Bm3 during the dry season, which is depleted by 15%, while the remaining 85% is degraded in quality (TDRI, 1990). The corresponding amount of water (0.3 Bm3) does not however goes to a sink but chiefly to the Chao Phraya River, where it contributes to controlling saline water intrusion.

1.4.10 Water released from the flood-prone area

At the beginning of December, the 2 Bm3 of water stored in the buffer area of the flood-plain start to be released (Molle *et al.* 1998). This water originating mostly from rainfall and from

[18] In reality much of Phophya release is pumped into the Chao Chet Project. The 0.5 Bm3 diverted to the West Bank includes this water and water diverted from the Mae Klong basin. This does not impact on the balance presented here, only on the respective contribution of the two flows, which does not matter *in fine*.

supplies channelled through the irrigation network, had been accumulated in order to allow the proper cultivation of the flood-prone area in the wet season. This corresponds to a beneficial use. Only 15% of this water, when released, will be channelled to the West Bank and reused for irrigation. Part of this water only (taken as 0.1 Bm3) is released after the 1st of January (Molle *et al.* 1998). Resulting high water levels in the Chao Phraya River allow the reduction of water releases at Chai Nat dam (sometimes under 50 cms), which means that part of BMA consumption in (early) January can also be ensured by this flow.

1.4.11 Crop consumptive use

Dam releases of 6.5 Bm3 allow the cropping of approximately 4.7 million rai[19] of rice equivalent. We must deduce from the area the portion of crop calendars which falls before the first of January or after the end of June[20]. A correction gives a total rice-equivalent area roughly equivalent to 3.8 million rai, which consume approximately 3.8 Bm3[21]. Considering the approximate acreage in each of the months and the formula giving the effective rainfall, we can estimate the contribution of effective rainfall at 0.7 Bm3 (of which 0.5 in the May-June period), leaving 3.1 Bm3 to be met by irrigation water.

Water in the waterways also sustains a significant area of perennial crops. In a recent research in the Kirinda Oya Project (Sri Lanka), water balances have shown that up to 55% of the water flow into the system was used by perennial crops not strictly grown in the irrigation plots (Renault *et al.* 2000)! Such positive externalities, together with the other multiple uses of irrigation water (fish, livestock, garden production, domestic use, etc), significantly alter both the overall efficiency and the economic impact of irrigation Projects when they are taken into consideration (Meinzen-Dick, 1997; Bakker *et al.* 1999). In the Chao Phraya Delta, in particular, one should not disregard the very large areas of trees planted on the higher land, in general on the river levees. These “domestic” trees, which surround most of the dwellings of the delta, cover a gross area of approximately 100,000 ha in the sole upper delta, which corresponds to 14% of the total gross area (see map[22] in Annexe 4). The corresponding amount for the lower delta is of the same order of magnitude (80,000 ha), as can be seen from the topographic maps (1:50.000). A total of 20,000 ha corresponding to the water bodies within these areas is deduced. These trees are sometimes

[19] In 1998, 6.6 Bm3 were released and 4.9 million rai (including triple cropping) were recorded.

[20] This correction greatly varies with effective calendars. In an average case (1900s), approximately 1.1 million rai are established in October or early November (Bang Pakong area + part of the West Bank: 1.5 month to be deduced); another 0.8 million are established in late November/December (lower delta: 1 month to be deduced); 0.4 million rai in the upper delta are planted before the 1st of January (- 1 month); and 0.6 million rai are established after the 1st of May (- 1 month). Altogether we obtain 3.45 month-rai, or 0.9 million rai of rice-equivalent for a 4 month crop assumed to have a constant consumption.

[21] See section 9.3. An estimate of the average crop consumption weighed by the percentage of crop establishment along the different months gives a value of 980 m3/rai (for 15 weeks of irrigation), rounded up at 1,000 m3 for convenience.

[22] This area was estimated based on GIS layers of tree areas as seen from satellite images. Only 60% of the upper delta was mapped giving 63,000 ha of gross area. This excludes small tree areas and trees along the dikes and field bunds (banana, coconut).

watered through pumping from the nearby waterways but also thrive on the infiltration coming from them[23]: not fortuitously they are located along the natural waterways (arms of the river in the delta) and man canals, where they can be supplied all year round.

The watering of these trees is considered here as a beneficial use as these trees provide a shady environment and wind-cutting, increase local bio-diversity and yield a variety of fruits, bamboo, wood, medicinal plants, etc. These 160,000 ha consume water along the 6 months (1,000 mm of ET) with a crop coefficient in general higher than 1, giving a potential consumptive use of at least 1.6 Bm3. As the trees may not be fully supplied at the potential level, it is assumed arbitrarily that only half (0.8 Bm3) is provided by irrigation water. Contribution of effective rainfall can be computed at 0.3 Bm3.

Other crop consumptive uses must be considered. Between Ayutthaya and Bangkok, but also along the upper reach, upstream of Ayutthaya, there are sizeable agricultural areas which area located out of the official irrigated area. The most notable area is that of the orchards and paddy fields on the right bank of the Chao Phraya River at Nonthaburi. These areas represent 35,000 ha which, if we assume that only 50% of the gross area is cultivated, gives a consumptive use close to 0.2 Bm3.

1.4.12 Diversion to BMA

The diversion of water by MWA (Metropolitan Water Authority) is taken as 0.75 Bm3. However 60% of this water (0.4 Bm3) is not consumed but degraded in quality and evacuated mostly to the Chao Phraya River. This water is not totally lost too, as it contributes to the outflow to the sea and to controlling salinity intrusion. As in the case of industrial wastewater, this is tantamount to repel saline water with polluted water…

1.4.13 Inland navigation

Most of the time, water releases at Chai Nat Dam ensuring the supply of BMA and salinity control are sufficient to allow inland navigation; however it is not always the case and releases must periodically be raised to 80 cms to avoid the bottleneck of Sing Buri to prevent navigation. This also occurs in the Noi and Suphan Buri rivers, where flows must also sometimes be increased to allow inland navigation. These requirements are estimated by RID at 0.3 Bm3.

1.4.14 Domestic use

A total amount of 0.5 Bm3 is allocated by RID to domestic water. This corresponds to the limited, and often intermittent, releases which are done to canals which are not supposed to receive irrigation water. This water is supposed to be used for animal consumption and domestic use; it is also used by a few factories (e.g. sugar mill in Don Chedi Project, small factories and rice mills, etc). Part of this water is unduly used for irrigation and losses by

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[23] By depleting the aquifer they also indirectly increase percolation from water ways.

infiltration in canals are relatively high (because of the high ratio *water used/ wet surface* in canals). Because of this, only 0.2 Bm3 are considered depleted by domestic uses.

Other domestic use is tap water which usually comes from deep wells. This consumption has been disregarded in the balance as it incurs no return flow.

1.4.15 Evaporation in waterways

The analysis of waterways with GIS facilities allowed the classification of waterways in the delta, yielding a total of 21,000 km, including 1,200 km of main rivers (see details in Annexe 5). Considering average widths for the 8 categories of waterways defined, we obtain an area of water body of 29,600 ha. If we consider a total evaporation[24] over 6 months of 1,000 mm, this gives a total loss by evaporation close to 0.3 Bm3.

1.4.16 Pollution control

It is hard to estimate the amount of fresh water which is lost to the rivers because of the need to flush waste water in some parts of the lower delta, in particular because this water may also contribute to salinity control. This does not concern waste water from BMA which is computed in all cases as a return flow to the river, but a discharge of 5-10 cms which goes through Khlong Thawee Wattana, in the lower West Bank, and flushes (extremely) polluted water to Tha Chin River. A total of 0.1 Bm3 is allocated to that purpose by RID.

The return flow of industrial wastewater in the eastern part of Bangkok is either channelled to the Chao Phraya River or stagnates in waterways and slowly evaporates. In the near future, it is planned to have this water treated in a new plant.

1.4.17 Non beneficial water depletion

In addition to the direct loss by evaporation in waterways, there is some evapotranspiration occurring in fallow land. This term is reduced in January (many areas still have residual field wetness, in particular the 300,000 ha of the flood prone area which has just been drained) and in May-June (rainfall contribution). In the 3 driest months, the plots located far from waterways dry up and ET is drastically reduced. Shrubs and isolated trees uptake water from aquifers. ET mostly occurs in areas contiguous to cultivated fields (seepage) and are attributed the closing term of the balance (0.3 Bm3).

1.4.18 Salinity control and water flowing to the sea

Water flowing to the sea is partly beneficial, as it controls the intrusion of saline water. Minimum flows for the Tha Chin and Chao Phraya Rivers are respectively 35 and 50 cms. Flows in excess of these values are non-beneficial and may be caused either by the release of dam water or by uncontrolled sideflows/return flows in the system. The main difficulty is

[24] Evaporation of water bodies is in general higher than ET. This latter value is used here in order to account for the shade which reduces evaporation in some waterways.

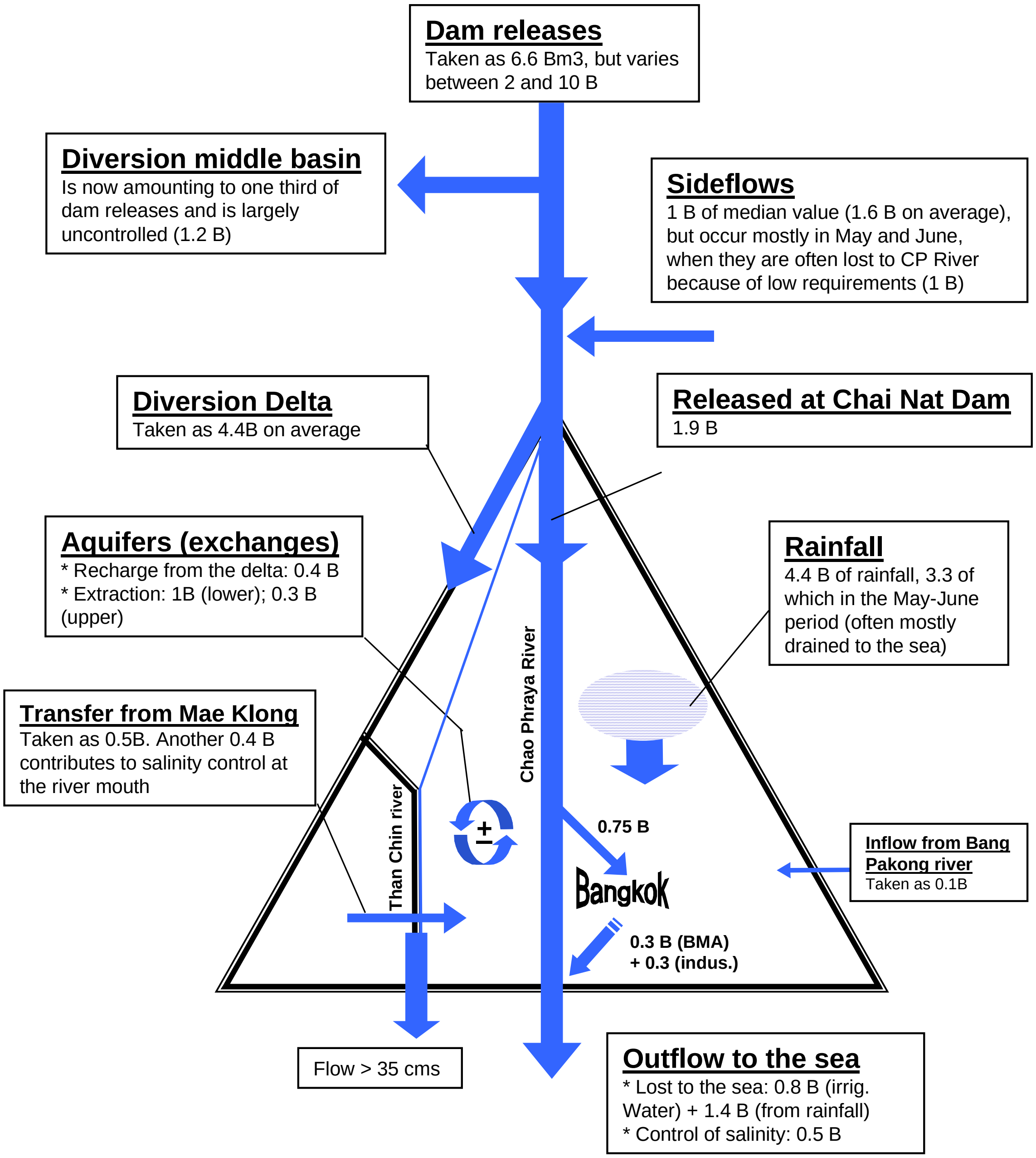
that the discharge of the Chao Phraya River at its mouth cannot be easily measured. Therefore, the outflow to the sea must be evaluated based on water balances. The limited release at Chai Nat dam during the January-April period (together with the frequent increase in salinity in the lower reach of the river) indicates that very little water is lost to the sea during this period.

More generally, RID now tends to reduce releases at Chai Nat dam and at Phophya Regulator (the last regulator on the Tha Chin River) at their minimum value. This means that they monitor daily the salinity in the lower reach of the two rivers and tend to increase supply only when salinity rises over the standard limit (5 g/l), or if there is another bottleneck, for example in inland navigation. Just before the occurrence of tides with maximum amplitude, RID will anticipate the needs for salinity control by releasing higher amounts of water. These requirements are estimated at 0.35 Bm3 by RID. The remaining 0.55 Bm3 needed to ensure an average outflow of 50 cms to the sea are provided by the return flow from Bangkok and from industrial groundwater pumping.

1.4.19 Combining flows

The main flows are symbolically represented in Figure 10.

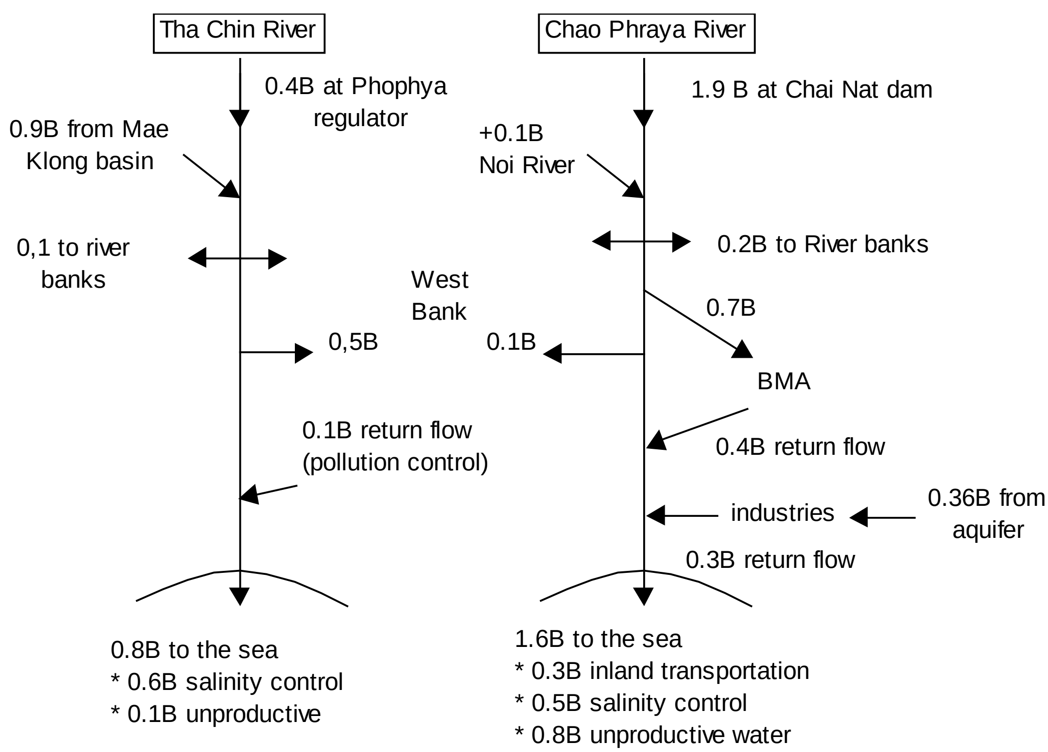
FIGURE 10: MAIN FLOWS OF THE WATER BALANCE OF THE CHAO PHRAYA DELTA IN THE DRY-SEASON



Sub-water balances can be achieved for different components of the system, namely: the Chao Phraya River (south of Chai Nat Dam), the Tha Chin River (downstream of Phophya regulator) and the Delta proper (from which BMA can be abstracted as a sub-unit). The water balances attempted here distinguish the water which is distributed through the irrigation system (and which comes from dam releases, with a supplementary inflow from sideflows in May-June) and rainfall water. Such a distinction is important because it allows us to pinpoint the contribution and destination of these two flows and to better understand what improvements in efficiency are or are not possible.

Figure 11 provides a schematic representation of water exchanges along the course of the two rivers. The total real return flows to the two rivers, and outflows to the sea also incorporate rainfall water fallen on the delta. The water balance of the delta and that of rainfall contribution are provided below (all values in Bm3).

FIGURE 11: WATER BALANCE ALONG THE CHAO PHRAYA AND THA CHIN RIVERS (LOWER REACHES)



6,5 Dam releases	Chao Phraya	6,3
1 + sideflows	Rainfall	5,0
1,2 - use in the middle basin	Other sources	1,3
6,3 Inflow at Chai Nat	**Total supply**	**12,6**

	1,9 passed on to Chao Phraya River
4,4 Diverted to the Delta	0,1 + from Noi river
-0,3 - to Tha Chin River	0,3 + return flow from industry (0.36)
-0,1 - to CP River at Phak Hai	2,2 Total
0,5 From Mae Klong	0,3 BMA depleted (0.7 with 0.4 return flow)
0,3 From tube wells	0,8 saline intrusion/inland navigation
0,1 From buffer	0,8 lost to sea, non beneficial
0,1 From Bang Pakong River	0,1 to West Bank
0,1 From Chao Phraya River	0,2 River banks
5,1 Inflow to rural Delta	
-0,2 Local non-agricultural use	
4,9 inflow for irrigation	**4,4 Rainfall on agricultural areas**
	9,3 Total inflow to agricultural delta

Water use	5.0 *Total Rainfall*
3,1 crops (3.8 Mrai rice equivalent)	4,4 Rainfall in agricultural areas
0,8 perennial vegetation (1,6 M ha)	0,7 Crops
0,1 pollution control (lower West Bank)	0,3 Trees
0,3 to aquifers	0,1 to aquifers
0,3 evaporation in waterways	2,4 Fallow
0,3 fallow land	0,9 run-off
4,9 Total use	0,6 Rainfall in non-agricultural areas
	0,1 Evaporated
	0,5 Runoff

1.4.20 Water balances of the delta in the dry-season

There are several ways to present a regional water balance. We will first consider all the flows specifies above and distinguish between irrigation water coming from the hydraulic network or from aquifers, and rainfall water. In a second step, we will re-aggregate these components following the terminology provided by Molden and Sakthivadivel (1999).

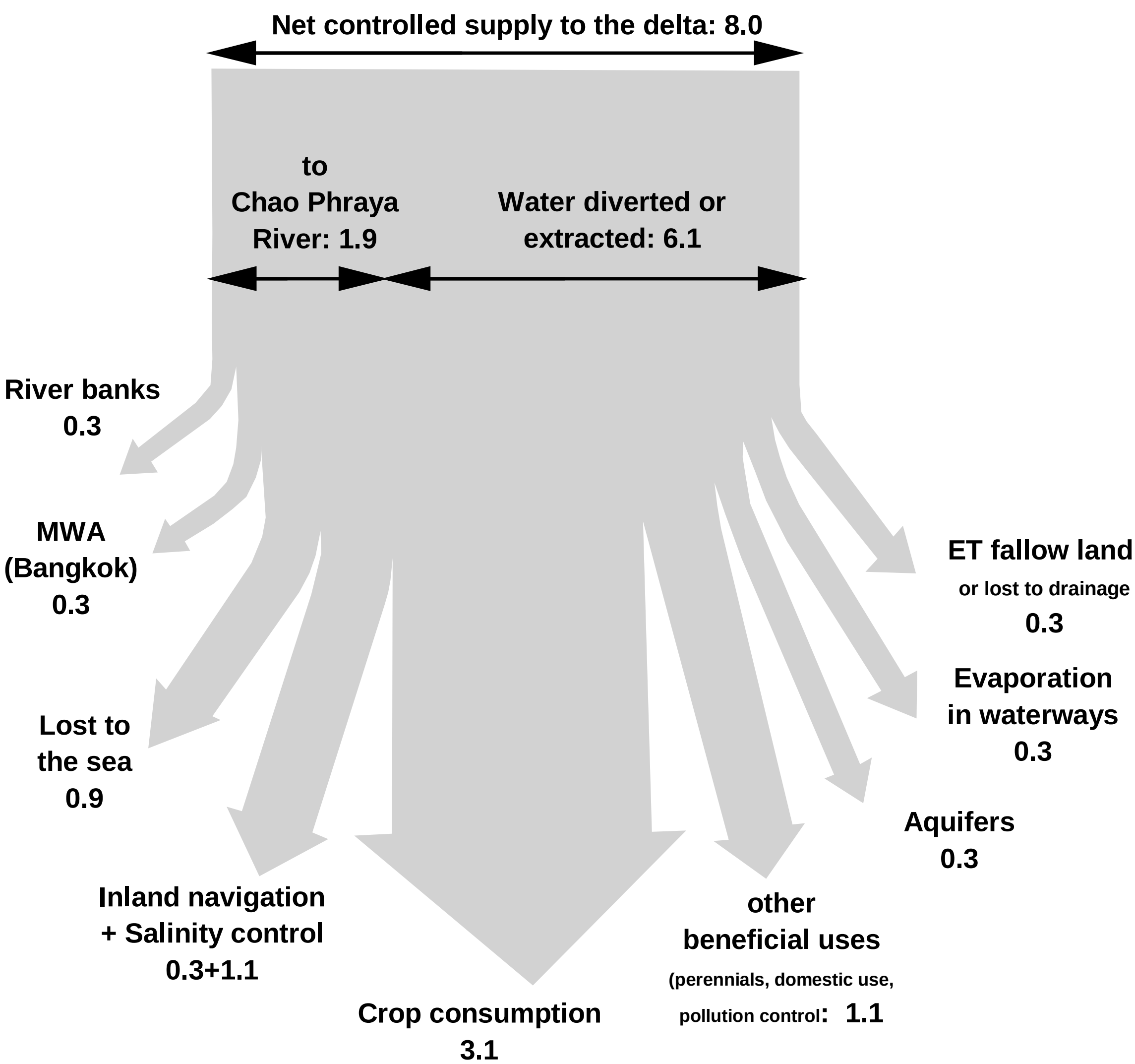
The total net controlled water inflow into the Delta[25] includes 6.3B from the Chao Phraya River, 0.9B from the Mae Klong system, 0.3B from shallow aquifers, 0.1B from the Bang

[25] The Delta includes here the Tha Chin River but not the irrigated area of the Mae Klong.

Pakong River, 0.1B from the buffer area and 0.3B from industrial returnflow (aquifer), giving a total of 8 Bm3.

This inflow goes to different uses. The major share (3.1B) goes to irrigated crop consumption, 1.1B to other beneficial uses (perennials + domestic use + pollution control); 0.3 to areas along the river banks (0.1 for Tha Chin and 0.2 for Chao Phraya River), 0.3B for inland navigation and 0.6B for salinity control; 0.3B for BMA; 0.3B to aquifers by percolation and 0.3B by evaporation in waterways; 0.3B to ET in fallow land and 0.9B lost to the sea without productive use (0.8 in the Chao Phraya River and 0.1B in the Tha Chin River). All these uses are summarised in Figure 12.

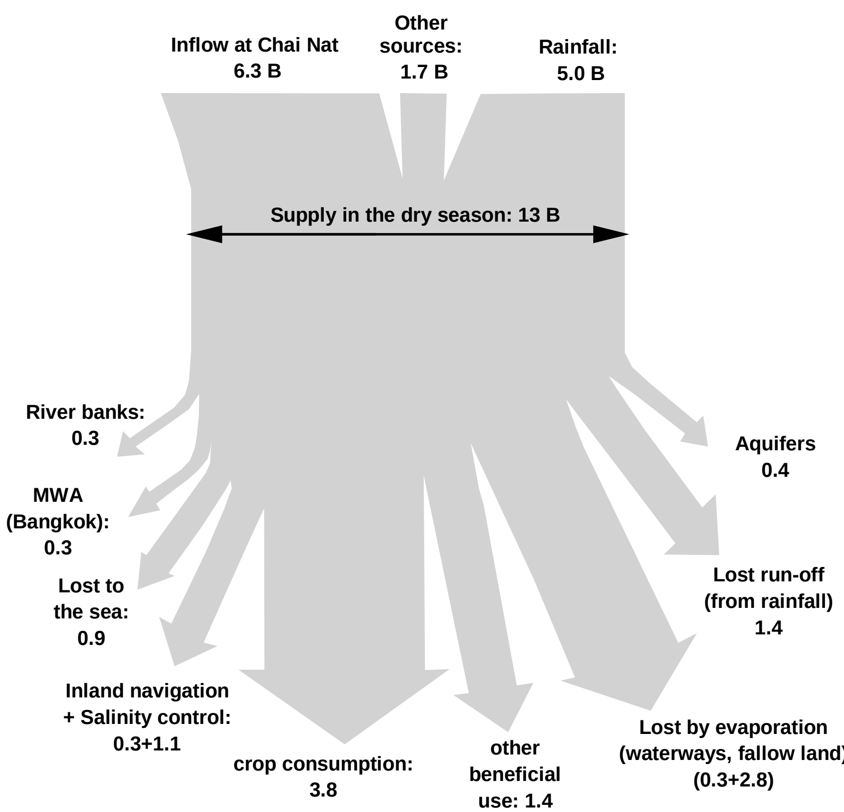
FIGURE 12: USE OF CONTROLLED SUPPLY TO THE DELTA



The total water depleted amounts to 7.1 Bm3, while non-productive water lost out of the system amounts to 1.4 Bm3 (0.8 Bm3 to the Chao Phraya estuary; 0.2 B by evaporation in waterways and 0.4 B in fallow land). This gives an efficiency of water use of 81%. However most of the water lost to the sea (estimated here at 2/3 of the 0.8 Bm3) is a result of the May-June period rainfall, when Chai Nat Dam releases part of the excess inflow generated by sideflows in the middle basin. Therefore, it can be said that this water is *uncontrolled* because there is no facility to store it. If we only consider the controlled part of this flow we obtained an overall efficiency of 88%. We may also include in the system the two reservoirs and compute their loss by evaporation as a price to be paid in order to operate the system. This adds a loss by evaporation of 0.4 Bm3 and decreases efficiency down to 83%.

Similar calculations can be done taking into consideration the 5 Bm3 rainfall, with the breakdown given earlier between rainfall on agricultural/non-agricultural areas, and the further division in crop use, infiltration and run-off to drainage. Because of the 0.9 Bm3 additional runoff to the sea and the ET/infiltration consumption in around 6 million rai of agricultural uncultivated land (2.4 Bm3), the total efficiency [*water use/total inflow to the delta]* of the delta drops to 61%. However, as in the preceding case, this run-off in the delta can also be considered as uncontrolled water (no possible storage).

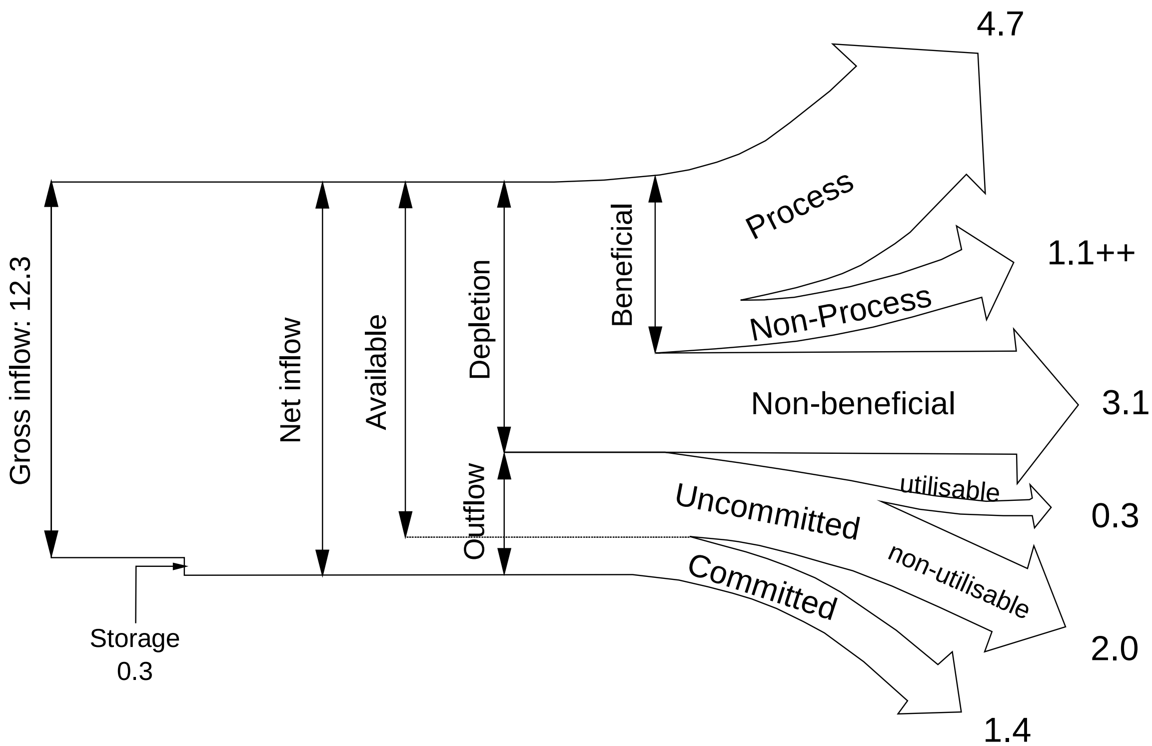
FIGURE 13: DELTA WATER BALANCE CONSIDERING TOTAL SUPPLY



We may now aggregate the different terms following the terminology proposed by IWMI. Beneficial use consists in (process) irrigated crop consumption, supply to river banks and BMA and domestic use, and pollution control; and (non process) beneficial use (perennials).

Non-beneficial depletion is evaporation from water bodies and ET in non-cropped land. The outflow includes both committed flow (navigation and salinity control) and uncommitted flow. Only 0.3 B of this outflow to the sea is considered to be usable (through management improvement), while the remaining is generated by rainfall/sideflows in the May-June period. Last, there is a use of 0.7 Bm3 of underground water against an estimated recharge of 0.3 Bm3, thus a net contribution of underground storage of 0.3 Bm3. All these terms are summarised in Figure 14.

FIGURE 14: WATER ACCOUNTING IN THE DELTA (DRY-SEASON) (IN BM3)



We may now calculate the water accounting indicators (Molden *et al.*, 2001).

TABLE 1: WATER ACCOUNTING INDICATORS (DELTA IN THE DRY-SEASON)

Indicator	Definition	Value
Depleted fraction (gross)	Depleted/Gross inflow	0.72
Depleted fraction (available)	Depleted / Available	0.79
Process fraction (available)	Process depletion/Available water	0.42
Beneficial utilisation	Beneficial depletion/Available water	0.52
For irrigated agriculture		
Process fraction (available)	ET/Available water for agriculture	0.78

1.4.21 Productivity of irrigated agriculture

The benefits derived from irrigation are often said to be very low, when compared with other uses. Estimates often consider very low yields, include the opportunity costs of family labour, and arrive at unrealistic figures. We will crudely estimate the value added from the different crops grown in the dry season in the Chao Phraya Delta. Because of the extremely high diversity of crops (notably of those with higher added value: fruits and vegetables), collecting all the production costs of these crops is a heavy work. Another difficulty is that perennial crops do not benefit only from water in the dry season and generally have a one year long cycle.

The average deflated rice price over the last 10 years in slightly above 5,000 baht/*rai*; for an average yield of 750 kg/*rai*, the gross value is 3,750 baht. Computing production costs[26] (inputs), the added value is approximately 2,500 baht/*rai*. A similar calculation leads to a value added of 2,000 baht for sugar cane. The value added for vegetables and flowers is drawn from Buntoon *et al.* (2000) who have estimated the gross product in the lower delta at 4.3 billion baht per year[27]. Fruits are attributed an average value added of 15,000 baht/year[28].

Aquaculture includes fish breeding, shrimp farming (*macrobacium* (only one crop per year) and Tiger Prawns), with an average value added of 50,000 baht/rai.[29] Areas for each crop are taken from RID data by Project. It is likely that productions with rapid expansion (e.g. aquaculture) are underrated.

These approximate figures give a value added of 22 billion baht for the dry-season. If we take an average inflow to agricultural areas of 6 Bm3, *we obtain a value of water at 4 Baht/m^3*. Even with severely conservative adjustments of the economic parameters, the economic value of 1 m^3 will remain over 3 baht/m^3. Of course, this is an aggregate value and returns per m^3 are very different for each production. Rice is one of the lowest (2,500 baht/*rai* with 1,300 m^3/*rai* gives a value close to 2 baht/m^3; 1.7 baht/m^3 if the price of labour is

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[26] The possible land rents are not considered (they correspond only to a redistribution of the value added); we have considered the costs of harvesting which partly remunerate capital (and therefore also correspond to a distribution of the value added) but not the cost of the family labour. The opportunity cost of labour is not considered here, as there is little evidence that the labour force which participates in farm operations in the dry-season would be allocated elsewhere in case dry-season cropping was marginally decreased. Our calculation is closer to a financial benefit. Other economic benefits include the incomes generated to shops (input), importers (chemicals), rice mills, exporters, etc. which are by no means negligible. If one wants to include the cost of labour, this can be taken at 2 man/day/*rai* * 150 baht/day (opportunity cost)= 300 baht/*rai*.

[27] Only for the part of the Delta included between the Bang Pakong and Tha Chin Rivers. This value is divided by 2 (dry-season only) and the average rate of productions costs is taken arbitrarily at 50%. This is a (probably conservative) average of data found in several reports of the Office of Agricultural Economics, Ollivier and Gillet (2000), Cheyroux (2000). Costs can amount to around 60% (sapotilla, rose apple, etc) but can also be much lower (rose, asparagus: 42%; grapes: 26-45%, etc)

[28] multiplied by 0.6 (as for sugar cane) to account for the benefit also drawn from water supply in the wet season.

[29] Fish raising income depends on the kind of fish (from 10,000 baht upward). Macrobacium gives an added value of 53,000 baht/*rai*/year and Tiger Prawns of 72,000 baht/*rai*/season (hired labour included) (Szuster *et al.* forthcoming).

considered), while Tiger Prawns may yield 30 baht/m^3 or more. We are, in all instances, very far from the 0.3-0.4 baht/m^3 bracket given by Binnie (1997)[30].

These benefits do not include the incomes drawn from fishing and all the benefits associated with the 160,000 ha of backyard orchards and gardens (fruits, bamboo, shade, biodiversity, etc).

TABLE 2: GROSS VALUE AND VALUE ADDED OF AGRICULTURE IN THE CHAO PHRAYA DELTA (DRY-SEASON)

	Sugar cane	vegetables/ flowers	Fruits	Aquaculture	Field crops	DS rice	Total
Area (upper)	174,362		79,937	20,522	27,253	2500,000	2,807,543
Area (Lower)	764		301,377	110,437	3,455	2500,000	2,946,257
Value added/rai	2,000		15,000	50,000	2,000	2,500	
Value added (upper)	209	108	719	1026	55	6,250	8,367
Value added (lower)	1	1,075*	2,712	5522	7	6,250	15,567
Total value added	210	1,183	3,432	6548	61	12,500	23,934

* estimated by Buntoon *et al.* 2000

1.4.22 Scope for improvement

What conclusions can be drawn from these indicators and these balances? It first appears that the Chao Phraya basin can be termed a 'closed basin', in that the potential demand (in the dry-season) is growing and exceeds the available resources. This may seem in contradiction with the fact that a portion of 2.3 Bm3 of the outflow is still uncommitted but this water corresponds predominantly to uncontrolled sideflows generated in the middle basin by rainfall in the May-June period. The fact that Chai Nat Dam and Phophya regulator releases are increasingly governed by the salinity level measured in the lower reaches of the Chao Phraya and Tha Chin Rivers shows that there are very few controlled loss out of the system.

Foremost, water accounting shows that return flows within the Delta are in general reused further downstream. The best example of such a situation is that occurring in the lower delta, in the so called 'conservation area', where, as the name indicates, water is conserved in a web of channels and the only non-beneficial depletion is direct evaporation in these channels (even deep infiltration losses are reused by pumping from the aquifers). *It is therefore clearly shown that there is very little, if any, water saving than can be expected from improving water management in the delta or at the plot level.* Placing emphasis on such issues is misleading and tantamount to repeat an error which has been intriguingly repeated in a number of closed basins.

Another striking finding is the large amount of rainfall contribution (5 Bm3), even concentrated in two months, and the very little fraction of it which is used in the fields. This is

[30] This interval is arrived at mostly because of considering the extremely low price of 3.5 kg/*rai*, together with 1,400 baht of labour cost/*rai* (which includes family labour).

mainly due to the fact that the area with standing crops (in a position to make a productive use of rainfall) is always under one fourth of the total agricultural area. This suggests that much could be gained by adopting, wherever possible, double-cropping calendars which closely dovetail the period of higher rainfall/canal water availability, that is May-December.

Limited, but nevertheless desirable savings, can also be obtained by avoiding releasing water from the dams in excess of demand, which also means better responsiveness to make better use of sideflows.

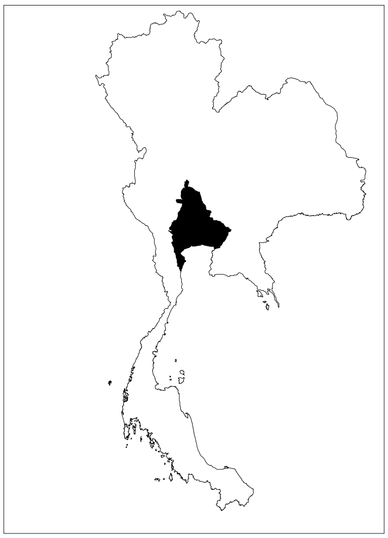
Last, it must be reminded that the balance presented in this section corresponds to the situation observed in the 1990s, with no deliberate dam releases for energy generation, as occurred in 1996 and 2000.

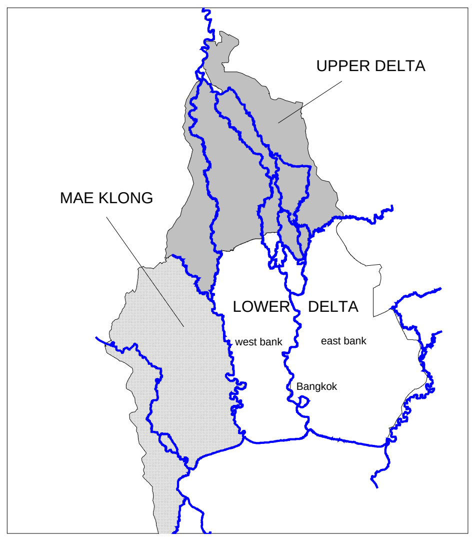
2 The Chao Phraya Delta and dry-season cropping: the setting

2.1 The physical layout and characteristics

The delta can be conveniently divided in a few sub-areas (Figure 15). On the western side, the lower part of the Mae Klong river basin is irrigated with water diverted from the Mae Klong river. The remaining part of the delta can be broken down between the upper part, irrigated (assumedly) by gravity from a network of raised canals, and the lower delta, itself comprised of the West Bank and the East Bank. In contrast, the lower delta[31] is criss-crossed by a dense network of excavated channels from which farmers pump individually.

FIGURE 15: LOCATION OF THE DELTA AND MAIN SUB-AREAS



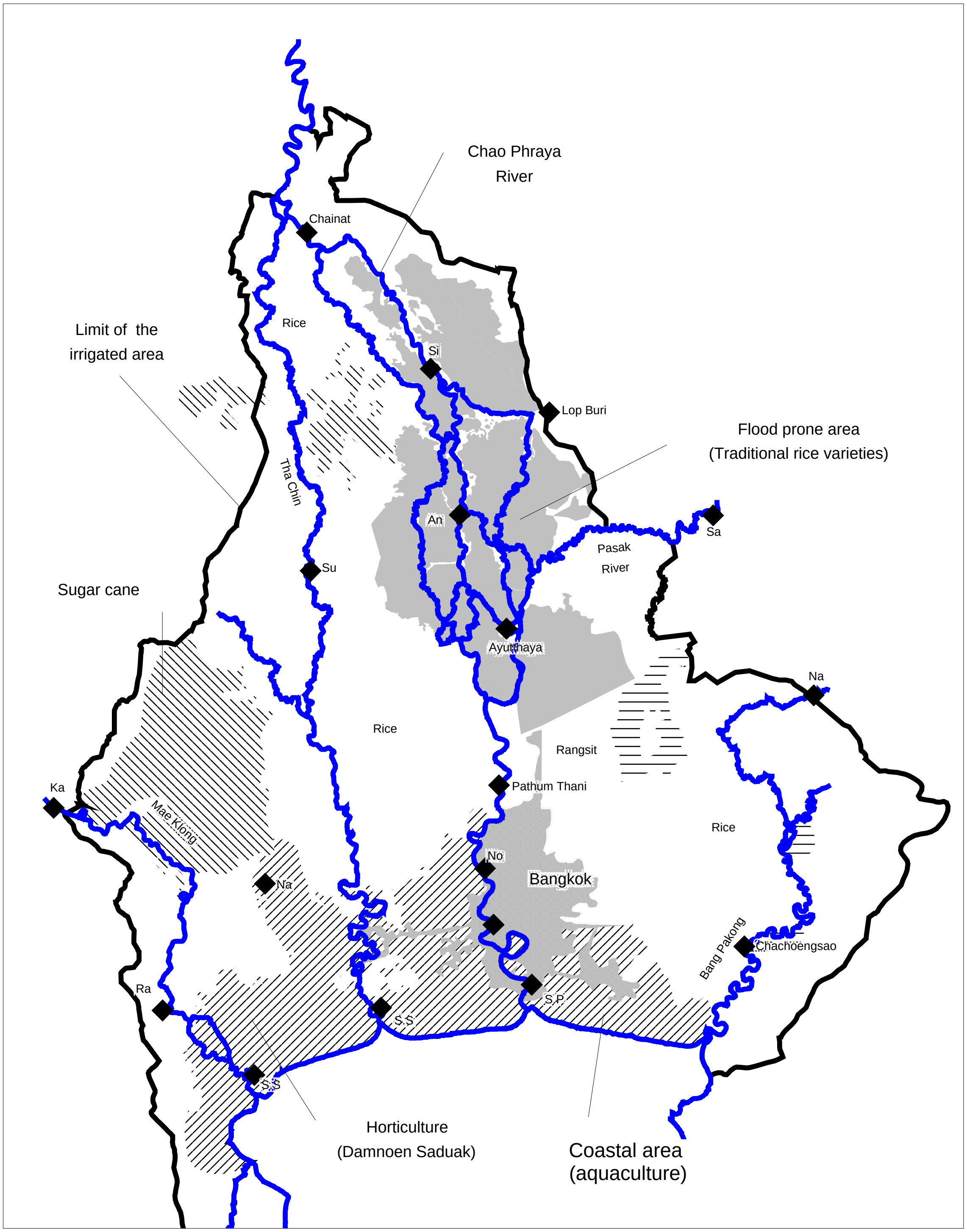


The region is sliced by five main rivers, roughly flowing north-south: the Tha Chin and Chao Phraya Rivers in its centre; the Mae Klong, Bang Pakong and Pasak Rivers on the western and eastern sides respectively.

While the dominant crop in the delta is rice, Figure 16 shows that there are significant areas cropped with other crops or urbanised: in the west, the Mae Klong area encompasses large areas of sugar cane and horticulture. Salt pans and aquaculture are found in the coastal zone, while the BMA occupies a large part of the lower delta. The rice cropping area can also be broken down in two sub-areas: the area shown in grey (hereafter the *flood-prone area*) is mostly home to deep water and floating rice varieties (hereafter *traditional varieties*, or TV) ; the remaining area (in white) is cropped with short duration High Yield Varieties (HYV).

[31] With the exception of its north-western part

FIGURE 16: HYDROGRAPHY AND SCHEMATIC LAND USE IN THE DELTA



From north to south: **Ch**: Chai Nat; **Si**: Sing Buri; **Lo:** Lop Buri; **An**: Ang Thong; **Sa**: Saraburi; **Su**: Suphan Buri; **Ay**: Ayutthaya; **Na**: Nakhon Nayok; **Pa**: Pathum Thani; **No**: Nonthaburi; **Ka**: Kanchanaburi; **Na**: Nakhon Pathom; **Ba**: Bangkok; **Ch**: Chachoengsao; **Ra**: Ratchaburi; **S.P**: Samut Prakan; **S.S**: Samut Sakorn; **S.S**: Samut Songkram.

Both the upper and lower delta are divided in units (both hydraulic and administrative for the Royal Irrigation Department) called *Projects*. The former is comprised of 15 Projects, while the West Bank and the East Bank are made up of 4 and 6 Projects respectively (Figure 17).

FIGURE 17: IRRIGATION »PROJECTS » IN THE STUDY AREA

2.2 A multi-level water allocation process

The delta is watered by the five rivers mentioned earlier. The Mae Klong area has its own irrigation system and is not considered in this study, albeit for its contribution to the water supply to the West Bank and BMA. The contribution of the Bang Pakong and Pasak rivers during the dry season is negligible. These two rivers are now provided with a dam (storage dam for the Pasak river, diversion dam in Chachoengsao for the Bang Pakong river), but these works have just been completed in 1999 and, therefore, are not relevant to the period considered in this study[32].

The "water chain" within the Chao Phraya Basin can be viewed as a set of successive embedded levels (Figure 18):

Level 1: the basin itself can be divided in three zones, as mentioned in the introduction: 1) the area controlled by the two storage dams (Bhumipol and Sirikit Dams), approximately 40% of the basin ; 2) the middle basin (the "upper central plains"), with its sideflows contributing to the Chao Phraya River flow in the rainy season ; 3) the delta proper. Other irrigated areas can be found in the middle basin. They are comprised of both official areas (managed by RID and DEDP (Department of Energy Development and Promotion) and unofficial ones (users pumping directly from the rivers).

Level 2: when the Chao Phraya River reaches Chai Nat, the location of the Chao Phraya Diversion Dam, its flow is divided into several main waterways:

- The Makham-Uthong (MKU) Canal, which marks the western boundary of the irrigated delta;
- The Suphan Buri (or Tha Chin) river
- The Noi River
- the Chao Phraya River itself ; water then flows freely down to the sea;
- The Chai Nat – Ayutthaya (CNA) canal, constructed on the eastern levee of the Chao Phraya River, along more than 100 km of its course;
- The Chai Nat – Pasak canal (CPK), which marks the eastern boundary of the delta;
- Seven smaller canals which also branch off the Chao Phraya River, in the proximity of the Chai Nat Dam.

All these waterways are of two kinds: some convey water to a defined irrigated area of the upper delta, while others also do but, in addition, channel water to the lower delta: this is the case of the Noi River, partly diverted to the West Bank, and of the CPK canal, which is the

[32] The Pasak dam has a clear impact on flood protection in the wet season but its contribution to the dry-season supply will be limited, because of new irrigation areas downstream of the dams.

main supplier of the East Bank[33]. In addition, the Tha Chin and the Chao Phraya Rivers must also maintain a minimum flow at their mouth in order to avoid salinity intrusion: these discharges are set at 35 and 50 cms approximately.

Allocation at the delta level therefore consists in setting the amount of water delivered to each of the hydraulic units supplied by different main canals, under the constraints of ensuring the supply of the lower delta (including BMA) and controlling saline intrusion.

Level 3: Along a given main canal are located several “Projects” (the RID administrative and hydraulic unit), each of them comprised of several lateral canals (or secondary) which branch off the main canal. The allocation process must, therefore, also define how much water is attributed to each of the Projects. The CPK canal, for example, supplies 4 Projects (Manorom, Chong Kae, Kok Katiem, Roeng Rang), before flowing to the lower delta.

Level 4: Within a given Project, several main or lateral canals can receive a share of the amount of water allocated to the Project. Each Project must plan which canals will receive water. This decision involves several factors, including cropping-patterns, canal characteristics, topography, soil type, farmers’ involvement and/or pressure, rotational policies, etc.

Level 5: Along a specific canal, several reaches are defined by successive check regulators. Planning must also consider whether all reaches will be supplied (which, in the dry season, often implies a rotation between reaches) or not (on the grounds that remote areas cannot be supplied with limited flows).

Level 6: Within a canal reach supplied with water at any point in time, water must be shared among concerned farmers. These either, and most often, access water directly from the canal, or from a ditch (tertiary canal) supplied by the lateral. In all cases, this often goes together with collective arrangements, either formal or informal.

The study does not analyse in depth all the levels of the water chain. Level 1 is addressed in that the inflow at Chai Nat is now dramatically reduced by sporadic water abstraction upstream. Levels 2 and 3, and to a lesser extent 4, are examined in detail in what follows. Levels 5 and 6, notably the latter, are addressed in the part of the study dedicated to social arrangements in water management (Report No. 2).

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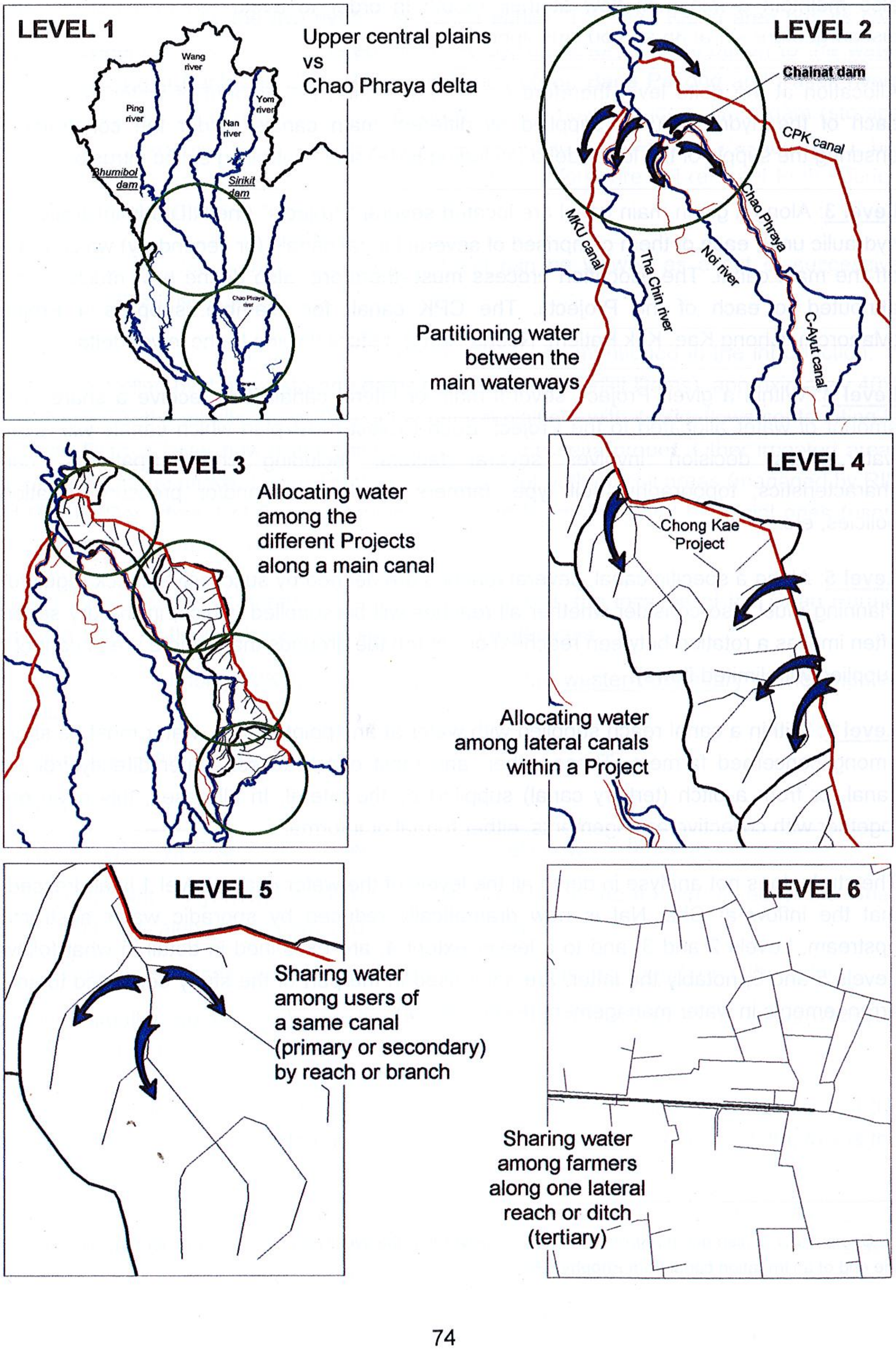
[33] Some water is also diverted from the Tha Chin River into the West Bank, through Pokhoi regulator located at the end of an irrigation canal from Phophya Project.

FIGURE 18: SIX SUCCESSIVE LEVELS IN WATER ALLOCATION



3 Patterns of spatial allocation, efficiency and equity (1977-1999)

This section examines the historical rise of double-cropping and scrutinises *where* and *how much* water has been delivered during the dry-seasons of the past 22 years. Therefore, it elaborates on aspects of equity (spatial patterns of distribution) and efficiency (amount of water supplied by unit area).

3.1 The idea of double-cropping

Although rice cropping in the dry-season is associated with the construction of the Chao Phraya Irrigation Project, together with the storage dams, some historical observations mention the use of short duration (traditional) rice varieties during the dry season. Thompson (1910), for example, deplores the lack of interest for double cropping: “the method of growing rice in Siam is that sanctioned by immemorial custom. It is said that the present cultivators are even more careless than their forefathers, and that in consequence the quality of the rice is deteriorating (...) by artificial irrigation two crops might be raised in the year instead of one. A small first crop is actually raised on irrigated land, and reaped in May or June”. At the same time, Prince Dilok (1907) also refered to double-cropping (*Kao bao-Kao nak* association), which could be observed in some irrigated plots.

The idea was raised a few years later by a report from the Royal Irrigation Department (1929) which proposed to dredge the head of the Suphan River to permit water to flow throughout the year, allowing farmers in Phophya to grow two crops per year. That double-cropping did not develop at that time must be ascribed to several factors, including: the low yield of such short term off-season rice; the greater benefit and opportunity to use the remaining unemployed family labour force by farming a larger area; the necessity to have reliable irrigation supply during the dry season; possible conflicts of calendar with adjacent areas growing only one crop (with seepage to these fields); the existing commitment of the family labour to other on-farm and off-farm activities.

Thereafter, we must wait until 1949 to find further mention of DS cropping. Even though, the FAO report (Ministry of Agriculture, 1950), which states that the “Chai Nat Project is urgently needed to bring the fertile paddy fields on this Plain into intensive production”, surprisingly only envisages that “in the dry season, there [will be] also sufficient water to supply irrigation for dryland crops such as groundnuts and soybeans which the people are already growing now on the upper reaches of the plain by relying on rain water only”.

Prior to the completion of the Bhumiphol Dam, initiated in 1956, the ministry of interior embarked upon a programme to encourage the production of a second crop of rice, based on the use of RID large pumps (Small, 1972). An estimated 11,000 rai were irrigated in 1964, aiming at reaping early benefits of the new irrigation facilities. The high costs of pumping discouraged RID to expand the experience.

3.2 The Chao Phraya Project and double-cropping

3.2.1 Dry-season cropping in the delta

From the completion of the Bhumipol Dam onward, double-cropping was still encouraged but farmers' responsiveness, nevertheless, remained low. A few dry years also delayed the opportunity to use the dam for supply in the dry season. A first hike in cropping area from 30 to 72,000 rai was observed in the year 1971 in the upper delta (Figure 19); three fourths of this increase is in the Samchuk region because of damage experienced in the 1970 rainy season and because of the dissemination made by Suphan Buri station, with two HYVs released in 1969 (Small, 1972). A second hike occurred in 1973, further to the beginning of the operation of the Sirikit Dam (Ngo, 1980).

The two dams were expected to provide a yearly release of 5 Bm^3 between January and June, but calculation showed that this available water was not likely to allow the irrigation of more than 25% of the upper delta, or approximately 0.85 million rai (Small, 1972).

However, the threshold of 2 million rai (whole delta) was reached in 1976; only three years later, the rice area amounted to 3 million *rai* (a little less than 500,000 ha), with 1.3 million *rai* for the upper delta, a value which can be taken as an average for the 20 ensuing years. During this period, the upper delta accounted for an average of 45% of the DS rice area, against 55% for the lower delta. Figure 19 also presents, for the sake of comparison, the rice area corresponding to the Mae Klong area and to the middle basin. From this figure pops up the evidence of a notable difference between the upper and lower parts of the delta: while the later, with an average value of 1.8 million rai, remains rather stable (although showing a gradual decline due to the encroachment of urban areas and a rebound in the mid-90s because of higher rice prices), the share of the upper delta is rather hectic. The most significant squeezes were observed in 1980, where almost no cropping was recorded, and during the depressed 1991-94 period. The all time record occurred in 1998, after three consecutive years in which the share of the upper delta exceeded that of the lower delta to reach 2 millions rai. This went alongside a surge of triple cropping, amounting to roughly 1 million rai in 1998 and 1999[34].

To put it short, the lower delta is at an advantage in years of shortage, as water is delivered to this area in priority, in order to ensure environmental sustainability, transportation and to control saline intrusions. With water filling up the extensive and dense network of channels of this flat area, there is little scope for farmers to refrain from pumping and for officers to prevent them to do so. In years of abundant water, large supplies are diverted to all main waterways branching off the Chao Phraya River at Chai Nat, and the upper delta can extract water first.

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[34] This can be compared with the prospective study carried out by ACRES in 1977. The average sustainable area was computed at 2.37 million rai. With increased efficiency (land consolidation) this target was expected to reach 3.31 million rai, with cutbacks being necessary 1 year out of 3.

3.2.2 Dry-season cropping in the middle basin

These considerations, however, do not include the cropping area in the middle reach of the basin (between the two dams and Chai Nat, the apex of the delta). Negligible in the seventies and early eighties, this area gradually increased with the completion of the Utaradit, Pitsanulok and lower Ping Projects. The first large-scale irrigated areas managed by RID in the Nan River valley were completed in 1983 (around 100,000 rai), and now exceed 800,000 rai (Binnie, 1997). In the lower Ping, there are four Projects[35] which have been completed between 1971 and 1985 and which are totalling 400,000 rai (Figure 1).

More difficult to assess are the areas irrigated by direct pumping in the lower Ping and lower Nan Rivers reaches (downstream of the dams). Data from the National Energy Administration for 1989 (ESCAP, 1991) show 21 pump sets on the lower Ping river and 64 pumps on the middle/lower Nan River, most of them located between Uttaradit and Phitsanulok. The Northern region is credited with 241 pumps but only 195 are said to be in operation. Later data (for 1991) refer to 46 in the lower Ping reach and156 stations in the lower Nan reach, but these are given by province and their exact position is not known.

A recent DEDP report (DEDP, 1998), sets the number of pumping stations in the whole Chao Phraya Basin at 505, with a corresponding area of 780,000 rai. If we limit ourselves to the lower Ping and middle/lower Nan reaches, the number of pumps was 69 and 159 respectively, quite similar to the 1991 data, with corresponding irrigated areas of 117,000 and 282,000 rai. At the end of 1998, the director of RID reported that 134 and 156 pumps were in operation in the lower Ping and middle/lower Nan Rivers respectively (The Nation, 1998 December 27). Given the percentage of pumps out of order, the uncertainty about their location, and the slack information on the cropping area and crop types of these schemes[36], it is rather difficult to derive a clear picture of the amount of water extracted by DEDP pumping stations.

The share of water officially allocated to DEDP during the official meeting for the preparation of the dry-season is around 400 Mm3. Distributed over 6 months, this amount of water corresponds to an average discharge of 25 cms. However, RID informally considers that one hundred pumps operate between Sirikit Dam and Naresuan dam, and another hundred down to Nakhon Sawan. With discharges of 0.25 m^3/s, these pumps would result in a diversion of up to 50 cms.

Binnie (1997) gives areas of 298,000 rai and 1,091,000 rai for lower Ping and lower Nan respectively for the 1995 dry-season (Table 3), while the share supplied by electric pump stations appears as 276,000 rai (including 34,000 rai of field crops). This would mean that only 69 % of the total estimated area of 400,000 rai was irrigated during that season.

[35] Nong Kwan (1971: 75 000 rai), Wang Yang (1974: 100,000 rai), Wang Bua (1979 : 140,000 rai) and To Thong Dang (1985 : 85,000 rai).

[36] From detailed data on the 1997/98 dry-season, it can be seen that only 12% of the Lower Ping area and 7% of the middle-Nan reach are cropped with non-rice crops.

TABLE 3: DRY-SEASON CROPPING AREA (1995/1996)

	Lower Ping		Lower Nan		Total	
	Area (rai)	Rice equivalent	Area (rai)	Rice equivalent	Area (rai)	Rice equivalent
RID scheme	105,058	79,355	457,962	456,633	563,020	535,988
RID small	53,053	41,306	279,623	147,532	332,676	188,839
Pumping (DEDP)	29,246	22,096	246,788	233,602	276,034	255,698
Total	298,494	226,313	1,091,541	932,578	1,390,035	1,158,890

Source: Binnie (1997)

Figure 22 proposes a tentative estimate of the cropping area upstream of the Chai Nat Dam (middle basin). Corresponding tabular data and hypothesises made for this calculation are reported in Annexe 3. The estimated total area is based on the water balance between the two dams and Nakhon Sawan during the three driest months (February-March-April). During this period sideflows are believed to be very small and the dams' releases minus the flow observed at Nakhon Sawan provides a measure of the amount of water diverted in the different areas of the middle basin, which can be further translated in terms of area[37]. The chart suggests that there is some area unaccounted for, either because of under-reporting in DEP/RID schemes or because some private irrigation pumps are not considered.

Figure 23 shows that the amount of water diverted, as estimated from the water balance in the three driest months and expressed first in cms, then in percentage of the dam releases, is both very significant and growing. While the middle reach was only consumed 5% of the dams releases in the seventies, it appears that in the last two years this rate was over 30% !

The figure specifies the share of the Lower Nan irrigated area (RID only), as given by the discharge diverted at Naresuan dam. The evolution in the last ten years clearly illustrates the loss of control of RID on water flows, even though some part of the diversion is controlled (Pitsanulok and Kamphaeng Phet Projects) and despite co-ordination with DEDP aimed at curving water abstraction down in cases of shortage.

[37] It is assumed that the dry-season cropping spreads over 5 months until 1990 and over 6 months in the last decade. The rice irrigation water duty for one rai is taken as 1,650 mm.

FIGURE 19: EVOLUTION OF THE AREA CROPPED WITH RICE IN THE DRY-SEASON

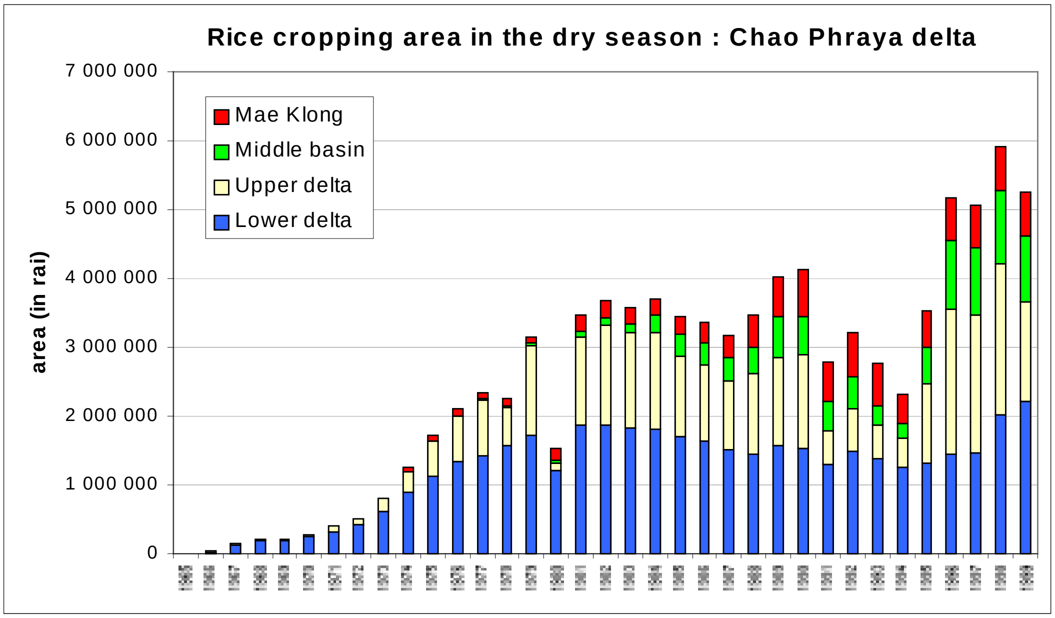


FIGURE 20: RICE CROPPING IN THE BASIN, IN %

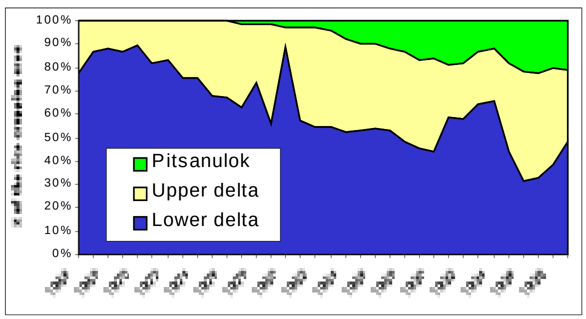


FIGURE 21: TOTAL CROPPING AREA IN THE DRY SEASON

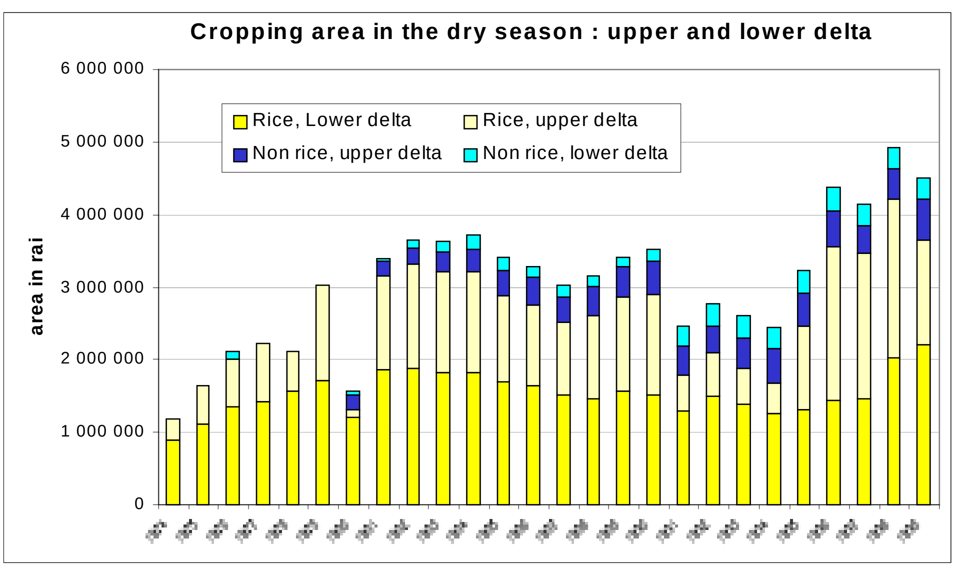


FIGURE 22: ESTIMATE OF DRY-SEASON CROPPING AREA IN THE MIDDLE BASIN (IN RAI)

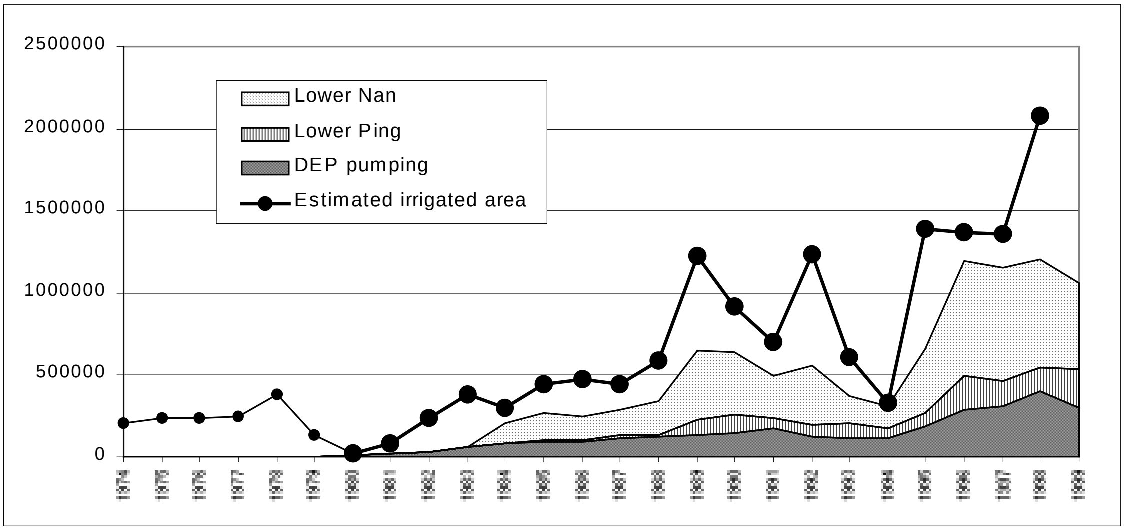
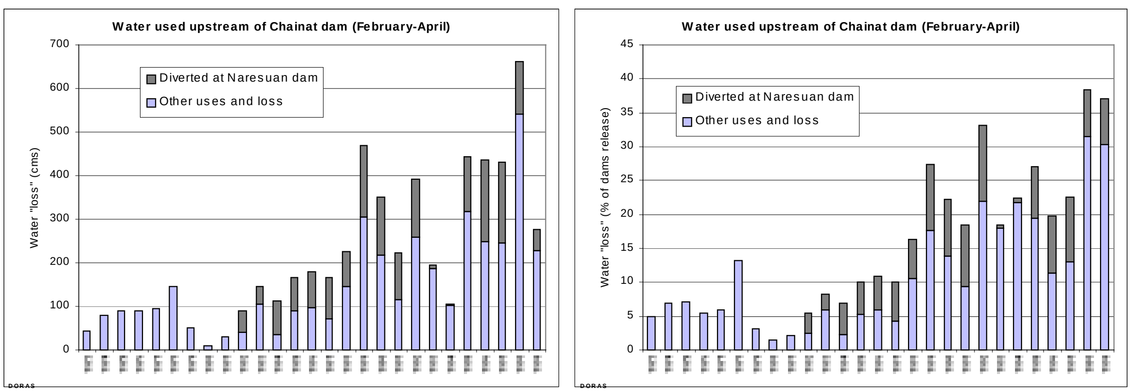


FIGURE 23: WATER BALANCE IN THE MIDDLE BASIN FOR THE FEBRUARY-MARCH-APRIL PERIOD



Based on RID data

Figure 20 shows that, expressed in percentage of the total cropping area, the lower delta is losing area (transfer to non-rice or non-agricultural activities), while cropping in the middle part of the basin is growing. Figure 21 provides additional information on the share of non-rice crops cultivated in the dry-season: this includes a part of perennials crops (orchards), vegetables (especially in the lower delta, around Bangkok) and field crops: it is worth noting how the latter category is inflated in the upper delta during the 1991-94 shortage period. This already suggests that while farmers prefer to grow rice they may be compelled to shift to field crops in case of water shortage.

3.3 Cropping intensity

These cropping areas can be translated in terms of cropping intensities. Figure 24 proposes a ranking by Project of the average *rice cropping intensity*, that is the ratio between the dry-season + wet season rice areas and the estimated potential rice area. These calculations are based on the data collected and published by RID at the Project level. These data, as will be shown in the next section, are not deprived of error. However, apart from being the only data available, their quality can be considered reasonably good, particularly when one acknowledges the difficulty of the task of recording land use data (see Molle *et al.* 1997).

1. A reservation must first be made for the East Bank, especially Rangsit Tai, for which data seems underrated. Although most of the East Bank achieves double-cropping[38] in a normal year, there is a fishy stickiness of dry-season acreage around 50%. This value is mentioned by officers as being the target indicated by RID's policy aimed at decreasing water use for DS rice cultivation. In addition, in contrast with the northern delta which has a denser network of field staff (zonemen and gate-keepers), these Projects have few staff to cover a large area (partly due to the limited number of structures to be taken care of). The follow-up of crop establishment and land-use is therefore very much of a guess estimate. This also applies to the West Bank.

2. The assessment of cropping intensity is also obscured by the fact that cropping calendars are mobile and shifting and that the distinction between wet and dry season is not always clear-cut. Some areas may grow only a DS crop and no WS crop, distorting the calculation of the potential rice area. This is responsible for some inaccuracy in the West Bank, notably Chao Chet and Phrayabanlue Projects and also affects the Pho Phya Project (which southern tip is under the same hydrological regime as the West Bank) and Phak Hai Project. In the last 10 years, this Project has undergone a drastic shift from WS floating rice mono-cropping towards dry-season HYV rice cropping, with some double-cropping in some favourable years and locations (Molle *et al.* 1999). This makes the assessment of the cropping intensity for this period rather difficult.

3. What is the potential rice area is not always known accurately. Taking the (running) maximum rice area cultivated over 3 years is not always correct because there might be some fallow land. In Chao Chet Bang Yeehon Project, for example, the official irrigated area is 406,000 rai but the maximum rice area is 310,000 rai. The difference includes non-rice crops, fallow land, and areas changed to built-up.

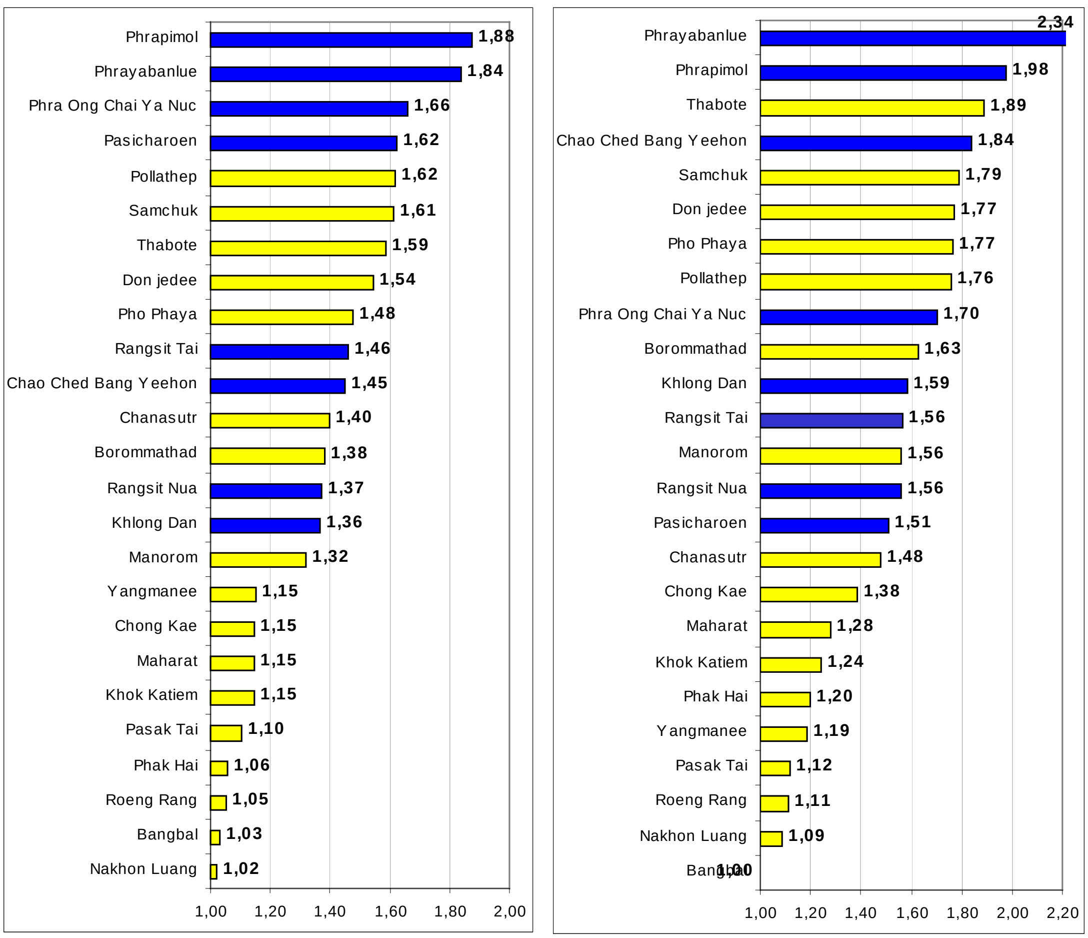
4. The trend towards highly flexible, site-specific and year-specific cropping calendars observed in the last 10 years, and most especially the last 5, makes it all the more difficult to define what the dry-season cropping is (see next chapter). In Chao Chet Bang Yeehon Project, where all calendars can virtually be found, officers consider as wet-season rice all the areas started after the 1st of June (RID's criteria). As calendars are shifted according to the importance and duration of the flood, the share of the area which falls under the wet-season or dry-season categories changes every year.

[38] The evidence of this from satellite images is strong on the eastern part of the East Bank but less clear in the proximity of Bangkok: the patchy land use of this area (with a lot of fallow land) makes it difficult to single out the rice area.

5. In addition, some areas practise *triple-cropping* which would be best described as *continuous cropping*, with little consideration to the seasons. Using short duration varieties (as short as 90 days), some farmers may even grow more than 3 crops a year. This happens in locations with year-round access to water and protection from floods. Typical examples are parts of the Samchook and Don Chedi Projects, areas of Borommathad Project also resorting to tube wells, or the higher parts of the Phrayabanlue Project (plots with protective dikes). It must be noted that triple cropping is only officially recorded by RID (and taken into account) since 1998, although it has already been practised for at least ten years, sometimes in quite significant proportions (e.g. the Samchuk and upper Don Chedi Projects, for which cropping intensities are therefore underrated).

Figure 24 (left) displays the average rice cropping intensity over 20 years for each Project. There are stark contrasts between upper values (6 Projects over 1.6, 4 of them indicated in dark, from the lower delta) and the 8 lower ones, with an index below 1.16. Considering the upper and lower delta, aggregated figures give indexes of 1.33 and 1.44 respectively, with an average for the delta of 1.38.

FIGURE 24: RICE CROPPING INTENSITIES BY PROJECT (LAST 20 YEARS AND LAST 4 YEARS)



The figure on the right shows the average indexes for the 1995-1999 period: all Projects, with no exception, have benefited from a hike in water supplies and four of them achieved an index close to 2, thanks to triple-cropping. Values for the upper and lower delta are 1.51 and 1.63 respectively, giving an overall average value of 1.56.

Cropping intensity can also be computed by adding field crops (FC) to the wet+dry season rice area. This entails an average increment of the index of 0.02 for the upper delta. It can also be computed by considering the total non-rice area under cultivation (Tot), including fruit trees, year-round vegetable production, sugar cane and aquaculture. The average index [DS rice + WS rice + FC + 2*Tot]/[Potential irrigated area], or the *Total cropping intensity*[39], is given in Table 4. It reveals that for the period running from 1981 to 1999, the total cropping intensity has been 1.34 for the upper delta and 1.52 for the lower delta (average 1.43). The same indexes, calculated for the last 5 years, yield overall values of 1.57 and 1.70. In conclusion, the upper delta appears to have around one third of its irrigated area cropped during the dry season, with a rather high elasticity in case of abundant or low water supply, while the lower delta is roughly half cultivated in the dry season. This last value, however, is strongly influenced by the inclusion of Pasak Tai and Nakhon Luang Projects, both with very low cropping intensity, in the East Bank. It is further pulled downward by values of DS rice area for the Rangsit Tai Projects which are believed to be underrated (see above). If we account for these two factors and restrict ourselves to the lower East Bank (Rice CI 1.50), combined with the West Bank (Rice CI of 1.70), we find a more realistic cropping intensity of 1.60 for the lower delta, and around 1.80 for the last 5 years. The total crop intensity index is at 1.65 for the lower delta (1981-1999).

TABLE 4: CROPPING INTENSITY INDEXES

	Rice cropping intensity	Rice + Fc crop. Intensity	Total cropping intensity	Rice cropping intensity	Total cropping intensity
Period	**1981-1999**			**1995-99**	
Upper delta	1,33	1,36	1,40	1,51	1,57
Lower delta	1,44	1,45	1,51	1,63	1,70
Total delta	1,38	1,40	1,45	1,56	1,63

These indexes are based on the cropping areas as recorded by officers and therefore refer to the plots located within the formal structure of the irrigation network. There is growing recognition that such approaches do not fully capture the real benefit of water. Given the magnitude of these tree areas, and their beneficial and productive contribution, they cannot be simply treated as by-products. Taking them into consideration, overall cropping intensities are increased by approximately 5%.

With the reservations made earlier, the temporal variation of the delta rice cropping intensity is given in Figure 25.

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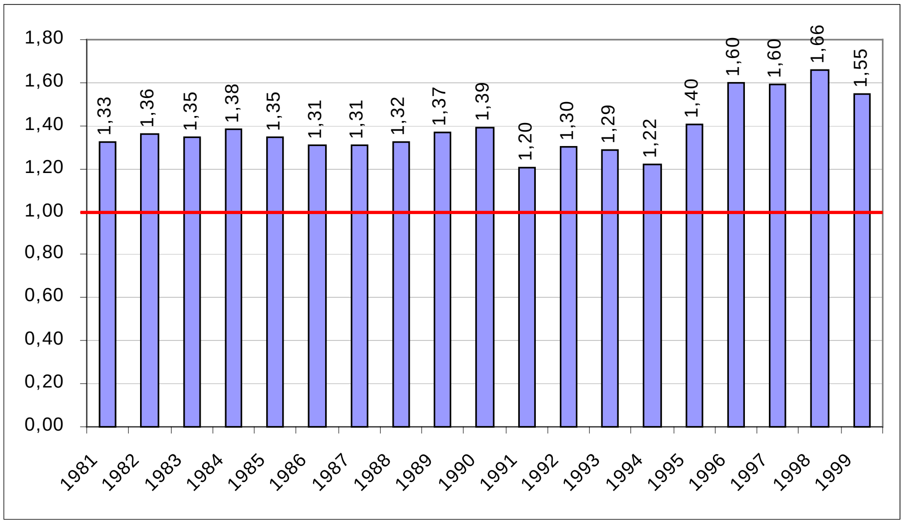
[39] Note that the area corresponding to perennial crops is multiplied by two. This is because the cropping intensity indexes considered here are relative to a seasonal rice crop, not to absolute soil occupancy along the year. Full rice double cropping gives an index of 2, whereas the corresponding soil occupancy index would be close to 0.65. Perennial crops are considered to be equivalent to two crops of rice.

FIGURE 25: AVERAGE RICE CROPPING INTENSITY FOR THE DELTA (1980-199)



3.4 Spatial patterns of dry-season cropping

The contrast mentioned earlier regarding the upper and the lower delta is likely to be sharpened when observing the smaller scale of the Project level. This readily defines a spatial heterogeneity, both year by year and on the average over 20 years, which translates in terms of (*in*)*equity*. The quality of the access to water is governed by several factors, including physical, technical and political, which contribute to shaping the spatial pattern of water allocation.

The first index considered here:

CI1= [(*DSrice + WSrice + F.Crops + 2*Tot)/agricultural potential cropping area*]

is indicative of the effective benefit drawn from DS cropping (or irrigation) by a given Project with its specific constraints ; it includes all crops and takes the *agricultural potential cropping area for one season* as a unit.

Figure 27 displays the spatial variation of CI1 both for the 1981-1999 period and the 1995-1999 period. The west of the delta appears to be characterised by much higher indexes than the east (especially upper east). The pattern was changed in the last 5 years (with an increase of the cropping intensity in the lower delta) but, while all indexes are on the rise, the central and eastern upper-delta still do not reap the full benefits of irrigation.

The Projects' total cropping intensities just shown are partly biased by the fact that the rice area in the dry-season has been implicitly compared with the *potential cropping area, which includes the potential rice area in the wet season:* this does not take into account the fact that some Projects encompass floating rice areas which are deprived of on-farm infrastructures (ditch, levelling, bunding) and which, therefore, are not candidate to DS cropping. The

Maharat Project, for example, presents some low lying areas north of Maharat District of Ayutthaya Province which have no irrigation facilities at the plot level.

Therefore, the question of what is, and where is, the real potential irrigation area for the dry-season is of crucial importance. We will investigate this issue in detail in Chapter 13. For the time being, we may consider the rice cropping intensity calculated with reference to the potential rice area:

CI2 = [1+*(DS rice + F.Crops)/potential rice area in the dry-season*]

CI2 compares *rice cropping intensities* on the *sole* area[40] which can, technically, achieve double-cropping: this serves as a formal index of spatial equity[41].

The values of CI2 by Project are displayed in Figure 26. Inequalities regarding Projects[42] partly deprived of on-farm infrastructures have been reduced but the sheer contrast has not disappeared. For the last 5 year period[43], the magnitude is raised but the order is slightly modified. The spatial display of these indexes is given in Figure 28 while the detail of all indexes appears in Table 5.

This section showed evidence of a spatial pattern of inequity in cropping intensity which remains whatever variant of the index is considered. The reasons for such a situation are manifold and will be dealt with later. Its consequences regarding the evolution of farming systems are also paramount and will be examined in Chapter 7.

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40 This index considers the *current* potential area. We gave up attempting to estimate the change of this area over the last 20 years. Therefore, the values of CI2 are underrated for those Projects which have undergone major changes.

41 This index, however, creates difficulties for Projects which are not fully cropped in the wet season (upper West Bank, Phak Hai, Phophya). It is therefore applied only to the Projects which do have restrictions in on-farm infrastructure.

42 Namely: Maharat, Yangmanee, Roeng Rang, Kok Katiem, Pasak Tai, Nakhon Luang, and to a much lesser extent Chanasutr, Borommathad, Chong Kae, Bang Bal.

43 The index is only for rice (field crops non included)

FIGURE 26: CI2, TOTAL CROPPING INTENSITY INDEX, CORRECTED VALUES (1981-1999 AND 1995-1999)

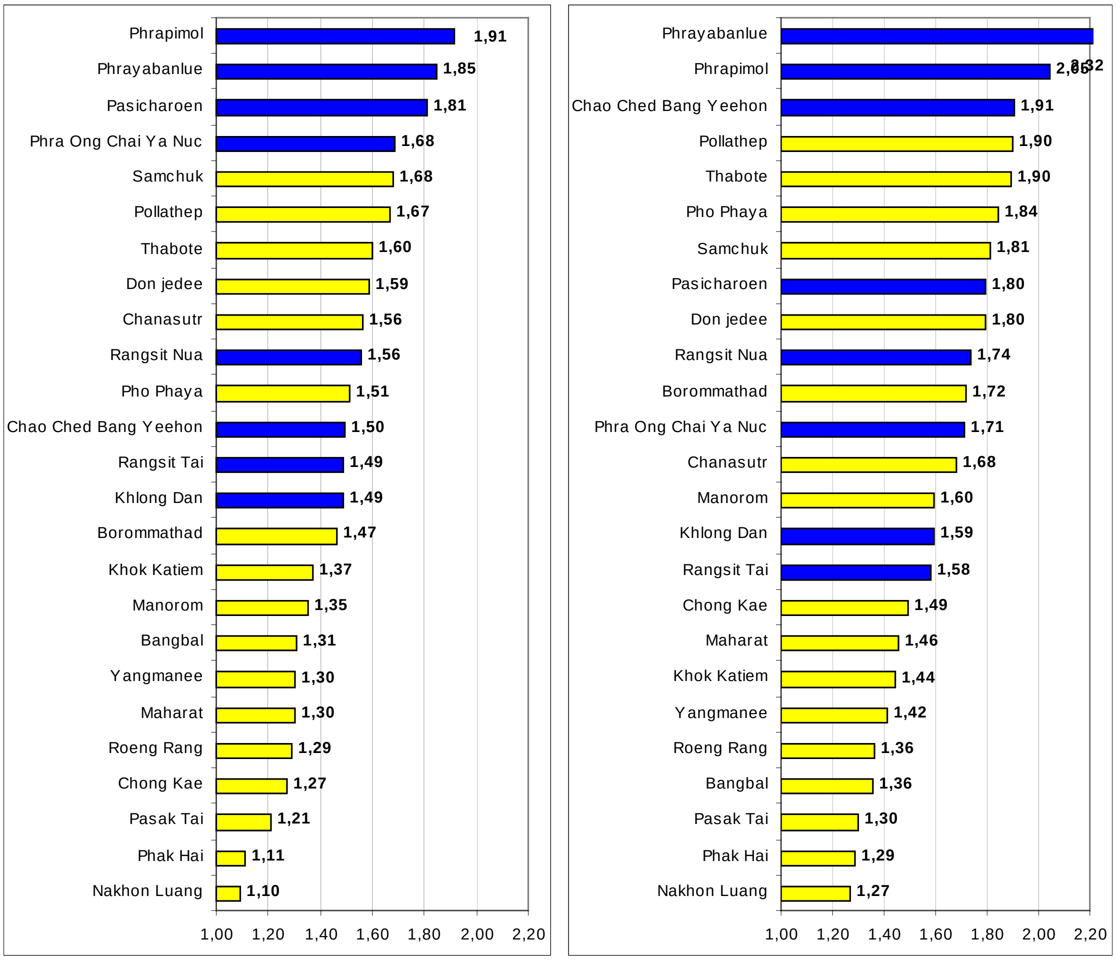


TABLE 5: CROPPING INTENSITY INDEXES, BY PROJECT

Project	Rice CI	Rice + FC CI	Total CI	Rice CI	Total CI	Total corrected Cropping intensity		%of area with no on-farm*
Period	1981-99			1995-99		1981-99	1995-99	%
Borommathad	1,38	1,41	1,44	1,63	1,68	1,47	1,72	5
Chanasutr	1,40	1,40	1,48	1,48	1,58	1,56	1,68	15
Chong Kae	1,15	1,19	1,22	1,38	1,40	1,27	1,49	20
Don jedee	1,54	1,55	1,59	1,77	1,80	1,59	1,80	0
Khok Katiem	1,15	1,19	1,22	1,24	1,27	1,37	1,44	39
Maharat	1,15	1,18	1,21	1,28	1,32	1,30	1,46	30
Manorom	1,32	1,32	1,33	1,56	1,57	1,35	1,60	5
Pho Phaya	1,48	1,48	1,51	1,77	1,84	1,51	1,84	0
Pollathep	1,62	1,62	1,65	1,76	1,87	1,67	1,90	3
Roeng Rang	1,05	1,11	1,17	1,11	1,22	1,29	1,36	40
Samchuk	1,61	1,62	1,68	1,79	1,81	1,68	1,81	0
Thabote	1,59	1,59	1,60	1,89	1,90	1,60	1,90	0
Yangmanee	1,15	1,16	1,21	1,19	1,29	1,30	1,42	30
Nakhon Luang	1,02	1,03	1,04	1,09	1,11	1,10	1,27	60
Pasak Tai	1,10	1,12	1,18	1,12	1,26	1,21	1,30	15
Phak Hai	1,06	1,08	1,11	1,20	1,29	1,11	1,29	55
Bangbal	1,03	1,06	1,06	1,00	1,07	1,31	1,36	80
Chao Ched Bang Yeehon	1,45	1,45	1,50	1,84	1,91	1,50	1,91	0
Khlong Dan	1,36	1,37	1,49	1,59	1,59	1,49	1,59	0
Pasicharoen	1,62	1,63	1,81	1,51	1,80	1,81	1,80	0
Phra Ong Chai Ya Nuc	1,66	1,66	1,68	1,70	1,71	1,68	1,71	0
Phrapimol	1,88	1,88	1,91	1,98	2,05	1,91	2,05	0
Phrayabanlue	1,84	1,84	1,85	2,34	2,32	1,85	2,32	0
Rangsit Nua	1,37	1,37	1,56	1,56	1,74	1,56	1,74	0
Rangsit Tai	1,46	1,46	1,49	1,56	1,58	1,49	1,58	0
TOTAL upper delta	**1,33**	**1,36**	**1,40**	**1,51**	**1,57**			
TOTAL lower delta	**1,44**	**1,45**	**1,51**	**1,63**	**1,70**			
TOTAL	**1,38**	**1,40**	**1,45**	**1,56**	**1,63**			

* These are estimates based on the expansion of dry-season cropping in 1998 and on the authors' knowledge of the fields.

FIGURE 27: SPATIAL RICE CROPPING INTENSITY (1981-1999 AND 1995-1999)

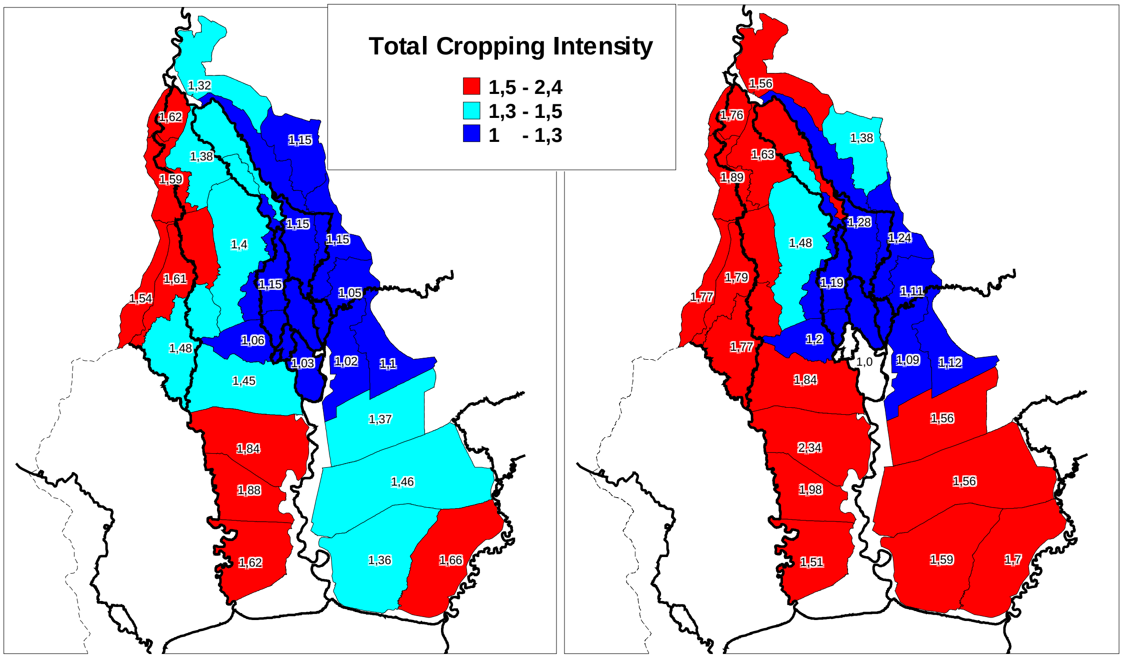
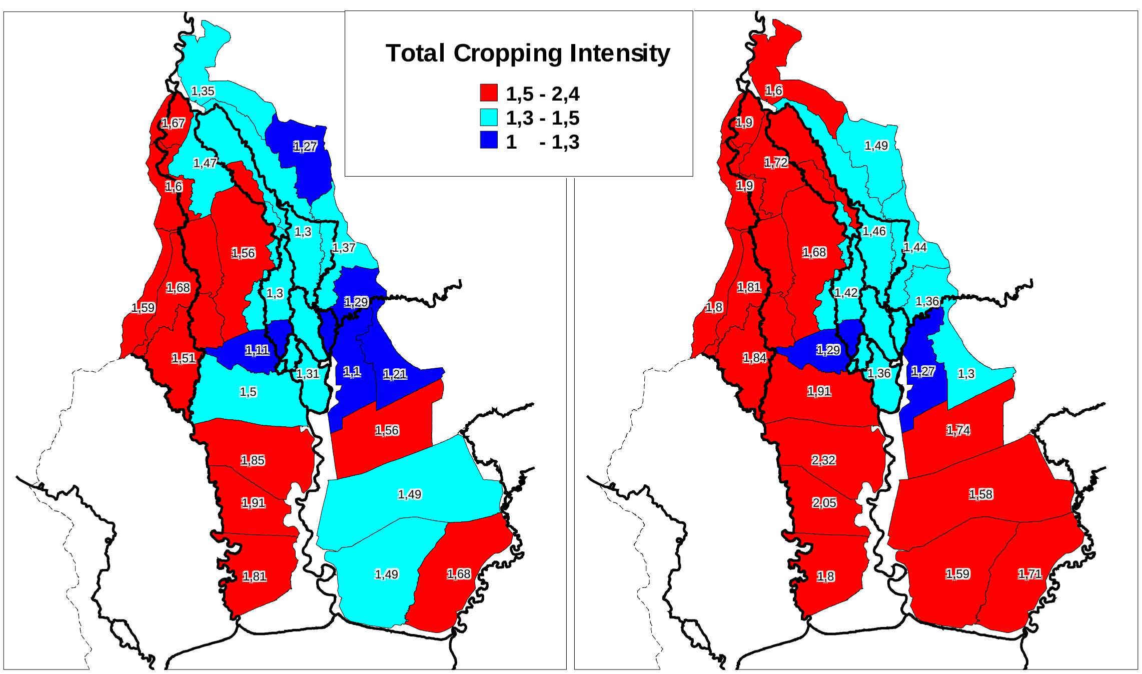


FIGURE 28: CORRECTED VALUES, TOTAL CROPPING INTENSITY INDEXES



3.5 Water supply and cropping area

Water supply (the sum of irrigation and of *effective rainfall*) can be compared with the total cropping area in order to derive standards of water use and to evidence differences between Projects or variations over time.

3.5.1 Water balances

Water balances can be achieved for hydraulic units which have records of inflows and outflows. Inflows are recorded five times a day at all the main regulators of the distribution network. Return flows to the drainage systems are unfortunately unknown. There are a few reasons to believe that these are not of any significant magnitude in the dry season: at the plot level, the great majority of farmers have to pump water from the ditch and they are eagerly combating any loss out of their plot of scarce water. At the Project level, most main and secondary drains are equipped with regulators in order to better retain water in the dry season (they capture superficial and sub-superficial run-off), and little water is passed on to downstream areas. Return flows remain much probably under the 5% threshold, except in case of heavy rainfall (May-June).

The delta may also get some inflow from adjacent upland areas in case of heavy rainfall. The most significant of this sideflow is provided by the Krasiew River on the West. It may account for negative water balances between Tha Bot and Samchok regulators, as it merges with the Tha Chin River in the middle of this reach. Other significant waterways on the eastern side are also intercepted by the Chai Nat-Pasak canal: they can be either be passed through it towards the drainage system of the delta, or incorporated to the canal flow itself. Some months with heavy rainfall have therefore been discarded.

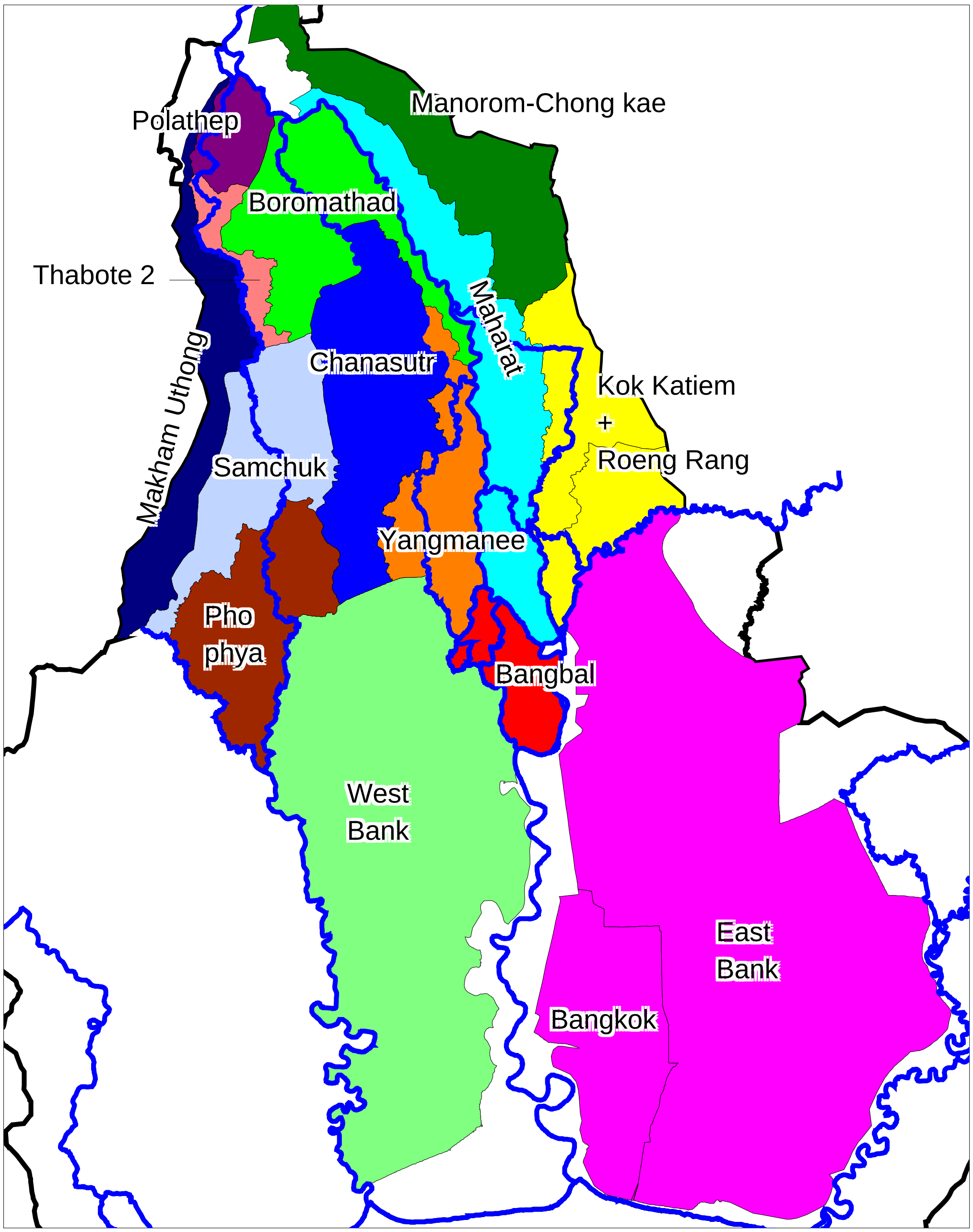
The upper delta has been divided in 12 hydraulic units, hereafter referred to as "*sections*". In the lower delta, water balances are precarious. There is a significant inflow, both by gravity and by pumping, into the West Bank from the Tha Chin River (which receives water from the Mae Klong system) and unknown flows from/to the Chao Phraya River. The East Bank receives less water from its bordering rivers. The inflow from Bang Pakong River is discontinued in January and is partly substituted by pumping.

Figure 29 displays the different sections that will be considered for the analysis of the water balance. Manorom and Chong Kae Projects have been pooled together (M/CK tract), and so have been Roeng Rang and Kok Katiem Projects[44]. The Thabote Project had to be divided in

[44] Unfortunately the Project areas do not exactly match the hydraulic units defined by the service areas of each principal canal reach. Canal 18R of Kok Katiem Project branches off upstream of Kok Katiem regulator and therefore belongs to M/CK tract. The irrigated area corresponding to this canal, estimated at 10% of the RR-KK tract irrigated area, has been added to it. In compensation, Canals 24R and 25R used to take water downstream of the Roeng Rang regulator and their inflow was therefore not computed (Since 1996, a feeder canal branching off the CPK canal upstream of the regulator is supplying them). We have considered that the corresponding amount of water was roughly compensated for by that of the 18R canal.

two parts, one named Thabote 2 while the other part was pooled with Don Chedi and a narrow part of Polathep to form Makham Uthong section.

FIGURE 29: SECTIONS (HYDRAULIC UNITS) IN THE DELTA

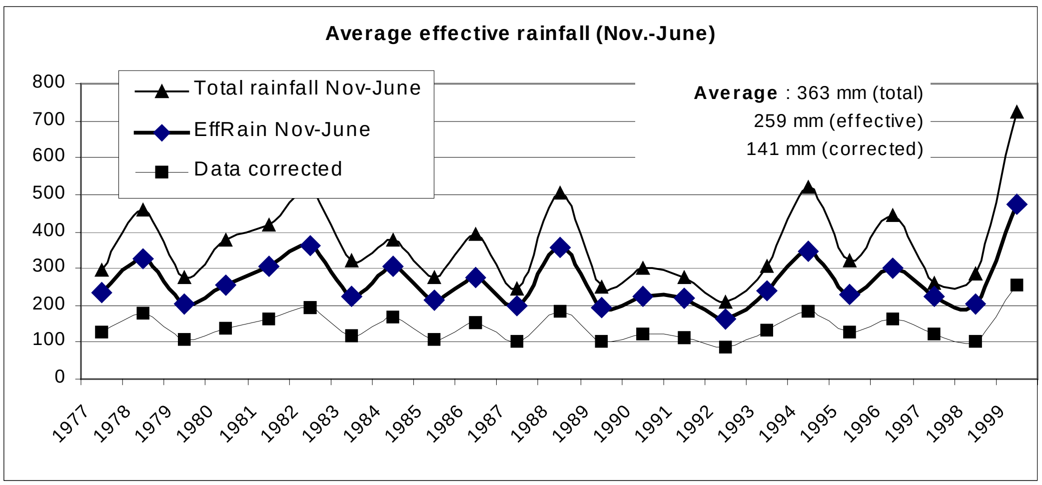


3.5.2 Magnitude of effective rainfall

Effective rainfall is the part of rainfall which is eventually retained in the fields and used by the crops. Its magnitude is governed by the patterns of rainfall intensity (mm/hour) and of daily rainfall succession. Heavy and consecutive precipitations will fill up the paddy fields and then be lost to the drainage system. Smaller and spaced-out rainfall will be more efficiently harvested and used. Effective rainfall can be calculated from formulas derived from models simulating daily water balances of paddy fields. We will use here the formulas given for rice and sugar cane (here, applied to all field crops) by Varawut (*pers. com.*)(see Annexe 6).

Figure 30 shows that the total and the effective rainfall in the delta over 22 years amount respectively to 363 and 259 mm on the average, for the period running from November to June. The values for the sole January-June 6-month period are 303 and 207 mm. Local cropping calendars however, do not cover such a span of 8 months. For each section, we have therefore considered the normal calendar of rice cropping and retained only the effective rainfall corresponding to this period. Averaging these values (weighed by the blocks area), we get corrected yearly effective rainfall much closer to the real contribution of rainfall to dry-season cropping. Its average for the delta is 141 mm.

FIGURE 30: AVERAGE TOTAL AND EFFECTIVE RAINFALL IN THE DELTA (1977-1999)



The percentage of rainfall potentially used, 75% of total precipitation, is rather high, because of the structure of rainfall during the dry and early rainy seasons. A figure in Annexe 7 shows this percentage for each of the years. However, it might be misleading to consider rainfall contribution without caution. This percentage corresponds to the amount of water which is likely to be captured *in-situ* by the paddy fields; run-off water may not be lost, as it is likely to be re-used downstream. Heavy rainfall in the late dry-season, especially in the West Bank, are nevertheless likely to be drained to the Chao Phraya River.

We may also investigate how this amount of effective rainfall relates to the total water supply. Over 20 years, data show that rainfall contributed to an average of 14% of the total water supply, with a variation inside the 8%-23% bracket. Table 6 specifies how much average effective rainfall can be expected for each month[45]. It indicates that most of the contribution is to be expected chiefly in the last 3 months, particularly May and June (75% of the January-June total).

TABLE 6: MONTHLY AVERAGE TOTAL AND EFFECTIVE RAINFALL (MM)

Month	Nov.	Dec.	January	Feb	March	April	May	June
Total rainfall	33	4	4	10	21	46	129	111
Effective rainfall	25	4	4	8	17	40	84	77

3.5.3 Relationship between water supply and cropping area

Several possible sources of error impair the accuracy of the estimation of both the water supply and the cropping area. Regarding water flows, a main source of error is inaccurate hydraulic formulas or the use of the latter in situations where their precision is not ensured. As flows in the canal (in the dry season) are generally much below the design level, errors are sometimes paramount. There are also not rare instances in which the water level in the primary is just enough to enter a given lateral. In such cases (as often occurs in the independent canals of Pollathep and Borommathad which directly branch off the Chao Phraya River, upstream of Chai Nat Dam), gates are wide opened and measurements are not possible (officers are believed to record guess estimates). In some instances, too, such an inflow is too small to serve any area and the gate is then closed, while a pump is set in order to transfer water from the main canal (or river) to the lateral[46]. There is no certainty as whether pumped volumes are estimated properly or not, and if they are or not.

More generally, flow records are subject to errors of reading (gauge), recording (in books) and, in some cases, ad-hoc over or underreporting.

Regarding water use, a first difficulty arises because of the multiplicity of crops planted in the delta. To simplify the water balance, we have expressed the cropping area in terms of *rice-equivalent*. In what follows, coefficients of 0.4 for field crops/vegetables, 0.7 for sugar cane, and 1 for orchards and aquaculture have been used.

Another difficulty is linked to our limited knowledge of cropping calendars in the dry-season. While we consider the amount of water delivered during the first six months of the year (January-June), calendars – including staggering - may sometimes be shorter, while in other instances they may start before January or end later than June. We will first compare the total cropping areas by *section* (based on RID reports, by Projects) and the amount of water

[45] These figures result from the aggregation of all the values of rainfall in the Thiessen polygons included in all the blocks. Therefore, the second line is not deduced from the first one by using the formula given in annexe (although results are of course quite similar).

[46] This occurred, for example, on canal 23 in Roeng Rang Project in the dry season 1999.

supplied (irrigation + effective rainfall) over the January-June period[47], but a correction will then be attempted.

Also unknown is the share of water distributed by the irrigation network which is used for domestic purposes (other than agriculture). Main canals in RID's Projects are seldom totally closed and some water flow allegedly directed to "*upaphok boripkok*" (consumption) is in general maintained. This supply is often also taken advantage of by farmers but, on the other hand, irrigation supplies are also used for diverse other uses. It has been assumed that this domestic consumption use amounted to between 5 and 10% in the upper delta, and 15% in the southern delta (golf courts, etc)[48]. This is consistent with the values considered by RID; details by section can be found in Annexe 8.

Water balances are also biased by unrecorded water abstraction along the river network. For example, some pumps operate along the Noi River in Borommathad Project (extracting a volume which is attributed, in the calculation, to Chanasutr Project). In normal times such pumping is limited, because of the high pumping head, but pumps numbered up to 213 units in the dry-season 1997 for the sole Borommathad Project.

With these reservations, the average values of water consumption per rai, in the *upper delta and in the whole delta* are shown in Figure 31 (upper part)[49]. We can observe that in the upper delta (the year 1999 excluded), the average of irrigation water use and rainfall contribution are 1530 m^3/rai and 222 m3/rai (total: 1752 m3/rai) and that there is a declining trend over the years (Table 7). The values for the whole delta appear much lower, with a total of only 1160 m3/rai. The overall decline can be explained by several factors:

- An increased use of shallow tube-wells, significant since the early 90's when their number have dramatically increased (see more on this in § 8.1). To the extent that part of this underground water is the result of a loss of superficial water by percolation, this contributes to raising the overall efficiency of water use, as seen earlier.
- An increased water use efficiency at the plot level, fostered by the growing pressure on the water resource and by the growing use of individual pumping at the plot level (which strongly encourages water savings).
- The gradual closing of the drains (construction of control structures in order to retain water in the dry-season).
- A trend towards shifting cropping calendars either earlier or later in the rainy season. This very significantly decreases water use for land preparation, as advantage is taken of the residual soil moisture at the end of the rainy season in the first case (see more on that in

[47] Effective rainfall, however, is corrected for each section, based on the average calendar.

[48] Only a small part of this water is used for domestic consumption, animals, etc. However this requirement correspond to the necessity to ensure intermittent flows in the areas which are 'out of turn' but still need water for animal farms, factories (e.g. sugar mill), cities, etc. These low flows proportionally incur in high loss by infiltration.

[49] the year 1980, where deliveries were at their lowest, was discarded because of distorted values.

§ 9), and on rainfall in the second case. It also shifts an increasing part of the crop cycle out of the January-June period and consequently underestimates the water effectively used by this crop.

- A growing use of shorter duration rice varieties, especially in triple cropping areas, which demand less water.
- The impact of the change from transplanting to direct seeding is controversial. The latter technique requires the drainage of the plot and increases the numbers of irrigation days, thus giving way to more water loss, but, on the other hand, it avoids the loss caused by the early water supply needed for nurseries and reduces the infiltration loss in the plot during the first few days.

TABLE 7: AVERAGE* WATER CONSUMPTION PER RAI OF RICE EQUIVALENT (M3/RAI) (YEAR 1999 EXCLUDED)

	Irrigation	Rainfall	Total
No correction			
Upper delta	1,530	222	1,752
Whole delta	977	183	1,160
With correction of calendars			
Upper delta	1,576	230	1,807
Whole delta	1,092	210	1,302
With overall correction of water supply			
Whole delta	1,288	210	1,498

The anomaly observed for the year 1999 is mostly due to the fact that most farmers, knowing about planned water restrictions, still wanted to benefit from high rice prices and started their dry-season crop very early, in the October-December period. This strongly distorted the water balance. Interestingly, it also gives support to the necessity to reassess water scheduling in the delta, incorporating consideration of water saving (see discussion in chapter 9). The anomaly also reflects the fact that triple cropping has been taken into consideration, notably in the West Bank where this almost doubled the recorded area…[50]

These values should therefore be incremented to account for the area partly cropped out of the January-June reference period and for the use of underground water. This corrections cannot easily be made because 1) calendars have been evolving over the last 20 years; 2) this evolution has been different for each Project; and 3) there is a year-to-year fluctuation in calendars according to hydrology and water stocks. The second row of Figure 31, however, attempts to introduce a correction to account for these differences in calendars. The West Bank cropping area, for example, has been decreased by 12.5% because roughly half of the

[50] This also reflects the total confusion in the conventional categories of wet and dry season brought about by hectic calendars. For example in the West bank, the pre-monsoon cropping (May-August) used to be considered as 'naa-pee' (despite the fact that the official limit is the 1st of June), whereas the post monsoon second crop (November-February) was considered as 'na-prang'. As light shift in calendars, and a surge in triple cropping, scrambled these earlier categories and two crops were computed as dry-season crops in 1999 and 2000.

pre-monsoon dry-season cropping falls outside our reference period[51]. To take into account the shift of calendars which occurred in the 1990s, we have considered one coefficient for the 1977-89 period and a second one for 1900-2000. With such corrections[52] (see coefficients by Project in Annexe 8), we get water duties rounded up at 1,300 m3/rai for the whole delta, including 210 m3/rai from rainfall. For the upper delta, corresponding values are significantly higher (1,800 m3/rai for the total water consumption).

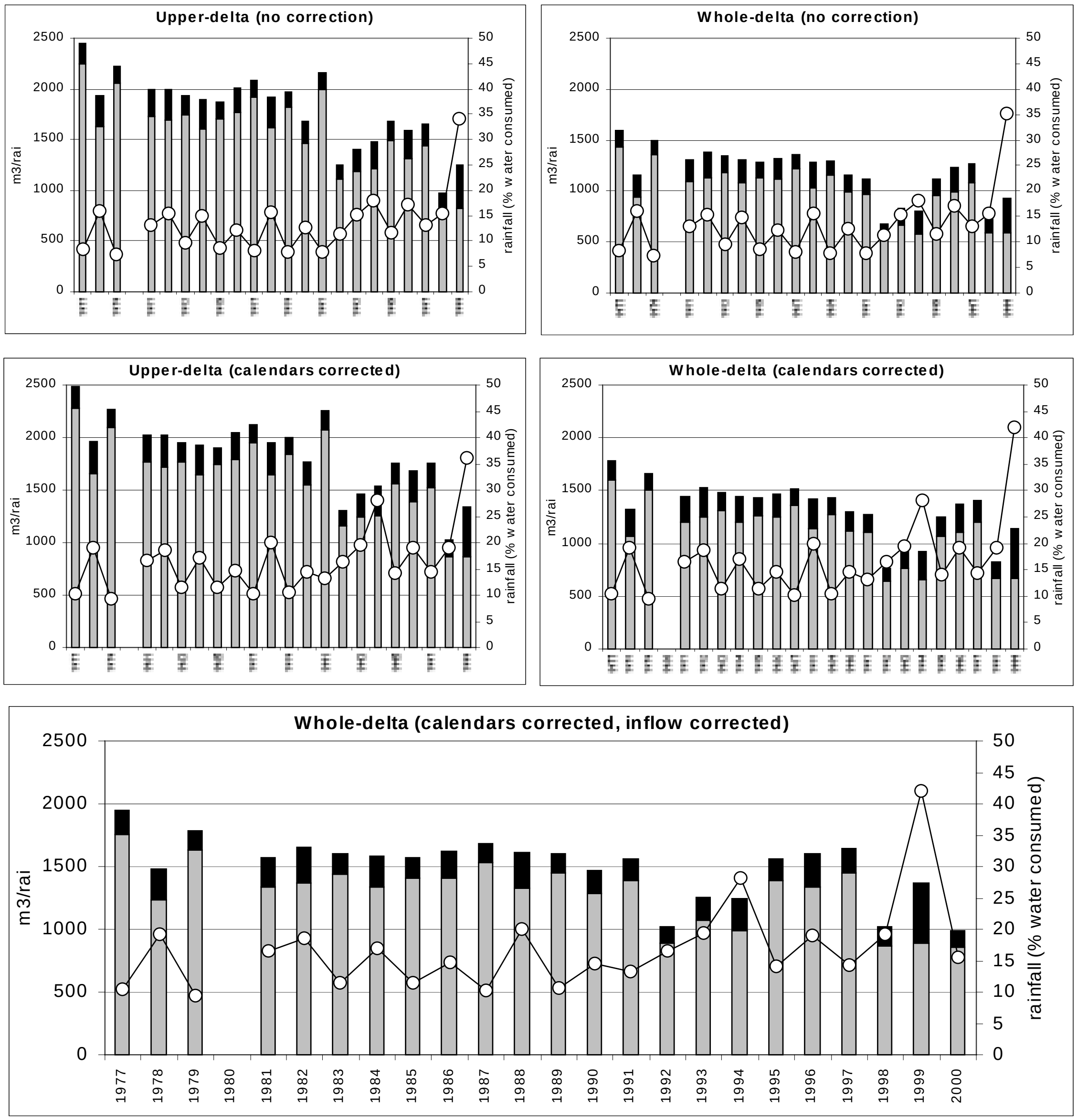
The difference between the upper delta and the whole delta is that the latter includes the lower delta which has both a much higher efficiency (all return flow is to the canals; seepage is minimal) and a greater part of the inflows non considered in the balance. These inflows include the contribution of the Mae Klong basin to the West Bank and that of tube wells in the upper delta (see § 1.3). In order to take into consideration this additional supply to the delta we have estimated the change in the contribution of tube-wells, Mae Klong basin, the buffer area and the Chao Phraya River over the last 20 years (see Annexe 8). With this more accurate estimate of water supply we get, for the whole delta, a *total water duty per rai rounded up at 1,500 m3, with 210 m3 from rainfall and 1,290 m3 of irrigation water*.

A similar analysis can also be made section-wise. We may also attempt to introduce some correction regarding the part of the crop cycle which lies out of our January-June period and which is unaccounted for in terms of water use. An approximate coefficient has been applied to those sections concerned by this problem, most especially the East and West Bank. Figure 32 provides the total average water use by section (including rainfall), for both corrected (dark) and uncorrected values (light fill), and shows dramatic discrepancies. The reading of the figure, however, requires some caution: the East and West Banks fare best partly because of better efficiency, partly because inflows from adjacent rivers are not recorded.

[51] 50% of the rice area planted before the 1st of January (November or December) does not imply a correction of the area by the same amount because only part of the cycle (and of water requirements) will be outside the reference DS period. The maximum reduction will be one half of 50% (two months out of four non computed, with demand supposed constant along the cycle for the sake of simplification). If the rate of planting is uniform during the two months the reduction will be only 12.5% approximately (25%*1.5/4 + 25%*0.5/4).

[52] Corrections of cropping areas and water supply have been made by year and by Project and aggregated at the Upper Delta and Delta levels.

FIGURE 31: AVERAGE WATER CONSUMPTION PER RAI IN THE DRY SEASON (1977-99; VARIOUS HYPOTHESISES)



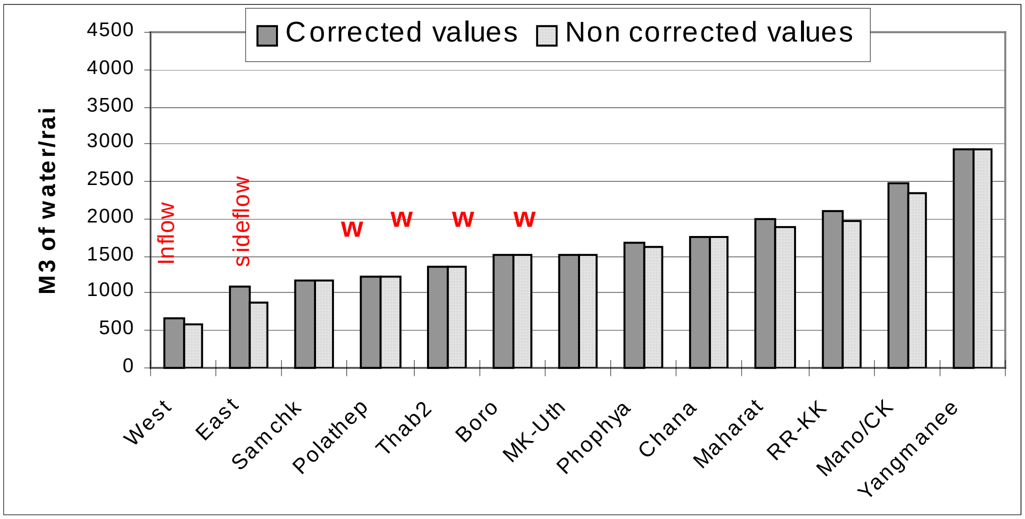
Samchok is credited with an average of 1,173 m^3/rai. This is due both to land consolidation and to the fact that sideflows sometimes accrue to the irrigation supply[53]. Among the sections with lower water consumption per rai, we find areas with a high density of tube-wells (W), better on-farm conditions and head-end location. On the opposite, the three sections which fare worst are those with very long dimensions (Maharat), thus higher conveyance loss, and which start dry-season cropping very late (Yangmanee, Man/CK, RR-KK tracts): not only is the soil dry, requiring a full 300 mm amount of water for land preparation, but the effective

53 It could be possible to consider only the total of water supplied to the main canal, rather that computing the difference between Samchok and Thabote regulators on the Tha Chin River. These data are not readily available and this heavy work (over 22 years) has not been achieved.

dry-season period is reduced. Therefore, the amount of water considered in the balance (January-June) is overrated[54].

These data should also be corrected to take into account other sources of water supply (wells, Mae Klong) but this not easy to achieve at the Project level. More generally, there might be some conservative bias from the fact that triple cropping and cropping on the margins of the delta have been largely unaccounted for.

FIGURE 32: AVERAGE WATER CONSUMPTION IN EACH SECTION (PERIOD 1977-1998, 1980 EXCLUDED)



There are several conclusions that can be drawn from this analysis:

It now clearly appears why the ratio of the total cropping area to the total water supply is both so low and fluctuating from one year to the other, as shown in Figure 33 which presents both the ratio for the basin (dam supplies/total cropping area in rice-equivalent) and that relative to the delta (water diverted at Chai Nat/cropping area)[55].

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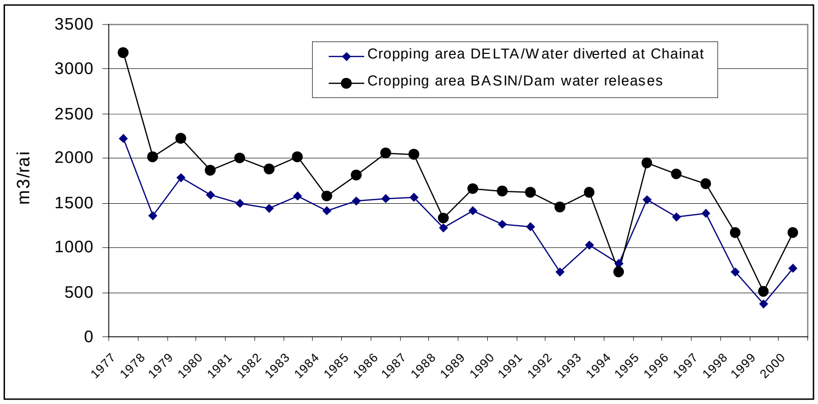
[54] In the Roeng Rang Project, earlier deliveries are directed to a limited production of taro and probably incurs in rather high relative water loss.

[55] Caution is required as these ratio do not represent the average amount of water consumed by one rai. The numerator does not include all water supplies and the denominator must be corrected according to cropping calendars.

FIGURE 33: RATIO CROPPING AREA/ GROSS WATER SUPPLY FROM DAMS



These fluctuations are due to the:

- Shift in calendars, with a variable portion of them falling outside the reference period (either before of after the January-June period);
- Growing use of secondary water resources;
- Difficulties in defining what crops should be considered as dry-season crops;
- The growth of triple cropping, the increased use of short cycle varieties;
- Unrecorded areas (such as those developing on the margins of the irrigated delta or in the middle basin) or unknown non-agricultural water use (golf courses, etc);
- Fluctuating contribution of rainfall.

However, even taking these factors into consideration it is hard to fully account for the variations observed in the latest years: while the extremely low ratio *[water diverted at Chai Nat Dam/cropping area]* of the year 1999 (367 m3/rai) is mainly attributable to a very early crop establishment (and a late one in April-May) and to the record of triple cropping, it is not clear why the 1998 value (732) is only half of the 1997 value (1,391). Part of the explanation lies in the record of one million rai of triple cropping in 1998 (no record in 1997) but this does not fully account for the difference. *We touch here the limit of a quantitative analysis based on the available data*.

It also appears that the conventional method for recording cropping areas is no longer adapted to a situation of complex and hectic cropping calendars, including a significant portion of triple cropping. Crop progress should be recorded in a computerised manner, so that relevant aggregations by Project, main canal or at the delta level could be easily available for the sake of monitoring. Records by zone could be centralised and transformed in a map by using a GIS generated 'visual dashboard' similar to that proposed by Molle et al. (1999) for the monitoring of the flood-prone area.

Considering these different results, we may consider as a good historical value the estimated average consumption of water per rai of 1,500 m3, or 9,200 m3/ha, from which 210 m3 (14%) are provided by rainfall, although it conceals a significant spatial variability and a slight temporal decline. Because of shifted calendars, shorter cycle rice varieties and better management, the actual water duty is probably slightly lower that the above value. This average value also conceals a difference between the upper and the lower delta, as the latter displays a higher efficiency and therefore a lower water duty.

These corrected values are believed to be reasonably close to the real values, despite the several types of difficulties which have been encountered[56]. If we now consider an average crop requirement of 980 m3/rai (see § 9.3), we obtain an efficiency of 60% (980-210/1498-210). This estimated efficiency appears to be at the level of best gravity irrigation standards (in the dry season) and should not suggest that the remaining 39% correspond to waste water. We have seen in § 1.3 that with the exception of the water lost by evaporation in the waterways most of the return flow is passed to the aquifers or benefit perennial crops. We did not compute here the (non-process) beneficial use of almost 160,000 ha of home gardens, which rely on seepage water from the different waterways and on the water stocks of the shallow aquifer.

[56] The last three year values may appear unrealistically low, which can mainly be attributed to accentuated calendars shifts and to the recording of triple cropping. We have nevertheless considered them in the average because the earlier values are probably, on the other hand, slightly overrated (due to the non computing of triple cropping, and of marginal new areas outside the delta).

4 Spreading over time and space: dry-season cropping calendars

4.1 The deregulation of cropping calendars

Until the end of the 80s, most of the dry-season rice cropping and corresponding water supply were scheduled from February onward. Only the Chachoengsao Province on the East and the West Bank had different calendars (Kasetsart University and ORSTOM 1996): the former would start dry-season cropping as early as late October, in order to complete it before February, when water gets salty in the Bang Pakong river. The later would attune its calendar to the flood duration and perform one crop before and/or[57] another one after. In a year of average flood, that is when little water is stored in the West Bank, which acts as a buffer, the area with earlier crop establishment (late October) is located in the middle-east of the West Bank (both higher land and better poldered area). As the water recedes, rice is established, with the lower/later parts being located along the Tha Chin River and in the north of Chao Chet Project (Figure 34).

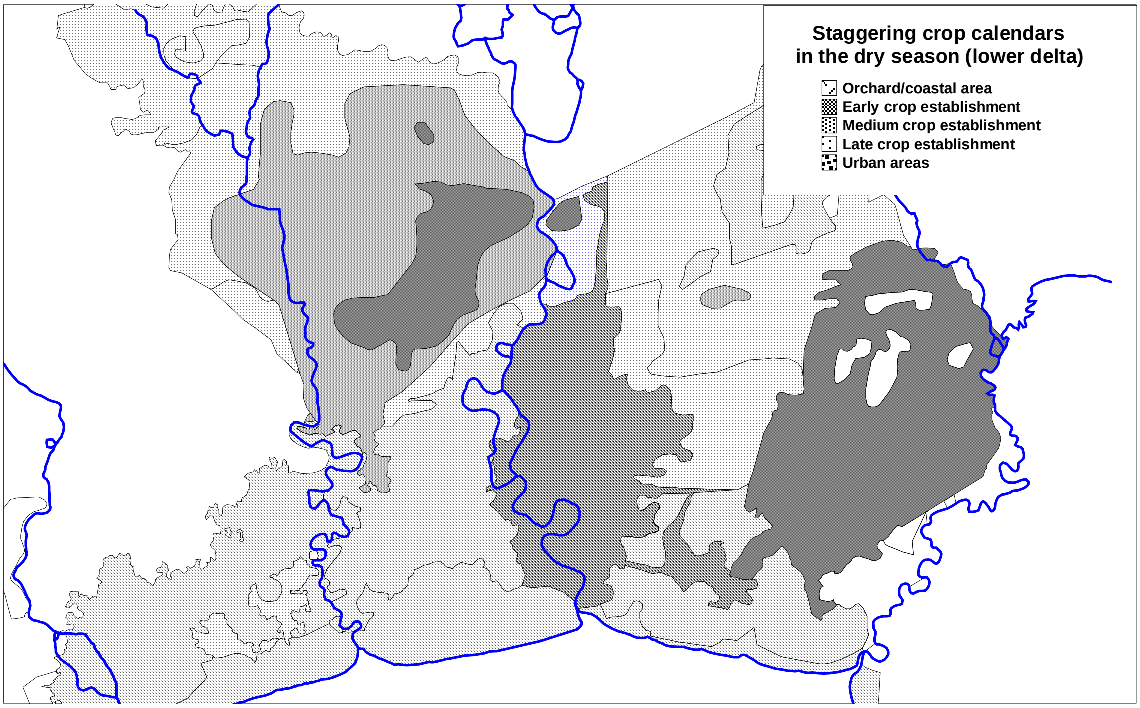
This pattern is altered in years of high flood and the areas which start in late October may be forced to postpone their crop until December (this, however, is of little importance, as farmers will still have time to grow two crops). The issue is just one of adapting to the flood pattern. This situation is also gradually altered by the growing diking activity in the West Bank. Farmers tend to increase plot protection and to overcome the flood constraint, allowing an earlier crop establishment. This flexible pattern corresponds to a remarkable adaptation to the hydrologic regime and allow the West Bank to keep on performing its role of buffer area in case of flood.

The last decade has witnessed a gradual and complete deregulation of the theoretical scheduling. This trend has been particularly obvious in the west of the upper delta (Don Chedi, Samchok, Phophya[58]). It has been fostered by the uncertainty as to whether (late) deliveries would eventually come and/or be sufficient for a crop of rice. Rather than waiting until late into the dry season, many chose to start their dry-season crop in continuation of the wet-season one (and in that followed the path of the West Bank). Such a shift soon proved much advantageous. Farmers would capitalise on the residual field wetness to cut the drastic peak need of water at land preparation time (between 250 and 300 mm in dry soils conditions). They would also not only benefit from rather abundant water remaining in the waterways until the end of December but also force RID to maintain some supply to sustain their crops during the period in which it should theoretically be suspended.

[57] Some parts of the West Bank have long been growing only one wet-season or dry-season crop ; the generalisation of double (or triple) cropping is recent and has been allowed by the use of pumping stations along the Tha Chin River.

[58] The southern tip of the Project (along Song Phinong river) follows a calendar close to the West Bank. Early supplies channelled through the main canals may have allowed upstream farmers to benefit from this water and shift calendars.

FIGURE 34: COMMON STAGGERING OF CROPPING-CALENDARS IN THE LOWER DELTA



While this shift could have prompted a smooth and acknowledged adjustment of the water schedule, a difficulty arose because of year-to-year variations in real cropping calendars and in the factors that determine them. A first factor is that farmers' interest for dry-season cropping is dependant on the price of rice. In depressed years, some farmers who, for example, must use tube wells or pump water in two stages (from main canal to lateral, and lateral to plot) may just find such efforts uncompensated for and a second crop unworthy.

A second factor is that the lower delta (plus areas located along Tha Chin and Song Phinong rivers) will engage in dry-season cropping when water recedes from the fields at the end of the rainy season. In years of significant flood in the West Bank[59], for instance, water may recede very late and the second crop may start only in January. In case of no particular flood, water remains mostly confined in the canals and the second crop can start as early as October in some parts, as shown in Figure 34.

A third reason is that earlier or later cropping calendars, most particularly in the upper delta, may also sometimes impact on the following wet-season rice calendar. This was very clear in the last few years, where triple cropping and the strong will of farmers to grow a second crop (sometimes as late as June if they are at the end of the distribution network) have scrambled

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[59] The West Bank acts as a buffer and receives excess water in case of flood conditions in the Chao Phraya River.

traditional calendars. Some late farmers found themselves in the impossibility to grow a wet season crop (Molle *et al.* 1999)[60].

The use of shallow wells (at least for one part of the cycle), has also contributed to deregulating calendars. Farmers with very high cropping intensity acknowledge that they don't even refer any more to conventional seasons (*na-pii, na-prang*). Mention is made of *na-pleng* (the third crop) but others admit that they just don't know what growing-season they follow.

This gain in flexibility has undoubtedly been one of the main factor responsible for the records of cropping-areas observed in the last few dry-seasons. Nevertheless, it has also blurred all the landmarks used hitherto for allocating water in the dry-season. This calls for the necessity to first recognise these changes, then to incorporate them into the definition of a more flexible and rational allocation process. Section 9 will discuss this issue.

4.2 Detailed analysis of the 1997-98 dry season

In order to get a clearer picture of how dry-season cropping spatially evolves over the November-June period, the year 1997-98 has been studied in detail. This recent year had the largest cropping area ever and an exceptional series of TM satellite images with few clouds was found to be available.

4.2.1 Data used

A rather great amount of data was used in the study. These include:

12 satellite images *Thematic Mapper* (see details in Annexe 11). A few quick-looks from Spot images were also used. Older images of former dry-seasons have also been used for purposes of comparison.

GIS layers of the delta

Rainfall data: monthly totals of 330 stations (RID and Department of Meteorology).

Hydraulic data: *monthly* total inflows recorded at 32 main regulators in the delta. Daily water levels in 14 regulators. Daily dam releases. Use of mobile pumps during the season (RID);

Agricultural data: cropping area, by week (24) and by Project (25), as recorded by RID officers;

[60] Particularly those planting deep-water rice in flood-prone areas.

4.2.2 Methodology

Rice areas appears rather sharply in satellite images. Images have been scanned, geo-referenced and overlaid with GIS layers. Rice areas have been contoured directly on the monitor, with one (map) layer per month. Some areas/periods with poor or missing data have been supplemented with quick-look from Spot images, although the quality of this information is generally very poor. Areas were divided into two categories: the first one is made of sharp colour areas which are considered to be planted with rice on 80% of their gross areas. Other less densely cropped areas have also been contoured and were attributed a ratio of 40% of rice. For some sections for which only poor or no images were available for a given month, the rice area was drawn approximately interpolating from earlier and later images.

RID weekly data on crop progress and satellite data have been homogenised to correspond to the middle of each month: the daily rate of area growth during a given month was used to correct these areas (depending on the date relative to each data).

Rainfall stations maps have been used to create Thiessen polygons and allocate monthly rainfall values to each polygons. These polygons have been split by the *section* layer and their rainfall values weighted-averaged to provide the average monthly rainfall values for each *section*.

Hydraulic data have been recombined to compute the monthly water balances of each section.

Note : A conclusion of the attempt made in this study to trace dry-season cropping by use of remote sensing pictures is that such a monitoring is infeasible on a yearly routine. Despite the exceptional series of satellite images for the year considered, many areas, for some months, remained covered with clouds. Thus we could not capture the full spatial expansion of the cropping-area. Even with the use of radar images, it is doubtful that the accuracy would allow to pinpoint rice in very heterogeneous areas. In any case, a cost-effective and practical method allowing proper monitoring still remains to be found. While remote sensing has been successfully employed in areas with more compact calendars and cropping areas, its use in the present situation is made all the more difficult because of the spread of calendars over 8 months and because some areas have a very diversified land-use.

4.2.3 Quantitative growth of the rice cropping area

On the whole, a rather loose fit was found between RID reports and the data derived from the satellite images. While there is concordance of data for the beginning of the season, estimates from the satellite images are lower at the time of maximum expansion (Figure 35). On the contrary, they appear to be higher in the later part of the dry-season when, it seems that RID data do not fully capture the start of late DS cropping/early WS cropping (especially in the lower delta).

There are two main reasons to explain this discrepancy: first, our criteria of 40% applied to non-fully cropped areas may be a bit low. Second, it is possible that RID officers more easily monitor the land preparation of new crops and add it to the area of the former week. When plots start to be harvested, the change in area is not readily recorded. The fact that there is more emphasis on newly planted areas might explain a certain time lag in recording plots which have been already harvested. It must be noted that such a bias, however, does not necessarily translate by the same amount into an erroneous total area cropped: the total area under cultivation at a given point in the season (in February) is overrated but differences in the final total recorded cropping area will be less. According to one Project Head, zonemen also tend to "record to fast", or in other words to overestimate the cropping area, which in some cases appears to be a way to justify a larger water supply and thus to minimise the problems in their area.

Figure 35 shows the evolution of both the rice cropping area and water supply in the whole upper delta. We can see that the cropping area is already significant in December [20 to 50%], mostly in the lower delta, and January [50 to 80%]. Most interestingly, the maximum cropping area at a given point in time is close to 1.15 million rai. This should be compared with the total cropped area during the season: 2.38 million *rai* (in the upper delta, 1998). *This means that the staggering of crop calendars over 7 months has allowed the cultivated area to double*.

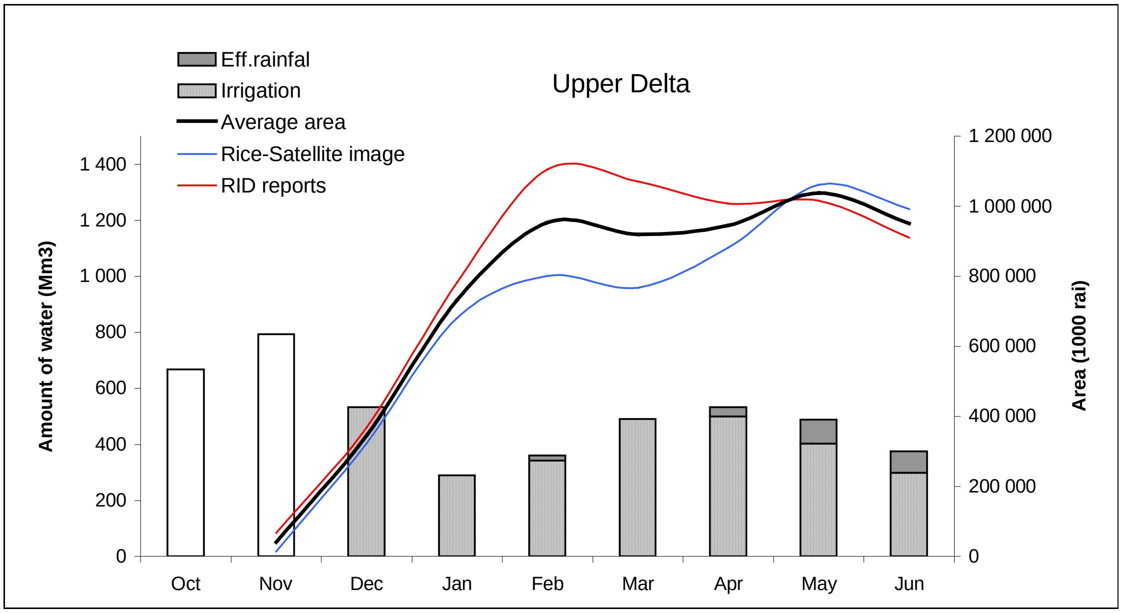
If we compare this evolution with the supply of water (see bars in chart) we find a ratio between 370 and 520 m^3/rai/month. This calculation, however, is biased despite the fact that the rice areas values have been adjusted and homogenised to correspond to the 15th of each month (they are not valid for the whole month as some plots start or end cropping within the month). It is worth noting that the sharp increase in acreage in December corresponds to high water deliveries due to residual run-off of the rainy season. This shows how an early crop establishment capitalises on both field wetness and on the residual excess water in the distribution network: this is tantamount to significant water savings.

4.2.4 Spatial expansion of the rice cropping area

We may now investigate more in detail how the cropping area spreads over space and time. We have seen earlier what is the normal pattern of expansion in the lower delta, with crop establishment spreading from late October to January.

Figure 37 details the crop progress for the 1997-98 season and shows the changes observed every two months. The four successive maps are made to show the spatial spread: plots already planted in December are still represented in June, so that additional areas brought under cultivation every two months are emphasised. In reality, the early crops have been harvested and, sometimes, followed by a second DS crop (triple cropping). As there is a continuum in space and time, it is not possible to separate late first crops from early second crops. Triple cropping cannot be easily mapped but statistics show which Projects had a higher proportion of it (see Annexe 12).

FIGURE 35: EVOLUTION OF RICE AREA AND WATER SUPPLY IN THE UPPER DELTA AND THE WHOLE DELTA



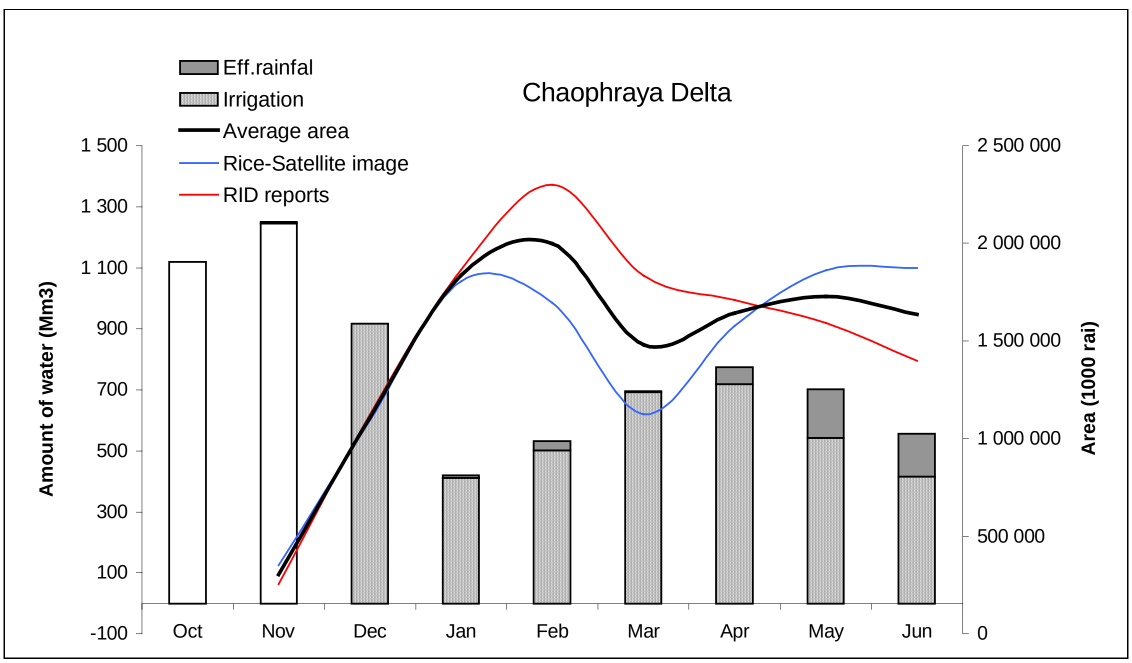
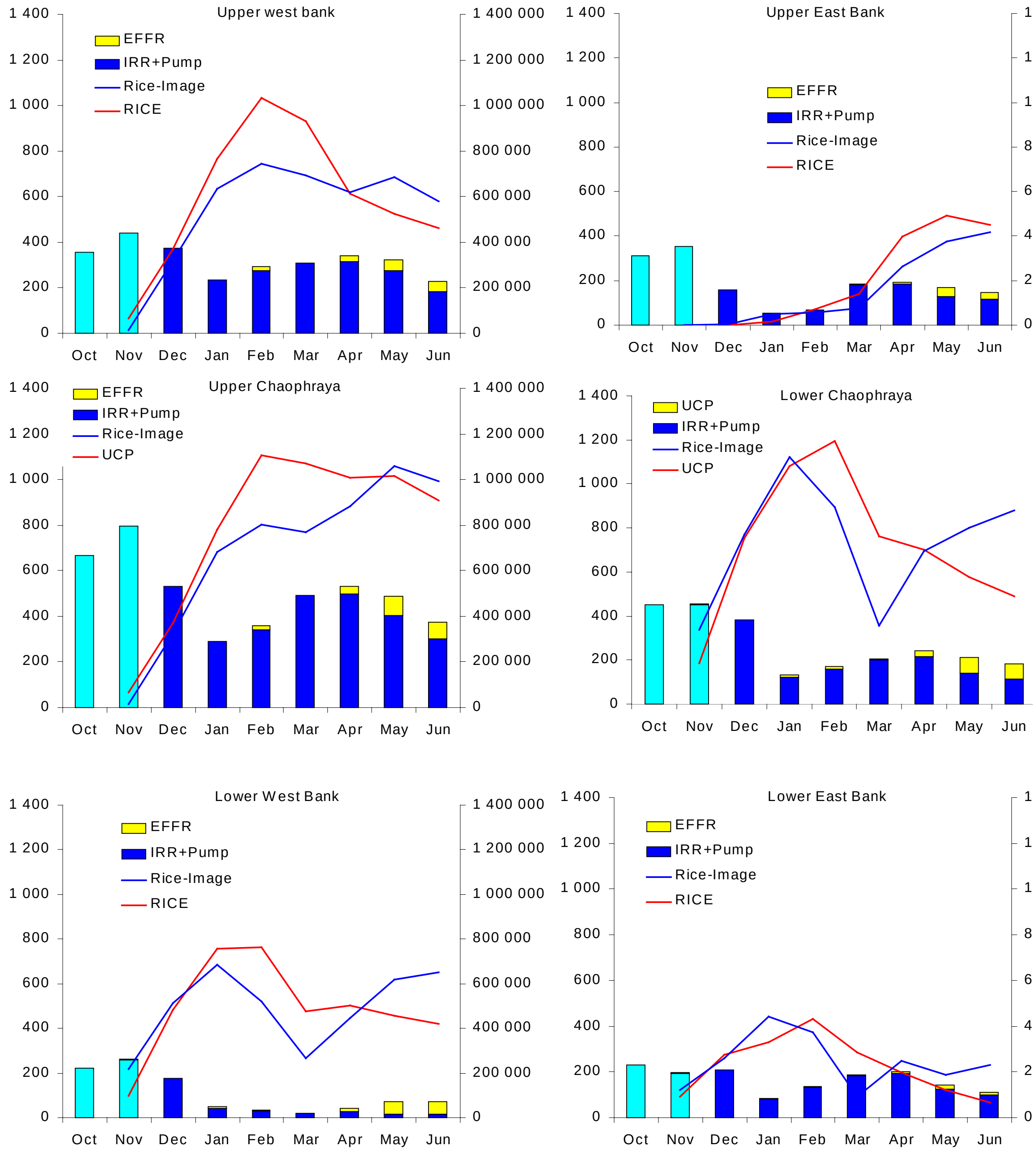


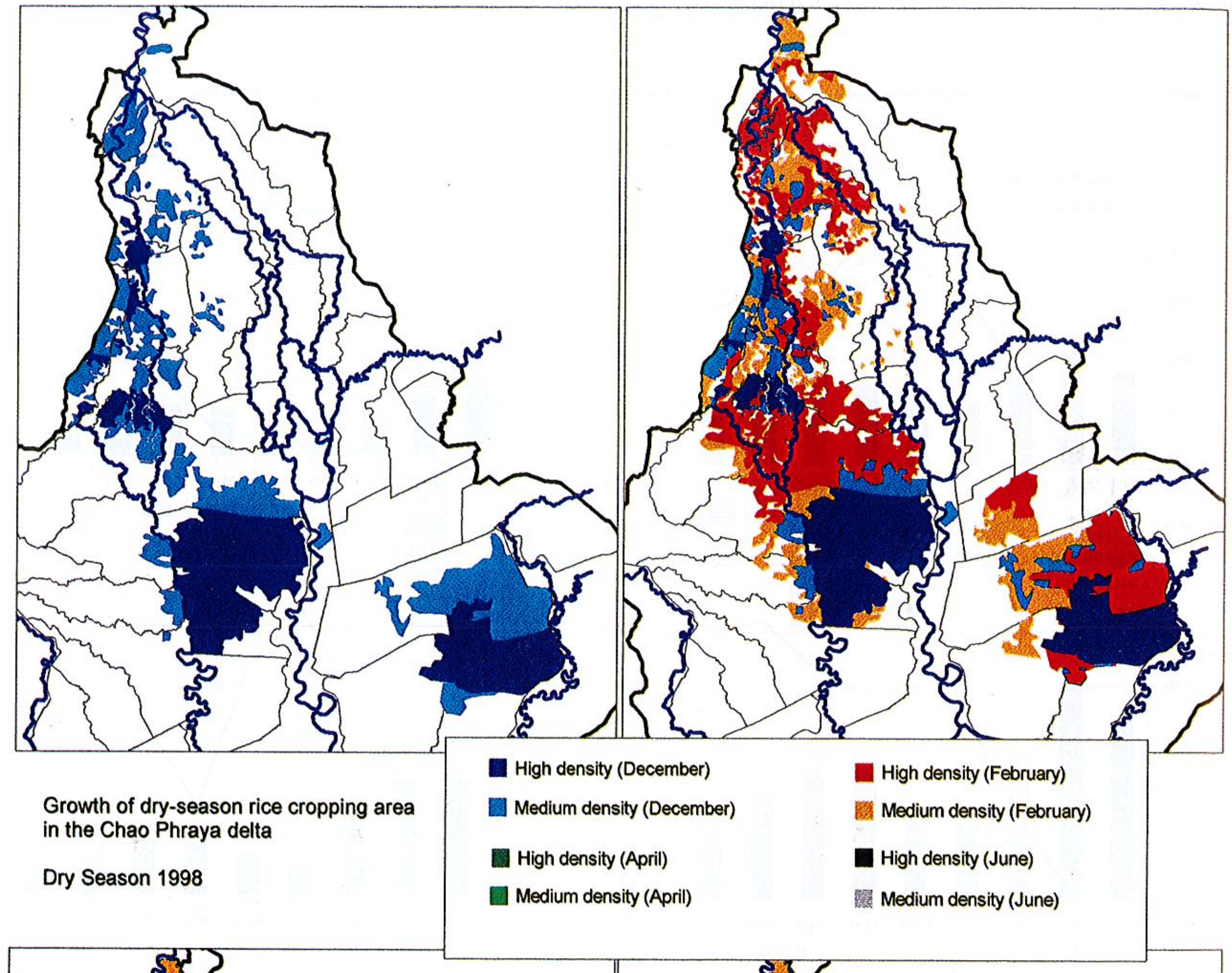
Figure 36 show similar data for all sections.

FIGURE 36: EVOLUTION OF RICE AREA (RID DATA AND ESTIMATE THROUGH REMOTE SENSING)



What is apparent from the series of snapshots presented in the figure, is that a significant area is already planted in December. This is achieved thanks to early supplies and to the use of tube wells, notably in the Tha Bote Project. Secondly, it shows striking evidence of a sustained growth on the western part of the upper delta, while land preparation in most of the eastern side is delayed as late as April !

FIGURE 37: EXPANSION OF DRY-SEASON CROPPING (1997-98)



A third conclusion is that the great majority of the delta has been able to grow a second crop (and even a third one, which is not shown in the figure): apart from the area of Samchok where sugar cane is grown, only the eastern fringe displays a rather poor final result. This unequal pattern is confirmed by statistics and by a figure in Annexe 13 which shows the expansion of dry-season cropping in the year 1994-95 and evidences a similar pattern.

This is further evidenced by Figure 38 which shows that only 23% of the upper delta (or 28% of the agricultural area) has not grown a dry-season crop (WS rice mono-cropping). More than half of the upper delta (53%), or 70% of the rice growing area, has grown 2 or 3 crops.

FIGURE 38: LAND USE IN THE UPPER DELTA, DRY-SEASON 1997-98, IN % OF GROSS AREA

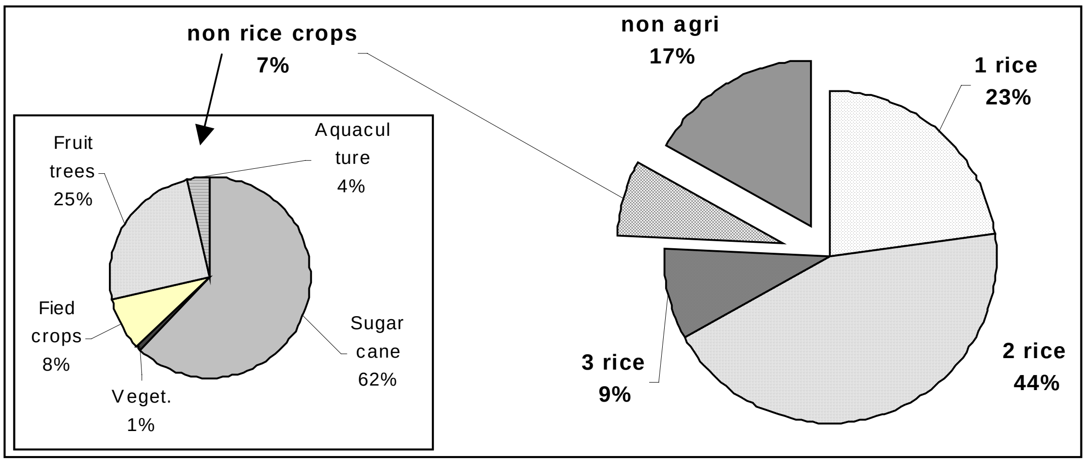


TABLE 8: LAND USE IN THE UPPER-DELTA, DRY-SEASON 1997-98 (IN RAI)

Gross area	**4,135,000**	Sugar cane	185,695
Rice 1	936,390	Vegetables	3,025
Rice 2	1,835,940	Fied crops	24,537
Rice 3	359,058	Fruit trees	75,127
Non agricultural	704,537	Aquaculture	10,691

An important consequence of these figures is that the area cropped with traditional rice varieties in the wet season (flood prone area) is increasingly fit for accommodating HYV in the dry-season. This gradual expansion of adequate on-farm conditions was mentioned earlier as one of the factors which accounted for the growth of water demand in the dry-season.

It is instructive to understand the changes which have occurred in this area and also why it was initially disregarded by planners and managers regarding water allocation in the dry-season. Reasons for this included:

- the lack of on-farm infrastructure (floating rice on uneven natural land);

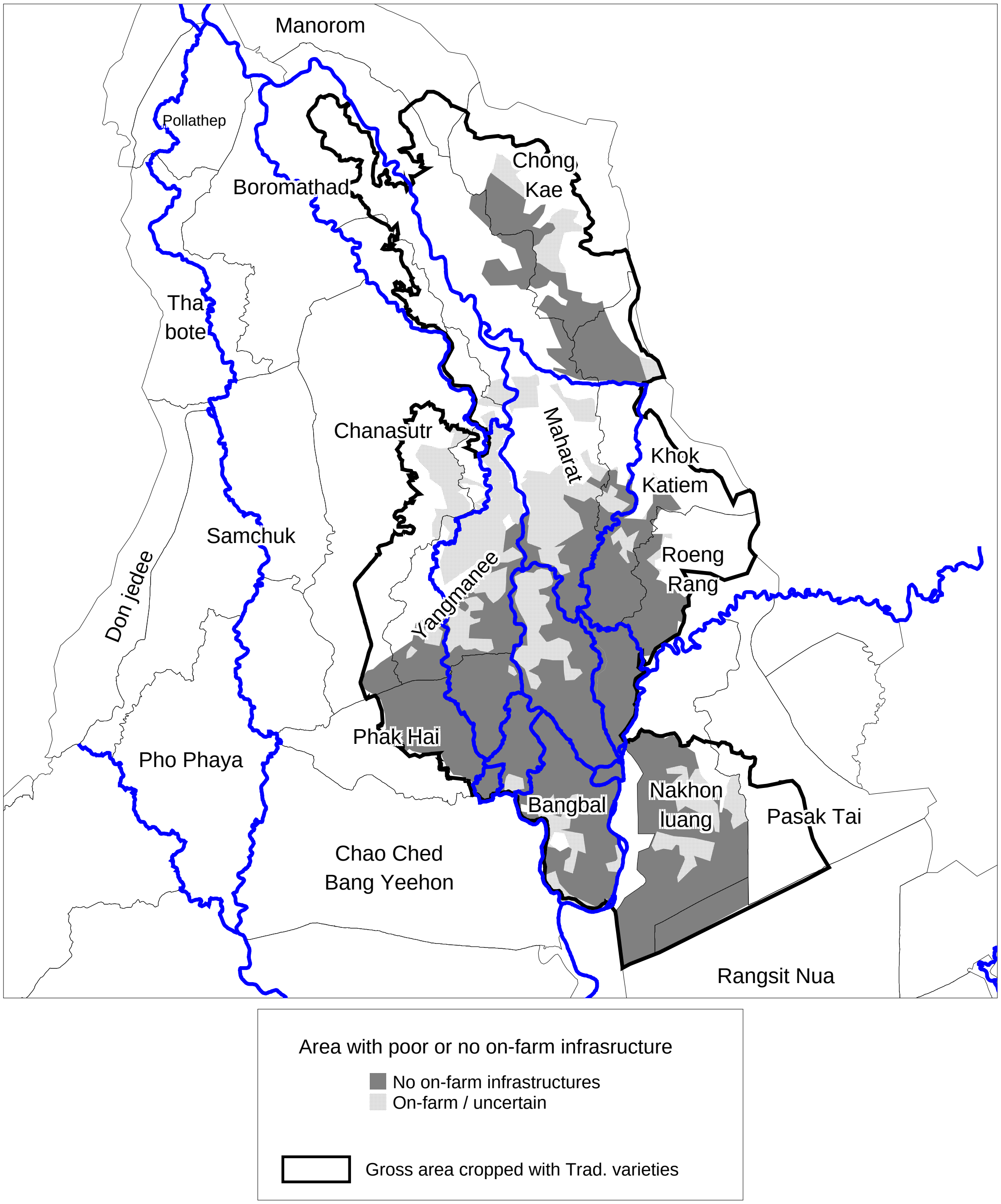
- the conflicting calendars between (dry-seeded) floating rice and dry-season crops and the lack of farm equipment in the flood-prone areas to grow transplanted rice (land preparation);
- the fact that most of these areas are located at the tail end of main canals;
- the will to favour areas were land consolidation had been recently implemented (on grounds of higher productive potential and because a financial contribution was requested from farmers);
- the overall insufficient water resources, which commanded that allocative choices be made.

We can see that some of the constraints existing in the early seventies have changed over time. Transplanting has given way to wet direct-seeding which is much more flexible in terms of calendars (Molle and Chompadist, 2000); deep-water/floating rice can be established quite late by this method. Many of the areas which grow TVs in the wet-season have gradually developed ditches and have improved their plots to grow a dry-season crop. In the 1997-98 period, for example, many farmers of these areas received water for the first time and improved their land to grow their first dry-season crop, showing a spectacular responsiveness to water allocation and rice prices. Figure 39 shows that a significant part of the actual flood-prone area is already in a position to grow HYVs. It must be noted that this flood-prone area is itself a 'shrunk' version of the flood-prone area of the early seventies; for example, half of the Phak Hai Project has shifted to growing HYVs out-of the flood period.

Therefore it should be reconsidered why the flood-prone area – at least its margin provided with on-farm development – is receiving little water. While this can be justified in terms of efficiency, it runs against considerations of fairness. As this area is already made precarious because of the lower profitability of flood-prone rice, it could be argued that, in compensation, it should be given some priority in the dry-season. Even if one is not willing to go that far, this argument is a strong point in favour of a “rebalancing” of water allocation in a more equitable way.

The different historical constraints to the expansion of dry-season cropping are summarised in the following table, which indicates if and how they have been bypassed.

FIGURE 39: APPROXIMATE RESIDUAL AREA WITH NO OR POOR ON-FARM INFRASTRUCTURES



Note: The area in white within the flood-prone area is considered to be provided with on-farm facilities because dry-season cropping was observed in 1998. Areas in grey had only 40-50% of dry-season rice and it cannot be ascertained that all plots have been transformed to accommodate HYVs.

Arguments and constraints to the spread of dry-season cropping

a) The irrigation facilities of the Chao Phraya Delta have been designed to supplement crops with water during dry spells of the rainy season. Therefore the capacity of the canals was calculated to provide a discharge of .81 l/s per ha. This discharge is not sufficient to cover the total water requirements of rice in the dry season.

b) The capacity of the two storage dams (Bhumipol and Sirikit) is not sufficient to allow, at least every year, the delivery of water to the whole area, especially if energy generation and other uses are taken into account.

c) A significant portion of the delta, approximately 300,000 ha, is deprived of on-farm infrastructure and plots are unfit for HYVs: in clear, there is no ditch to bring water to (distant) fields, and the plots are unbunded and uneven, making it impossible to carry out transplanting in good conditions.

d) Furthermore, most of these unfit areas are cropped with floating rice with very long cycles: this adds one constraint in that it is difficult to accommodate a dry-season crop between the harvest (December to beginning of February) and the period of crop establishment through dry-broadcasting (April to June).

e) Structure of the network: some canals are very long (up to 120 km), and it is not possible to deliver water to their very end without indulging in a huge loss of water.

f) When operating the canals with flows much smaller than full-supply discharge, the water level in the main canals does not reach the level of the sill of some laterals and/or the level of the pipes (Farm-turn-out).

g) Excessive double-cropping is not compatible with the available labour force.

Corresponding evolutions and current issues to partly by-pass the constraint

a) 1/ A few canals have been enlarged. 2/ The expansion of the DS cropping area has mostly been possible because of the lengthening of the allocation period (8 month span) and the use of varieties with shorter duration [see chapter 3 and 9].

b) The inflow into the two dams tends to decrease because of upstream uses. Dam releases are increasingly tapped by other irrigated areas or sectors (Bangkok). Dam management can be improved in order to store more water for the dry-season [chapter 6 and 11]. Supply has also been increased with tube-wells, drain regulators and reservoirs within the irrigated area [chapter 8]. In the future, trans-basin transfers may increase the water stored in the dams [chapter 14].

c) Farmers (and local administrative bodies) have gradually developed farm ditches and drains. They also invested in plot levelling and bunding, even in areas which very seldom grow DS rice [chapter 13]. The area which can receive and use water in the DS has increased a lot.

d) Technical changes have provided different solutions to this problem. Several paths for the intensification of rice cultivation in the flood prone area have been identified (Molle *et al.* 1999).

e) The constraint remains. However pumping units can supply water from the river to these distant areas.

f) Some check gates have been added in the main canals. Above all, farmers have invested in individual pumping devices to cope with the problem.

g) Technical change has allowed the by-passing of the constraint [chapter 13].

5 Planning of water allocation and real management

After the description of the expansion of the cropping area in space and time and of its variability over the years, we now turn to the analysis of the process of water allocation in the Chao Phraya Basin itself.

5.1 The basin scope, its water uses and constraints

The allocation and the distribution of water are subject to several physical constraints. Minimum discharges or water levels need to be ensured in some parts of the network in order to allow a proper hydraulic functioning or (basic) priority needs to be met. These main constraints are reviewed in this section.

5.1.1 Sea water intrusion

The first constraint relates to the necessity to keep water discharges in the river mouth over a certain level, in order to avoid saline intrusions which may damage or destroy crops, in particular orchards. Studies by AIT have shown how the average daily salinity gradient in the lower reach of the Chao Phraya and Mae Klong rivers vary with their discharges.

It is widely accepted that discharges of approximately 50 cms must be maintained in the estuaries. Regarding the Tha Chin River, this discharge (35 cms) is obtained thanks to part of the water coming from the Mae Klong basin through two waterways (Tha San Ban Plaa and Chorakee Samphan drains) and by the water released at Phophya regulator. For the Chao Phraya River, part of the discharge is made up by the returnflow of waste water from the capital (see section 1.3).

5.1.2 Navigation

The Harbour Department considers that discharges at the Chai Nat Dam must be over 80 cms in order to ensure proper navigation in the Chao Phraya River (near Sing Buri). A discharge of 25 cms must similarly be maintained at the Phophaya regulator (near Suphan Buri) for navigation in the lower reach of the Tha Chin River. Other navigation issues also relate to transportation by boat in canals. In some areas, such as the East/south-east of Bangkok, a significant number of people (in particular children going to school) use boat for daily commuting. Constraints on navigation are not absolute, in that extremely serious shortages may lead to the suspension of transportation by boat for a few weeks. This happened in early 1994 and 1999. In normal years, RID Planning for the dry season considers (except in dry years) an amount of 300 Mm3 for the purpose of navigation. This water is allocated in periods in which releases are sufficient for other uses (BMA, salinity control) but not for navigation.

5.1.3 Domestic consumption, ecology

The consumption of water in the BMA has increased at almost 10% a year in the last two decades (see Chapter 1). Most of the water is coming from the Chao Phraya River[61] but underground water use is also paramount, in particular for industries. RID committed itself to ensure a flow of 50 cms in the year 2000 at the entrance of Klong Prapaa, the main feeder of the capital ; me may take this value as Bangkok's requirement for superficial water. This consumption obviously has little elasticity: restrictions were imposed on some areas of the city in 1999 but Bangkok's share cannot be reduced by more than 20% without extreme disruptions.

The amount of water needed for domestic uses in other parts of the delta (and in the middle basin) are not well known. In a normal year, RID allocates amounts of 500 and 600 million m^3 during the six months of the dry-season, for the delta and the middle basin respectively. This corresponds – at least in the planning of allocation - to rather generous discharges of 32 and 38 cms which come under the category of "*upaphok boriphok*", which sometimes serve as a convenient "reserve of flexibility", as we will see later. An unknown share of this water is probably used for agricultural production and it does not eventually appear as a quantitative constraint.

However, populations along the reaches of the lower Ping and Nan River quite heavily rely on these water streams for their daily life. It is known that one or two million m^3/day (say 15 cms) must be released by each of the dams in order to avoid disruptions and complaints by riparian populations.

5.1.4 Perennial crops

Some areas which grow perennial crops or practice aquaculture, have succeeded to acquire some kind of implicit advantage regarding water allocation. Because their activity is comparatively more capital intensive, these farmers succeed in building up some kind of pressure to ensure that they do not remain too long without water supply. Examples of such categories of farmers who have "institutionalised" their water demand include the orchard growers of North Rangsit Project, shrimp farms in the Don Chedi and Samchok Projects, or taro growers in the Roeng Rang Project. Almost continuous supplies, even if not amounting to large amounts, are then taken advantage of by rice farmers who tend to plant rice with little or no interruption, forcing RID to increase discharges.

5.1.5 Pollution dilution

A growing share of water is and will have to be allocated to the control of water quality. These needs are not well quantified at the moment but they are already significant in the lower West Bank[62] and in Bangkok: the metropolitan authorities sometimes have to request

[61] The West Bank (Thonburi) will increasingly rely on water diverted from the Mae Klong basin (quota of 45 cms)

[62] RID officers in Pasi Charoen Project mention that their Project should be termed a "poor water (nam sia) drainage Project", rather than an "irrigation Project".

RID to release water from neighbouring canals (in Rangsit Tai and Khlong Dan Projects) in order to flush out polluted water to the sea. Pollution dilution in the Thawiwathana canal and adjacent streams of the Pasi Charoen Project needs 10 cms inflow from the Tha Chin River (Team *et al.*, 1992). Saline water is being combated with polluted water, with increasing deterioration of ecological conditions in the rivers mouth and lower reaches.

5.1.6 Chai Nat Dam stability

The difference of water levels, upstream and downstream of the Chai Nat Dam, must not exceed 9.5 m by design, 10 meters in practice. For a functioning of the dam in the dry season, with an upstream water level of 16 m MSL, 80 cms must be released in order to ensure a downstream level of 6.00 m in the river. It is not rare to have 5.50 m downstream and, therefore, a limitation of the water level upstream at 15.5 m. 120 cms is necessary to raise the downstream level to 6.50 m, allowing the full supply of canals with a level of 16.5 m.

In other words, if more water is to be diverted at the Chai Nat Dam, more water is to be released to the Chao Phraya River, with potential loss if this exceeds downstream uses.

5.1.7 Khlong Rapiphat stability

Khlong Rapiphat is the main canal bringing water from Rama VI dam, on the Pasak river, down to the East Bank. If the inflow is lower than 40 cms, serious landslides are observed in the canal, resulting in extremely costly maintenance interventions.

5.1.8 Uncontrolled pumping

5.1.8.1 Water use upstream of the delta

One of the main constraints to both planning and management is the growing share of uncontrolled water abstraction in the rivers, between the dams and Chai Nat. Most of the groups of farmers use individual pumps or pump sets implemented and managed by the Department of Energy Development and Promotion. The average discharge of these pumps is 250 l/s. In fact, this water abstraction only partially deserves to be labelled “uncontrolled”, as it has been fostered by an official Department, which participates in the policy-fixing meeting in November. The question of the multiplicity of water use developments, without the co-ordination necessary to ensure their compatibility with the available resource appears here as a major issue (which will be dealt with in a later chapter).

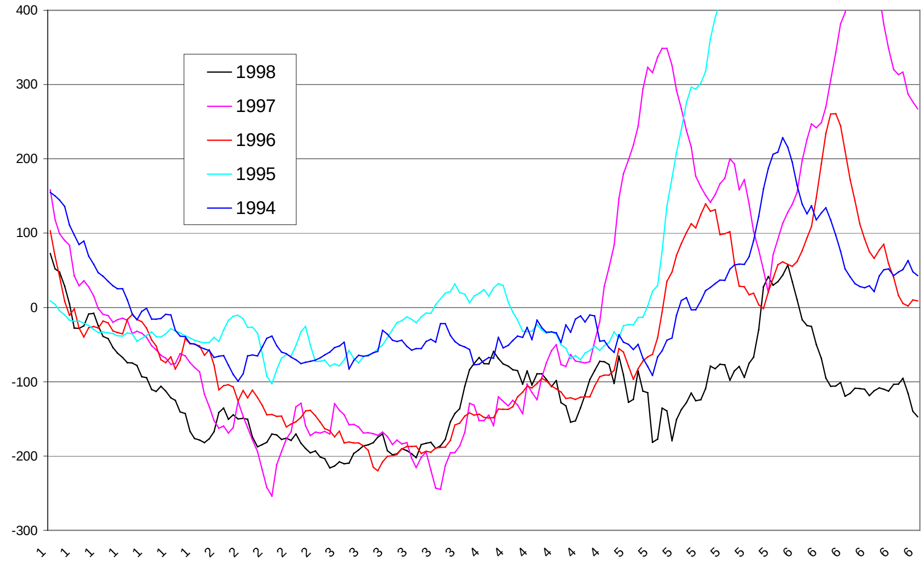
At this stage, we are concerned with the quantitative estimation of how much water is withdrawn from the rivers before they reach Chai Nat, at the apex of the delta. The multiplicity of uncontrolled sideflows does not allow the establishment of accurate water balances. However, we may reduce the margin of error by comparing the two dams releases with the discharge measured at Nakhon Sawan, a few kilometers before Chai Nat, during the driest period: February-March-April. During these three months sideflows are extremely limited. The difference between the two discharges account for 1) RID diversion in several Projects (principally Phitsanulok and 5 Projects on the lower Ping); 2) pumping by groups under the DEDP; 3) individual or collective (uncontrolled) private pumping; 4) the balance of underground and superficial runoff with infiltration in the rivers bed.

All are dubbed here “water loss”, with reference to the delta[63]. Figure 23 showed that while water abstraction in the *middle basin* was only around 5% of the dams releases in the 70’s, it has now increased to, say, 25%, with a peak of 38% in 1998 ! This includes “controlled” uptake by RID in the Phitsanulok Project (since 1982), shown in the figure, and in the Lower Ping area (since 1990) but also accounts for the growth of scattered private and DEDP-run pumping stations. It is noteworthy that while the water shortages of 1991-92 were strongly passed on to the Phitsanulok Project (inflow reduced to almost zero), these independent pumps remained unabated. This points out to a crucial point of lack of control, with particular impact in case of water shortage. It appears that the share of the middle basin in the past years has been much larger than suggested by RID data on cropping areas.

Given the magnitude of the water use unaccounted for by the diversion at the Naresuan Dam, it should be investigated with more details where does water “disappear”. Another view at this partly uncontrolled use of water in the Middle basin is provided by Figure 40. While in 1994 and 1995, the missing term of the water balance was under 100 cms, in the three subsequent years it soared to 200 cms. Officers in Bangkok monitor the curve but are not totally in a position to interpret it quantitatively. Sideflows or underground seepage may partly explain it, while the real amount of water pumped from the rivers is also beyond their direct control. This adds to some obvious under-reporting, in the lower-Ping RID Projects, for example.

[63] This does not mean that the delta should necessarily be favoured. However, if we consider that it infrastructure is the oldest and that irrigation had been planned based on the available water resources, it is also legitimate to reckon that later schemes have in fact been built based on the same water resource and that they depleted the initial share of the delta. This will be questioned on the ground of elementary economic logic.

FIGURE 40: WEEKLY AVERAGED VALUES OF THE MISSING TERM IN THE WATER BALANCE



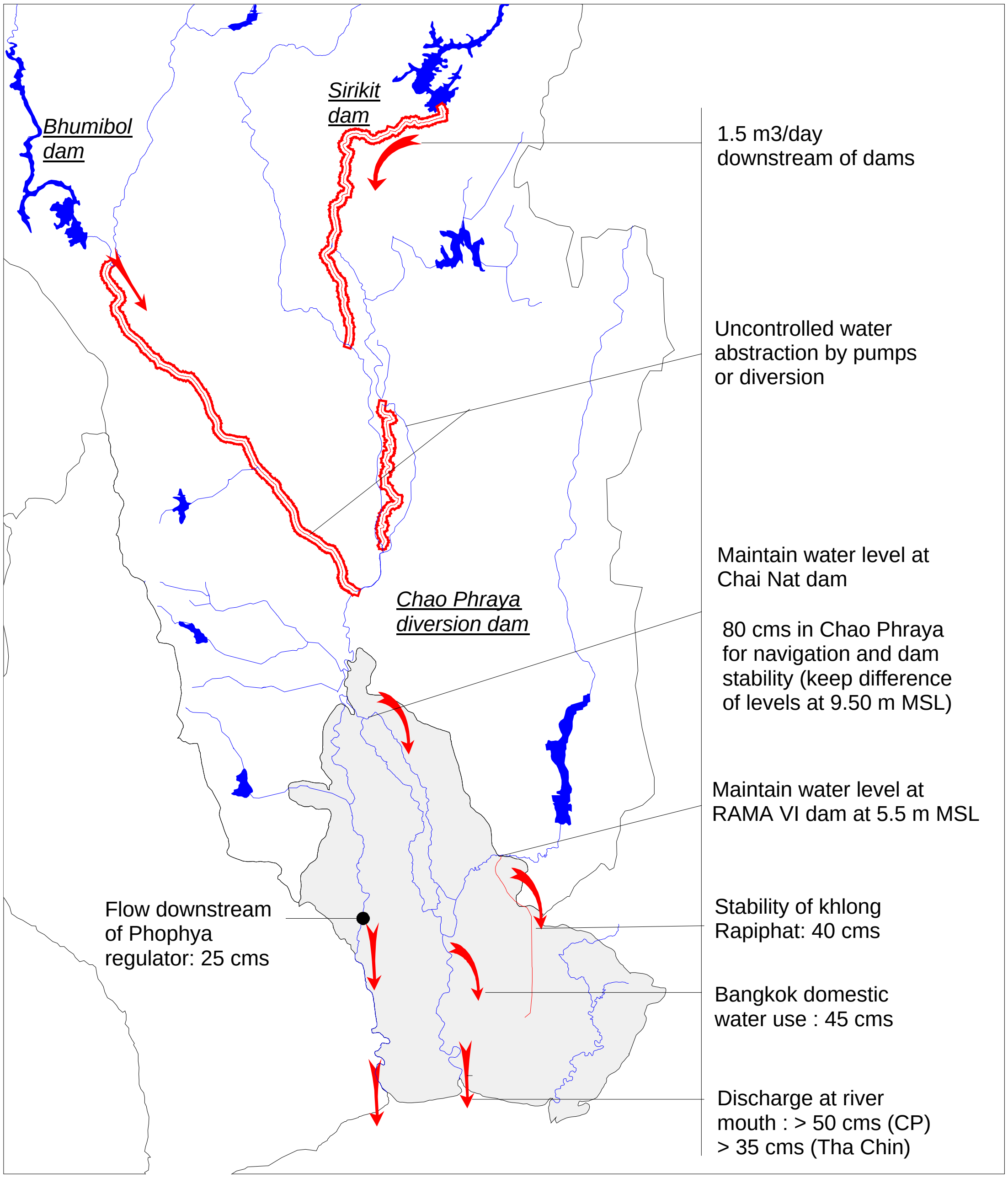
5.1.8.2 Uncontrolled water use in the delta

A similar phenomena of semi-controlled water abstraction is also developing on the margins of the delta proper. Farmers located along the Makham-Uthong and Chai Nat-Pasak canals (the eastern and western boundaries of the delta) tend to increase pumping from these waterways. In the Chong Kaew Project, for example, fruit growers have installed very powerful pumps along Chai Nat-Pasak canal and even sell water to some other farmers ! It must be noted, however, that a major share of these newly irrigated marginal upland areas have also accessed canal water with the technical and financial help of provincial authorities (including RID regional offices). On the Western side, along the Makham-Uthong canal, it is believed that these areas now represent at least 80,000 rai. Large ditches branching from the main canal have been dug as far as several kilometres inland and several pumping units can be observed along the canal (many of them belonging to RID). Although this is another example of infrastructure development based on water resources already allocated, the rationale for such a development is that these farmers suffer from flood (sideflows accumulating along the canal embankment in excess of the drain-through capacity) and must be compensated for with irrigation water in the dry season[64].

All these constraints are summarised on Figure 41.

[64] Such a legitimate claim for a substitution crop may however lead to diverting water to further areas not affected by flood and already gives way to double-cropping.

FIGURE 41: CONSTRAINTS TO WATER ALLOCATION IN THE CHAO PHRAYA BASIN



5.2 Formal pre-season planning

Keeping these various points in mind, we may now turn to the analysis of both the theoretical and effective processes of planning water allocation for the dry-season.

5.2.1 Water basin level

5.2.1.1 Consultation and policy definition

In 1981, the Cabinet appointed the Dry Season Cropping Promotion Committee, chaired by the Ministry of Agriculture, to prepare an annual plan, objectives and promoting measures for dry-season cropping. A sub-committee was appointed to collect relevant data and, each year, to prepare a plan. After acceptation of the plan, users and agencies would know the schedule for dams release and operate accordingly (Binnie, 1997). During the 1991-1994 drought period, it proved impossible to manage the system according to the plan and the committee ended its work. However the sub-committee continues to meet yearly in order to achieve some co-ordination between agencies.

Normally, at the end of the year (November), the sub-committee (or working group), with representatives from the various Ministries involved (MOAC, DOAE, RID, EGAT, DEP, etc.) is convened with the aim to examine the situation for the whole country and to define the national policy for the coming dry-season. Data are presented by several technical offices and a preliminary target is set up for the dry season area cultivation. The policy is mostly based on the projection of the active water storage for the 1st of January presented by EGAT. On its side, RID (regional offices) has consulted the Provincial agricultural services and comes out with a crude pre-repartition of the target cropping-area by Province[65], with areas broken down according to crops (rice, field crops, trees) and water status (irrigated/non irrigated). Some other aspects are discussed and may also be taken into consideration (this year the Office of Agricultural Economics warned that rice prices were declining and that the planting area should be controlled; in 1996 and 1997, supplies were increased to compensate for the flood damage undergone during the preceding wet season, etc.)[66]. The share of water which can be pumped by DEDP pumping stations along the river is also specified.

These recommendations are further endorsed and made official by the Dry Season Committee, of which the minister of the Ministry of Agriculture and Co-operatives (MOAC) is chairman.

5.2.1.2 Step 1: active storage, global target release and areas

The principal figure presented to the meeting is the assessment of the available water for the next dry season, which is carried out in November, at the end of the rainy season, based on the actual status of Bhumipol and Sirikit Dams. A projection of the water stock on the 1st of

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[65] This shows that RID has to conform to a politico-administrative process in which it is accountable to the Provinces for how much water will go (or is supposed to go) to each of them. Despite their irrelevance in issues of water (more consistent with river basins and irrigation Projects) the political boundaries are always considered in planning, showing the weight of the administrative structure in decision making.

[66] The official rule is : the areas which do not grow wet season rice (e.g West Bank) are given first priority; then are considered areas with crop loss over 50% and areas greater than 300 rai. Water is then allocated to those who are "in turn" (assuming a rotation on a two year basis) and, if any amount left, to the areas with fully developed on-farm infrastructures.

January is made and the two dead storage volumes of the dams are deducted from this amount. This Available Volume, or *active storage*, (hereafter called AV) is expressed in Bm^3 and generally varies between 5 and 15 Bm^3, but happened to be as low as 3.6 Bin 1980 and 2 Bm^3 in 1992.

Only a share of AV is planned to be used in the dry-season (January-June). Using the whole of AV would be too risky for two reasons. The first one is that some volume must be carried over in order to ensure year-to-year regulation in the dams. The second reason is that it would also be too risky, for the considered year, to base the supply needed for the following rainy season only on the run-off to come. In fact, water requirements are quite high in the July-Aug-September period and can, for most years, hardly be met with natural run-off: this calls for the necessity of keeping a reasonable amount of water in the dam (above dead storage) at the end of the dry season. There is, however, no definite standard on how much water must be kept[67] but 2 Bm^3 seems to be a minimum basis.

Therefore, from the available volume AV (which gives an indication of whether the coming dry-season is to be considered as "dry", "normal" or "wet"), a Target Volume (TV) of water release for the January-June period is issued. The value of TV is transformed in cropping area. This Target Area (hereafter TA) is expressed in *rai* and generally varies between 2 to 3.5 million rai.

The relationships between AV, TV and TA are grounded on past experience and are approximately based on the following rules (RID, *pers. com*.):

Active storage AV > 10 Bm3, released plan TV = 6.5-7.5 Bm3; for paddy area TA= 3.1 – 3.3 M.rai

Active storage AV = 7.5-10 Bm3, released plan TV = 6 Bm3; for paddy area TA ≈ 3.0 M.rai

Active storage AV = 5-7.5 Bm3, released plan TV = 4 Bm3; for paddy area TA ≈ 2.0 M.rai

Active storage AV < 5 Bm3, released plan for domestic use and other constraints only.

The definition of TV, here based on experience, is obviously the cornerstone of the allocation process, on which will depend the sustainability of dam regulation in the following months and the risk of shortages. Issues related to the methodology and consequences of its determination are addressed in section 5.7.

5.2.1.3 Step 2: Allocating shares to the various users in the basin

The global release target TV is subsequently distributed among the various water uses within the basin (divided here between "the delta", south of Chai Nat Dam, and the middle basin, upstream of it), and by IRD Region. All regional Offices are informed about the amount of water allotted to them.

This is done by preparing the following table (Table 9) which presents the main water uses: consumption and agriculture, both in the *middle basin* and in the *delta*, together with needs for transportation, Bangkok and the control of sea water intrusion. The table also recalls the

[67] Or in other words, on what is the risk associated to a given remaining water volume.

planned and real supplies of the former years: it can be seen that the effective supply is higher than the planned value in most years, with a difference of up to 15%.

This repartition follows a formal ranking of priorities established as follows:

1. Domestic use (especially BMA, with some industrial use)
2. Control salinity intrusion at the river mouth
3. Irrigation of orchards, vegetables and shrimp farms
4. Rice
5. Inland navigation
6. Energy generation

5.2.1.4 Step 3: Distribution of the global target (TV) over 6 months and sub-areas

The next step in the process is the specification, for each week, of how the total discharge attributed to each Regional Office (Region 3 (the middle basin), Region 8 (roughly the eastern bank of the Chao Phraya River and Region 7 (the western bank)) is to be further divided by main canal by the Regional Offices concerned:

Region 7: Klong Makham Uthong
Suphan River
Noi River
Other canals (Pollathep, Borommthad)

Region 8: Klong Chai Nat-Ayutthaya
Klong Chai Nat-Pasak
Other canals (Manorom)

The allotment of water and cropping area among the three Regional Offices is also based on past experience and customary practices. The flows diverted to RID's Projects in the middle basin is added to an estimated volume abstracted by private and DEDP pumping schemes. The shares of Regions 7 and 8 are also defined following past records rather than periodically re-assessed based on equity or other criteria.

The planning process further sets a rough estimate of how the shares of water will be distributed throughout the six months. Although it will be shown later that this is a key aspect and that there is much to discuss about it, this distribution is made based on past years records which define a curve similar in shape to that of water requirements for a given crop. Water releases, as planned, rise until a maximum value around mid-March and further decrease. This has much to do with the former RID's allocation plan in which deliveries were scheduled from February onward, as still practised in the Mae Klong system. In-season irrigation deliveries to the main canals are tentatively broken down in 26 chronological weekly values, expressed in million m^3. The key point in the process is that the total appearing at the bottom line be equal to the Regional target set by the Central Office (for example 2 Bm^3 for the various waterways of Region 7).

TABLE 9: MACRO WATER ALLOCATION WITHIN THE BASIN FOR THE DRY-SEASON (IN MILLION M^3)

Planning of allocation	2536 **1993**	2537 **1994**	2538 **1995**	2539 **1996**	2540 **1997**	2541 **1998**	2542 **1999**	2543 **2000**	2544 **2001**
AV (1 January) Mm3	**5,357**	**2,408**	**12,733**	**14,852**	**12,107**	**8,200**	**3,900**	**11,900**	**13,500**
Consumption use	**550**	**700**	**1100**	**1800**	**1650**	**1600**	**700**	**1300**	**1,300**

Middle basin	250	300	500	900	800	800	300	800	800
Delta	300	400	600	900	850	800	400	500	500
Crop use (total area)	**2,100**	**500**	**3,300**	**4,950**	**4,200**	**3,400**	**1,900**	**3,000**	**4,300**
Middle basin	100	0	300	800	500	500	200	300	
Delta	2,000	500	3,000	4,150	3,700	2,900	1,700	2,700	
Transportation	300	0	300	400	300	300	0	300	300
Bangkok	650	550	700	750	750	750	650	750	750
Sea intrusion	400	250	600	600	500	450	350	350	350
Total planning (TV)	**4,000**	**2,000**	**6,000**	**8,500**	**7,400**	**6,500**	**3,600**	**6,000**	**7,000**
(million m^3) real	4,610	1,894	7,216	9,643	8,556	6,656	2,730	6,530	
Crop area planning (TA)	1.5	0	2.8	3.5	3.3	2.7	1.9	3.1	3.35
(million rai) real	1.96	1.77	3.19	4.15	4.06	3.79	3.49	4.90	
Middle basin record		300	800	1,700	1,300	1,300	500	1,300	
Delta record		800	3,600	5,050	4,550	3,700	2,100	3,360	

Source: RID

5.2.2 Regional Office and Project levels

After receiving the pre-planning from the Central Office, each Regional Office considers its share of cropping area and distributes it over its different Projects. A letter is sent to each of them, informing the Project officers about:

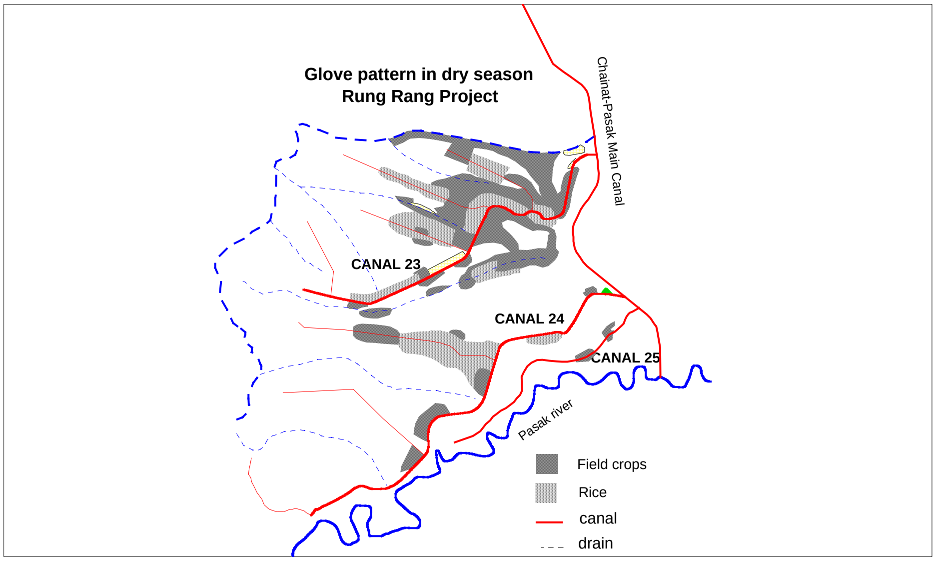
- The dam status in the basin and the available water
- The policy adopted for the coming season, including whether a rotation must be set within the Project (that means only half of the Project should receive water).
- The Project's share of cropping area by main canal and the planned schedule for deliveries, as established tentatively by Regional Offices.

And requesting the following actions:

- To plan their cropping target area and to break it down by sub-district, district and province, and also by canal (main and lateral). This must be done specifying the areas, if any, which may have suffered some loss during the wet season (flood, grasshoppers, etc) and which should be compensated for.
- To map the target areas, including rice and non-rice crops
- To plan the use of RID's mobile pumping stations
- To set a weekly calendar for water supply in all the main canals in the Project.

Officers in the Project then work out a map showing the target area, based on their experience of where does the cultivation area expand for a given level of water supply. This translates into a crude map which often follows a "glove pattern": irrigated area are planned (or rather “expected”) only along the main canals, with a width of, say, 500 m, deduction being made of most tail-end reaches (which are known, by experience, not to get water) and some particular areas (“high” land, sandy soils, etc).

FIGURE 42: EXAMPLE OF “GLOVE PATTERN” (CROPPING AREA IN THE ROENG RANG PROJECT)



The total area on the map is calculated and expected to match the share of area which has been allocated to the Project[68]. In practice, the real irrigation area may be very different from what appears on the planning map. A good example of this is provided by South Rangsit Project, which has long drawn “zebra” maps with stripes along the main canals, while in reality rice covers the whole area on the eastern side of the Project and is rather found along the drains on the western part. As a rule, these maps also never mention areas achieving triple cropping and often focus on cropping areas along drains and canals, although those relying on tube wells are sometimes paramount. *Such discrepancies have absolutely no impact whatsoever on the real allocation process* and this mapping tends to be regarded as a routine burden by officers[69].

Little importance is given, too, to the setting of a weekly water supply calendar, distributed by main canal (lateral). In fact, the Project officers know that the water they will eventually receive is unlikely to conform to the target values they are asked to set up. Some simply set a constant value for the whole season ; others reproduce average past records ; some even plan a formal rotational distribution between two main or lateral canals but eventually release a constant flow to both of them. Most significantly, in many instances, there is no direct

[68] In some years, Project officers are requested to prepare their plan without (or before) having been informed by the Regional Office of their share. They do so on the basis of the already known relative availability of water in the dams and, if any, of which sub-area is “in turn”. These areas are later adjusted by the Regional Office.

[69] Which in fact gives reason for their little enthusiasm in spending time refining these maps.

matching, versus the 2,000 m^3/rai standard or otherwise[70], between the area allotted to the Project and the aggregated demand of its main laterals[71] sent back by the Projects to the Regional Offices.

Officers at the Regional Offices consider the tables giving the allocation of *cropping area* by provinces and districts, and aggregate them to get overall figures. To what extent they also consider the *weekly allocation schedules* of the Projects is unclear. It seems that the Project schedules are aggregated to get the overall demand for each feeder canal but this generally does not impact on the general schedule prepared earlier. If, in quantitative terms, a Project's demand is not compatible with the share of the feeder canal, then the Project is asked to reduce its figures (in practice the Regional Offices impose a new value, but may also fail to inform the Project concerned, with no particular impact however, as planning values are taken as mere indications).

If the Regional Offices detect unusual discrepancies between the Project's requests and the usual pattern, something believed to be rather exceptional, it can also request an adjustment from the Central Office. This has recently been the case when Projects of Region 7 increased their request for the beginning of the dry-season to cope with the rising water demand at that time. However, any change is constrained by the overall supply target (TV) and the solution adopted was to increase supply at the beginning of the season while decreasing it at the end (partly with the hope that rainfall would make significant contributions at that time).

5.2.3 Project planning and farmers

In parallel, each Project organises meetings at the *zone*[72] level in order to inform farmers about the cropping area allocated to their zone. This is generally done together with the gate keepers, zonemen and sub-district extensionists. Rather than the figure itself, farmers first give attention to the overall policy adopted each year: "*it is prohibited to plant*", "*there is little water this year*" or "*this year, water is good*" form the basic "*hearsay scale"* on which farmers rely in order to decide to engage in cropping or not. The planned cropping area is also taken as an indication but it is adjunct to further advice from officers which qualifies the risk. These often suggest that more area can possibly be planted but that, in that case, RID cannot be responsible for possible water shortages. The way this is put is also interpreted as rather an encouragement or not.

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[70] Some officers also mention a 2,400 m3/rai rule. Other Projects were found to use discharges of 0.12 l/sec/rai for rice, 0.069 l/sec/rai for field crops and 0.1 l/s/rai for aquaculture.

[71] Officers often look at the discharge planned for the inflow of the feeder canal they depend upon, itself a reflection of the overall level of supply for the current dry-season. Based on these data they basically estimate, by experience, the discharge they are likely to be able to divert to their Project ("1.5 cms for canal A and 3.0 cms for canal B). Transcribed to the weekly scheduled they are asked for, these numbers are often disconnected from the cropping area allocated to the Project.

[72] A sub-unit of a Project (approximately 1000-1500 ha)

We touch here an important aspect of the disjuncture between planned and effective cropping areas. Project Officers tend to be conservative on the latter as a *protective measure against a possible drastic water shortage lying beyond their control*. They commit themselves to ensure water supply for a limited area, but at the same time suggest that a larger cropping area is likely to be possible.

5.2.4 Final step of the planning process

The weekly schedules prepared by the Regional Offices are sent to Bangkok[73]. The Central Office also aggregates target areas by Province for political and administrative purposes. Unless some particular situation has arisen in the meantime, calling for an adjustment either of the Target TA or of the weekly scheduling, the plan is endorsed and communicated to EGAT so that energy generation be planned in accordance with the dams releases requested by RID.

5.3 Plan revisions

In some instances, peculiar conditions may call for the revision of the whole plan. This generally occurs at the beginning of the season, in January or early February. Two instances of adjustment in the planned weekly calendar have recently occurred. They are believed to be representative of the two main causes of plan revision: a) discrepancies between technical and political criteria; b) severe mismatch between the planned schedule and the effective crop progress.

5.3.1 Technical vs. political criteria

At the end of 1998, the dams were at their lowest, with only 3.9 Bm^3 available for the 1999 dry-season. Objective technical considerations led RID's Central Office to define a "zero *rai*" option, with regards to the risk of a severe water crisis, with impact on the capital water supply. This technical stance was challenged by a more politically oriented one, as local politicians at the provincial level expressed their concern about low targets. The farmers' demand at that time was particularly high, because of a relatively high price for rice, and this pressure ended up passed on to the governmental level. On such ground, the plan was reviewed and a target of 1.9 million rai set up for the basin (with 1.7 for the delta).

The balance at the end of the season was rather appalling, as 3.4 million rai were recorded, including 1.2 million rai of triple cropping. Although this was greatly due to an obvious easing of the situation in April, when abundant rainfall dismissed the fears of a crisis and enticed

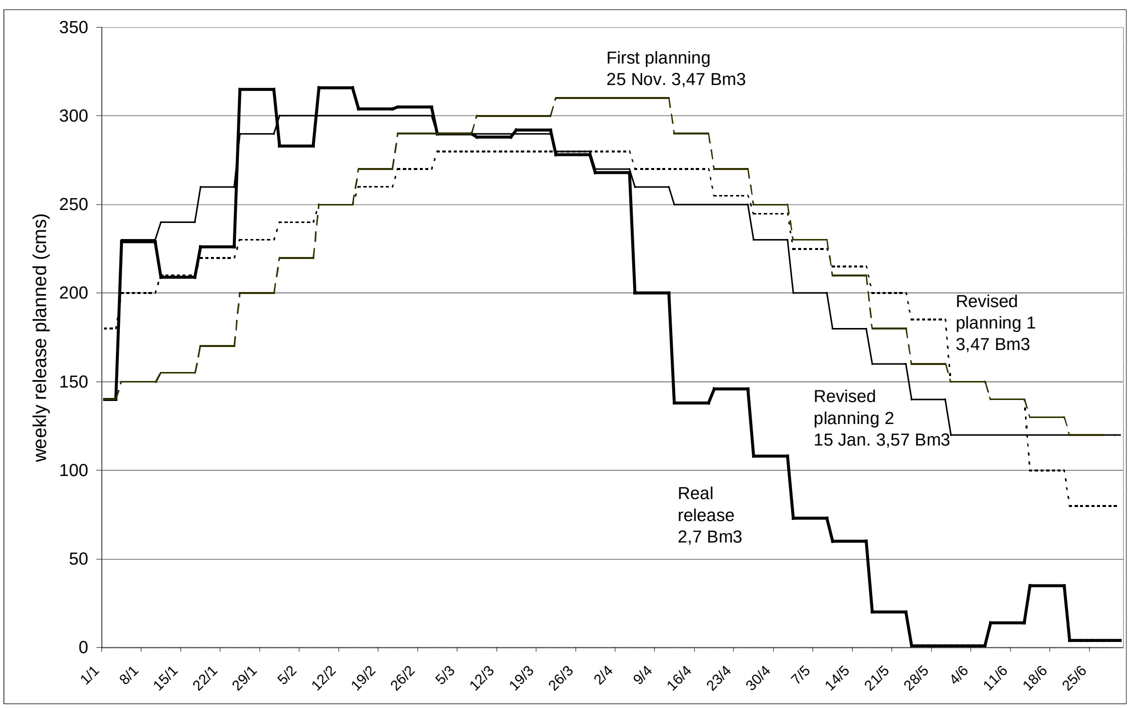
[73] The full process does not follow a definite pattern which would be applied each year. From numerous discussions with the officers involved and from the examination of the corresponding official letters and documents, it became clear that there are variations in the way information is requested, and used or not. In some years, for example, the weekly schedule for each main canal is sent by the Central Office to the Regional Office together with the overall target (drawing on previous records). In other years, the schedule is done by the Regional Offices, sometimes considering the Projects' schedules but most of the time not. Corresponding tables are sometimes expressed in terms of volume/week, sometimes in discharge.

farmers to grow a late dry-season crop, it must be noted that things might have evolved towards a much darker scenario ; this question of risk-management will be touched upon later.

Figure 43 shows the initial plan, with an exceptionally low peak discharge of 300 cms. Knowing about the poor status of dam storage as soon as November and about the obviously coming prohibition of dry-season cropping, many farmers rushed to grow an early crop, starting in November or December. This generated an unusual high water demand in January, jeopardising the allocation plan and clearly threatening the supply of Bangkok in case of another catastrophic hydrologic year.

The revised plan therefore acknowledged the demand derived from the already planted rice fields and increased early supplies at the expense of later ones ("revised planning" curve on Figure 43). This was not enough, eventually, to ward off prospects of dramatic crisis and the policy was changed again (without apparently being translated into a third plan: "real release" curve): farmers were insistently informed that on-going crops would be supported until the end of February only, and that no responsibility would be borne by RID beyond this date, when only basic consumption needs would be met. Figure 43, however, shows that RID was forced to supply water until late March, when deliveries were abruptly discontinued to avert a crisis.

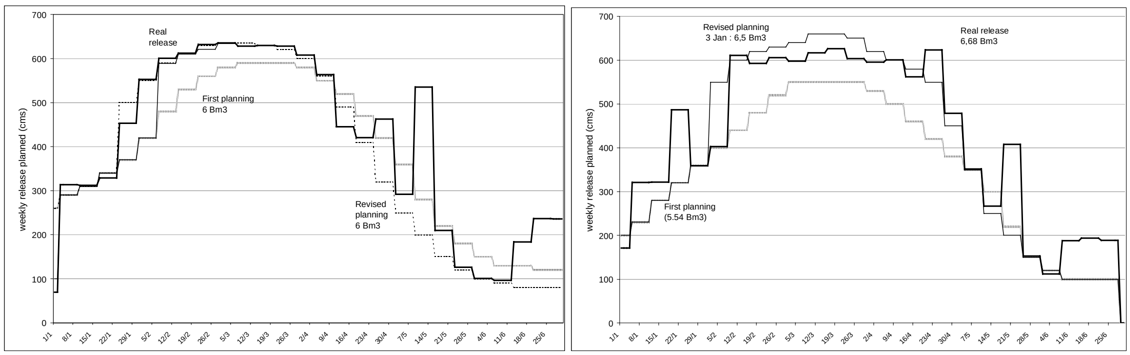
FIGURE 43: PLANNING REVISION IN THE DRY-SEASON 1999



5.3.2 Early mismatch between water supply and demand

Another example of plan revision is provided by this year (2000). In early January, a crisis materialised because of the very early water demand generated by a wide shift of cropping calendars earlier in time. This crisis was not due to the insufficiency of available water but, rather, to the mismatch between demand and supply (and therefore the planning of supply) (RID, 2000).

FIGURE 44: PLANNING REVISION IN THE DRY-SEASON 2000 AND 1998



Farmers along the Ping river started rice cropping in early December 1999 and caused havoc in the system: water levels in the river dropped and many pumps could not operate; navigation was interrupted in the Sing Buri reach and salinity in the Chao Phraya River lower reach rose to 10 g/l (standard is 2 g/l). This was dealt with in January by doubling dam releases and by resorting to Pasak Dam too[74]. The shortage was also dealt with by means of rotational arrangements and the intervention of politicians. Likewise, "much water was also allocated for early wet season paddy cultivation in June". The lower Ping reach was credited with a cropping area of 143% of the target, probably much lower than reality considering the extent of unregistered triple cropping. The figure (right) also shows that the 1998 plan had to be revised because of the strong demand which materialised and forced RID to supply more water.

In summary, the allocation process can be typified as supply-driven, guided by experience rather than by clear-cut technical parameters, somewhat flexible rather than rigidly pre-determined. It focuses on the allocation at macro level, with little control on the day-to-day fluctuations experienced at the lower levels but with a concern not to stray too much from the weekly planning, as a way to ensure that the total water released at the end of June do not differ from the overall target by, say, more than 15%. Water supply at lower levels (laterals) is very loosely defined and uncertain.

5.4 In-season plan adjustments

This planned schedule, like all plans, is not meant to be strictly adhered too but, rather, to serve as a guideline: indeed, several uncontrolled factors will demand in-season adjustments.

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[74] "farmers still demanded paddy cultivation outside the target area, by asking through Members of Parliament and Provincial Governors of Suphan Buri, Chai Nat and Sing Buri province" (RID, 2000).

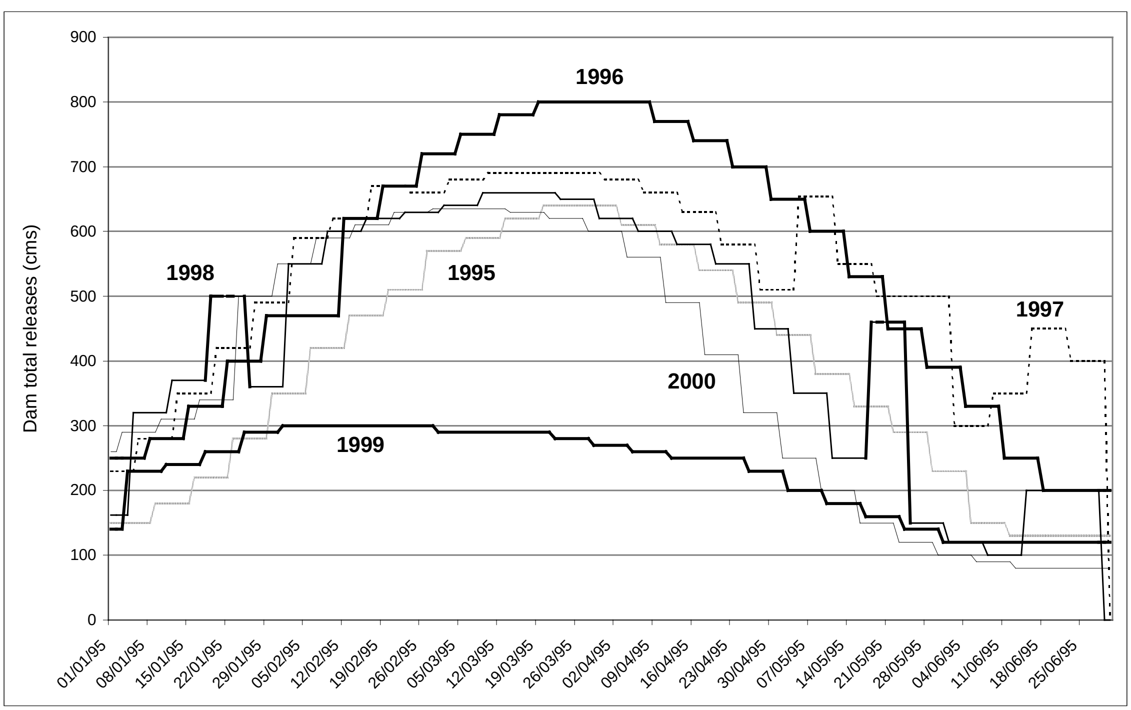
At the basin level, three main types of perturbation may occur and lead to an adjustment of the weekly targets:

- Imbalance between the middle basin and the delta, due to uncontrolled and excessive water abstraction in the middle basin. The delta may end up receiving much less than expected, resulting in water shortage.
- Imbalance between the real and the expected cropping area in the delta at a given point in time (or, in other words, mismatch between the real demand and the supply as estimated in the plan). This is mostly due to the “anarchic” pattern of cropping calendars over space and time: we have seen earlier that the whole 1999 plan had been reformulated for such a reason ; more commonly, more specific or local mismatches can also occur during the season and call for limited adjustments.
- Climatic situation: a very hot period, boosting water demand, or heavy rainfalls, with an opposite effect, may lead to significant variations in the water demand and call for adjustments of the dams releases.

In such cases, RID must direct a request to EGAT so that the next weekly release targets be adjusted. If of wide magnitude, the request may come together with a full new weekly schedule. On average, it is estimated that this kind of adjustment is made once a year.

Figure 45 exemplifies a few of these in-season adjustments. It shows the effective weekly RID requests for the last 6 dry-seasons. The year 1997 is marked by a neat increase in water demand for the months of May and June, while the year 1998 shows both an early and a late adjustment.

FIGURE 45: ADJUSTED REAL RID WEEKLY REQUESTS (1995-2000)



In some cases of rare emergency, however, RID could be forced to ask for a modification of the target of the on-going week. However, this is constrained by the fact that there is a minimum period of 48 hours between the request and its possible effectuation. This is due to the daily plans issued by EGAT regarding the production of energy at the national level. This (almost) "real time adjustment", in practice, is done for the following week: requests must reach EGAT office on Wednesday at the latest, so that it is examined on Thursday and sent on Friday to the dams, the normal day to send the next week release plan due to start on Monday.

In the last years, this process became more flexible and less formal and could be resolved by a phone call from RID's head of branch. More recently, EGAT asked for such requests to be officialised through a written document, but the old practice has been now reactivated.

It is worth noting, in passing, that there is no seasonal plan for the rainy season, although EGAT does make a seasonal planning based on average past records. Adjustments are made week by week, depending on the situation, in particular regarding precipitations.

5.5 Operational real-time adjustments

After the setting of weekly dams release targets, first at the onset of the season, then with possible – although rare – in-season adjustments, RID officers focus their attention upon day-to-day water management. Although EGAT appears to release water amounts very close to those requested (more on this later), irrigation managers have to cope with the three kinds of uncontrolled perturbations mentioned earlier: pumping irrigation in the *middle basin*; hectic cropping calendar; and climatic events. The first type of perturbation, and partly the third one (possible sideflows in May and June), impact on the discharge eventually reaching Chai Nat Dam. This section examines the difficulties experienced in regulating diversion flows at that point.

At the Project level fluctuations are the rule. While there is a certain inertia at the basin level, Projects often have to cope with day-to-day fluctuations. A first category of fluctuations originates from fluctuations of the water level at Chai Nat Dam. A second one is due to the uncontrolled nature of water use along one main canal, which means that uncertainty and fluctuations generally increase from head to tail.

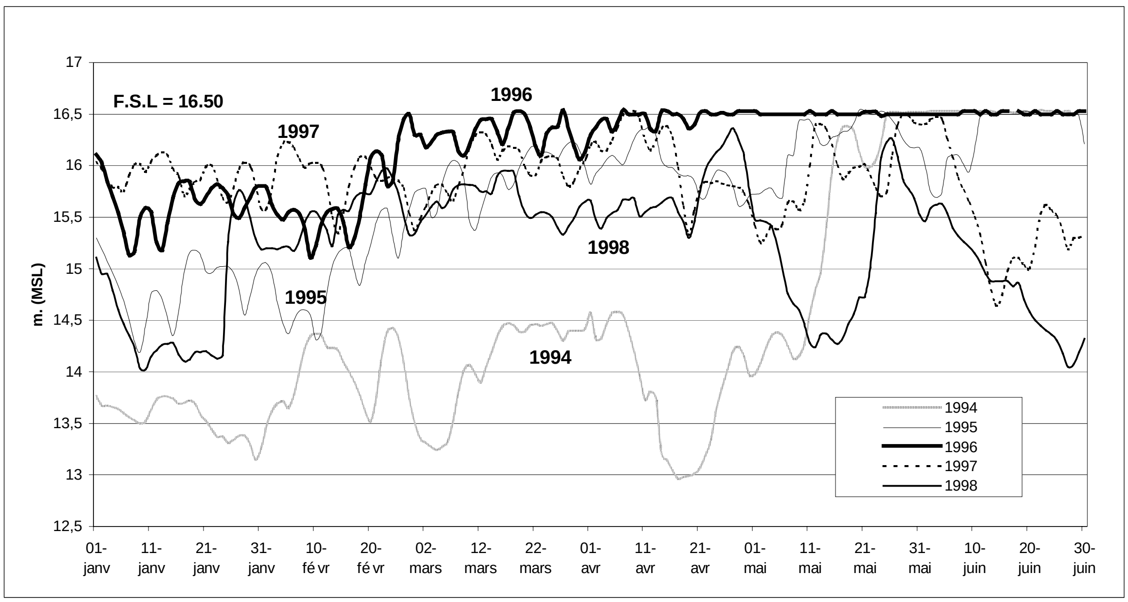
5.5.1 Fluctuations of the water level at Chai Nat Dam

An irregular inflow at Chai Nat translates into fluctuations of the water level upstream of the dam. This further disrupts the discharge of all the regulators which control the waterways branching off the Chao Phraya River, upstream of Chai Nat Dam.

The main reasons for such fluctuations are the uncontrolled water use in the middle basin and the decrease in dam releases during the week end. As the demand for energy diminishes (many factories and offices close), EGAT reduces releases accordingly. This effect takes approximately 5 days to materialise at Chai Nat Dam. In order to limit this phenomena, EGAT has agreed to maintain daily releases during the weekend over 60% of the average value for the week considered. Nevertheless, disruptions are still perceptible and resented by RID officers. This point will be addressed in Chapter 11.

Daily data for the dry-seasons of the years 1994 (dry) to 1998 (wet) are used here to show the extent of these fluctuations upstream of Chai Nat Dam: 1994 sticks out as very problematic year in which virtually no irrigation water was supplied and the water level remained below 14.50 m MSL, this is 2 meters below 16,5 m, the full-supply design level used in the wet-season. In "normal" dry-seasons, the level generally fluctuates between 15.5 and 16.0 m. Other years also show significant fluctuations and difficulties to ensure a proper level, especially during January and February.

FIGURE 46: VARIATION OF THE WATER LEVEL UPSTREAM OF CHAI NAT DAM (19994-98, DRY-SEASONS)



How these fluctuations impact on the discharges observed at the head of the different waterways is easy to understand. As flows are a function of the difference of water levels upstream and downstream of the regulators (more precisely of $[H_{up}-H_{down}]$^.5), a variation of the water levels will alter discharges. When the upstream level is so low that no regulation by the gates is possible, then these are left wide open and water flows freely – in limited amounts – through the regulator inlet. When the water level drops below the sill level of the regulator, then no inflow is possible. In this last situation, end even before, when discharge gets really small, the gate must be closed and a pump is installed to provide some emergency inflow into the canal.

The sill level of the head regulator of the different waterways is therefore a crucial parameter in a context of a semi-controlled and fluctuating upstream water level. Figure 47 shows that the first canals to be affected by a drop in the water level close to the 14 m MSL level are those of Pollathep and Borommathad Projects, together with Makham-Uthong canal. Next, Chai Nat-Pasak and Chai Nat-Ayutthaya canals will undergo some problems, while the three rivers inflows (Chao Phraya, Noi and Suphan Rivers) are less or little affected.

5.5.2 Inflow in main waterways at Chai Nat

The impact of the fluctuations of the water level upstream of Chai Nat Dam upon the inflow into the different waterways varies according to whether the year is "dry" (little or no supply) or "wet" (normal supply).

FIGURE 47: WATER LEVEL AT CHAI NAT DAM, COMPARED WITH WATERWAYS SILL LEVELS (IN M MSL)

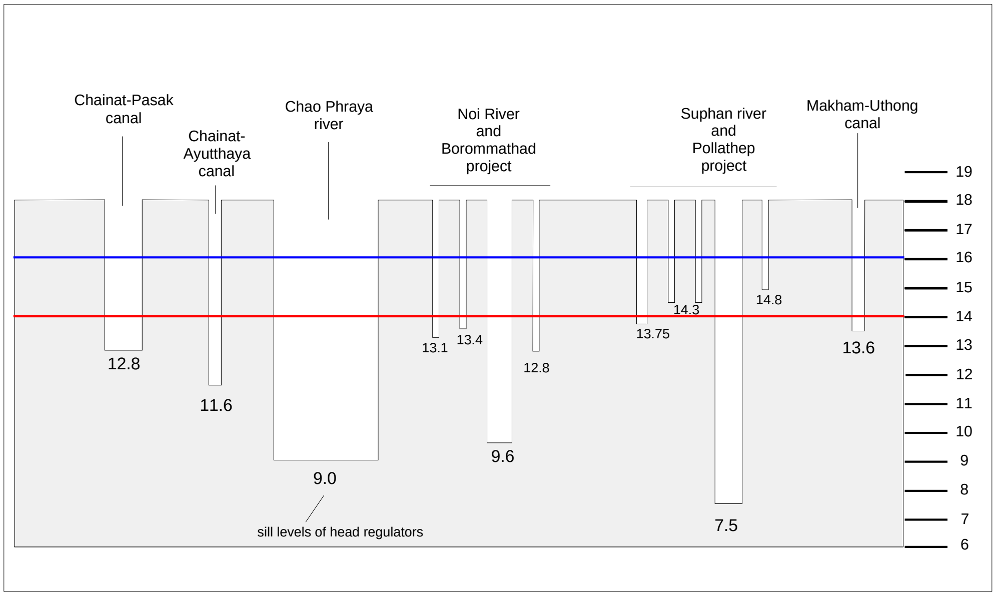


Figure 48 reproduces the critically low water level observed in the crisis year of 1994, in which no dry-season supply was planned. The level remains around 14 m MSL until mid-May, when abundant rainfall authorised a return to normal supply. It can be seen that all inflows are kept within the 0-20% bracket (discharges are expressed in percentage of the full-supply discharge); Manorom regulator, at the head of Chai Nat-Pasak canal receives more water because it is the main feeder canal supplying the East Bank area. Makham-Uthong canal is seen to be rather privileged, as it is allowed to maintain an inflow close to 20% of its full-supply module of 35 cms. However, in early March and late April, when the water levels drops down to 13.5 m MSL, all inflows are drastically affected and almost zeroed.

Figure 49 gives a different picture, corresponding to the dry-season 1998, a rather "normal-wet" season. From February to April, the water level fluctuates around 15.5 m MSL, while January and May experience neat slumps. It can be seen that the canals with higher (relative) fluctuation of the inflow are the two with the highest sill level: Boro 1R and Makham-Uthong canals. The figure deserves some caution as some fluctuations are the result of, or are dampened by, voluntary gate adjustments. Whereas the late May water hike could allow maximum discharges in the Noi and Suphan Rivers, regulators are operated in order to maintain inflow at the same absolute level (in *cms*). These waterways with low sill level are controlled down to a low level corresponding to an absolute discharge which fits dry-season conditions, while those smaller ones with high sill levels fluctuate much more in relative terms.

FIGURE 48: VARIATION OF INFLOW INTO MAIN WATERWAYS AT CHAI NAT DAM (1994) (DRY YEAR)

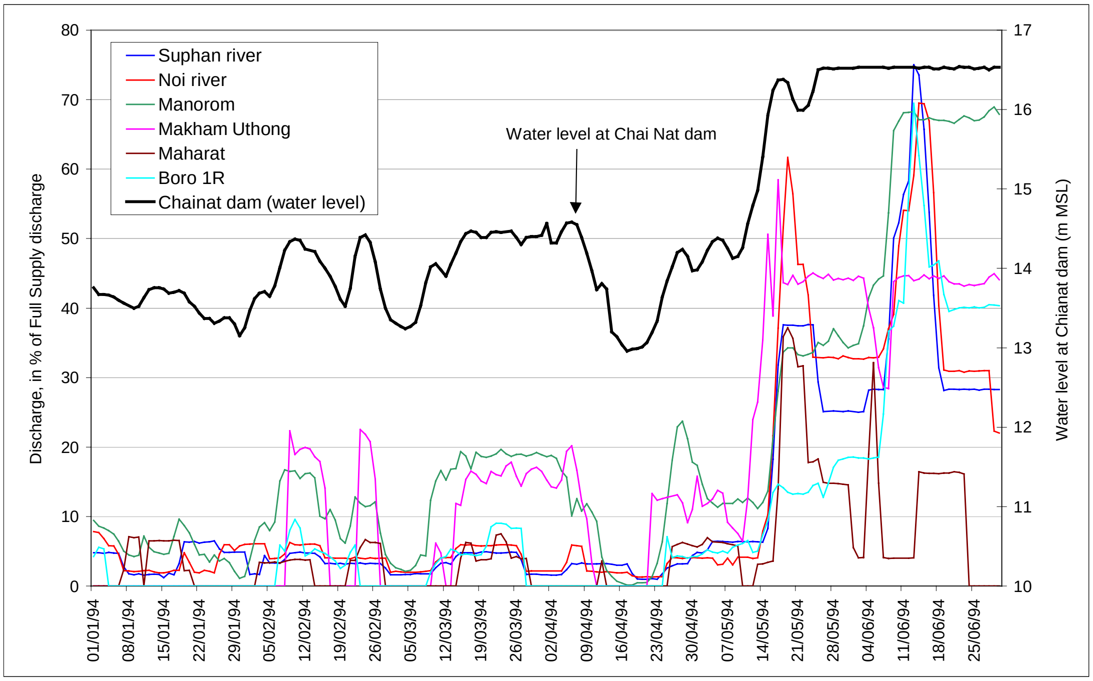
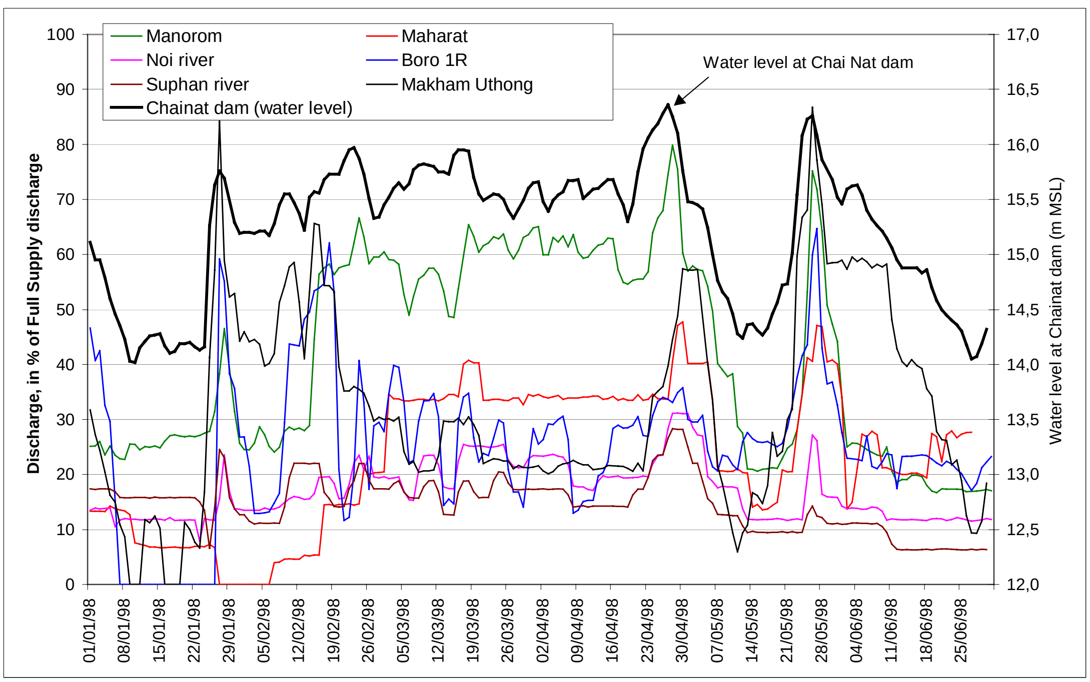


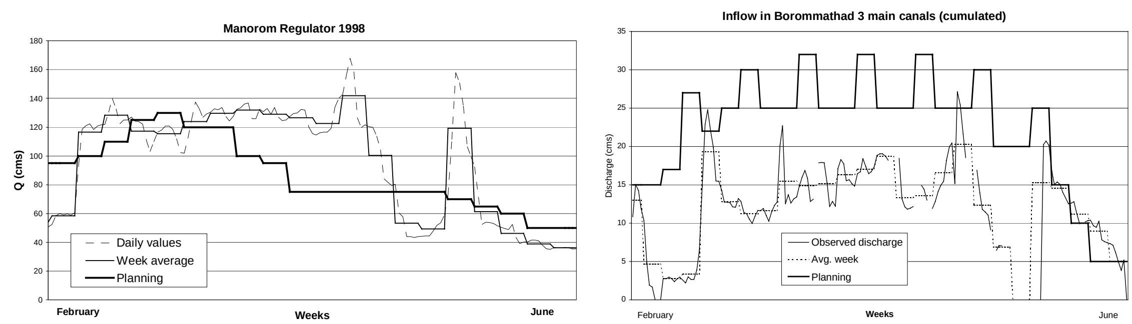
FIGURE 49: VARIATION OF INFLOW INTO MAIN WATERWAYS AT CHAI NAT DAM (1998) (NORMAL YEAR)



While the inflow in the main waterways branching off the Chao Phraya River at Chai Nat are governed by both the water level in the dam and the gate settings, the inflow into Projects located further downstream along these waterways is likely to be increasingly hectic, as uncertainty adds up. Gravity inflow may not be ensured and pumps need to be used.

Figure 50 gives a few examples of discrepancy between the planned and effective inflow in some of the main canals branching off at Chai Nat and deserves no further comment on how both values are likely to differ.

FIGURE 50: EXAMPLES OF DIFFERENCES BETWEEN PLANNED AND EFFECTIVE INFLOW IN CANALS



5.5.3 Management and adjustments at the Project level

In normal situations, Project managers ensure/adopt a continuous flow to all their laterals, even though there might be a rotation between two or three reaches (typically 5 or 7 days). If the policy is to follow a year-by-year rotation in which half of the Project only is supposed to grow rice, then the flow to the other half is maintained low, but rarely cut, at least in the head reach. How these limited flows are compatible with classical earth canals equipped with sluice gated regulators and designed to provide gravity flows to laterals at the full supply level is not readily obvious to the observer. In fact, situations vary according to topographical features but the most common case is that of farmers compensating for the lack of gravity flow to their FTOs (Farm Turn Out) by using individual pumping devices. *If operational constraints experienced by RID have forced farmers to develop their pumping capacity, it is all the more true that this – in return – has discouraged whatever regulation improvements RID would have otherwise been pushed to achieve*. Rotational arrangements are part of the paraphernalia but as their implementation entails significant transaction costs, RID officers understandingly prefer the actual *statu quo* according to which their role is to ensure water in the canal, even at the bottom of it, while farmers have implicitly integrated the fact that they will often need pumping devices to access water.

The development of the individual pumping capacity has been paramount in easing water management in the dry-season and in providing farmers with the flexibility to easily access any pounding or flowing water. On the negative side, it is equivalent to substituting managerial exigencies for increased monetary costs (pumping equipment and operation), which burden is borne by the farmers. A more subtle negative aspect of this process has also been the embracing (or the strengthening) of a pervasive individualistic conception of gaining access to water. Although collective arrangements are sometimes necessary and implemented (see report No 2), there is ample evidence that individual pumping has implicitly reinforced the acceptance that locational advantages necessarily translate into a privileged access to water: head enders can pump water as soon as it appears, in total independence from a possible collective rotational arrangement or other efforts aimed at raising the water level in the canal or increasing equity.

The way supply and demand adjust to one another in a context of rather high uncertainty is not obvious and cannot be easily reduced to the classic distinction between a demand-driven process (supply is adjusted to a given demand) and a supply-driven one (inflows are fixed and known in advance and the irrigated area is calculated accordingly). A careful analysis shows that it may in fact be a blend of both, with a delicate and fluctuating dosage of ingredients.

The objectives, constraints, risks and trump cards of the main two parts concerned are schematised in Table 10. Farmers, unless rice prices are really depressed, usually attempt to grow a dry-season rice area as large as possible, two times or more if possible. They must evaluate the risk of doing so according to the information given by RID and the media. By starting their crop massively (by resorting to secondary water sources or by using the water available at the end of the wet season), they may force RID to further supply their crops until the end of the cycle. In case of drastic shortage, they may request local politicians to intervene in order to get an extra supply.

On their side, RID officers both want to serve their farmers and to minimise risk. In some instances the second aspect may override the first one and officers are likely to adopt strategies aimed at limiting the expansion of the cropping area. In some instances, they are seen opening middle-reach check regulators, allegedly to provide consumption water to downstream areas, but in reality to prevent upstream areas to grow too large an area, which would dramatically increase the risk of future shortage. For officers, shortage means farmers' unrest, political interventions and hierarchical superiors possibly asking for explanations, all things which must be avoided as much as possible. Their margin of flexibility lies in a certain degree of slack in water allocation: they may sometimes allocate poorly reported extra water supplies through releases into drains, by setting pumps along the rivers or by treating them as "*upaphok-boriphok*" (domestic consumption) water. Under-reporting may also occur in times of tighter quota monitoring.

An important protective measure is to commit to a low standard target area, in order to transfer risk-taking onto farmers, while giving *off-record* indications on how much risk should be reasonably taken. This is why RID officers are reluctant to plan large areas, even in their formal request to the Regional Office. Field staff may also be tempted to over-report cropping areas in their areas, as a way to justify further preferential allocation.

This system is served by the implicit philosophy conveyed by the development of individual pumping. By fostering the acceptance that farmers along the canal do gain privileged access to water, it chokes claims of greater equity, with their cohort of demanding measures, and fits RID's concern to control the expansion of the cropping area: if the *first-pumping-first-served* principle is endorsed, then any water flowing in the laterals will swiftly translate into a green "glove pattern" rice area. The width and the length of each "finger" depends on the flow itself, the roughness of the canal, topography and the pumping capacity of the farmers along its banks.

Should this be seen in a negative fashion ? Does not, after all, pumping lead to a very efficient water use at the plot level and ensure that even limited flows are fully made use of ? It may also be ideally adapted to a water supply characterised by its irregularity and sometimes, uncertainty. However positive these aspects may be, this is achieved at the expense of equity, an issue which will be touched upon later.

TABLE 10: ASPECTS OF FARMERS-OFFICERS INTERACTIONS DURING THE DRY SEASON

	Farmers	**RID Project officers**
Objectives	Grow as much rice as possible, in area and frequency ;	Serve farmers, while trying to limit the cropping area down to low-risk standards Limit complaints from farmers and from superiors
Strategy	Forcing RID to ensure sustained supply by starting a crop when water appears or with water from other sources On-farm water storage; wells; drains	Limit supply to control the spread of the cropping area Fix a low "commitment" target area, as a protective measure; Refer to water as "*upaphok-boriphok*" supply
Constraints	Lack of on-farm infrastructure; pumping needed Rats, water seepage, in case of isolated cropping	Partial control of the flow allocated to the Project ; fluctuations and uncertainty of inflow
Risk	Excess areas, beyond the target, may face water shortage, reduced yields or crop loss.	Water shortage Complaints, protests from above and below
Trumps	Intervention of politicians Low sensitiveness of rice to spaced out supplies Secondary water sources	Forward request/complaint to higher levels Divert non-computed water to drains in case of quota restriction ; request special supply in case of shortage; pump extra water from rivers.
Pressure reducing factors	Low price of rice. The risk is higher and the pressure on water reduced. Rainfall	Same as farmers

5.6 Management in critical years

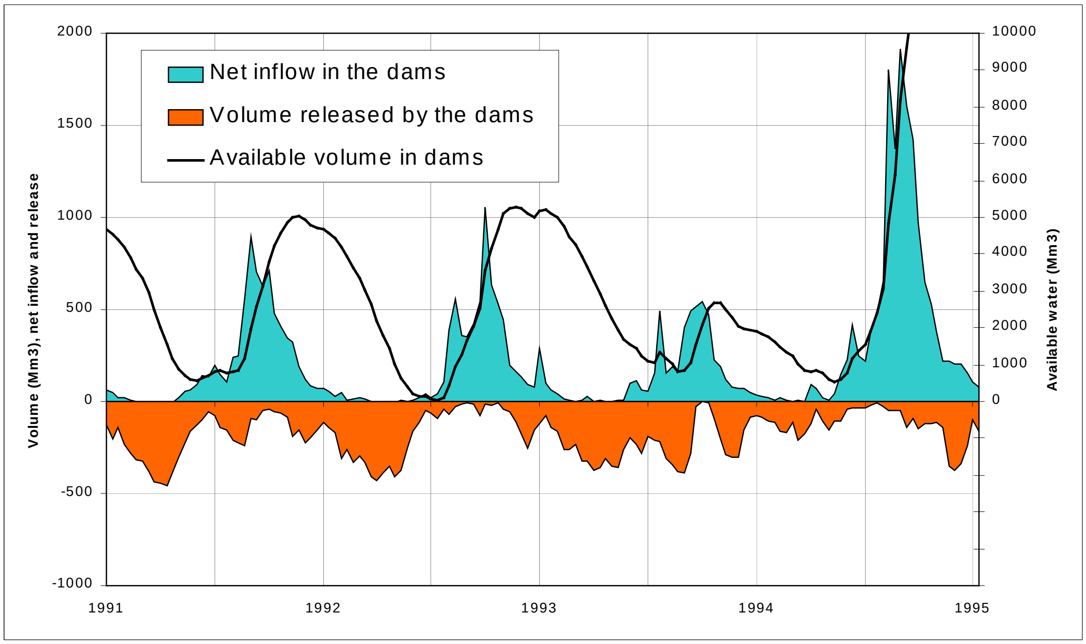
It might be instructive to investigate more in detail the reasons of the most recent and dramatic "water crises", namely that of 1991-1994 and that of 1999, as a way to increase our understanding of "what went wrong" and of how crises might be averted in the future.

5.6.1 The dry spell of 1991-1994

The dry season 1991 started with 4.7 Bm3 available in the two dams, a rather low value, consecutive to a poor rainy season (see Figure 51). A total of 4.5 Bm3 was released during the 6 dry months (with 70% of it diverted at Chai Nat), while the dams record an inflow of 1.1 Bm3. The ensuing rainy season brought a rather low additional inflow of 6.6 Bm3 (to be compared with an average value of 9 to 10 Bm3), while releases were limited to 2.5 Bm3. This brought us to the onset of 1992 with the same amount of available stored water as the previous year: 4.7 Bm3. The 1992 dry-season was a repetition of the former one (4.65 Bm3 released, 0.5 gained) with a *record low* in the total active storage: 650 Mm3 in the beginning of July ! The releases of the following wet season were reduced down to 1.3 Bm3, causing some water shortage, while the dams inflow also remained at the value of 1991 (6.6 Bm3).

The 1993 dry-season followed an identical pattern as that of the two former ones *but* rainfall remained at the lowest level during the following wet-season. In a bid to secure the main rice crop, in a context of 3 meagre consecutive dry-seasons, RID released 3.7 Bm3 which were eventually not replaced by late rainfall and run-off, as the season yields its lowest dam inflow: only 4.7 Bm3 ! This led to a catastrophic situation: the dry-season 1994 started with an incredibly low 1.8 Bm3 volume ; total dams releases remained close to a depressed 100 cms while the flow released at Chai Nat Dam bottomed down to 33 cms in April, provoking saline water intrusion fatal to many orchards along the river. Providential abundant rainfall in May and June restored hope and were the prelude to a rainy season which would yield 13.7 Bm3!

FIGURE 51: DAMS INFLOW AND RELEASE DURING THE 1991-1994 CRISIS



season	DS	WS	DS	WS	DS	WS	DS	WS
net inflow**	0.8	6.3	0.3	6.4	0.6	4.4	1.6	13.3
dams release	4.5	2.5	4.7	1.3	4.6	3.7	1.9	2.5
available stock*	4.7	1.0	4.8	0.2	5.3	1.3	2.0	1.7

Volumes in Bm3 * at beginning of season ** 2 dams inflow-evaporation loss

What lessons can be drawn from this extremely critical period ? This four year sequence combined low yearly inflow and excessive, although limited in absolute terms, releases in the dry-season. The 4.5 and 4.7 Bm3 released in the first two dry-seasons were oversized in that very little water was left for carry-over security at the end of the season. While this could have had no consequence with an abundant or even normal ensuing wet season (in 1992, for example, only 1.3 Bm3 was released in the wet season, without drastic shortages), the situation was critically compounded by a record low net inflow of 5 Bm3 in 1993, which meant that a large volume was needed to prop the main wet season crop. Indeed, even the 3.7 Bm3 released were insufficient to properly supply the flood-prone area (most of the "*drainage boxes"* were not filled up and suffered from water shortage: see Molle *et al.* 1999).

This shows how insufficient security storage at the end of the dry-season can be challenged by a subsequent "dry wet-season" in which dams must be called to rescue the situation. It reminds us that the Chao Phraya Irrigation Project was initially designed to provide supplemental irrigation in the WS and that the corresponding amount of water, in the driest years, may be anything but negligible. *In short, the crisis was due to an exceptional series of dry years which was not properly addressed, in particular by failing to curtail supply in the 1992 DS and by allowing stocks to near 0.5 Bm3.* If the 1993 WS had occurred one year earlier, the crisis would have reached an even higher magnitude.

What was the risk of a major crisis, including the possible disruption of supply to BMA? This can be assessed by looking at the really incompressible needs in the basin (see section 5.7.2). The situation is still manageable because floor DS water requirements are estimated at 2.5 Bm3, an amount of water which can be provided by the worst rainy season storage gain, together with some security carry-over storage in the dams. This calls for establishing a *security standard* (amount of water to be ensured at the end of the dry-season: tentatively 2 Bm3 (more on this later), in all cases more than was left in 1991 and 1992) but, *also,* indicates that this standard will have to be increased gradually, as the incompressible water requirements of the dry-season are bound to increase, in line with BMA expansion.

5.6.2 The year 1999 crisis

During the 1998 wet season, the year 1993 record of the lowest WS dams inflow ended up broken, with a total of only 4.2 Bm3. Although EGAT kept dams releases at a rather low level during this season (1.7 Bm3), the water stock on the 1st of January 1999 was only 3.89 Bm3. The situation was not as catastrophic as in 1994 but political pressure led to the enforcement of a Target Area of 1.7 million rai, which further translated in a cropping area of twice the target... Three months later, the available stock was only 1 Bm3 and supply had to be drastically discontinued.

Thanks to the cut in water releases at the end of March, a stock of 1.5 Bm3 was reached at the end of June 1999. The situation was not as bad as in 1991 and 1992 but was similar to that of mid-1993. In other words, it was highly sensitive to a bad wet-season in which supplemental irrigation needs would be almost as high as the net dams inflow, as in 1993 [75].

The abundant rainfall of the year 1999 allowed the situation to come back to normality, while the repetition of the preceding hydrological year would have created critical shortage in the following dry-season. This illustrates how politically motivated excessive dry-season release may endanger the system, even though the absence of negative consequences may have reinforced the feeling that the decision was right… As mentioned above, the increase of incompressible needs in the dry season will make such events potentially more dangerous if there is a failure to recognise that security stocks must be raised accordingly.

[75] In such a case, it must be noted that the flood-prone area will be the first to suffer from insufficient water in the wet-season. This means that favouring the over-planting of dry-season rice may be economically sounded but done at the expense of the already more precarious flood-prone systems, therefore increasing unfairness.

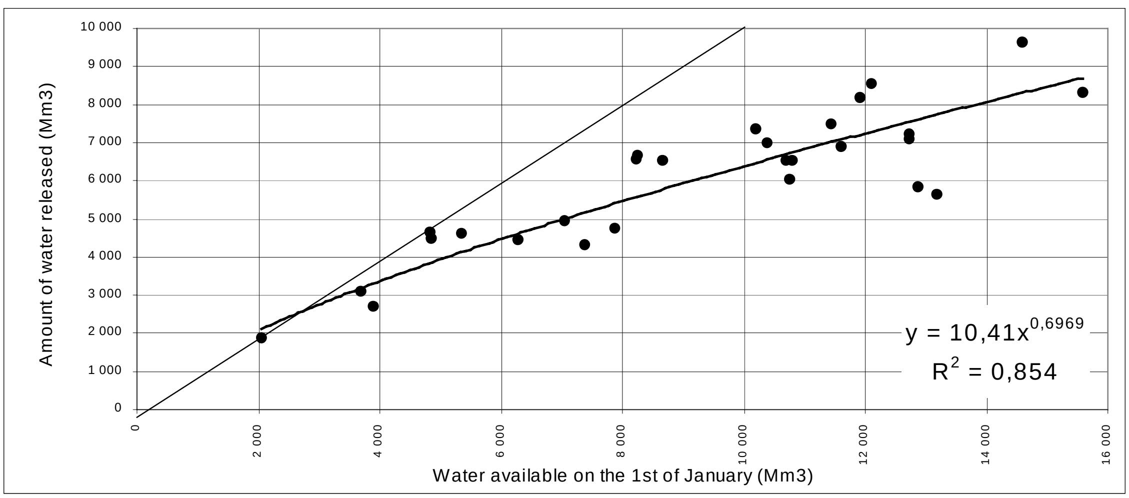
5.7 Total water release during the dry season: decision-making

The total amount of water to be released by the dams during the six month period running from January to June (or, as an equivalent, the security water stock to be kept at the end of it) is therefore the key parameter of the allocation process and of the inter-annual dam management. In normal years, this amount was historically around 6 or 7 Bm^3. The year 1996 set a record close to 10 billion, while two years of crisis have received less than 4 Bm^3 (1980 and 1994). This section looks at the way this amount has been determined in the past.

5.7.1 Relationships between the available volume (VA) and effective releases

It is interesting to first examine how the active storage volume on the 1st of January and the 1st of July relate to the amount of water effectively released during the dry-season. Figure 52 shows that higher active storage capacities tend to be associated with larger dams releases but that the relationship is not straightforward.

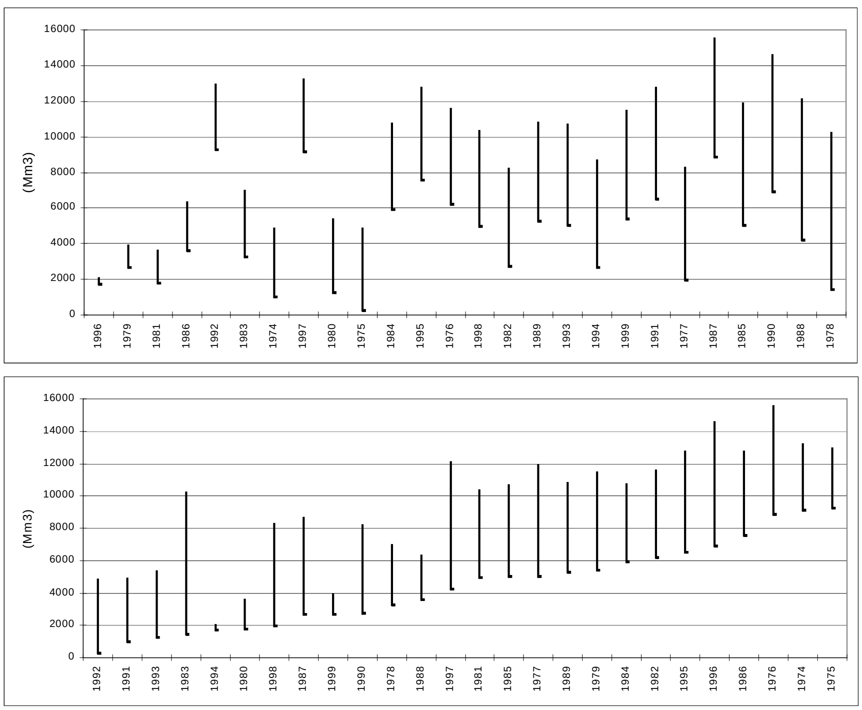
FIGURE 52 : AMOUNT OF WATER RELEASED DURING THE DRY SEASON, ACCORDING TO AVAILABLE WATER



There are several other ways to look at these relationships. We may also consider the magnitude of the drawdown of the dams active storage between the 1st of January and the 1st of July (this also considers dams inflow during the season). Figure 53 displays the corresponding values classified by magnitude and also shows the initial and final stored volumes. The lower figure shows these drawdowns classified according to the final volume (1st of July). The years 1974, 1975 and 1976 stand at the extreme right. In those years, Sirikit Dam had just been set into operation and water demand in the dry-season was still limited. It is less clear why, for example, the year 1986 only witnesses a release of 5 Bm3, while almost 8 Bm3 are still available at the end of the dry-season; or why the year 1983 starts with more than 10 Bm3 but releases so much water that only 1.4 Bm3 remains 6 months later, incurring in some high risk[76].

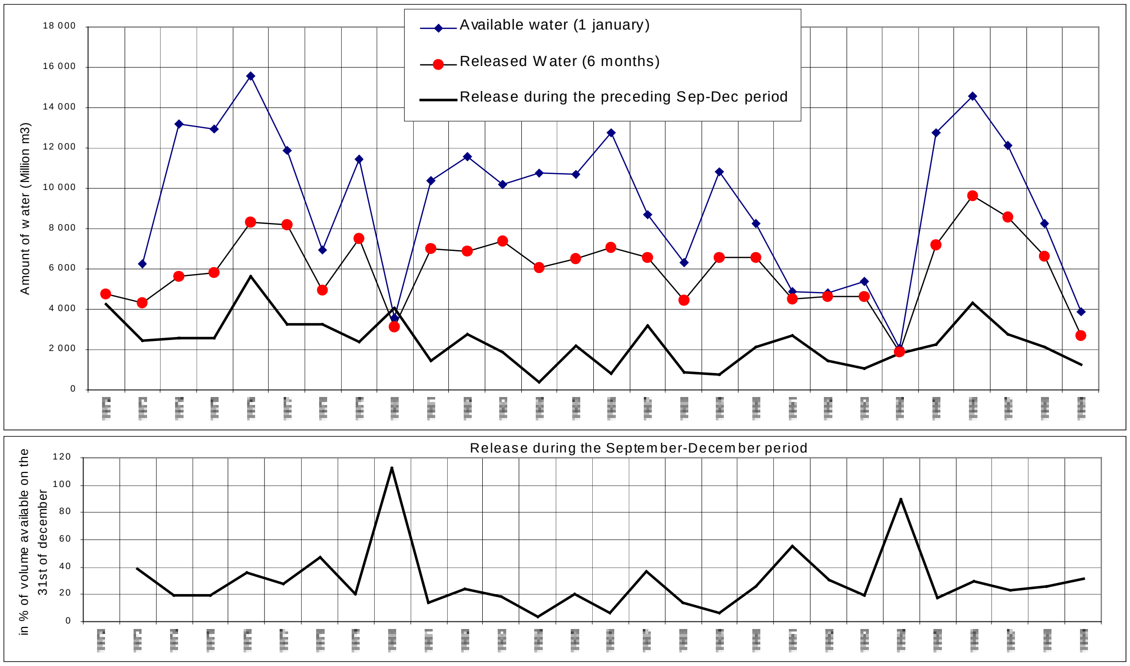
Figure 54 shows that the available water (over the dead storage volume) is in most years significantly higher than the amount of water released. This mirrors the will of interanual regulation and/or the limits of the diversion capacity. The lower (thicker) curve indicates the total amount of water released during the end of the rainy season (September to December). It shows that the 1980 crisis was partly generated by the undue release of 4 Bm^3 during these four months. This was also the case in 1991 and in 1994, as highlighted by the lower part of the figure which expresses this amount of water released in percentage of the remaining water on the first of January.

FIGURE 53: ACTIVE STORAGE DRAWDOWN BETWEEN THE 1ST OF JANUARY AND JULY, CLASSIFIED ACCORDING TO THE MAGNITUDE OF DRAWDOWN AND TO THE FINAL ACTIVE STORAGE



76 This high release was probably decided by EGAT based on some constraints or on unrestricted desire to use the dams for energy generation (with inadequate, if any, standards of security)

FIGURE 54: SEASONAL RELEASE COMPARED WITH AVAILABLE WATER (1972-1999)

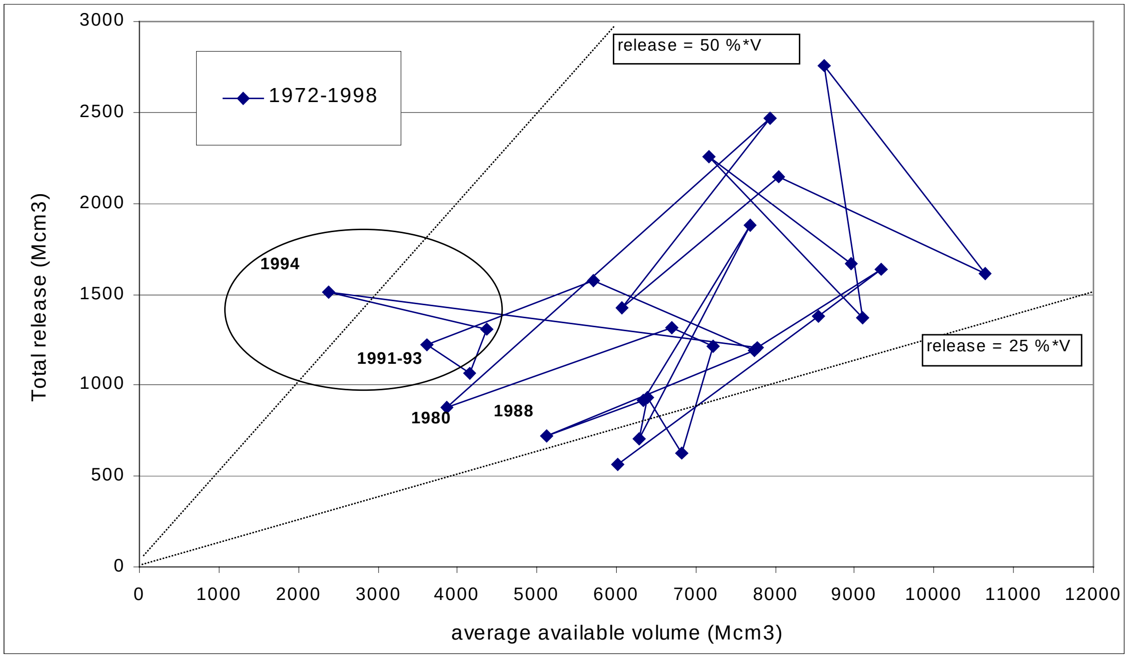


We would expect that years with lower water stocks (or limited inflow) during the second half of the rainy season are also years in which releases have been reduced, in order not to impact negatively on the water stock to be made available in the next dry-season. This does not appear to be the case because in such dry years – with little run-off in the basin - *the demand for complement irrigation is also higher* and the supply is more likely to be needed for agriculture, with little waste to the Chao Phraya River. This was particularly the case in the drought year of 1993: 1.1 Bm^3 were requested by RID during the sole month of August[77], a little bit less than the available water volume at that time !

If we limit ourselves to the last 3 months (October-December), we should nevertheless avoid most of these perturbation, as the 2 Bm^3 buffer of the flood-prone area is just full (see Molle *et al.* 1999) and the rainy season is both more abundant and at its end. Figure 55 shows that the releases during these three months are loosely related to the available volume: in some years (1983, 1985, 1998), these represent less than 25% of the (average) available volume during the 3 months (which is still considerable) ; in others (1991 to 1994), releases are still quite high, especially when expressed in percentage of the depleted water stocks (40-50%).

[77] Even though, the real demand of the 1993 wet season was much higher and not fully met, as shown by the insufficient filling up of the flood-prone area (Molle et al. 1999)

FIGURE 55: RELATIONSHIP BETWEEN THE AVERAGE STORED VOLUME AND DAMS RELEASES DURING THE OCTOBER-DECEMBER PERIOD (TOTAL OF 2 DAMS), FOR THE 1972-1998 PERIOD



From all these observations, it follows that the effective deliveries in the dry-season, although widely governed by the available stored water, does not follow a very strict rule. Significant variations are evidenced between the years, even for similar initial stocks of water. These can be attributed to the fact that the technical criteria is somewhat loose and that it is often challenged by more political decisions which reflect the intensity of demand, itself widely correlated to the price of rice. It also mirrors the fact that dam management was sometimes driven by considerations of energy generation rather than of agricultural use. Such political interventions or management logic, together with poor control of cropping calendars, which sometimes forces RID to supply water to crops already planted, in some instances lead to a very chaotic situation and high level of risk for the coming seasons.

There are several difficulties in determining the most opportune amount of water to be released in the dry-season. One aspect is whether the dams release (and the cropping area) is allowed to take totally different values every year, depending on the stock, or whether it is preferable to have a constant average target, from which will be departed only in exceptional years (very low active storage). Although this problem is classical, there are very few, if any, examples of policy favouring stability/equity instead of instability/efficiency. This point will be further investigated in Chapter 13.

5.7.2 What technical guideline for the determination of the Target Volume ?

It stands to reason that the determination of the target volume (TV), that is the total amount of water to be released during the January-June period, is a direct measure of the risk perceived and accepted. This risk is dependent upon the “intensity” of the demand (farmers and political pressure). If a low value of TV is chosen, then there will be enough water to regulate whatever situation may arise in the coming months. On the contrary, if most of the available water is released, the risk that water requirements will be high during the next wet-season is more serious, which generally goes together with a low run-off into the dams.

How can we assess the value of TV corresponding to a given level of risk ? This is a classical problem of optimising water resources allocation in a hydraulic system regulated by reservoirs. It is not the purpose of this study to engage in a modelling exercise aimed at answering such a question. Models give varied answers depending on their structure and on the series of hydrological input considered. Observed series are "real" but all hydrological events are unique and the model which shows no failure does not give sufficient statistical security. Stochastic models may do so but their output varies for each simulation and the law adopted may not represent accurately the reality, in particular the evolution of the hydrological regime.

We will limit ourselves here to sketching out the main constraints of inter-annual regulation in the Chao Phraya Basin, based on a simple partition of the year in two periods (the dry and wet seasons[78]) and on crude water balances.

5.7.2.1 Dry season

The dry season is characterised by less hydrological variability and less uncertainty. Dry-season cropping is seen as supplemental and it is accepted that it be almost zeroed if circumstances demand it. In practice, this is not feasible as water will have to be supplied to the West Bank (with its early dry-season crop), and most probably to some areas where the expansion of some early cropping cannot be totally controlled (upper delta). Run-off in the dry-season is not necessarily negligible but still secondary: the median values (those exceeded one year out of two) of the dams net inflow and of side-flows are 1.2 and 1.0 Bm3 but the deciles (values ensured 9 years out of 10) are only 0.6 and 0.5 Bm3. However, when sideflows occur, usually in May or June, they may not be totally tapped and some loss may occur, and they also come too late to fully contribute to the dry-season supply.

The minimum water requirements in the dry season are comprised of 350 Mm3 for controlling salt water intrusion, 750 Mm3 for Bangkok and a less accurate amount for "consumption" in the middle basin and the delta set by RID at around 700 Mm3[79]. This gives a total of 1.7 Bm3. Approximately 1.1 Bm3 of this floor value may be provided (9 years out of 10) by dam inflows and sideflows, leaving a minimum 0.6 Bm3 to be supplied by the dam stocks. This arithmetic, however, does not work because most of these natural flows occur in the late dry-season. Dams must ensure supply in most of the season.

[78] This is simplified by the fact that these two hydrological seasons can roughly be identified to the two semesters.

[79] Little of this water is consumed as the necessity to ensure some intermittent flow in waterways incurs high infiltration loss.

Historical series show, perhaps more realistically, that the minimum dams release of 1.9 Bm3 occurred in the 1994 dry-season (when damage from saline intrusion was experienced); the decile value is much higher (4 Bm3). *It seems fair to consider a minimum value of 2.5-3 Bm3*, which accounts for the increase in non-agricultural use since that year and for the necessity to avoid saline intrusion. With some late contribution from sideflows, this amount of water can be considered to meet, under the current conditions, the minimum flow requirements in the Chao Phraya River and in the hydraulic network. With a dams net inflow (probability 0.1) at 0.6 Bm3, *the minimum net loss in active storage is around 2-2.5 Bm3*. It can be noted that with the current 0.75 Bm3 contribution of the Chao Phraya River to BMA's needs expected to double or triple in the next 15 years[80], this floor value will have to be incremented accordingly during the same time span.

5.7.2.2 Rainy season

The rainy season is more uncertain. Inflow in the dams, side-flows in the middle reaches of the basin and rainfall in the delta may combine in very different proportions and greatly vary from year to year. The delta may, in some years, widely depend on irrigation supply from the reservoirs whereas, in other years, it may struggle to get rid of excess water, while dams releases are limited. Minimum requirements are more difficult to assess.

While rice cropping is considered as an adjustable complement in the dry-season, the main rice crop is still regarded as the main income of rice farmers and, as such, receives strong support and priority. How much is needed for that crop during the last 6 months of the year greatly varies according to the year. Figure 56 shows that sideflows offset diversion requirements *on average terms*. However, if we consider a year with low sideflows (the monthly values ensured 9 years out of 10), and with high diversion requirements (the average of those observed in the 5 driest years[81]), we see that there is a sheer imbalance, in particular in July, August and November. This reasoning, however, deals with monthly values; the wet-season inflow of probability 0.9 (calculated as 6.7 Bm3) is higher than the sum of the 6 monthly inflows of probability 0.9. As for the water diverted in Chai Nat, the 6 month total values observed in these 5 driest years average 7.5 Bm3 (against 6.8 Bm3 for the median year). Thus, in a dry year, but even in a normal year, water requirements in the wet season appear to be very significant.

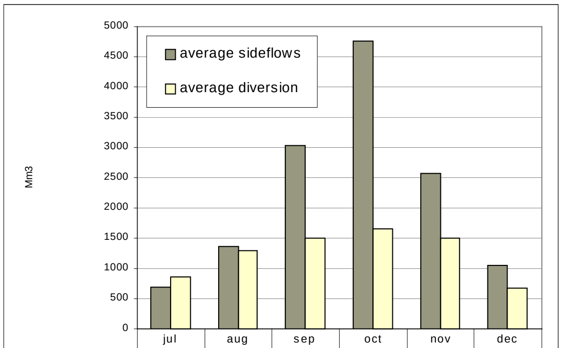
In addition to these diversion requirements, a flow must be maintained in the Chao Phraya River. Historical data show that in a median year this flow amounts to 4.7 Bm3. It is, of course, mostly made of uncontrolled excess sideflows and no dam water should be needed. In a dry year, it decreases down to 2.7 Bm3 (a minimum value of 1.6 Bm3 was observed in 1993). However, Figure 56 shows that in all months with a decile value of sideflows, water from the dam must also be added to natural sideflows in order to meet the diversion

[80] Under an hypothesis of 3% or 5% annual growth for BMA and other non-agricultural uses (see Chapter 1).

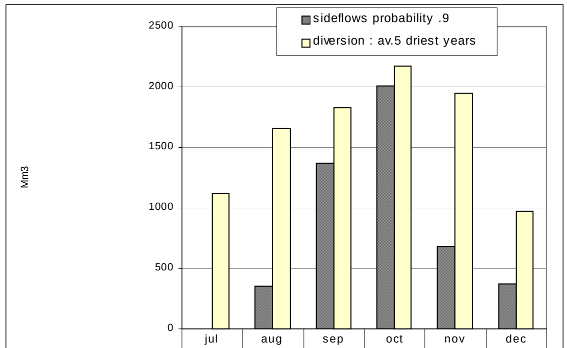
[81] It would be erroneous to consider the diverted low with an occurrence of one year out of 10 (6058 Mm3) because in excess years the irrigation network is also used to relieve the Chao Phraya River. We preferred to consider here the average of the observed values in the 5 driest years (those with the lowest release at Chai Nat Dam) : 7500 Mm3.

requirements observed in a dry year. This means that dam water must also be supplied to the Chao Phraya River at Chai Nat Dam. This is more likely to be the case in July, August, November or December and the dams must compensate for this with extra releases. Historical observations of the 6 driest years show that, on the average, dams had to supply 4.2 Bm3 during the wet season (against 3.8 Bm3 in a median year).

FIGURE 56: COMPARISON OF SIDEFLOWS AND DIVERSION NEEDS IN THE RAINY SEASON (1972-99)



	jul	aug	sep	oct	nov	dec
average sideflows	682	1358	3030	4751	2569	1043
average diversion	866	1287	1500	1663	1499	677



	jul	aug	sep	oct	nov	dec
sideflows probability .9	0	352	1369	2007	678	372
diversion : av.5 driest years	1123	1653	1829	2176	1952	973

5.7.2.3 <u>Annual balances and carryover</u>

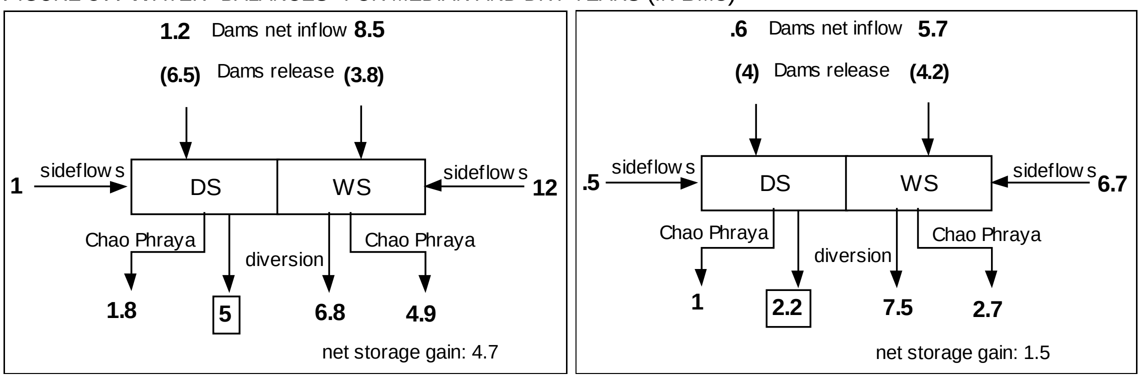
The order of magnitude of the components of the water balance exposed above provide a few simple guidelines and thumb rules. These balances are imperfect, as considering a same frequency of occurrence for all terms cannot lead to an exact balance (Figure 57), but they suffice for the purpose of illustrating the magnitude of the different terms and the risk generated by dry years.

In a median year (Figure 57, left), the Chao Phraya system receives (dams inflow+sideflow) around 20.5 Bm3 of water in the wet season, which are partly used, released to the sea or stored in the dams (net gain of 4.7 Bm3). In the dry season, there is a median inflow+sideflow of 2.2 Bm3, *which makes an overall yearly median surplus of 5.9 Bm3, to be released during the dry season.* This is slightly less than the median value of the observed dams release, about 6.5 Bm3. This means that what can be stored in the dams in the wet season is close to what is released in the dry-season, emphasising the regulative role of the dams.

In a dry year (with a return probability of 1/10), however, much imbalance is deemed to occur (Figure 57, right). Water requirements in the wet season are on the rise and, as sideflows amount to no more than 6.7 Bm3, the dams must slightly increase their supplemental role (4.2 Bm3) to cover an incremented demand in the irrigated areas. With such a release, *only 1.5 Bm3 are stored in the dams during that season*[82] ! With a lower water stock on the first of January, dry-season supplies need to be curtailed.

The amount of dam water released in the dry-season ensured 9 years out of 10 is around 4 Bm3, while these are compensated by a net dams inflow of only 0.6 Bm3 (Figure 57, right). This shows that ensuring such a (low) supply entails a net loss in active storage of, say, 3 Bm3 (between 2.8 and 3.6 Bm3, for probabilities of dam inflow between 0.5 and 0.1). Considering a coming “dry wet-season” of probability 0.1 [1.5 of net gain] and willing to ensure the above level of supply [of probability 0.1: net loss of 2.5] during the following dry-season, demands that there should be an active storage of at least 1.5 Bm3 at the end of a given dry-season. This value must be doubled if we want to deal with two consecutive dry years.

FIGURE 57: WATER “BALANCES” FOR MEDIAN AND DRY YEARS (IN BM3)



DS = dry season; WS = wets season

If things get worse (longer draught period, exceptionally dry years), the dams releases in the dry season must be drastically curtailed to a floor level estimated earlier at 2.5-3 Bm3. With a dams net inflow of only 0.6 Bm3, this means that there will be a deficit of at least 1.9 Bm3, rounded up to 2 Bm3. This is still above the 0.1 probability value of the net storage gain in the rainy season (1.5 Bm3), at least under present management practices.

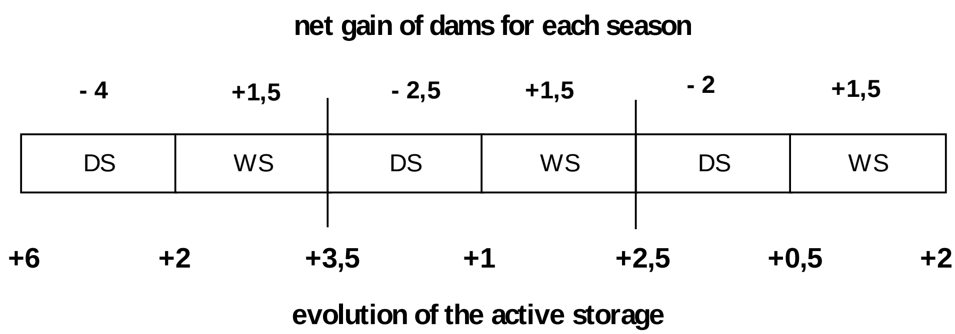
The example of the 1991-1994 period discussed earlier is very instructive on how an exceptional drought can be tackled by limiting dry-season releases, but it also serves to warn us that things were not far from jumping out of control. Figure 58 shows an example of sequence of three years which could lead to end a year with 2 Bm3 of active storage, the absolute crisis threshold. In the first dry season, starting with an average-low stock of 6 Bm3, water is released so that the stock is only 2 Bm3 at the onset of the following rainy season (a value observed 1 year out of 4). The wet season is poor (probability 0.1) and the net gain in dams is only 1.5 Bm3, raising the active storage at 3.5 Bm3. Severe cuts are imposed in the next dry-season but a net loss of 2.5 Bm3 is recorded. A second dry rainy-season (+ 1.5 Bm3) makes the stock at the end of the year rise to 2.5 Bm3. Absolute restrictions limit loss

[82] For historical series of net gain in water storage capacity during the rainy season, see Annexe 17. It can be seen that only in one year out of two was the net gain in stored water over 4 Bm3. The year 1979 is conspicuous because of its negative balance (over-release).

in the ensuing dry-season at its minimum of 2 Bm3, but a third consecutive poor rainy season leads to a dramatic end-of-year stock of 2 Bm3. This example furthers the two periods of crises examined earlier and emphasises again:

1. the crucial impact of the security stock kept at the end of the dry-season;
2. the way poor wet-seasons can fail to rebuild stocks;
3. how the dry-season supplies can (must) be reduced in order to avoid zeroing the stock;
4. how the rising incompressible needs of the dry-season will limit this latter possibility, thus raising the recommended security stock values.

FIGURE 58: EXAMPLE OF SEQUENCE OF SEASONS WITH LOW DAM INFLOW



In fact, the most worrying aspect of this water accounting is that prospects for the future are gloomy. Sheer deficits are all the more likely to appear in cases of :

- Forced outages of EGAT plants, demanding extra releases.
- Exceptional dry years, which tend to come up with growing frequency because of climatic vagaries and because of the growing water abstraction upstream of the dams.
- The continuous growth of inelastic water requirements, in particular for BMA, in the near future.

In short, with dams inflow cut down by, say, another 1 Bm3 in the next two decades, and with an incompressible demand rising by half this amount, the probability of crisis will increase if it is failed to recognise that technical security standards must be respected; this will remain true whatever savings and improved management are achieved, although these may help mitigate the risk.

6 Irrigation and energy generation: issues of dam management

6.1 EGAT and RID's management logics

The logics of dam management for irrigation and energy generation are different in some respects but not totally antagonist. RID wants water to be delivered in the dry-season AND in the rainy season – most especially the months of July, August and September - , when and if the rainfall pattern dictates that dams water be used to meet specific requirements. These requirements will depend on local rainfall but, above all, on the amount of side-flows generated in the basin downstream of the dams and upstream of the main irrigated areas. Contrarily to common wisdom, this latter requirement is by no mean small and, should sideflows be insufficient, large amounts of water will have to be released by the dams during this period. In years of abundant runoff, water releases are also commanded by concerns of flood control and dam safety, aiming at maintaining a basic control capacity in the dams. Ideally, water should be stored during the rainy season as much as possible and released during drier months.

EGAT, on the other hand, is managing a wide diversity of energy generation plants, the largest part of which is thermal based, with hydropower making approximately 8% of the total installed capacity (Figure 86). All the sources are not equivalent in terms of cost and flexibility. Hydropower generation is most especially appreciated for its cheaper production cost and for the facility of switching it on and off at will, which is not conveniently feasible with thermal plants. It is therefore used to cope with peak demands (generally during three periods in a given day: 9 to 11:00 a.m; 14:00 to 16:00, and 18:00 to 20:30) and with outages or emergency shut-down of thermal plants. These are rather common and the dam turbines are frequently solicited to "fill up the blanks". These flexibility needs do not show any significant variation along a given year and EGAT's needs are therefore rather "season-insensitive". On the other hand, absolute energy requirements are higher during the dry-season and this matches irrigation demand too.

Should we fail to consider this aspect of scheduling (peaks) and flexibility, we would readily get to the conclusion that the dams should be managed according to RID's logic: in fact, except for a negligible share of water going through the spillways, the amount of water going through the turbines remains basically unchanged in the long run, as all of it (minus the loss) is sooner or later eventually released. The total amount of power generated is therefore unchanged, but for slight differences in the average head in the turbine: keeping more water in the rainy season leads to a higher average water stock and corresponding head in the generators. On the other hand, loss by evaporation is increased, as the water body exposed to the sun is larger. On the whole, energy gains or loss derived from changes in management are at best of the second order and, in any case, not significant enough to govern, or even influence, the policy and schedule of water allocation and release.

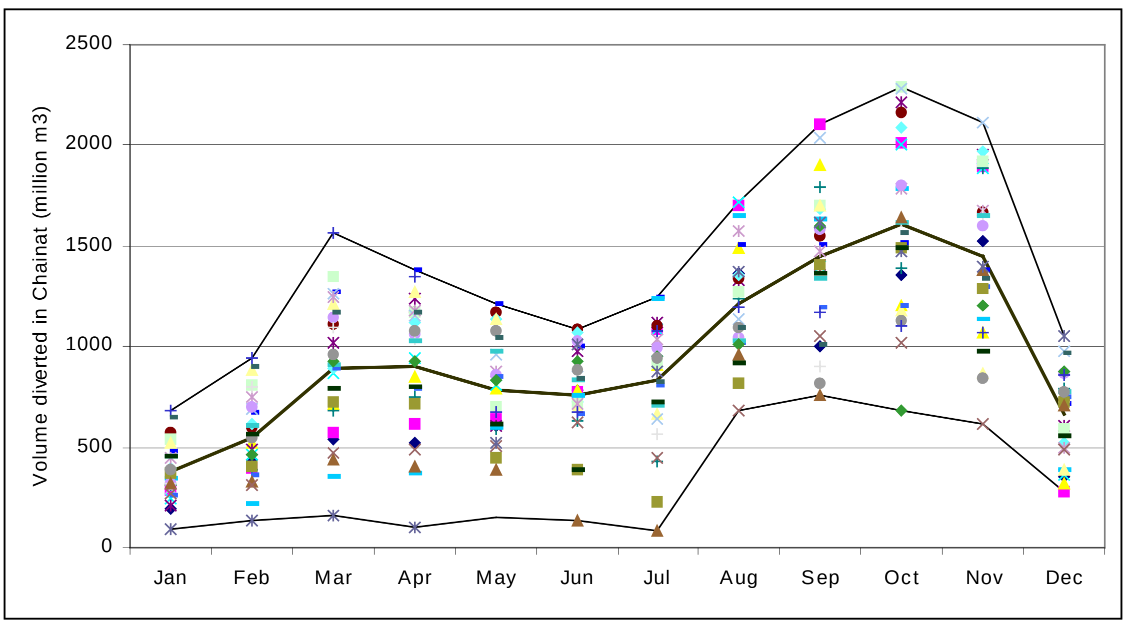
We will here explore whether and how much water is eventually lost (for irrigation) because of the EGAT's driven management. Later, in Chapter 10, we will examine the feasibility and the costs of shifting towards a RID's driven management of the dams.

6.2 Historical monthly dam releases

A first look at the historical data of dams release (Bhumipol and Sirikit) and dam diversion (Chai Nat) will allow to set the order of magnitude of their monthly values.

Figure 59 shows that water diverted upstream of Chai Nat Dam for irrigation purpose is higher in the rainy season: this is, of course, due to the fact that water supplies are sufficient to ensure full supply in that season, but also because all the waterways are used to spread water in the delta in excess years (through overloading of canals, when flows exceed the capacity of Chai Nat Dam); in addition they are used to channel an average of 1 Bm^3 of water to the deep-water rice area (Molle *et al.*, 1999). It also appears that 1.5 Bm^3 can be diverted in one month, while the overloading of canals can raise this value to over 2 Bm^3/month. The theoretical maximum diversion capacity is around 1,000 cms, or 2.5 Bm^3/month. The year 1994 provides the first four values of the minimum curve, and the year 1996 the first four of the maximum curve.

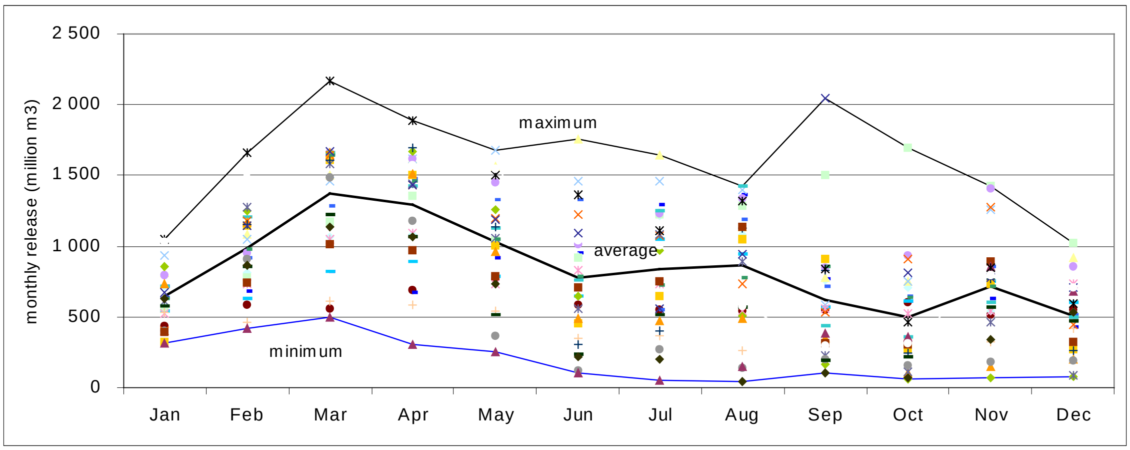
FIGURE 59: MONTHLY HISTORICAL VALUES OF THE AMOUNT OF WATER DIVERTED AT CHAI NAT



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Tot.DS
Average	377	548	890	904	779	755	830	1208	1450	1606	1451	665	11570	4253
Maximum	685	942	1564	1379	1213	1083	1243	1720	2107	2290	2110	1051	14436	6017
Minimum	96	132	156	104	155	137	82	683	756	680	616	281	6971	1657

Releases from the two storage dams are plotted in Figure 60. In contrast with the preceding chart, it can be seen that releases are higher in the dry-season, with a peak in March. However, the two dams also release significant amounts during the rainy season (on average always over 500 million m^3/month). This reminds us that the rainy season must also be supplemented with irrigation water (in fact the first objective attached to the initial investment of the Greater Chao Phraya Project).

FIGURE 60: MONTHLY HISTORICAL VALUES OF DAM RELEASE (TOTAL OF TWO DAMS)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Average	645	985	1 368	1 294	1 029	781	841	863	620	499	715	509	9 917
Maximum	1 049	1 664	2 169	1 891	1 674	1 756	1 642	1 428	2 044	1 698	1 427	1 026	14 824
Minimum	313	423	495	305	253	105	53	47	105	59	73	79	4 373

6.3 Dams management and water loss

Assessing how much water has been unused, or lost to the sea (the discharge needed to control salinity intrusion and water pollution being already taken into account) cannot be estimated directly from releases at Chai Nat Dam. This is because the flow reaching Chai Nat is composed of both controlled (dam releases) and uncontrolled flows (natural sideflows). The picture gets clearer only in the dry season, when sideflows are generally negligible, with the exception of periods with punctual but heavy rainfall (as is common between May and June). The next section is looking at the fit between RID's demand and dams releases while the following one attempts to categorise excess water releases at Chai Nat Dam according to their causes.

6.3.1 Dams release vs. RID's demand

We have at our disposal the weekly water demands formulated each week to EGAT by RID. Six years data at the week level were provided by RID, while EGAT officers have kept record of this demand, aggregated by month[83] since 1984. We may therefore compare the (adjusted) RID demands and the effective releases by EGAT.

Figure 61 first displays these values corresponding to the last 6 dry-seasons. It can be seen that the fit between the two curves is usually satisfactory. Exceptions to this rule appear in the late 1995, 1996 and 1999 dry-seasons. The reasons for the latter has been explained earlier but the reason for the excess releases of 1995 and 1996 is not clear. Rainfall seems normal for the corresponding months and it can be hypothesised that significant staggered (and late) rice planting (after 4 years of water shortage) have raised the water demand in this period, prompting a hike in supply. The over-release can also be due to the sole initiative of EGAT, and due to energy generation concerns.

FIGURE 61: DRY-SEASON WEEKLY REQUESTS AND EFFECTIVE DAMS RELEASE (1995-2000) (SOURCE RID)

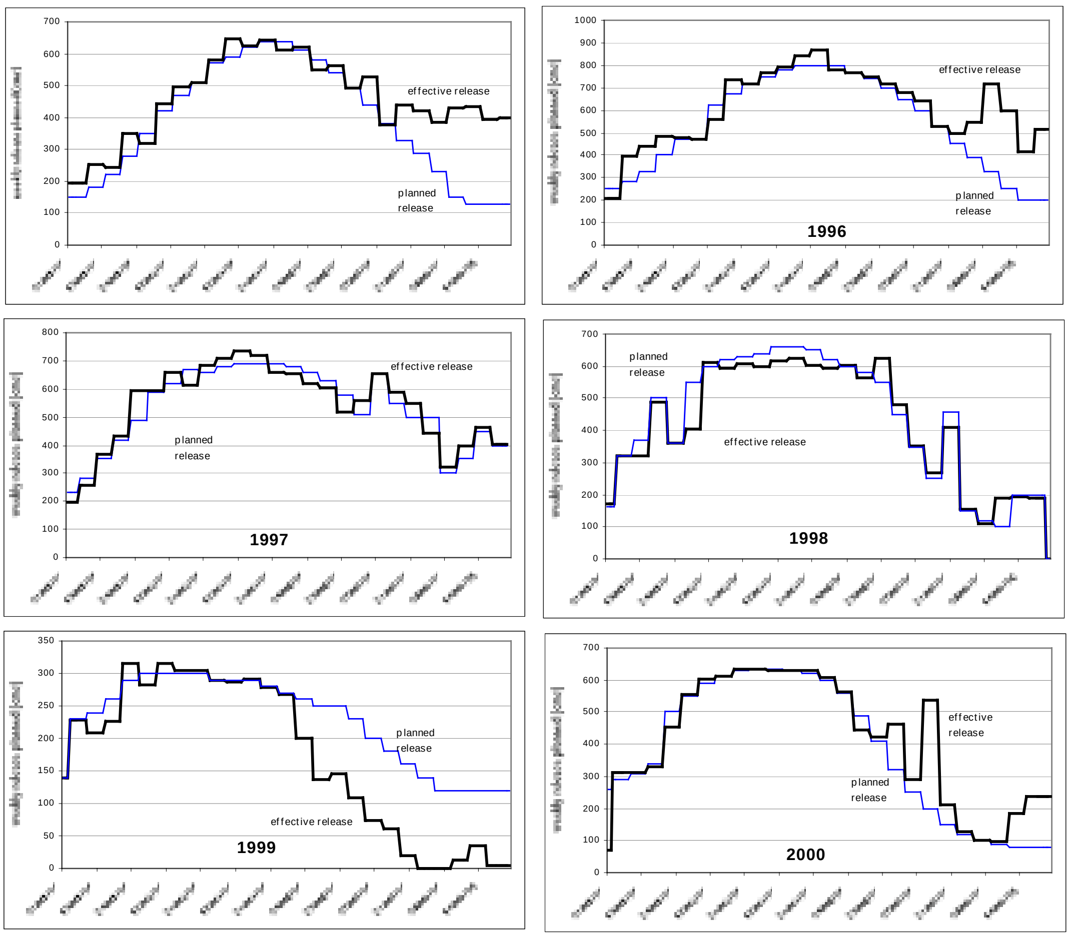


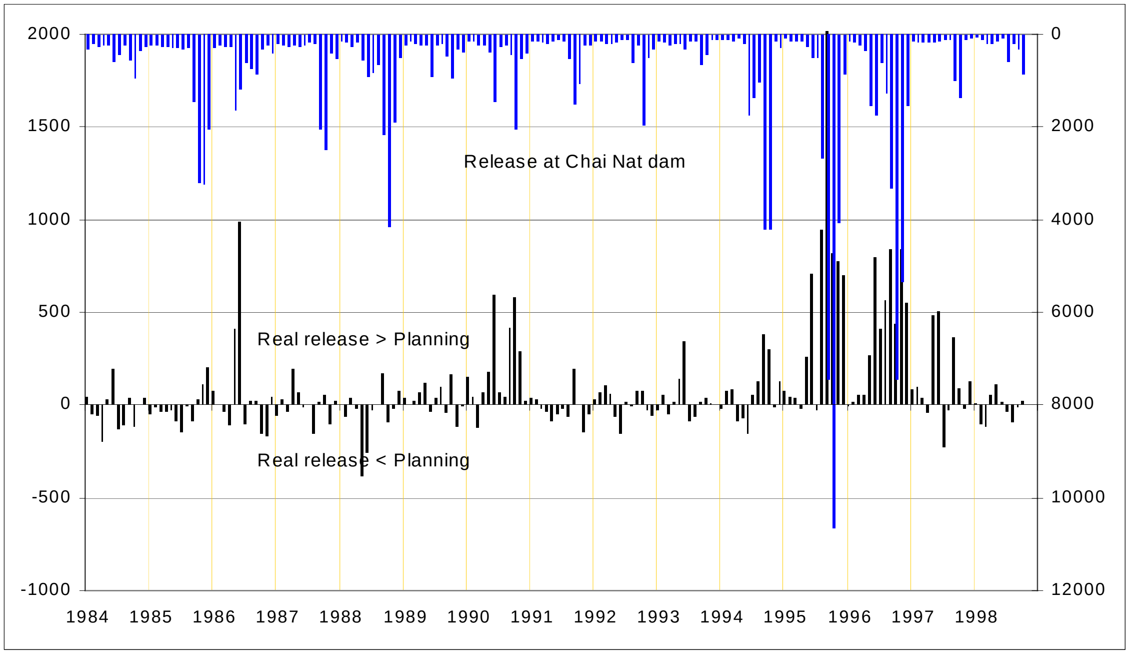
Figure 62 now plots the values of the difference between the adjusted request and the effective *monthly* dams releases for the 1984-1998 period (both dry and rainy seasons). It shows that it is more common to have effective releases higher than requests, although the opposite also occurs. If we filter these values by 10% (i.e. only the differences greater than

83 with ad-hoc interpolation for the weeks straddling two months.

10% of the demand are kept), we find that 41% of the months remain. For filter values of 15, 20 and 30% respectively, the remaining percentages of the 182 months considered here are 31%, 25% and 18% respectively.

Four years show considerable over-release: 1986, 1990, 1995 and 1996. The first two cases seem to correspond to emergency releases by EGAT for energy generation. Most of the year 1995 over-releases can be attributed to the controlling of high water levels in the Sirikit Dam. On the other hand, the huge loss corresponding to the 1996 rainy season (2.5 Bm^3) can only be explained by emergency requirements from EGAT due to power plant outage, or deliberate policy. (which is suggested by the fact that over-releases occurred during 5 months).

FIGURE 62: DIFFERENCE BETWEEN PLANNED AND EFFECTIVE TWO-DAM RELEASES (MILLION M3)



Examining the impact of such discrepancies on water waste/saving, we can distinguish 4 cases:

- *Case 1*: RID receives *less* than requested and no water is wasted to the Chao Phraya River at Chai Nat (i.e the amount of water released at the dam is less than 200 million m^3). All the water is used and we may assume that there is a *water shortage*, as the demand is not being met.

- *Case 2*: RID receives *more* than requested but makes full use of it and no water is wasted to the Chao Phraya River at Chai Nat. There is *no water waste*.

- *Case 3*: RID receives *less* than requested, but is also found to release water at Chai Nat Dam in excess of the minimum threshold[84]. This means that the demand was poorly assessed, or that rainfall have affected it, and that by reducing water releases EGAT has contributed to *water saving* (irrespective of whether this has been done on purpose or not).

- *Case 4*: RID receives *more* than requested, and may take advantage from part of the excess or not, *but* is also found to release water at Chai Nat Dam in excess. Demand has been poorly assessed and/or the mismatch has been aggravated by excess release from EGAT. *Water is wasted*.

These four cases are specified over the period from January 1984 to October 1998 (182 months). These releases account for the flexibility granted to EGAT to exceed RID's demand in accordance with its needs or convenience. There is currently no clear standard defining the limits within which EGAT may operate and exercise its tacit "right".

Table 11 provides estimated occurrences for filters of 10 and 20%. It shows that the first and second cases are rather uncommon, as EGAT follows more carefully the RID requests in the dry season or, more generally, in situations when water releases at Chai Nat are maintained at the lowest.

Cases of water saving (case 3) are slightly more common; they occur in both seasons and correspond to *average* yearly values ranging from 100 to 180 million m^3, depending on the filter considered. These water savings are in fact concentrated in certain years in which they amount to several hundred million m^3; they are nevertheless rather limited.

Case 4 is by far the most common, especially during the rainy season. Water released in excess by EGAT does not correspond to any irrigation demand and is wasted to the Chao Phraya River: this over-release corresponds to more than 1 Bm^3/year, or 10% of the yearly inflow, and is therefore significant. A closer look at the detail of these losses year by year reveals that these have been particularly huge in 1986 (almost 1 Bm^3 during the sole month of June !), in 1990 and 1995-1996. As shown earlier these two years show appalling releases of 5.6 and 4.7 Bm^3 (in the sole wet season) which cannot be easily explained (for 1996). If we disregard these two years, the yearly average loss corresponding to case 4 is around 0.5 Bm^3.

Whether these over-releases are decided in instances when the actual stored water is rather high is shown on Figure 63, which finds no evidence that releases over, say, 500 Mm^3 are decided when water stocks are plentiful. On the contrary, there are a few quite high releases in times in which the active water stock is less than 5 Bm^3.

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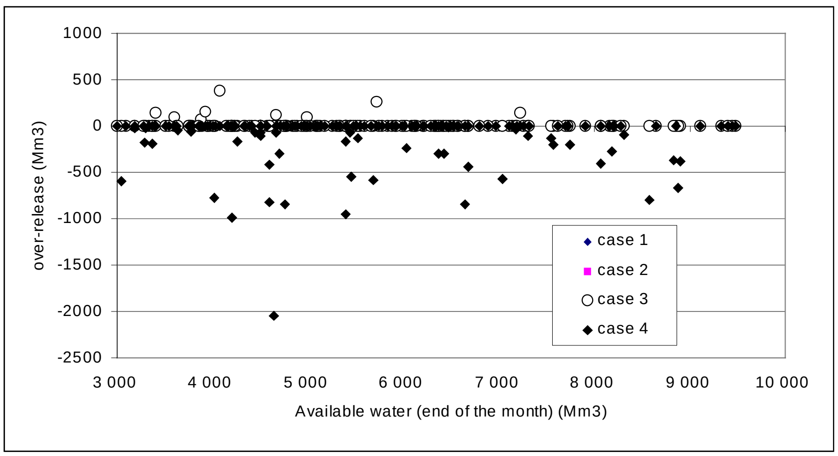
[84] This threshold of 200 Mm3 corresponds to 76 cms and is rather generous, in order to get conservative estimates of loss.

These releases account for the flexibility granted to EGAT to exceed RID's demand in accordance with its needs or convenience. There is currently no clear standard defining the limits within which EGAT may operate and exercise its tacit "right".

TABLE 11: ANALYSIS OF DISCREPANCIES BETWEEN PLANNED AND EFFECTIVE DAMS WATER RELEASES

Situation:	Unit	Filter 10%		Filter 20%	
		Dry season	Wet season	Dry season	Wet season
1 RID receives less water than requested, no loss to the Chao Phraya River **(shortage)**	Nb. of months	4	2	2	0
2 RID receives more water than requested, no loss to the Chao Phraya River **(RID increases its use)**	Nb. of months	7	1	5	1
3 RID receives less water than requested, but there is loss to the Chao Phraya River **(water saving)**	Nb. of months	7	15	4	5
	Mm³/year (average)	79	102	58	39
4 RID receives more water than requested, but there is loss to the Chao Phraya River **(water waste)**	Nb. of months	16	37	12	17
	Mm³/year (average)	-277	-853	-268	-839

FIGURE 63: OVER-RELEASE VS. AVAILABLE WATER IN THE TWO DAMS (MONTHLY VALUES, 1984-98)



6.3.2 Dams releases *vs.* Chai Nat Dam release to the Chao Phraya River

The preceding section has compared the planned and real allocation and interpreted differences as possible loss. However, there is no certainty that planned values were corresponding to the real needs. Effective mismatch between dam releases and water use can also, and more effectively, be traced by looking at whether water is released in excess at Chai Nat Dam (that is to say *in excess of* downstream minimum requirements for BMA and salinity control) but, departing from the preceding section, *independently* of the planned values. This is unlikely to happen in the dry season, as the available water is eagerly awaited by farmers along the canals, but, rather, during the rainy season. Such possible water losses, however, may be both controlled or uncontrolled. The different situations can be broken down into 6 cases, as described below and sketched out in Figure 64.

Situation 1: In the dry season, the system is supply oriented. A given amount of water is released by the two dams (D), based on the stored volume. Irrigation (here including all water uses along canals: Ir) adapts to the water supply and vice versa, but with much less elasticity in the second case. No water is lost at Chai Nat[85].

Situation 2: if, in the situation just described, water is released at Chai Nat in excess of a given minimum threshold (rather generously chosen here as 80 cms[86]), then the difference is computed as a *controlled* water loss (to the sea) for the system. This is shown in red (CP) (case 1).

Situation 3: in the March-June period approximately (the later part of the dry season and early rainy season), some significant natural sideflows may occur in case of rainfall. If there is a situation of water shortage, then sideflows are added and incorporated to the deliveries. In other cases, this water is taken advantage of to reduce dam deliveries[87]. There is no loss.

Situation 4: Because, for some reason, deliveries have not been reduced, the inflow at Chai Nat is found to be exceeding demand (or the level of supply that RID wants to maintain to avoid triggering overcropping). In that case, water must be passed on to the Chao Phraya River, resulting in *controlled* loss (case 2).

Situation 5: In the rainy season, sideflows may amount to huge discharges which exceed the needs and/or the diversion capacity at Chai Nat. The excess water is passed on to the Chao Phraya River as an *uncontrolled* loss.

Situation 6: if, in such a situation, water is also released from the dams, this release will accrue to the excess water and will not be used. If water is released because of dam safety reasons and/or because of the will to limit the probability of unproductive spill (no energy generated), then these releases are not considered as loss. If this is not the case, all amounts released *in excess* of the minimum requirements for ecological preservation and domestic use downstream of the two dams (1-2 million m3/day/dam) are considered as *controlled* loss (case 3).

Other situations: Without records of forced outages of EGAT's plants and of how much water had to be released to cope with them, it is not possible to estimate how much of these losses must be attributed to these emergency cases.

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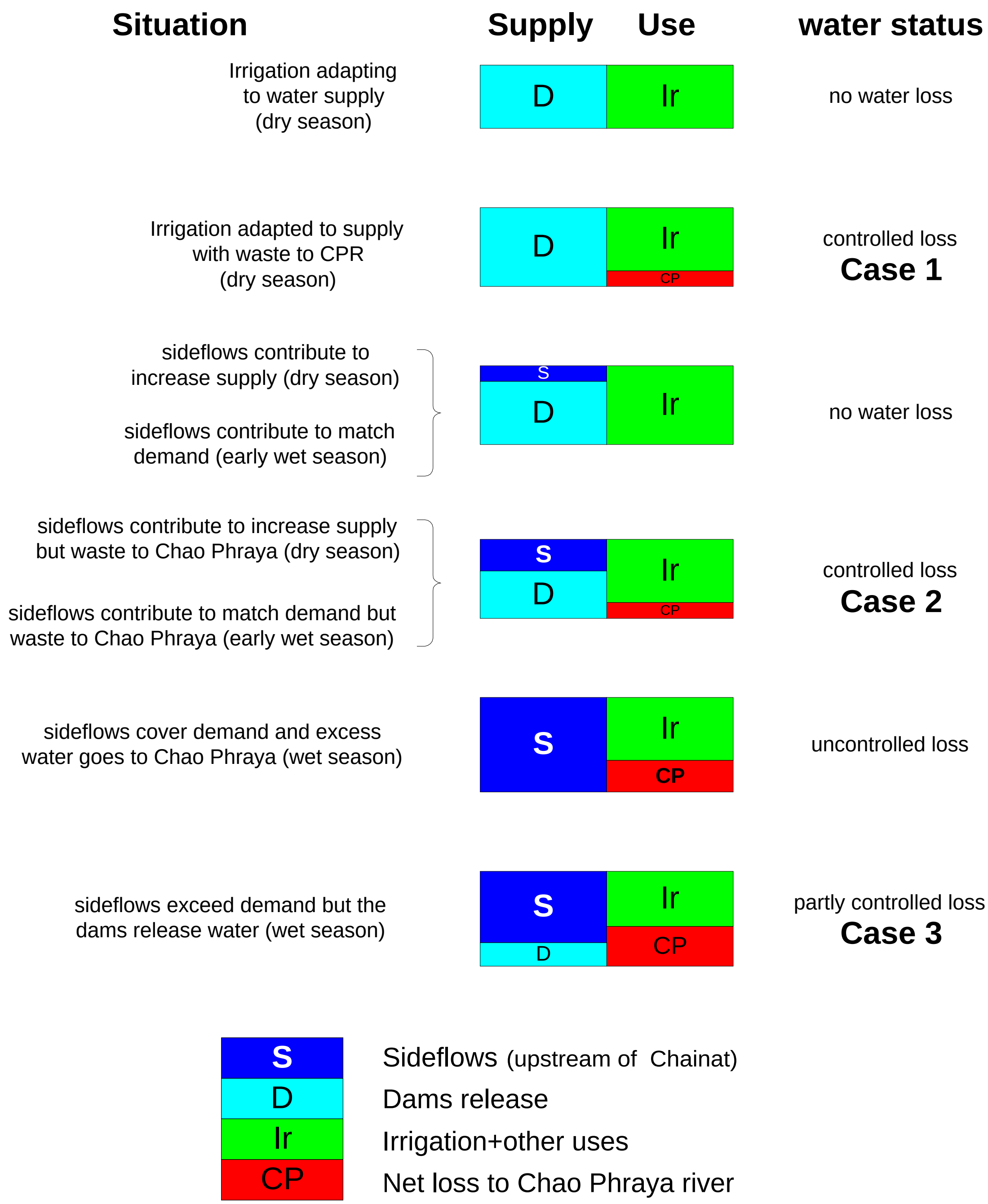
85 In fact, there is often insufficient release at Chai Nat Dam, sometimes provoking damage by salinity intrusion or disturbance in navigation.

86 With the exception of January where 60 cms are sufficient (because of the emptying of the flood-prone area). The threshold value for the wet-season is taken as 60 cms.

87 Especially if the deliveries in the first part of the dry-season have exceeded target values.

FIGURE 64: SITUATIONS IN WHICH WATER LOSS TO THE SEA MAY OCCUR



Controlled releases triggered for safety reasons or by a situation in which possible future non-productive spill must be avoided - the water level in one of the dams is above the upper rule curve - can be estimated based on the monthly values of this curve. This situation can be shown to be quite rare: it occurred only once, in 1975, for the Bhumipol Dam (together with some spill) and five times for the Sirikit Dam (in 1974, 1975, 1981, 1995 and 2000).

This description may imperfectly represent all the possible situations but it nevertheless allows a categorisation of the different types of loss and an evaluation of their respective shares within the overall *loss*. These can be tentatively estimated based on monthly values of the water balance in the basin.

Figure 65 first provides the monthly averages of the three kinds of loss, together with spill-control releases, for the 1972-1999 period. As expected, losses corresponding to case 1 concentrate in the first five months of the year. Case 2 losses dominate in the June-August period, while Case 3 losses are paramount in the September-December period. These losses are quite considerable in quantitative terms, especially in the rainy season. Figure 66 reveals a complementary picture of the yearly total loss along the 1972-1999 period. We can observe: 1) a striking variability of the yearly total water loss; 2) a decline of the total loss, suggesting that a decreasing inflow paralleled by a growing demand have fostered a stricter management of the dams; 3) that the decline affects the three types of loss.

In quantitative terms, the total average yearly loss amounts to 2.9 Bm^3, or 30% of the average inflow in the two dams, including releases for spill control together with effective spill which amount to 380 million m^3. Case 1 is rather limited in magnitude (327 Mm^3), while Case 2 and Case 3 losses have similar magnitudes (1.00 and 1.25 Bm^3 per year on average). One, however, must be careful in considering such average values. They include the 1970s in which dam management was openly directed towards contributing to the generation of energy, hence the high value of “lost” water (lost for irrigation but not for energy generation).

As the share of hydroelectricity in the national energy generation declined, and as the pressure on water resources built up concomitantly, it appears clearly that EGAT has adjusted its management, despite some punctual counter-examples. Possible further gains are therefore better captured by a value of 0.5-1 Bm3 than by the historical overall averages.

As noticed earlier, the year 1996 sticks out as an horrendous counter-example of the improved management (in terms of loss reduction) observed in the 1990s. Around 7 Bm3 were dumped to the sea. It can be observed that most of the 2.8 Bm3 released in May and in June[88] have been lost to the sea (2.6 Bm3); this may have been partly due to a lack of response to relatively high precipitation (300 mm in the delta). Similarly, 1.3 Bm3 have been released from the dams in August, out of which 1.1 Bm3 was lost to the see. The water level in Sirikit was quite high (between 145 and 149 m) but had not reached the spill level (150.5 m). During the three following months the water level in Sirikit Dam remained below the recommended level for spill (158 m) but considerable volumes were nevertheless released (2.1 Bm3 from the two dams, most of it lost to the sea). It seems that during this period EGAT has both taken advantage of high stocks to generate electricity and been influenced by the dramatic preceding year to release water in excess of what should have been done (fear of facing the same hydrological events). This would indirectly impact on the future drop in available water along 1997 and 1998.

[88] value already 65% over the average

FIGURE 65: MONTHLY WATER RELEASE AT CHAI NAT IN EXCESS OF REQUIREMENTS: THEORETICAL LOSS (26 YEARS AVERAGE)

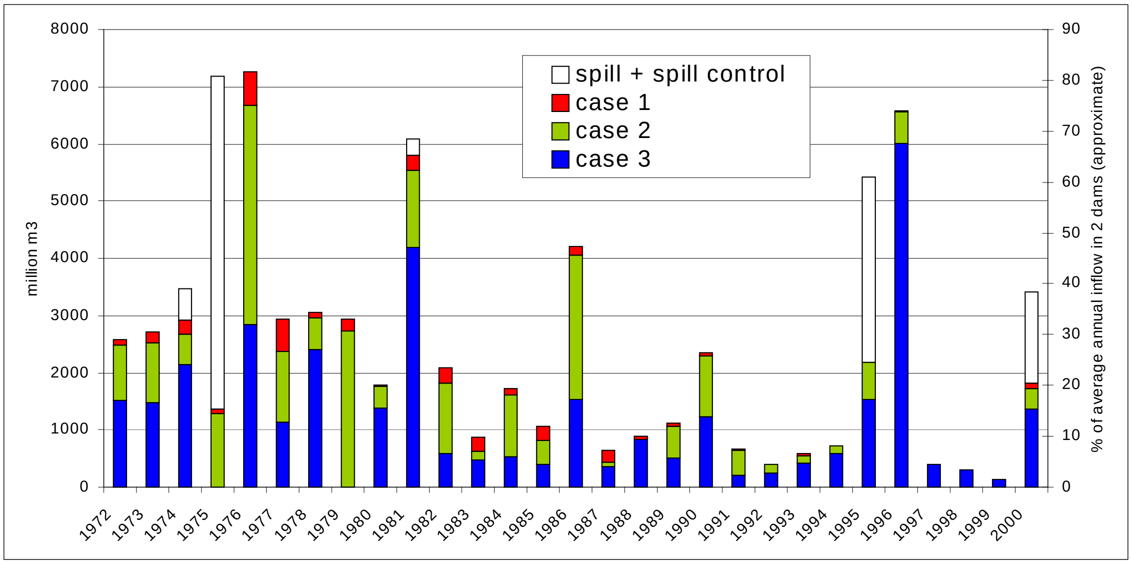
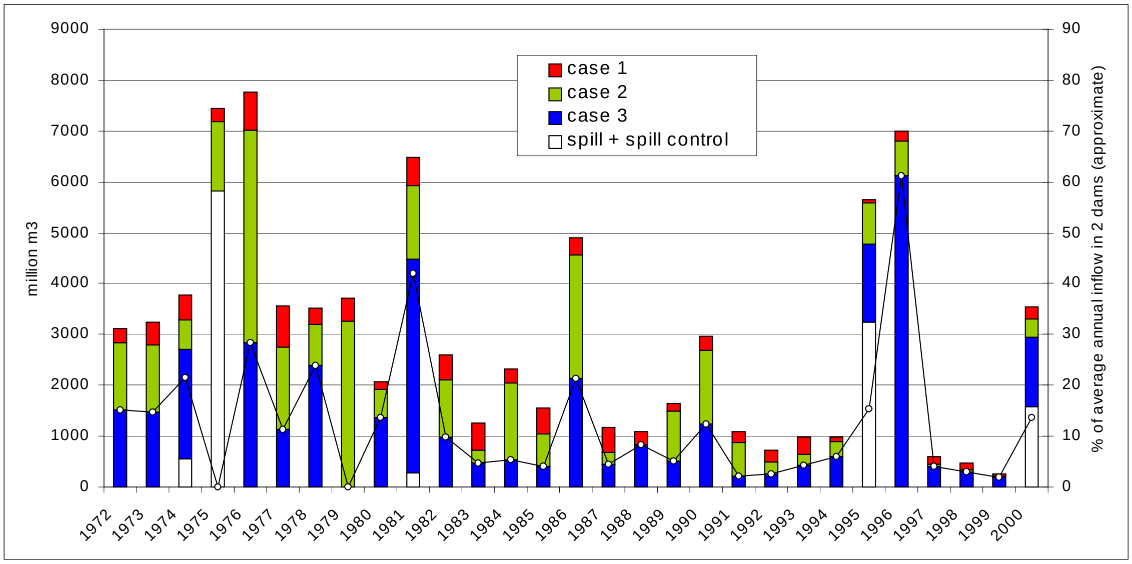


FIGURE 66: YEARLY WATER RELEASE AT CHAI NAT IN EXCESS OF REQUIREMENTS: THEORETICAL LOSS, BY TYPE



During the May-June 2000 period, EGAT released around 1.2 Bm3 that were lost to the sea "due to high demand in electricity" (RID, 2000). This is hardly acceptable as the production of energy decreased in 2000 and seems rather to have been caused by the optimism of EGAT officers who observed heavy rainfall in the early wet season and bet on high coming dam inflow. Fortunately, reality conformed to these expectation and these water losses were offset by significant run-off, especially in the Sirikit dam. Water had eventually to be released from Sirikit Dam in order to control spill, but this was done in most instances before the water level reached the upper rule curve. Despite such considerable release, almost 1 Bm3 was also released from Bhumipol Dam during the wet season. Although the releases of May-June did not end up as a waste because of large subsequent inflows, it might not have been the case. The decision was potentially detrimental to water stocks and is illustrative of a policy which is now outdated.

What must also be emphasised, however, is that many significant releases observed from April to September, despite the occurrence of some rainfall, are in general motivated by irrigation requirements and are not, as often claimed by NGOs, released for the sole objective of energy generation[89], although this case may still happen, as illustrated above.

This approach, however, probably provides an overrated estimate of the water loss. By considering monthly values, we ignore both the errors due to not considering carryover from one month to another (the water released during the last five days of a given month is used downstream the following month) and the more significant constraints of real day-to-day management: the lagtime corresponding to adjusting releases to uncontrolled factors, including rainfall; and the delay between such adjustments and their impact at Chai Nat (5 days). On the other hand, the minimum releases considered for the different dams are rather generous. In the case of the Chai Nat dam, it ignores the fact that the major part of 45 cms diverted to BMA every day return to the river system (with a degraded quality).

Another possible shortcoming of this approach is that the excess water in the wet season (more especially in case of flood) is not only wasted to the Chao Phraya River but also to the different canals. However, such a situation generally occurs when sideflows exceed demand and this does not affect the estimation of loss (case 3). The calculation should also consider possible losses at the Phophya regulator on the Tha Chin River, but data show that the corresponding amounts are small relatively to those in the Chao Phraya River.

A few sensitivity analyses can also been done. For example, when the minimum flow to be maintained downstream of the Chai Nat Dam is increased by 10 cms, then the average yearly loss is decreased by 6%.

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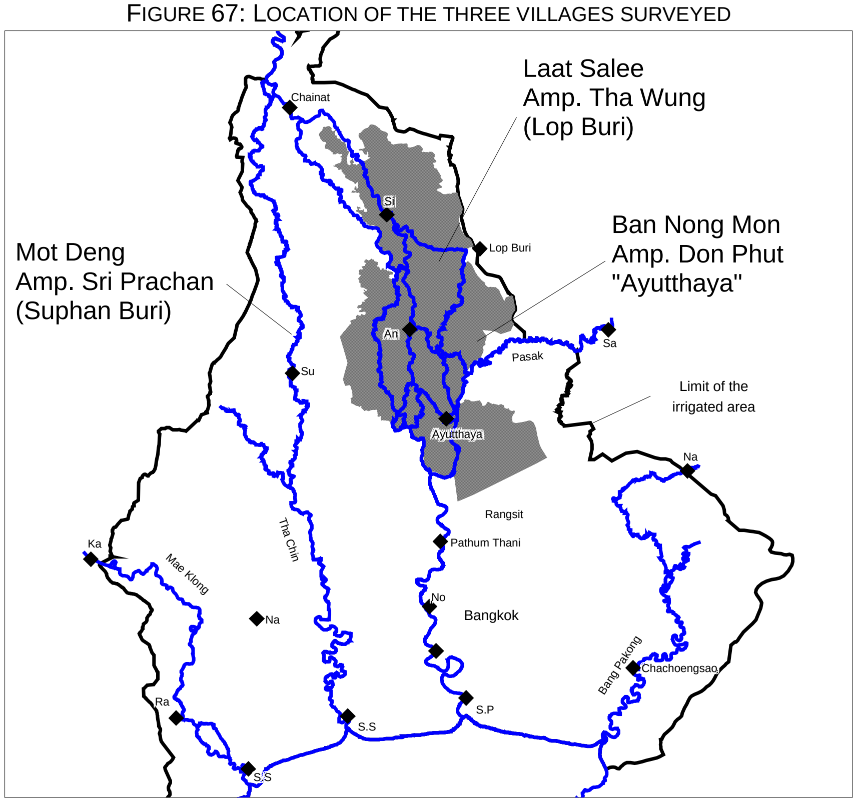
[89] A good example is the editorial of *Watershed* (1999), which states that between April and September 1998, "EGAT used over 3 Bm3 of water, with the priority of generating electricity. (…) By the end of the rainy season, the RID announced that the amount of water in the Bhumipol and Sirikit reservoirs available for irrigation in the coming dry season was less than 3.6 Bm3, hence the "Water crisis".

7 Access to water as a differentiation factor: impact on farming systems

The evidence raised earlier of dramatically contrasting indexes of cropping intensity over space and time in the Delta may remain a table of dull numbers. In order to document the impact of varied levels of access to water in the dry season on the sustainability of farming systems, a field survey has been undertaken in three villages[90]. These villages have been chosen in three contrasting environments: the first one (*tambon* Mot Deng, *amphoe* Sri Prachan, *changwat* Suphan Buri) is one of the finest areas in the delta, commonly grows two or three crops of rice and also cultivates water chestnut, a labour intensive cash-crop. The second one (*tambon* Lat Salee, *amphoe* Tha Wung, *changwat* Lop Buri) receives limited supply during the dry-season. The lower part of the *tambon* is cropped with floating rice and only recently engaged in dry-season cropping. The third one (Ban Mo, *tambon* Don Phut, *amphoe* Tha Rua, *changwat* Saraburi) is a typical floating rice area and only recently started to grow some field crops in the dry-season. As this village is straddling the frontier of Saraburi and Ayutthaya provinces and is more representative of the latter, we will refer to these three villages by the province names (Suphan Buri, Lop Buri, Ayutthaya).

FIGURE 67: LOCATION OF THE THREE VILLAGES SURVEYED



[90] A full account of the comparative study can be found in (Molle *et al.* 2001c)

In each village, approximately 70 households were surveyed. In addition, the whole village households were listed and analysed in terms of family structure, land endowment and occupation. The survey included questions about the family (last 3 generations), migration, occupation, agriculture, assets, indebtedness, income, and covered both the actual situation, the history of the farm and its strategy regarding the future. Data were analysed comparatively and interpreted based on a few factors, with special attention to the degree of agricultural intensification allowed by a given access to water. Some salient features are commented in this section. The following account shows the impact of inequity in water allocation upon farming systems.

7.1 Household structure and labour force

The very definition of what is a household and who is the head is problematic from the onset. There is a wide range of situations such as:

- The house is registered at the name of an old man (woman) who lives with one or several of his children. This formal household head may still be economically active, or only contribute by some income such as land rental, or may be totally dependent upon his children.
- The house is registered at the name of an old man (woman) but he lives in another house, sometimes not in the village (typically with one of his children in Bangkok) and the house is occupied by another child (or the wife).
- In some cases, an old couple (or single person) is totally dependent upon one of the children who lives next to them in another house which has not been registered formally. The head of the household (old person) is not the real one. The opposite case also happens where 3 generations live together but members want to access credit independently. In that case they ask for a new house number in order to be able to open a new account in the bank.

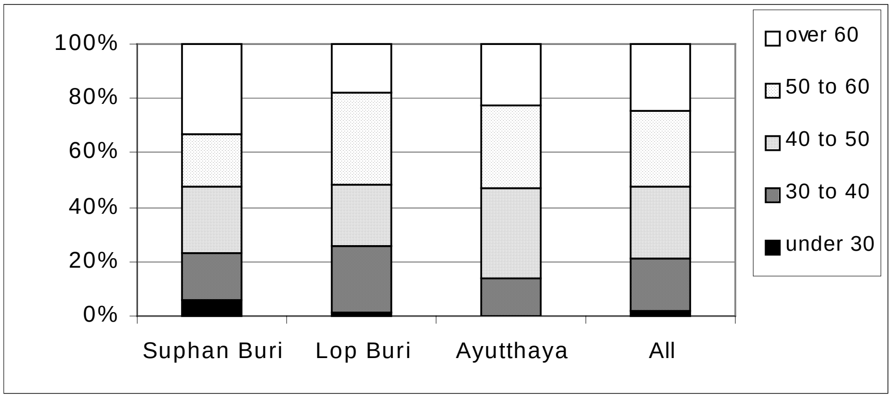
Although it was attempted to identify who was the head of the household (in terms of economic decisions), these difficulties have introduced a certain bias in the categorisation of households. Table 12 shows the distribution of the whole population of the three villages by main age class. The main striking difference is the much lower percentage of children under 15 in Ayutthaya. This can be attributed to a higher rate of out-migration of families with young children and, possibly, to a lower fertility.

TABLE 12: DISTRIBUTION OF POPULATION BY AGE CLASS (IN %)

Age class	<15	15-59	> 60
Ayutthaya	18	63	20
Lop Buri	29	49	22
Suphan Buri	27	48	24

Studies at the level of the whole delta (Kasetsart University and ORSTOM, 1996) have shown that the heads of agricultural holdings tend to be older in the flood prone area than in other areas. Figure 68 gives details on the distribution by age of *farming household* heads and shows that there are proportionally more people over 60 years old in Lop Buri, while the percentage of the population over 50 tends to be the same.

FIGURE 68: DISTRIBUTION OF THE AGE OF THE FARM HOUSEHOLD HEAD (WHOLE VILLAGES)



Demographic factors (fertility, out-migration rates) translate in varied average sizes of households and also affect the available labour force. Ayutthaya has significantly smaller households (only 3.5 members) and the available labour force[91] is also much more reduced (Figure 69). This shows the impact of migration and the differences between the three environments in terms of labour absorption capacity.

In the 1950s and early 1960s, the delta was experiencing an agrarian crisis, when the increasing population density was not paralleled by an increase in crop productivity nor by the development of other job opportunities. Figure 70 shows that the currents heads of households (and to a lesser extent their parents and their children) have been involved in the migration flows between the delta and the upland which developed at that time [to the point that the absolute farming population decreased between 1960 and 1970 (Molle and Srijantr, 1999)]. On the whole, 55% of families in Lop Buri and Ayutthaya had members concerned with a temporary or permanent move to the upland, against 34% in Suphan Buri. Although the whole delta was concerned by these migrations, Suphan Buri was provided with better farming conditions and could more easily accommodate its growing population than the flood prone area.

These discrepancies in land productivity also appear in the much lower percentage (22%) of Suphan Buri households with at least a member working, or having worked in a factory (Figure 70, right). In Ayutthaya, this percentage is as high as 46%. The fact that such jobs rarely last beyond 40 years old is probably responsible for the higher rate of members having worked in factories in the past than at present. It must be noted that only 21% of the total job factories reported were in Bangkok, the other ones being found in the Province itself (or the neighbouring ones).

[91] Children or grand-parents helping occasionally (on week-ends) have been considered as 0.25 units of labour. Adults were attributed a factor of 0, 0.50 or 1.0, depending on their level of involvement in farming.

FIGURE 69: HOUSEHOLDS SIZE AND LABOUR FORCE

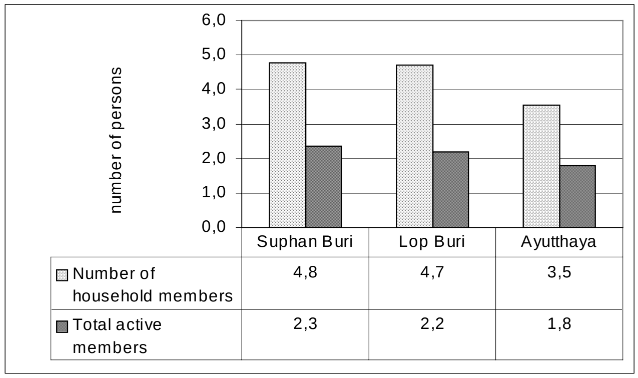
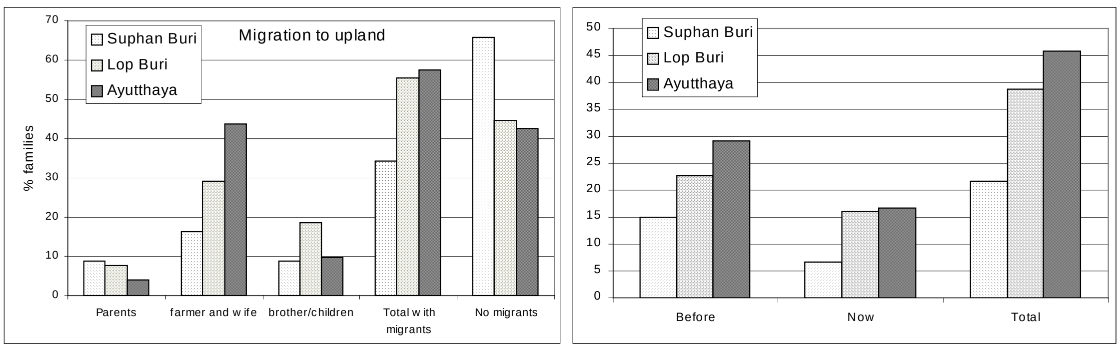


FIGURE 70: PERCENTAGE OF FAMILIES WITH UPLAND MIGRATION AND FACTORY LABOUR



7.2 Occupations

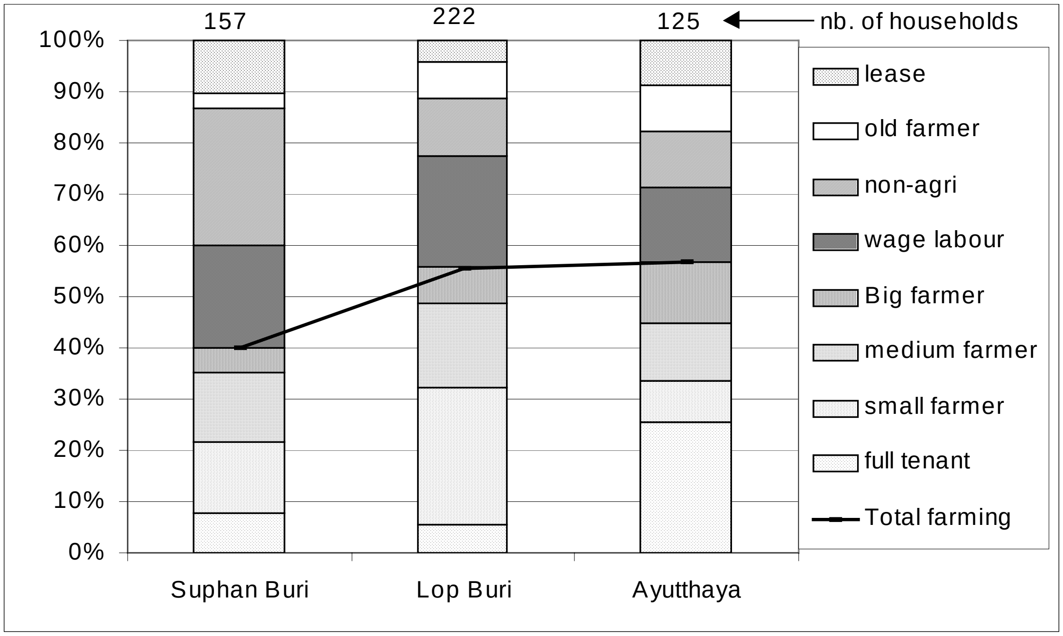
The classification of households according to their main activities appeared from the onset as an arduous task, as households with only one economic activity were exceptional. In many cases, it was difficult to select which was the main activity (or if both the husband and the wife had a full time job, which one was to be chosen). The number of people contributing to the household income was also a source of confusion. Some people mainly work in Bangkok but still have their main residence in the village (one is even member of the Tambon Administration Organisation), where another member of the family (wife, son) may still take care of the rice fields. Some older people may lease most of their land, still have one of the children cultivating a few rai for them and receive remittances. Other households are composed of 2 or 3 single adult siblings with different activities. In other words, *the difficulty of defining households mentioned earlier, together with the composite nature of the household economy (both in terms of contributing members and diversity of activities) appear as main features, deserving emphasis rather than being seen only as disturbing factors affecting the relevance of classificatory attempts*.

Households classified as relying on a single main activity do have in reality several minor economic activities (one son repairs motorcycle, another catches fish, the wife dries up chilli for the Women Group, they grow home vegetables and raise poultry, join groups for harvesting, receive occasional remittances, etc). It is obviously extremely difficult to quantify the income derived from all the activities as well as the degree of food self-sufficiency, but they are many cases in which these are obviously not negligible and even sometimes paramount. This suggests that classical household surveys and resulting aggregated statistics very imperfectly capture the complexity of the rural household economy. These shortcomings also partly apply to this study and the following results must be interpreted keeping in mind this more general situation.

A first view limited to the main occupation of the household heads is shown in Figure 71. The classification was done according to the list of households provided by the Tambon Administration Organisation (TAO) and checked with the village headmen. It was therefore not possible to specify cases of multiple income nor to know the exact occupation of those classified as ‘employees’: these include ‘*khon rap jang*’ who look for daily wages from a diversity of short-term tasks (harvesting, spraying crops, construction, etc.), employees such as truck or tractor drivers, guards or factory employees, while 'non-agri' occupations refer to own-account workers (blacksmith, electrician, etc) or officers (teachers, nurse, etc). The 'lease' category refer to (often old) farmers who are renting out all of their land and who either receive remittances or have other activities (e.g. teacher). The first striking point is that only 40% of the households in Suphan Buri can be classified as farmers, while this rate is close to 60% in the other two villages. This is rather consistent with macro census data for the delta[92] but it must be kept in mind that a wide variety of (administrative) villages can be found in the Delta and that it is possible to find villages in rural areas with only 10% or so of the households engaged in farming. It can also be seen that the 'non-agri' category is large in Suphan Buri. This can be attributed to the diversion of economic activities allowed by capital accumulation and greater local purchasing power. They include transportation, construction, commercial activities, but also official positions allowed by better educational levels (investments in education). Full tenants are prominent in Ayutthaya, as will be seen later.

[92] But the Population Censuses also classify as 'agricultural households those who derive their main income from agricultural wage labour.

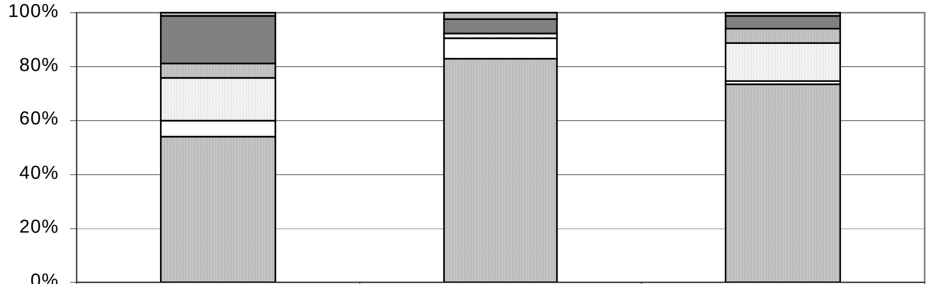
FIGURE 71: DISTRIBUTION OF MAIN ACTIVITIES IN THE 3 VILLAGES



From these sets of households, sub-samples were chosen in order to focus on the population predominantly engaged in agriculture. This was motivated by the chief objective of investigating the impact of the access to water on farming systems and, therefore, a first sample of farmers was chosen, with caution to cover the whole range of farm types and farm size. In a subsequent step, it was felt that the surveys would gain from adding households from the landless category, in order to better understand their role in providing labour. Therefore the sub-samples were completed by questionnaires directed to landless households. A limited number of these eventually appeared to correspond to villagers non involved in farming but they were nevertheless kept in the sub-sample. They include landowners leasing the totality of their land, some landless families with no agricultural income (either wage or fixed salary), and inactive people (in general old persons taking care of grandchildren and sustained by remittances). Wage labourers were divided in two categories[93]: '*wage_agri*' are characterised by the fact that wage labour in agriculture is the chief income of the family, while '*wage*' are only secondarily (or not at all) engaged in agricultural wage labour. '*Non-agri*' households have no land, a fixed salary (truck driver, officer, etc), and may also have some income from wage labour (including agricultural). The structure of our final sub-samples according to main occupation is given in Figure 72. It can be seen that non-farmers are under-represented with regards to the whole village, except in Suphan Buri.

[93] This was done *a posteriori*, based on the economic data collected

FIGURE 72: DISTRIBUTION OF SUB-SAMPLES ACCORDING TO MAIN OCCUPATIONS



	Suphan Buri	Lop Buri	Ayutthaya
No activity	1	2	1
Non-agri	12	4	3
Lease	4	0	4
Wage	11	1	10
Wage agri	4	6	1
Farmers	38	63	52

A closer examination of the stratification of occupations by age class show that while more than half of the senior generation is engaged in agriculture, this rate has been halved for the junior one, except in Ayutthaya where the decline is even more drastic (down to 10%). Also noteworthy is the growing division of labour between grand-parents and parents, whereby the former take care of children while the latter work out-of the village, either on a daily commuting or a temporary basis. This was clear in Ayutthaya where several lonely grand-mother were taking care of grand-children (*faw laan*). Around 30% of households have elderly taking care of young children, except for Lop Buri (only 9%).

7.3 Agriculture

7.3.1 Farm types

Households engaged in farming as their main economic activities include landed households (full owners and mixed owned/rented farms) and landless ones, which further divide in full-tenants (hiring land to cultivate) and agricultural wage labourers (who hire out their labour force).

It readily appears from Figure 73 that Suphan sticks out with its high percentage of wage labourers (40%, but only 11% with main income from agricultural tasks), which is mostly due to sample constitution[94]. Ayutthaya displays high level of tenancy (and mixed farming), which results from the higher stock of land in the rental market released by both urban investors who have bought land in the area, and from local people who have migrated but still retain their right on land. This is also indicative of a higher vulnerability of Ayutthaya farming systems to crop failure and economic failure, with a large part of the land sold out to outsiders. In contrast, the percentage of full and mixed owners is higher in Lop Buri, where

[94] All values are expressed in % of the total of households with own-account farming activity.

fewer full tenants can be found. It is also interesting to note that no one in Ayutthaya is found to both cultivate and lease land. Farmers either grow rice or don't, but the low land productivity makes part farming just not an option.

FIGURE 73: TYPES OF AGRICULTURAL HOLDINGS

	Suphan Buri	Lop Buri	Ayutthaya
wage	29	2	19
Agri wage	11	10	2
leasing	11	0	8
tenant	26	14	44
mixed	39	40	38
owner	21	33	17
owner+lease	13	13	0

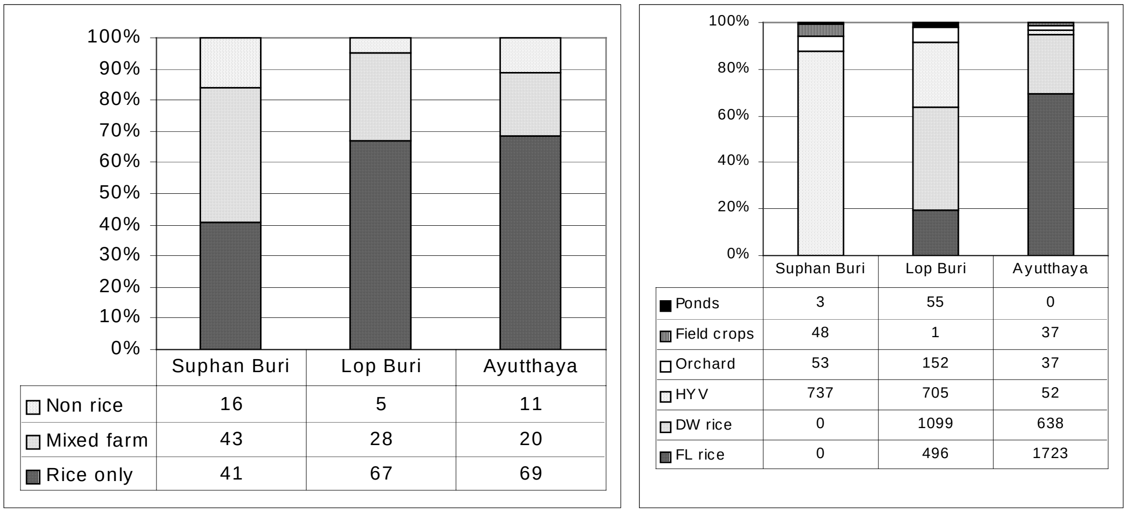
7.3.2 Land use

Suphan Buri village is noticeable by the rather low number of farms which rely only on rice (40%), although it is commonly featured as a typical intensive rice area (which is also true as triple cropping is common). Diversification is mainly due to the cultivation of water chestnut. Lop Buri and Ayutthaya are rice-based villages (two thirds) but associations with non-rice crops are not rare and are economically important. Cases of farms in Ayutthaya not growing rice include some farmers growing only chilli or corn in the dry-season and one man raising fish.

7.3.3 Farm equipment

The type of farm equipment owned by the households is of course related to their ecological environment. Four-wheel tractors (4W) are more common in Ayutthaya and in Lop Buri, where they are used to plough the land in dry conditions (dry broadcasting). Two-wheel tractors are widespread in Suphan Buri (79% of the households have one).

FIGURE 74: FARM TYPES AND LAND USE



The degree of equipment in pumping devices is impressive. Households with at least one pump set amount to 95%, 87% and 62%, in Suphan Buri, Lop Buri and Ayutthaya respectively. Many have several sets and the overall equipment average is 1.6, 1.7 and 0.96 in the three villages. The farms are also well endowed with sprayers but it can be observed that Suphan Buri is equipped with more expensive motorised sets in almost half of the cases.

7.3.4 Labour and hired service

Many farmers hire labour for the main operations of rice cropping. This is due to several reasons, including the lack of physical capacity (older villagers), lack of equipment (tractors), aversion to drudgery, or physical absence (landowners settled temporarily outside the village). A total of 57% of farmers growing HYVs in all villages (48% in Suphan Buri) hire land preparation service (because few farmers have 4 wheel tractors in Ayutthaya, nearly all rice growers resort to service). Full owners hire such service in 66% of cases, full tenants in 81%, and owner/tenants in 37% of cases.

TABLE 13: PERCENTAGE OF FARMS HIRING SERVICE

	Land preparation				Spraying			
Farm type	Full tenants	Mixed tenure	Full owner	All	Full tenants	Mixed tenure	Full owner	All
Suphan Buri	71	29	60	48	29	57	60	52
Lop Buri	88	44	68	61	0	24	50	33

Land preparation in Lop Buri is mostly done with 4 wheel small tractors.

7.3.5 Land resources and tenure

Distribution of land by tenure also shows marked differences (Table 14). Lop Buri stands out as the village with less cultivated land rented (30% of total). On the other extreme, Ayutthaya has two third of his land cultivated by tenants. With 18% of the land leased by local farmers, 47% of the land belongs to owners living outside the village. This percentage is only 17 and 22% for Suphan Buri and Lop Buri. The table (right) also gives these percentages for our samples and shows that the rented part of the cultivated land is even higher than for the whole village (reaching 73% in Ayutthaya).

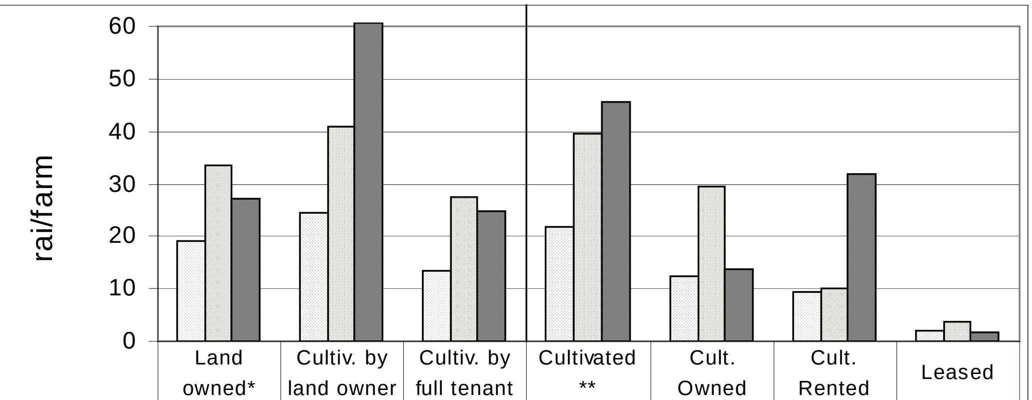
TABLE 14: DISTRIBUTION OF CULTIVATED LAND BY TENURE TYPE

	Whole village					Samples	
	Total cultivated (rai)	Owned (%)	Rented (%)	Leased (%)*	Rented-leased	Owned (% cultivated)	Rented (% cultivated)
Suphan Buri	1,220	59	41	23	17	49	51
Lop Buri	4,044	70	30	7	22	64	36
Ayutthaya	3,210	35	65	18	47	27	73

* expressed in % of the cultivated area

Figure 75 provides more details on the respective average areas owned and cultivated by farms in each village. There is a clear ranking which matches the productivity of the land itself. This illustrates how land division by inheritance is constrained by the capacity to develop intensive agriculture, itself closely related to ecological and water conditions. This translates in average farm sizes of 22, 39 and 45 *rai* for Suphan Buri, Lop Buri and Ayutthaya respectively, in line with land productivity.

FIGURE 75: LAND ENDOWMENT PER FARM



	Land owned*	Cultiv. by land owner	Cultiv. by full tenant	Cultivated **	Cult. Owned	Cult. Rented	Leased
Suphan Buri	19	25	13	22	13	9	2
Lop Buri	33	41	27	39	30	10	4
Ayutthaya	27	61	25	45	14	32	2

* Average land owned by all farmers owning some land;** Average land cultivated by all households with own-account farming activity.

It was attempted to better capture the relationships between the tenant and the land owner and to specify the origin, place of residence and occupation of the latter. It was apparent that most of the land owners (over two thirds) in Suphan Buri and Lop Buri were local residents, whereas in Ayutthaya many (two thirds) where residing in the province capital or in Bangkok.

Kinship links between the tenant and the landowner existed only in 50% of the cases in Ayutthaya, against 70% in the other two villages.

7.3.6 Credit and indebtedness

Access to credit was also investigated by looking at the present state of membership of credit institutions and in current loans (short, medium and long term). Data on credit institutions membership show that most farmers are members in Lop Buri and Ayutthaya, while farmers in Suphan Buri seem to auto-finance their activity in 67% of the cases. Co-operative membership is dominant in Lop Buri, while BAAC is the most common credit provider in Ayutthaya. It must however be noted that 42% of the farmers who are member of an institution do not have pending credit at the moment, while the two other villages have half of this rate.

TABLE 15: MEMBERSHIP IN CREDIT INSTITUTIONS

	No %	Yes %	No credit at the moment*	BAAC	Co-operative	Farmers group	Other and non specified
Suphan Buri	67	33	23	23	2	0	8
Lop Buri	32	68	24	24	41	3	0
Ayutthaya	27	73	42	42	28	1	1

* in % of farmers members of one institution

Pending short term credit is very limited in Suphan Buri, as most farmers seem to have the financial capacity to fund their running costs, including the purchase of fertilisers, but is also rather limited in the two other villages, as only one third of the households resort to this kind of credit[95]. Many farmers mentioned that they do not automatically use credit facilities: this depends on the year, on whether they have enough cash at the moment it is needed to buy inputs. These short-term loans typically amount to 30,000 baht or so.

Mid-term credit (1 to 3 years) is insignificant in Suphan Buri (one case), while limited in the other two villages (10%), and amounts on average to 60,000-120,000 baht. Surprisingly, long-term credit (>3 years) is rather common and even concerns 19% of households in Ayutthaya, with amounts typically of a few hundreds thousands baht.

7.4 Income

7.4.1 Return from main crops

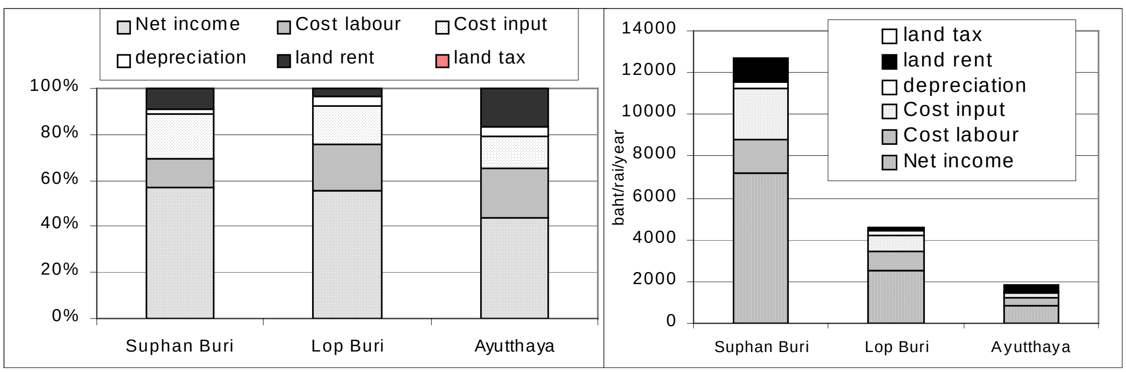
Rice cropping in these three different environments of course have contrasting production costs and value added. One first reason is the cropping intensity *per se*. Over the last 10 years the average cropping intensity (number of crops per year) was 2.9, 1.45 and 1.02 in

[95] This may underscore reality as it is possible that some farmers were interviewed at a time (or a season) in which they did not have taken credit yet.

the three villages. If we consider only the last 5 years, these values are raised to 2.9, 2.65 and 1.03. A second reason is the yield of each type of rice cultivation: predominantly floating rice in Ayutthaya (367 kg/*rai*), together with deep-water rice (421 kg/*rai*), deep-water (460 kg/*rai*) and HYVs (748 kg/*rai*) in Lop Buri, and HYVs (849 kg/*rai*) in Suphan Buri. A third reason is that production costs are higher for HYVs than for traditional varieties.

Figure 76 provides the distribution of average costs and net incomes of rice production in the three villages, in percentage and absolute values, for one *rai* and one year. The net income amounts to 60% of the value added in Suphan Buri and Lop Buri, but to only 43% in Ayutthaya. The cost of hired labour corresponds to approximately 20% (less in Suphan Buri) of the value added and the share of land rent is, of course, higher in Ayutthaya. The resulting net incomes are 7,195 baht/*rai*, 2,560 baht/*rai* and 822, baht/*rai*[96].

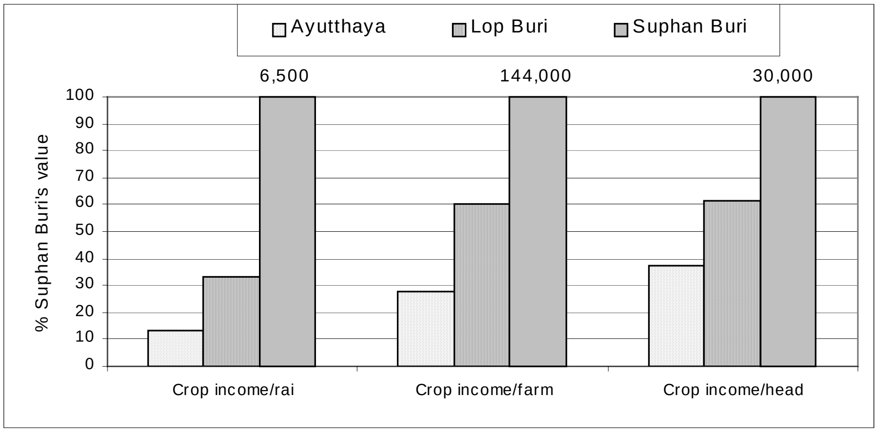
FIGURE 76: RICE PRODUCTION COSTS AND INCOME (IN % AND BAHT/*RAI*/YEAR)



This sheer discrepancy in land productivity must however be taken with caution. Figure 77 provides insight on a rather fascinating re-balancing of this initial starch contrast. Because the average farm size is correlated to the ecological conditions (farms in Ayutthaya are twice larger than in Suphan Buri), the gap is significantly decreased if seen in terms of crop income per household. Furthermore, because of the lower number of people in a household in Ayutthaya the gap is further reduced, albeit obviously not bridged, when expressed in terms of crop income per capita (household member).

[96] Including non-rice crops (principally water chestnut in Suphan Buri and corn/chilli in Ayutthaya), the net income per *rai* was 6,494 baht, 1,966 and 843 baht in Suphan Buri, Lop Buri and Ayutthaya respectively.

FIGURE 77: COMPARISON OF NET INCOMES



7.4.2 Household income

As is apparent from the multiplicity of occupations observed earlier, the household income is also very composite. Moreover, it was not always possible to determine accurately the real income derived from wage labour, fishing, etc. However our estimates provide an overall clear picture of farm incomes when all sources are considered. A first factor is the large amount of non-crop agricultural income in Lop Buri. Animal farming, most prominently chicken, chicken/fish, ducks and swine, has grown dramatically in the last decade and is now almost equalling the crop based income of the farm sample. Figure 78 shows the respective shares of crop (agri), non-crop (agri), and non-agricultural net incomes for the whole sample and for those with own account farming activities. Considering the latter group of households, it appears that agricultural activities make up 75% of the household income, except in Ayutthaya, where the level of 50% is not reached. If we consider the full sample, the share of agricultural income varies widely, from a low 34% in Ayutthaya, to 70% in Lop Buri, while Suphan Buri is at 55%. These values are obviously overrated as our sample is biased towards farming households. The overall picture emerging from these data is that in the three environments and in three villages, which can still be considered as rural and agricultural villages, the *income from crop production is unlikely to exceed one half of the total net income*. Lop Buri distinguishes itself because of the high income derived from animal breeding.

We may now examine the net income of those households engaged in own account farming activities (farms), which are directly concerned with the impact of the access to water. Figure 79 gives a clear view of both the differences between villages and the contribution of the different sources of income. It shows that the hierarchy in farm income is in line with that of land productivity but that differences in land endowment, family size, and pluri-activity contribute to reduce the sharp initial contrast.

FIGURE 78: CROP/NON-CROP INCOME SHARES

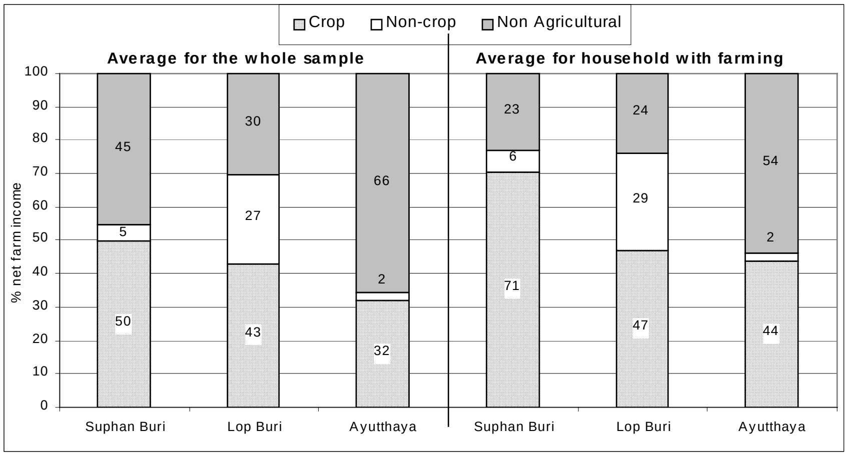
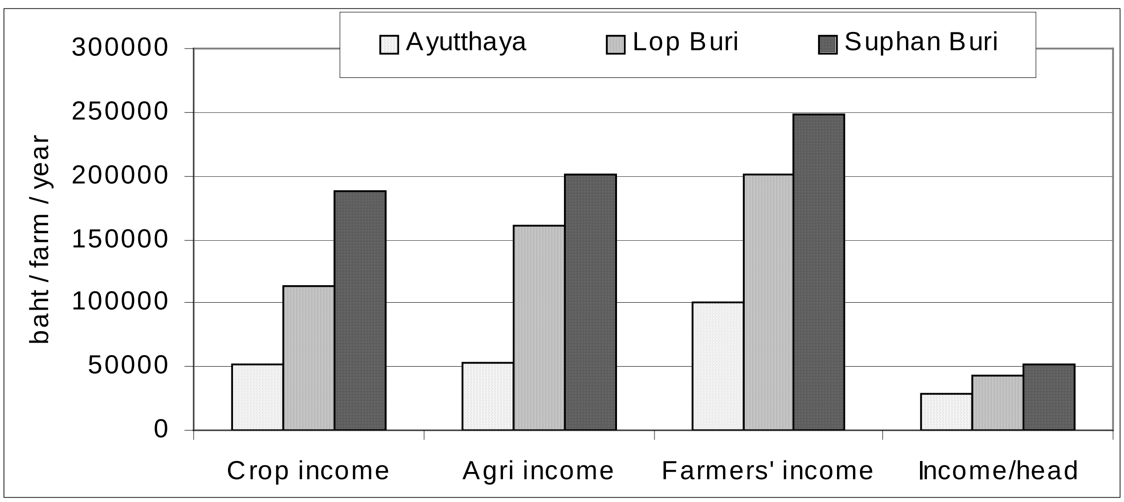


FIGURE 79: YEARLY INCOME FOR FARMING HOUSEHOLDS



7.5 Farm economic differentiation and farmers' strategies

The overall picture which emerges from these data is that the differences in ecological conditions and in the access to irrigation water translate in contrasting farm structures, incomes and strategies. Ayutthaya has households with smaller family and larger land but a very low cropping intensity (1.02). A higher part of the cultivated land is rented and out-migration has drastically reduced the labour force, particularly of the youngest population strata. Low rice and agricultural incomes are nevertheless doubled by off-farm work and remittances, but the average yearly income stands at 100,000 baht/year. Most farmers are ageing and few strategies of investment in agriculture can be observed. We are is a situation of demise of the agricultural sector (see Molle and Srijantr, 1999).

Lop Buri combines traditional rice varieties and HYVs, with a medium cropping intensity (1.46). The sustainability of farming system is strongly linked to the development of animal production. However, this activity concerns only 25% of all farms, and the average values shown above tend to distort the overall picture as the important revenue from animal breeding is not distributed to all farms. Land sale and out-migration have been very limited, if compared with Ayutthaya, because of these new activities.

Suphan Buri reaps the full benefit from its very high cropping intensity and full use of HYVs. Higher rural incomes have also fostered the development of non-farm activities and induced economic diversification. With a larger supply of jobs both in the agricultural (triple rice cropping and water chestnut) and non-agricultural sectors, the village has been able to capitalise (little use of credit, high level of equipment in farm machinery, many modern newly built houses, etc), to invest in the education of children, and to retain most of its labour force (little out-migration to uplands in the 1960s) and of its ownership on land (40% of the cultivated land is rented but landowners are local resident in 80% of the cases and have kinship links with tenants in 70% of the cases).

In conclusion, it can be seen that the respective development paths of the three villages are strongly governed by the level of intensification allowed by the access to and control of water. Not all of these differences are attributable to lopsided patterns of water allocation in the dry-season. Ayutthaya village, for example, has little facilities to grow HYVs in the dry-season. However, Lop Buri village is indicative of a quite large area formerly exclusively dedicated to wet season deep water rice cultivation, but which has gradually improved both its link to the irrigation network and its on-farm facilities. Equity concerns thus suggest that triple cropping should be controlled in order to distribute the benefit of double-cropping to areas with partial access to water in the dry-season. Regarding the floating rice area (Ayutthaya), a degree of intensification can be achieved through the delivery of water to drains, where it can be pumped to support field crops. This, however, is subject to high risk at the marketing stage, a still unresolved issue.

Part II

Perspective for the improvement of water allocation and management

This second part of the report will present various suggestions and recommendations regarding several aspects, some of them minor, others major, of water allocation and distribution in the basin and in the delta. Not all the options for improving access to water will however be considered. In particular, no mention will be made of the different large-scale water resources development projects envisaged (new dams, transbasin diversion, etc), not because they are considered irrelevant but because they have already received enough attention in other technical studies.

8 Potential and constraints for the use of secondary water sources

Much efficiency has been gained in the past two decades through the tapping of secondary water sources. This has been allowed principally by the development of farmers' individual pumping capacity, the construction of regulators in the drains (to retain water in the dry-season), the drilling of tube-wells and the excavation of small reservoirs in swampy low-lying areas. A few comments are provided here on the latter two aspects of water use.

8.1 The development of individual tube-wells

Tube-wells are now a common features in some parts of the delta. They are typically 3"-4" in diameter and 15 to 30 m deep and are drilled in shallow aquifers which can be accessed with suction pumps, or in other words which depth does not exceed 8-9 meters from the natural ground. Their price is relatively low (5-6,000 baht) when the power can be provided by an existing motor, most commonly by the engine of a two-wheel tractor, thus avoiding the investment in a new engine.

These tube-wells are seldom used as exclusive sources of water for rice cultivation because of the higher costs in gasoline entailed by the pumping of underground water. They are used as supplemental sources in case of water shortages or to start dry-season cropping ahead of the normal delivery schedule.

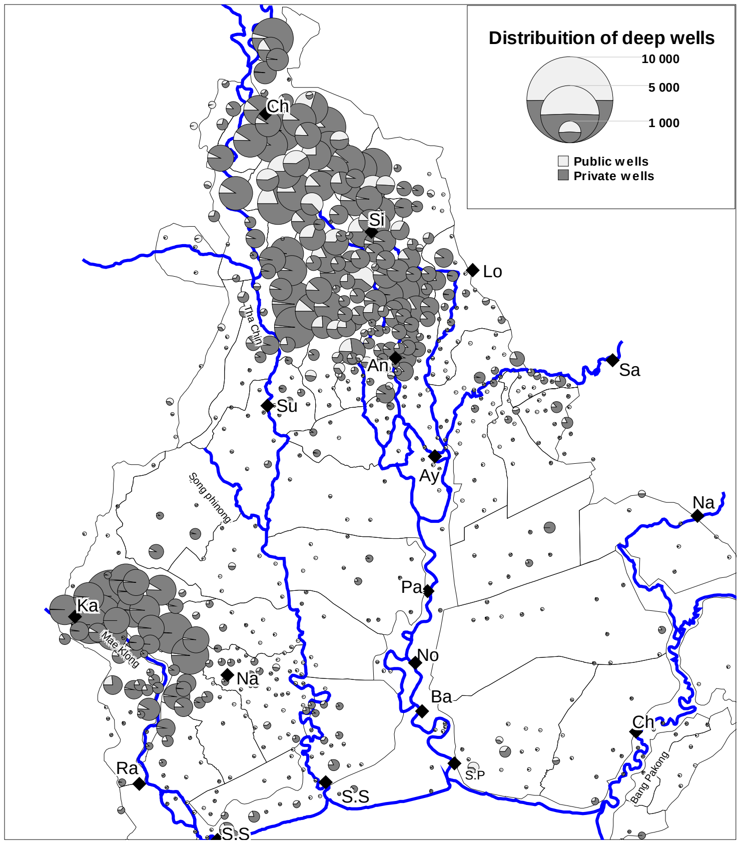
The anarchic development of such wells in some regions has sometimes resulted in the drawdown of the aquifers. In dry years, when many farmers resort to them, the water level may drop below the level which allows the use of suction pumps, thus making the use of wells impossible. This situation is dealt with by farmers by digging a 1 m large hole around the upper extremity of the well, sinking a prefabricated concrete section of pipe in it and lowering the pump body in order to maintain the head under the theoretical 10 m limit (in practice 8-9 meters). The pump is then linked to the motor through belts.

The development of these tube-wells has been driven by a need to access reliable water sources for both diversification and intensification, and constituted a response to the water shortage experienced in the early 90's. It was mostly achieved by the farmers themselves but several Provincial initiatives were taken in the early 90s aiming at drilling thousands of (free) wells in the country-side (see statistics in Annexe 14). If some of these wells are quite old, the majority have been dug after the implementation of the irrigation Project which provoked the rise of the water table. In a study area of the Mae Klong area, Molle *et al.* (1998) have found a growth of 100% over the last ten years and densities of around 20 wells/100 ha, which are quite considerable.

A survey carried out in 1994 at the village level has inventoried 89,000 of them in the Central Plain, mostly in the upper Chao Phraya Delta and the upper Mae Klong Project (Kasetsart University & ORSTOM 1996) (Figure 80). This spatial distribution of the tube-wells density follows by and large the availability of underground water of adequate quality. It must be noted that: 1) more wells have been constructed since 1994, but also 2) that many of them, especially those dug hastily by governmental programmes without sound assessment of the availability and quality of water[97], are filled up and cannot be used.

The role of tube-wells in achieving reliable water supply is a paramount aspect of agricultural diversification in the Mae Klong area and cannot be overemphasised.

FIGURE 80: MAP OF TUBE-WELL DENSITY IN THE DELTA



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97 This shows that fully subsidised governmental actions are seldom successful. Farmers must partly contribute, as a way to ensure the relevance of the investment.

8.2 Excavated reservoirs in low lying public areas

Another way to store water locally for further use in the dry-season is provided by reservoirs, with a capacity ranging from a few thousands to a few tens of thousands of m^3. As most of the low-lying swampy areas are classified as public land, several governmental projects have been designed to dredge them and turn them into reservoirs, most of them located in the back swamps of the flood-prone area. Whether these reservoirs are effectively used for agricultural or other purposes in the dry season is not clear and a case study was carried out to better assess the constraints affixed to the use of such reservoirs.

8.2.1 The Nong Sing reservoir and surrounding villages

A case study was carried out in "Nong Sing (NS)" (tiger pond) which is located straddling Tambon Ban Luang, amphoe Don Phud, Saraburi province and tambon Rong Chang, amphoe Maharat, Ayutthaya province[98]. Its shape is like a tiger's tail and its total area is about 155 rai. NS receive the excess water from the irrigation canals and, in the past, was always covered by the floods. This area is planted with floating rice. NS was developed by RID provincial office of Ayutthaya in the 1996-1999 period. The total budget for its excavation was 13,692,000 Baht and it has now been transformed into a reservoir expected to store about 870,000 m3. The alleged objective of the project was to constitute water stocks for agricultural in the dry season and to keep natural fish resources after the flood.

NS is located in the lower part of a small basin, with a village and an irrigation canals on each of its two sides. On the east of NS, there are 700 rai of farm land belonging to tambon Ban Luang, distant by 700 m from the pond. On the west of NS, there are 1,100 rai of land situated between NS and the irrigation canal of tambon Rong Chang. The average distance from the irrigation canal to the border of NS is about 1,500 m. Four small ditches were dug in the past to serve as tertiaries but are now very shallow.

The case of NS appears as special because some farmers did originally use the pond to water field crops in the dry-season (corn, chili or mungbean). Because the excavation works took 4 years and had to be carried out during the dry season (with the pond being dried up), these farmers had to move to other areas, renting land near waterways. Now only 9 households out of 24 use NS area, while others grow dry-season near other water sources or do not farm in the dry season. One of the difficulties encountered was that the available water was only 260,000 m3, much less than in the project justification.

Through other rapid appraisals carried out in 'thung maharat' (in 'Wat Ulom' drainage unit: see Molle et al. 1998), together with the NS study, several constraints to the use of such reservoirs could be identified.

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[98] For more details on this study see Chankoed (2000) and Chinnawong (2000)

8.2.2 Constraints and opportunities of use

The studies revealed that the voluntary public investment in reservoir digging is not sufficient to ensure that the water stored will eventually be used. Making water available is necessary but not sufficient to trigger agricultural activities.

Relevant factors constraining action include:

Physical aspects

- The reservoir is relatively far from the villages and there is no convenient road to go there
- Farmers have no clear idea of whether water would be sufficient for a given collective use
- The plots are not levelled and must be improved
- The reservoir is now surrounded by a high dike (earth dredged out of the swamp) and the water is not accessible without rather powerful pumps (conventional low-lift axial pumps may not be sufficient and more investments are required)

Farming systems

- Investments in capital are required (plot improvement, pumping)
- Rice dry-season cropping requires different cropping techniques for which farmers may not be skilled and for which they have no equipment: therefore they must either invest or hire service for land preparation;
- Many farmers are old in the area and are not willing to engage in new activities, with corresponding risks and investments
- Many farmers have already seized off-farm employment opportunities and farming appears only as a secondary activity. Therefore they are not interested by dry-season cropping or do not have enough time to devote to it.
- Some of the plots adjacent to the reservoir are rented in by tenants who are not likely to invest in land improvement

Other aspects

- The dike is now a home to rats which can conveniently escape the flood and increase pest pressure in the area
- Individual initiatives are therefore exposed to high crop damage. Only a collective move can be envisaged, but this is more demanding in terms of organisation and implementation.

This list shows that many constraints must be taken into consideration before indulging in such investments. There is no clear information on the extent of reservoir use in the dry season but scattered observations suggest that it is generally low. Successful cases seem more frequent in areas where the reservoir can be used as a secondary water source for rice, even during the wet season. In such areas with double-cropping of HYVs, the reservoir is readily taken advantage of, while in floating rice areas the above constraints tend to limit water use.

In summary the potential for developing secondary water resources is limited. Wells already exploit most of the easily accessible aquifers. Many reservoirs have already been excavated but those located in distant swamps are often not used as expected for a series of reasons which should be identified before initiated the excavation works.

9 Increasing the efficiency of irrigation

9.1 In search of water losses

When considering the improvement of efficiency, one generally thinks about avoiding loss in the canals (lining) or at the plot level (use of water by farmers). The first point is a question of civil engineering and will not be touched here. It is assumed that some canals, especially in more sandy areas, would benefit from such interventions, but the determination of the most favourable areas is left to the engineers of the Regional Offices. It must be noted that some laterals have been lined along the years, although not on a large scale. In any event, if such investments are welcome locally their efficiency at the macro level is unfortunately doubtful (see footnote 105).

Common wisdom assumes (because the price paid for water is small or nil) that water waste in irrigation is widespread and that large amounts could be saved and redistributed. As many observers who propose the introduction of economic tools (more on this later) keep harping on, “since water is not appropriately priced, it is used inefficiently, and consumers have no incentive to economise” (Christensen and Boon-Long, 1994)[99]. This argument runs counters to reality, as will be briefly shown here.

Let us first turn to the evidence that farmers are getting the lion’s share of Thailand’s water resources and pitifully squander it. What comes to the fore, when one looks at the process of water allocation, is that farmers are not getting a larger share through some kind of privilege or preferential treatment but, rather, that they are eventually attributed *the water which is left in the system* (if any). To some extent, it may be misleading to speak of conflict on water as one may infer that there is a kind of struggle to get water before or instead of other users. Such a situation occurs, in an open-access system when riparian users have the possibility to extract water by themselves, without referring to any collective institution, or despite it. If independent individuals or groups have *technically* access to means of diversion/abstraction which exceed the available flows within a given river system, then conflicts are likely to arise.

In other (semi)controlled centrally managed water systems, allocation is partly or totally controlled by a public agency. Therefore, conflicts occur rather as a *consequence of the*

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[99] This seems to be taken as indisputable evidence. See, for example, declarations of a high ranking official of the Ministry of Agriculture “Water should be priced in order to increase the efficiency of its use in the farm sector” (The Nation. 2000. April 21); “Agricultural experts agree that water-pricing measures would help improve efficiency in water use among farmers” (The Nation, 1999 Feb. 17); the Director of the National Water Resources Committee director: ”In reality water is scarce, and the only mechanism to save water and encourage efficient use is to give it a price” (The Nation, 2000. April 23); the resident advisor for the ADB in Thailand: “International best practices suggest that efficiency in water management can be improved considerably through imposition of nominal water user fees” (Bangkok Post 2000, June 11). This echoes an endless list of similar outright statements: “if water is cheap, it will be wasted” (The Economist, 1992); “Currently, most farmers don’t have to pay for irrigation water and, thus, have little incentive to conserve water or to use it efficiently on high-value crops. As a result, irrigation efficiency is under 30%” (TDRI, 1990), etc.

policy adopted to apportion water among the different users. In the Chao Phraya Basin, for example, releases in the dry season and their spatial allocation are decided mostly by RID. Priority in water allocation is, rather consistently, given to the domestic supply of urban areas, to industries, and to controlling salt water intrusion at the mouth of the rivers. Last comes the agricultural sector, which uses the remaining water, coping with an obvious year-to-year fluctuation and uncertainty in water supply. As shown earlier, RID has been challenged in recent years by an increasing water abstraction from riparian users in the middle reach of the basin, amounting to up to 35% of dams releases in the dry-season. However, the negative impact of this loss of control has been passed on to the delta irrigated area, which saw its share dwindling down, and not to non-agricultural sectors.

It follows that it is incorrect to state that farmers are wasting water just because their share of water is by far the largest. It is so only *as long as* other sectors have not raised their demand to more significant levels, and *because* the government has, in the past, developed infrastructures to allow a productive use of water in irrigated areas. The hierarchy of priorities reflects the higher opportunity costs in non-farm sectors but, also, the evidence that domestic demand has to be ensured in any cases, due to the obvious importance of water as the daily prerequisite of life.

A second assumed evidence which must be put under scrutiny is whether farmers are using water efficiently. Based on common knowledge that efficiency in large state-run irrigated schemes is often found as low as 30 or 40%, there is a tendency to stick to this overall vision without questioning it any further[100]. The first point which needs to be emphasised is that such situations are often found in water systems, common in monsoon Asia, which are not *opened*, i.e which have by and large resources in excess of demand and out of which some usable water supply is left. The second type of systems are *closed* systems. There has been recently wide recognition of the fact that focusing on relatively low water efficiency at the on-farm or secondary levels could be totally misleading (Keller *et al.*, 1996). Many systems, and river deltas typically account for the most significant of them, *eventually display extremely high overall efficiency*. More generally, what has often escaped the attention of many commentators is that such systems have not been passive in front of growing water scarcity. On the contrary, they have been extremely responsive to it in recent times and have gradually developed flexible ways to access water in all places *where it can be found*. Nowadays, no conventional gravity systems is functioning as it has been designed to. Individual pumping capacity has developed in order to tap water in canals, drains, ponds or aquifer and there are often few unused return flows.

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[100] "Currently, most farmers don't have to pay for irrigation water and, thus, have little incentive to conserve water or to use it efficiently on high-value crops. As a result, irrigation efficiency is under 30%. Urban consumers and commercial and industrial users pay only nominal water fees that do not reflect the marginal cost of supply" (TDRI, 1991). This unfounded statement has spread as common wisdom. See for example Kraisoraphong (1995): "The factor which contributes further to the water shortage is the continued inefficient use of water. With the below 30% efficiency rate of the irrigation system, the agricultural sector still accounts for up to 90% of overall water use, free of charge". If 70% of the water delivered to irrigation areas is assumed to be lost, it should also be shown where does such an amount of water disappear to !

The Chao Phraya Delta in the dry season provides the most illustrative example of such a closed system. This has been demonstrated in Chapter 1 and a few conclusions are briefly reminded here. The first point is that most of the return flow from fields or canals is reused downstream. Favourable specific locations where double cropping is well established are often found along drains, most of which have been gated in order to retain superficial and to capture sub-superficial flows. Pumping in drains is often more reliable than depending on canal water. If we consider the efficiency of irrigation at the macro level, we must reckon that the only waste water is the water which eventually flows out of the delta system, that is to say flows to the sea. As this flow is hardly sufficient to control pollution and salinity intrusion in the rivers mouth (in the dry season), it follows that no or only negligible water is lost. The second component of water loss is the infiltration. It occurs that such a loss is channelled either to shallow aquifers or to deep aquifers: in the first case, it is tapped again trough tube wells or soon returns to the drainage system where it is reused. In the second case it reaches aquifers which flow to the Bangkok area where they are notoriously over-exploited, resulting in land subsidence and horrendous costs in upgrading flood protection and in flood damages[101]. We may therefore venture to state that *infiltration losses in the delta are not sufficient* to offset the depletion of the aquifers.

Even when we examine carefully plot irrigation, it is hard to find the decried pattern of wasteful practices. The main reason is that most farmers access water through pumping. This is true for all the farmers located in the lower delta (in this so called flat *conservation area,* water is integrally and individually pumped from a dense network of waterways) and for an approximate 60 % of the farmers in the upper delta. Altogether, it follows that approximately 80% of farmers are resorting to pumping, the great majority using low-lift axial pumps. Field observations show that, in some cases, farmers may even resort to up to 3 or 4 successive pumping operations, from a remote drain “step by step” up to their plot ! Even in the more modern of the Mae Klong area, studies of water use at plot level have shown that conjunctive use and pumping are widespread (Molle *et al.*, 1998). Although the Chao Phraya and Mae Klong schemes were designed to supply water by gravity, RID experienced severe difficulties in managing reduced flows in the dry season. To offset this constraint, farmers have, along the years, developed an impressive individual pumping capacity allowing them to tap whatever little flow might appear in the canal. It follows that because of the costs incurred by these water lifting operations, there is little likelihood that farmers may be squandering water[102].

A corollary of this situation is that, in contravention to official declarations, most farmers *do not get water free*. This applies to numerous small and medium scale irrigation Projects developed under RID or DEDP which rely on a collective pump to get access to water and where operational costs are shared between users, as well as for most of the delta, as explained above, and probably most other large scale schemes in the country. It goes

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[101] It is estimated that the damages of the 1995 flood amounted to 50 billion baht, that is 2 billion US $!

[102] In times of shortages farmers may tend to hoard water in their plot, thus increasing marginally losses by infiltration. However, this is a marginal phenomena and it is socially controlled in time of drastic shortages (see report 2).

without saying that these investments in pumps, motors and gasoline are not negligible. It has been shown that these pumping costs, because of very long application times caused by poor land levelling, may even be as high as discouraging sugar-cane growers to apply the adequate amount of water, despite water being available in the adjacent ditch (Srijantr and Molle, 1999). It must therefore be acknowledged that *farmers do pay to use water in the dry-season*, partly in consequence of the failure to supply them with gravity water. It follows that the argument that farmers tend to ignore the value of water is significantly weakened.

Estimates of water use in the delta given earlier have also shown that the macro efficiency in the dry-season is rather high[103]. Calculating the ratio of the water supply to the total cropping area (expressed in rice equivalent), what led us to a reasonable modulus of 1,500 m3/rai, is misleading for two reasons:

1. This corresponds to a macro level efficiency applied to the irrigation system only and wrongly suggests that farmers are using much more water than required by the rice crop. This average ratio (1,500 against 980 m3/rai, see next section) is around 0.6, twice that commonly stated ! It is therefore quite high and most of the missing 39% should not be ascribed to farmers but to the different losses by seepage and evaporation on the way between the dams and the farmers' plots. As mentioned earlier, most of what is drained out of the plots (in any case a limited amount of water) is reused downstream.

2. Sticking to the above ratio and implicitly explaining it by users practices is now recognised as a flawed approach. The water "lost" by seepage 1) benefits large areas of vegetation outside the formal hydraulic network (in our case 160,000 ha of home gardens); 2) goes to shallow aquifers where it is tapped by tube wells, and 3) to deep aquifers which end up supporting the supply of BMA. *In a closed basin, infiltrations must not be seen as a loss but as a transfer to underground storage*.

Considering all this evidence, it appears that harking back to this erroneous picture of the farmer as a wasteful villain is altogether thoroughly flawed, unfair[104] and at least misleading regarding the debate under consideration here. Instead, it is high time to recognise that we are dealing with a closed system, with interconnected superficial and underground water flows, and that there is little scope about achieving substantial overall savings[105]. What is the

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[103] Again this may not be the case in the wet season, when the system can be considered "opened". It may also not be the case in the Mae Klong system but this is consonant with the fact that it still is – even in the dry-season – an opened system and has no consequence at the macro level: all the water possibly lost to the drains flows either to the Tha Chin River, where it is redistributed to the West Bank, or to Damnoen Saduak area, where it is re-used in gardens.

[104] Charoenmuang (1994) reports that in some conflicts in the Mae Taeng Canal Project (Northern Region), "villagers urged city dwellers and government agencies to economise on water consumption".

[105] For example, investments to line canal in order to limit loss by seepage would probably impact negatively on the use of tube wells. Meinzen-Dick (1997) reports: "Ironically, many measures to improve the "efficiency" of irrigation water use can reduce the total output of the irrigation system by restricting other uses and users. In the Minipe Naga Deepa system in Sri Lanka, introducing canal lining to reduce seepage losses lowered the water table beyond the reach of the hand pumps people used for drinking water".
Another example of negative macro consequences of efficiency improvement is provided by the american West,

crux of the matter, rather, is the way these insufficient water resources are allocated. Water efficiency in closed systems is a red herring.

9.2 Shift towards low-consumption crops

Another often stated option to achieve water conservation is to induce a shift away from rice to field-crops, which consume approximately 40% of the amount of water needed for rice. This, ideally, would allow more farmers to benefit from a second crop in the dry season. Such a shift could be boosted by differential taxes, fixed according to the kind of crop. Such diversification policy has been a recurrent issue for decades, was already a recommendation of the FAO as early as the 1960s, and is the alternative which "received the most attention" from Small in his study of the upper delta (1972): "in recent years, low export prices for rice, and the difficulties encountered by Thailand in maintaining her export markets have further intensified the interest in stimulating the production of upland crops" is a typical sentence which could apply to any period of time. Australian and Japanese cooperation engaged in agronomic tests in the late 1960s and 1970s to propose adapted field crops for the irrigated areas. Yet, dry-season non-rice crops have remained limited.

Evidence of dynamics of diversification in the Delta (Kasetsart University and ORSTOM, 1996) show that farmers display great responsiveness to market changes and opportunities (a point definitely evidenced by the recent spectacular development of inland shrimp farming). Good transportation and communications allow marketing channels to perform rather efficiently. The main weak point remains the risk attached to the higher volatility of field crops prices, which discourages farmers from shifting significantly to non-rice crops. As long as the economic environment of field crop production remains uncertain[106], there is little scope to push farmers to adopt such crops or to sustain criticism on their growing rice, as many have incurred losses by growing field crops (either by will or suggestion from extension services). Inducing shifts in cropping patterns to achieve water saving by means of differential taxes is believed to be unrealistic while such risk remains.

In addition, there are several other constraints (agro-ecology: heavy soil with little drainage, not favourable to growing field crops; labour and capital requirements, skill-learning, development of proper marketing channels, etc.), which condition the process of diversification and it is doubtful that, in addition to public policies aimed at fostering it, its pace may be increased beyond what is already observed. Contrary to common rhetoric, farmers do not need to have their water priced to shift to other productions. They will increasingly do so if uncertainty on water and prices is lowered. They have time and over shown dramatic responsiveness to constraints on other production factors, such as labour for

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where new irrigation technologies decrease return flows to downstream users and affect the right of use-dependent appropriators (see the example of the Snake river and the Columbia Basin Project given by Huffaker et al. 2000)

[106] It can be argued that rice marketing is also uncertain. However, the political sensitivity of rice production is such that there are limits which cannot be easily trespassed. In contrast, no one really matters if the price of chili (a very intensive cash crop with heavy capital investment) swings from 30 to 2 baht/kg in one year and scattered growers have little means to voice their distress and limit their loss.

example, and have already sufficiently experienced the scarcity of water to adapt their cropping patterns, should conditions be favourable[107].

This suggests that public intervention should be limited to “upstream” (water conditions) and to “downstream” (marketing) aspects of production. If such aspects improve, farmers will naturally shift to other crops, when the benefits and the risk become acceptable to them. Persuading them to do so on a wide scale, as occurred in the Agricultural Diversification and Restructuring Programme of the Thai Government launched in 1993, may lead to misplaced advice and failures (Siriluck and Kammeier, 2000). All in all, there is some irony in the fact that farmers are held responsible for their 'lack of cooperation' as suggested by Cumming's observation that "the biggest headache, analysts agree, is farmers' failure to prepare by switching to less water intensive crops or commodities than rice" (1999).

9.3 Cropping calendars and their impact on water consumption

The choice of cropping calendars entails wide differences in absolute water requirements. It must therefore be investigated how these calendars have been fixed in the past and whether the logic which governed this choice is still relevant under changing conditions.

When dry-season cropping developed on a large scale in the early seventies, the calendar of dry-season was reasoned along the following lines:

- Maintenance of infrastructures is needed and water distribution should be halted for a few weeks in order to perform the interventions needed.
- Lowlands grow traditional rice varieties and their harvest, during the months of December and January, demands that water be drained. Irrigation supply in the upper lands is not desirable because part of this water will flood the lower parts and hamper harvesting operations.
- Some Projects (especially Chanasutr and Samchok) also grow sugar-cane and their harvest also demands dry land conditions, in particular to allow trucks to enter the plots and load the cane. As harvest also concentrates during the first weeks of the year, it was rational to delay the second crop until later in the year.
- The lack of on-farm infrastructures, although dry-season cropping tended to first develop in areas provided with land consolidation, meant that the plot-to-plot system was used and that much co-ordination between farmers was needed, calling for a collective, regular and predictable start of the season.
- In the same line, more precise scheduling and calendars were needed because of the use of transplanting. This technique requires to have a nursery grown around one month

[107] The spectacular endogenous spread of sprinklers in vegetable production observed in the Mae Klong area shows that farmers are not opposed to investing and adopting water saving devices. However, as in the case of Chile (Bauer, 1997) and many other places, it can be shown that the adoption of this improved technology is driven by considerations of labour availability and easiness of use rather than by water saving purposes.

before the plot is ready to be transplanted. Water must therefore be available at the right time, otherwise seedlings will be too old or lost.

For these reasons, water supply was scheduled to start around the beginning of February or later. The general use of transplanting at that time implied that, during the following 5 months, there was little room for the staggering of water supplies.

A first exception to this rule was the shift of calendars observed in the West Bank. It has been shown how this area shifted its calendars to accommodate one crop before the flood and a second one after (see § 3.4 and Kasetsart University and ORSTOM, 1996). The post-monsoon crop turned out to be convenient because fields were already soaked for land preparation and the canals of the West Bank could also benefit from the water stored in the flood-prone buffer area and released from mid-December to the end of January (Molle *et al.* 1999).

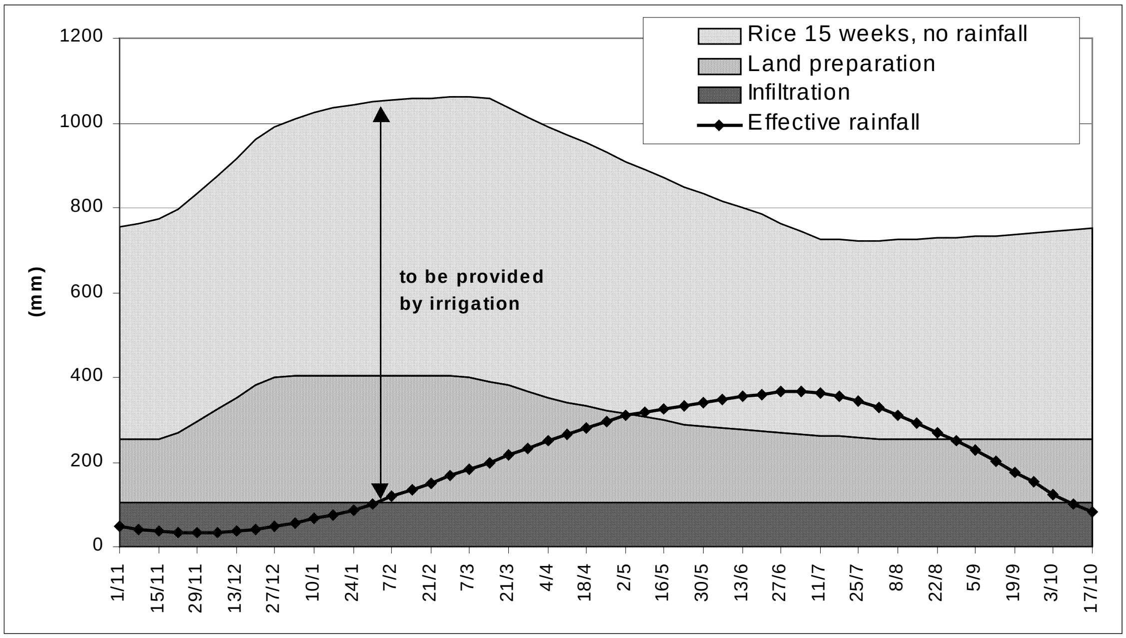
As opposed to the rigid and 5-month long dry-season cropping period, *spreading calendars over the November-July period almost doubles the time available to grow a second crop* (and allow some farmers to grow three crops over the whole year) (see § 4.2.3). This clearly offsets part of the hydraulic constraints of the network, as implied by its limited flow capacity.

A second important point to be enhanced here is *the impact of calendar shifting on crop water use*. As climatic conditions (precipitations and ET) vary along the year, the water needs of a given rice crop of, say, 15 weeks, also vary.

In addition to this, the water requirements for land preparation also vary according to time. Land preparation, as practised for rice crops established with transplanting or with the wet broadcasting technique, includes soaking land, ploughing, puddling, levelling and draining water out before sowing. These agricultural operations, depending on the soil characteristics and its initial wetness, can take as much as 300 mm of water. In some types of clays which give way to large cracks when they dry up (as observed in some parts of the eastern part of the delta), this amount can even be of greater magnitude[108]. This is considerable, when one remembers that the rest of the cycle will request between 650 and 850 mm. If the land is already soaked or wet at the time of land preparation, a significant amount of water can therefore be saved.

[108] Acres (1979) considers values between 200 and 300 mm (but 350 mm can be observed in some soils with cracks), while Panida (1972) reports values in the 300-350 bracket. Other values are given by Sanyu (1989) and Pattanasiri (1996), who use 190 and 250 mm respectively.

FIGURE 81: WATER REQUIREMENTS FOR DIFFERENT DATES OF CROP ESTABLISHMENT



As for rainfall, a crop grown later in the season will statistically benefit more from rainfall than if it is grown early in the year. Regarding ET, evapotranspiration[109] will be at its maximum during March-April, resulting on higher water needs during this period (percolation rates are taken at 1 mm/day).

We can overlay – and aggregate – these different factors in order to see how the overall water requirements vary *with* the date of crop establishment. Figure 82 speaks for itself and shows the significant variability of crop water requirement with the date of planting, under several hypothesis on the effective rainfall. A common variety of 15 weeks will require 1,050 m^3, if planted in early February but less than 835 mm if planted before December[110]. The figure also indicates that for a reduced effective rainfall contribution (half of the average), plantings later than early May are significantly penalised by 200 mm or more.

For different hypotheses on land preparation (e.g 250 mm instead of 300 mm) or infiltration (e.g 2 mm/day instead of 1, or 1.5 mm in the DS and 1 mm in the WS), the values given by the curves can be easily adjusted.

Figure 83 shows the same curves but expressed in percentage of the maximum value. It can be observed that approximately 25% of the total water is saved for an early planting on the

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[109] Kc and ET parameters were borrowed from RID but the calendar adopted was 15 weeks instead of 13. This corresponds to a cycle of 115-120 days with irrigation suspended 10-15 days before harvest.

[110] These values are consistent with those considered in several other studies. Pattanasiri (96) uses a value of 704 mm for a 10 week only variety, with only 56 mm for percolation. Sanyu (1989) estimates requirements at 1,006 mm for a rice transplanted in January, with 15 mm for nursery, and 1 mm/day for percolation. AIT (1995) uses values of 975 mm for the Meklong area.

1[st] of November, 15% for mid-December. Water savings can be all the higher for a very late planting, with a high variation according to rainfall. What is the latest date for establishing a crop of rice depends on water control? In low lying areas the wet season rice crop must be established at least before July, but this date can be delayed until mid-August as one goes upward along the toposequence. Farmers may sometimes establish dry-season crops to be harvested later than these unwritten limits, after which the risk of flood on the young seedlings is too high. In this case, farmers prefer to grow a dry-season crop because of the higher yield of the former, although this is at the expense of the possibility to grow the wet-season crop.

In areas with good irrigation and drainage control, there is no real limitation apart from that of water availability. Dry-season cropping may be so late that it is unclear whether it is still a late dry-season crop or an early wet-season crop. In continuous rice systems, where cropping intensity and calendars are attuned to water availability, these season based distinctions become meaningless.

If these figures are of any help, however, it is in the clear demonstration they offer of the variability of crop water use according to the calendar chosen. This point has been insufficiently considered in the past. It calls for spreading cropping calendars over the season, in order to increase the percentage of early and late planting, which consume less water. There is, however, a hydraulic constraint to such re-scheduling. Serving sub-areas with stricter calendars (that is shorter periods of time) requires that higher discharges be ensured in canals. This can be achieved only if the water level at Chai Nat dam is high enough, ideally close to the 16 MSL level which allows full supply levels in the different waterways (see § 5.1.6). This, in turn, is possible only if at least 80 cms are passed on to the Chao Phraya River, in order to ensure the hydraulic stability of Chai Nat dam. In other words, we need to accept the loss of more water if we want to raise the water level upstream of the diversion dam. When downstream requirements are under 80 cms, the loss will be increased. However, in quantitative terms the loss appears limited. (If measures are taken to curtail groundwater overuse in the BMA, then more surface water will have to be used and this loss will be further reduced).

FIGURE 82: VARIATION OF WATER USE FOR ONE CROP OF RICE, ACCORDING TO THE DATE OF PLANTING

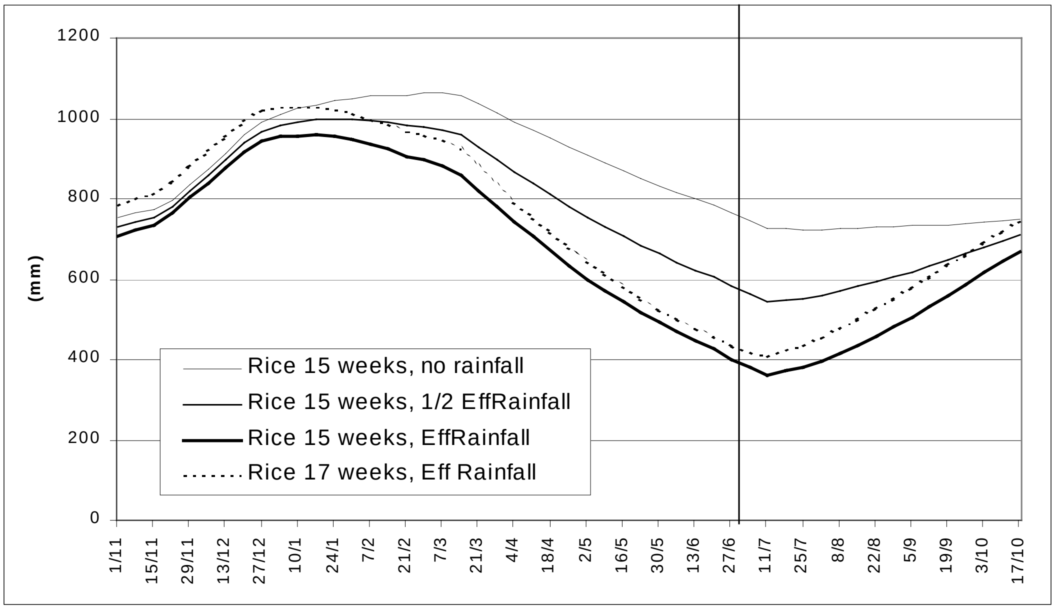
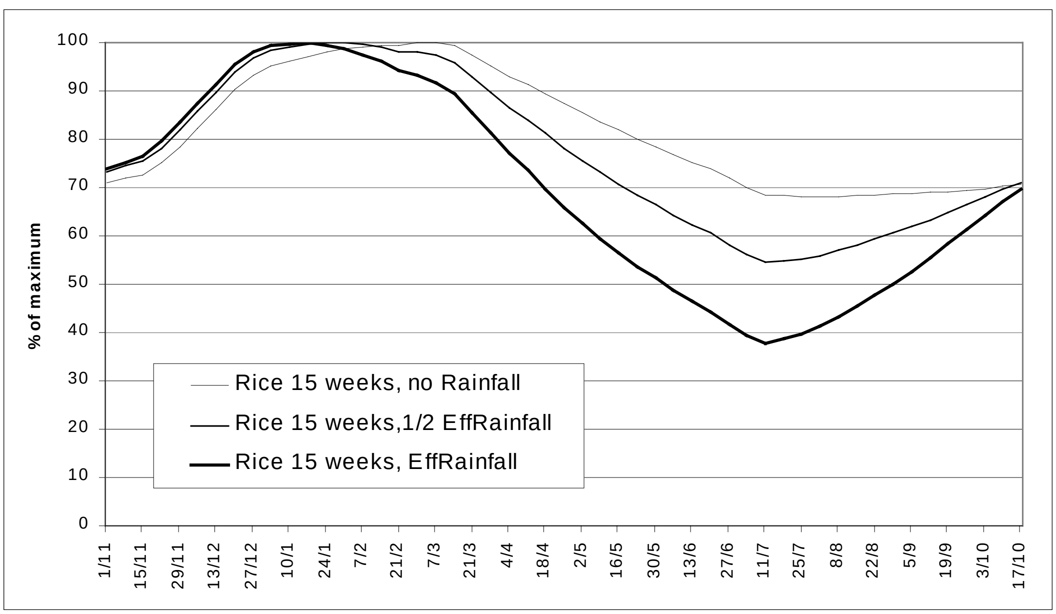


FIGURE 83: WATER USE FOR ONE CROP OF RICE, ACCORDING TO THE DATE OF PLANTING, IN % OF MAXIMUM



10 Dissociating irrigation and energy generation: an overall gain ?

At the completion of the Sirikit Dam in 1972, hydropower generation accounted for almost one third of the total electricity produced in Thailand (after having reached 70% in 1965 !). Therefore, the rules and patterns of dam management were designed with the objective to maximise energy generation. The management of the reservoirs, significantly, was attributed to EGAT. Ten years ago, technical studies suggested that the economic benefits of one m^3 of water used for electricity generation or for agriculture were of the same order of magnitude ; electricity, however, was still given the highest priority, on account on its vital role for the daily life of the country. This chapter investigates whether changing conditions could call for a revision of this once prevailing logic.

10.1 Compared benefit of water in agriculture and energy generation

The economic benefit from hydropower generation is strongly dependant upon the investment and maintenance costs of the reservoirs, together with their operational costs. Currently (1999 data), the production cost of 1 Kwh is around 1.2-1.3 baht. EGAT sells it to Provincial Energy Authorities at 1.5 baht and the final price to consumers is 2.1 baht. Although some dams may have higher production costs than others, we will consider here these average figures.

The energy produced by one m^3 of water passing through the turbines of the dam depends on the water head, that is the water depth in the dam. For the Bhumipol and Sirikit Dams, this energy varies commonly between 0.17 and 0.27 Kwh for the former and between 0.13 and 0.20 for the latter. Average values of 0.23 and 0.17 Kwh/m^3 are considered in what follows, which translate in monetary values of 0.29 and 0.20 baht/m^3. With an average water duty of, say, 1,500 m^3/rai of rice, the quantity of water needed to grow one rai of rice generates *435 and 300 baht of energy worth* when released by each of the two dams.

We must now estimate the economic benefit of these 1,500 m^3 once transformed into rice production. The task is made arduous by the fluctuation of rice prices (Figure 84). We chose here an average value of 5,000 baht/ton of paddy, which is slightly under the average of the deflated values of the national average rice price in the dry-season[111], over the last twelve years. This price is expressed in current baht (1999). The average productivity of dry-season rice is around 750 kg/rai (close to 4.5 t/ha) while the monetary costs of production[112] are close to 1,200 baht/rai: these do not include land rent and hired labour costs, as these costs are also transformed in socially distributed monetary benefits. The opportunity cost of labour is not considered here, as there is little evidence that the labour force which participates in farm operations in the dry-season would be allocated elsewhere in case dry-season cropping

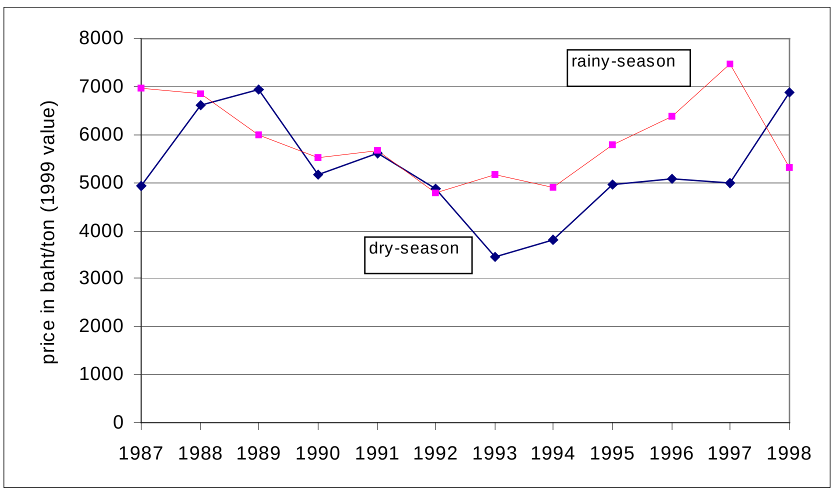
[111] As can be seen from the graph, the average price in the rainy season is higher than the value in the dry-season.

[112] Includes fertiliser, pesticide, seeds, gasoline, equipment depreciation, and land tax.

was marginally decreased[113]. This sets the overall economic benefit of the 1,500 m^3 applied to one rai of rice at roughly 3,000 baht, distributed among the operator, the land owner (if any) and the wage labourers (if any). To this should also be added the benefits and incomes generated for the operators along the marketing channels of both agrochemicals and rice.

It can be concluded that the benefit of water for rice cultivation in Thailand, at the macro level (say 3,000 baht/rai), is much higher than the production costs of the energy the same amount of water can produce (around 400 baht). In other words, it is worth using alternative modes of energy generation (even if they are more expensive than hydro-electricity), instead of releasing water to be used only for moving the turbines and later lost to the sea. Of course, this opposition occurs only when the water released is further wasted to the sea. In case this water is *also* reused for irrigation, which is the most common situation, *the benefits are cumulated*. The comparative advantage of agriculture is all the more enhanced when one considers cash crops (less use of water, higher cash income), orchards or shrimp farms (income 20 times that of rice). In addition, if we consider – as evidenced in this report (see chapter 7) – that the sustainability of agricultural holdings is strongly governed by the cropping intensity achieved, then these social aspects dramatically accrue upon the already favourable economic balance.

FIGURE 84: AVERAGE RICE PRICES IN THE LAST 12 YEARS (IN 1998 VALUES)



Source : Office of Agricultural Economics

10.2 Towards an irrigation-oriented dam management: conditions for a shift

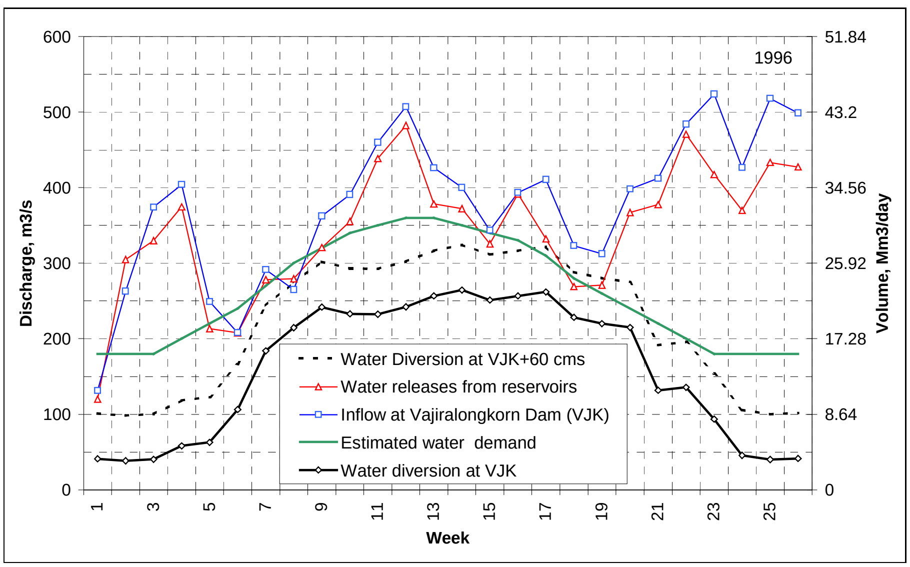
These volumetric considerations, again, while they confirm the priority which agriculture should receive, do not address the question of whether it would be technically feasible to shift to a RID-oriented dam management. Section 6.2 has already shown that EGAT's management actually embodies the water requirements expressed by the different

113 There is no seasonal migration in the Central Plain, as it can be observed in the Northeast at harvest time. Computing the total cost of labour gives a total of 4 man-days/rai * 120 baht = 480 baht.

downstream users, in particular RID. Therefore, it would be misleading to refer to a move away from an EGAT-oriented management to a RID-oriented management. This would suggest that the two logics are antagonist while, in reality, EGAT only manages for its benefit and energy generation purposes the *remaining margin of flexibility,* once downstream demands are served.

It can be shown that in the case of the Mae Klong system this margin is rather high, because of the overall water surplus status of the basin. Satoh *et al.* (1999), using a similar way of assessing "savable water", have found that between 14 to 74% of the yearly total release came under this category, showing that EGAT enjoys a significant degree of slack which can be resorted to according to specific energy-generation requirements. Kositsakulchai *et al.* (1999) have also evidenced this fact, as appears in Figure 85, which shows that dams releases are much higher than the estimated demand (the manageable surplus can be computed at 30% approximately). However, there is at the moment no clear standard which allows one to distinguish between 'usable slack' and over-releases which impact on the security (of supply) of the system.

FIGURE 85: AVERAGE DAM RELEASES AND WATER REQUIREMENTS IN THE MAE KLONG BASIN



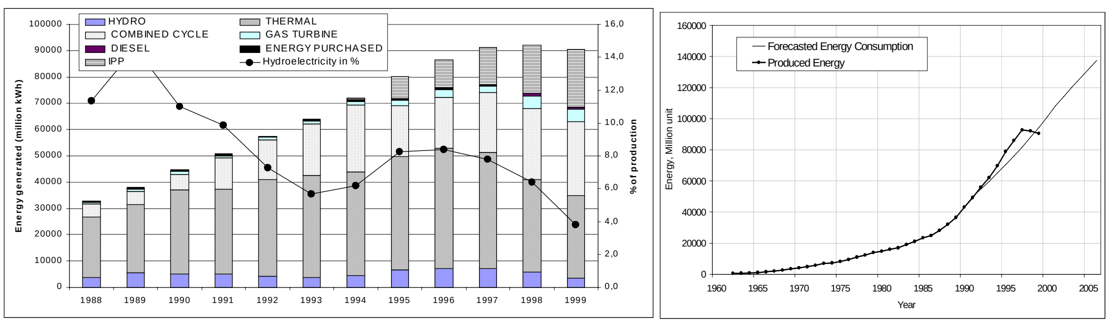
Source : Kositsakulchai *et al.* (1999) VJK = Vajiralongkorn diversion dam

In the case of the Chao Phraya River basin, the situation is clearly the opposite one. Yet, because of the early orientation of dam management for energy generation and because of the flexibility offered by the dams to compensate for forced outages of thermal power plants, EGAT has continued to enjoy a certain liberty in managing the dams. Section 6.2, however, has shown that this margin of flexibility has been drastically reduced in the last 10 years. As water is getting scarcer in the basin and conflicting interests arise, resources and their management come under growing scrutiny.

The most important point to be considered here is whether and how EGAT can give up the benefit it draws from managing the marginal “excess” water of the basin[114]. New elements show that this possibility can be envisaged and that a dam management by and large independent of EGAT is both technically and economically desirable.

1. A first element is that hydropower has undergone a dramatic decline in relative importance as a source of energy for Thailand. From one third of the national production installed capacity in the early seventies, it now amounts to only 8% of it and is generated mostly by five major dams (Figure 86) ! If we ascribe half of it to Bhumipol and Sirikit Dams, they eventually jointly represent only 4% of the national production capacity and their effective share in generation is in general much lower (the dams are rarely full).

FIGURE 86: ELECTRICITY GENERATION BY SYSTEM TYPE (SOURCE EGAT)



2. A second point is the overcapacity inherited from both the economic crisis and overrated projections considered in the past (Watershed, 1999). Energy consumption has levelled off since the end of 1997 whereas the projections – on which were based the development of new sources – were made under the assumption of a 12% annual growth rate during the 1990s and onward. This appears in the chart above (right).

   Sangarasi (1999) reports that the reserve margin, or added installed capacity, is 25% at EGAT (and was 29% in 1999 (EGAT, 2000)), while international standards are normally around 15%. As the year’s peak load is 40% higher than the yearly average, to add another 25% leads to a high overcapacity. In addition, EGAT admittedly uses a coefficient of security of 1.35 in its planning; this means that an estimated growth of 10% is translated into a planned increase of capacity of 13.5%. Altogether, there is currently a significant overcapacity in production which must be used instead of resorting to hydro-electricity in case of emergency.

3. A third element is the increase of the share of energy produced by gas turbine and combine cycle plants in the last 5 years (making up now more than one third of the installed capacity). This includes the conclusion of the gas pipeline between Burma and

[114] In fact, this “excess” does not exist any more on a long term basis but there is so far nothing which prevents EGAT from considering that a given relatively high active storage is not partly a surplus and can be marginally used out of the schedule defined by downstream uses.

Thailand which is going to serve the plant of Ratchaburi, with an installed capacity of 4.600 MW[115]. This (gas-turbine) plant and others are in a position to offer most of the peak generation facility formerly provided by the dams (730 MW for Bhumipol Dam and 500 MW for Sirikit Dam).

4. A fourth element is the growing importance of IPP (Independent Power Producers), which also partly operate plants with gas turbines. In May 1998, power purchase agreements had already been signed with seven IPPS for a total capacity of 5.944 MW, with a total of 1.750 MW to be delivered in 1999-2000 (Sangarasi, 1999).

5. Fifth, the completion of a main storage dam in Laos, which is also expected to sell part of its energy to Thailand. In 1999, hydroelectricity from Laos corresponded to a power of 340 MW. The Lam Takhong pumped storage Project is also starting operations with two turbines of 250 MW, while this capacity is to be doubled.

These last three evolutions are raising the capacity to respond to peak energy demand and the burden on dams should be decreased accordingly. Because of their importance for agriculture and other use, *priorities have been reversed* and the two dams should not be resorted to for peak generation beyond the ceiling defined by downstream uses.

6. Sixth, according to EGAT (2000), the rate of forced outages has been significantly reduced through the upgrading of facilities and improved maintenance. This should translate into limited occurrences in which dams, or other emergency sources, need to be resorted to.

7. Lastly, if we consider the extremely limited current flexibility enjoyed by EGAT, we may infer that this would only be the recognition of the changes occurred, but at the same time it would preclude such years like 1996, when a huge waste was observed.

The data relative to the 1995-2000 period show that weekly over-releases by EGAT are limited and rarely exceed 100 Mm3. This shows that emergency cases in the dry-season have been dealt with limited water waste. This cannot be ascertained for the rainy season but, as the level of the total energy produced is lower in that period, this problem should be easier to solve than in the dry-season.

If the combined changes in the relative benefits of water and in the production structure of energy in Thailand are acknowledged, then national policy-makers should endorse it, together with three major consequences: The Bhumipol and Sirikit Dams will continue to produce a (declining) share of the country energy, *but without, or only in extremely exceptional cases,* incurring the water losses provoked by: 1) releases in excess of the downstream demand, either for (1a) peak energy demand or (1b) because of plant forced outages; 2) the spill-avoiding logic of the upper rule curve of the Sirikit Dam.

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[115] The first phase started recently with a capacity of 1.380 MW

While the first point is easy to translate in term of operation (releases must follow downstream requirements), the second, together with other technical points and possible improvements, is addressed hereafter.

11 Proposals for improving dam management

Four aspects of dam management are considered in this section:

- the first one refers to the possibility to better attune dam releases to variations in net demand (the water requirements not covered by sideflows);
- the second examines the impact of the drop in dam releases on Sundays and holidays;
- the third calls for a revision of the upper rule curve in order to maximise the final stored volume rather than the total energy generated;
- the fourth point refers to the possibility to exceptionally resort to the dead storage volume of the dams;

11.1 Improvement of in-season (weekly) management

Whether the loss of water characterised earlier as *Case 2 or Case 3* (the dams release water which is partly wasted to the Chao Phraya River at Chai Nat) can be saved is a matter of whether and how quick RID's demand is attuned to hydrological events within the basin. The responsiveness of RID (and EGAT) to hydrological events, mostly during the wet season, depends: 1) on the rapidity and accuracy of the transmission and process of relevant hydrological information and 2) on an improved co-ordination between RID and EGAT, allowing the information to be transformed into operational orders (*command* function).

11.1.1 Responsiveness to hydrological events

The responsiveness of irrigation officers is rather high in the case of local heavy rainfall, as Project managers reduce the inflow in their main canals by closing the regulators; it is probably rather low when the excess water originates in upstream areas and only materialises through an increase of the flow at Chai Nat, which is further simply wasted to the Chao Phraya River.

It is beyond the scope of this report to explore the possible improvement, in particular through real time sensing of rainfall, water levels and discharges in key points of the network. Such measures are parts of a process of modernisation which are needed at the basin level. When compared with other crucially important water basins in other parts of the world, there is no doubt that much still can be achieved in terms of technological monitoring of hydrological events.

11.1.2 Co-ordination between RID and EGAT

The hydrological data transmitted to the Central Office must be analysed, processed and transformed in relevant operational instructions. RID must issue a special request to EGAT if it wants the dam releases to be modified. This process is not necessarily smooth and possible adjustments are sometimes just dealt away with. In any case the possibility of improving the responsiveness of the management chain is constrained by a minimum lagtime of 48 h, under which no adjustment is possible. This is due to the daily planning of energy generation, which must be fixed two days in advance.

These real time management constraints mean that an unknown share of the water losses computed above, specially those related to case 2 and 3, cannot be avoided, which does not however invalidate the necessity to improve the responsiveness of EGAT to hydrological changes.

In addition the responsiveness to hydrologic events can be improved but never be perfect because of the time lag for the transfer of water from the storage dams to Chai Nat (5 days) and from Chai Nat dam to the sea (4 days). Therefore heavy rainfall, say, near Nakhon Sawan, cannot easily be taken advantage of because a change in dam releases would only have a delayed impact.

11.2 Improvement of in-week (daily) dam management

A point often mentioned by RID officers as a constraint to irrigation management is the irregular daily releases from EGAT. Because of the drop in energy consumption during the weekend, EGAT also reduces water releases, although it committed itself in maintaining them above 60% of the average weekly value.

Plotting daily releases (Figure 87) and the water level upstream of Chai Nat Dam in the 1998 dry-season clearly shows these fluctuations. Figure 88 also indicates the points of the curve which correspond to Fridays (a lagtime of five days is considered between the dams and Chai Nat). Fridays neatly correspond to the slumps of the 1998 curve, while in the dry year of 1994 these weekly fluctuations are dampened by the highly erratic pattern of inflow at Chai Nat Dam. These data lend support to the claim that the EGAT-induced water level fluctuations make operation more difficult and allow the estimate of the amplitude of the phenomena at around 40 cm. This situation can also be found in the Mae Klong basin, where this phenomena has also been shown to be significant (Vudhivanich *et al.*; 1998).

It appears that the lower releases on weekends are somewhat dampened on the way. If we look at the daily dam releases for each of the weeks of the 1998 dry-season, we find that in fact there are slumps on Sundays. On the average over the 26 weeks, the decrease is 61% of the week average, that is almost exactly the value agreed upon. However, 5 weeks have Sunday releases under 55%, with 3 of them under 50% of the week average.

11.3 Reconsideration of the upper rule curve

Excess releases of water are ordered when the water level gets higher than the so called “upper rule curve”. This curve is designed to limit unproductive loss through the spillway and to avoid water levels which could lead to a dangerous overflow of the dams. Given the declining importance of hydropower generation (see discussion in chapter 10), it is recommended that these curves be revised in order to maximise (under the constraint of safety) the *amount of water stored on the first of January, rather than the amount of energy generated*. The logic must be changed, because the benefit in energy generation derived from the maximum avoidance of spill is small compared to the benefit generated by more water use in the dry season[116].

FIGURE 87: EXAMPLE OF DAILY RELEASES FROM THE BHUMIPOL DAM (1996)

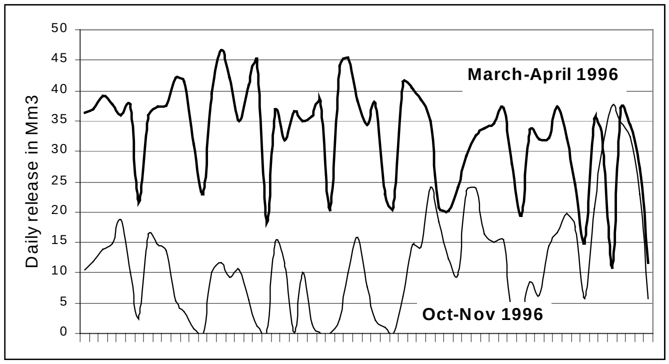
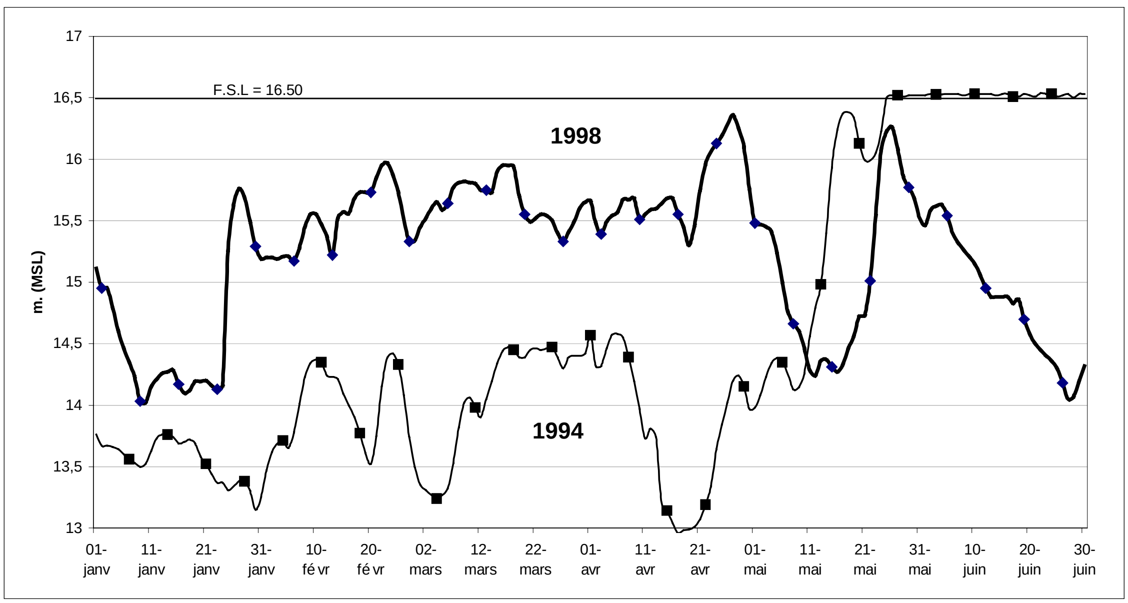


FIGURE 88: DAILY WATER LEVELS UPSTREAM OF CHAI NAT DAM, IN 1994 AND 1998



This issue only refers to Sirikit Dam, as Bhumipol Dam is more and more unlikely to spill in the future.

A look at the series of daily inflows in Sirikit Dam shows that the maximum observed value was 372 Mm3/day. Next values, however, were only 351, 292 and 275 Mm3; the percentile of probability 0.01 is 104 Mm3. On the other hand, the historical spill of 1975 was initiated at a water level of 161.9 m and produced a maximum daily spill of 35 Mm3. In 1995, a record

[116] In addition, the energy generated by the additional water stored will be higher because of the higher average head. This will partly compensate for the increase of water spill.

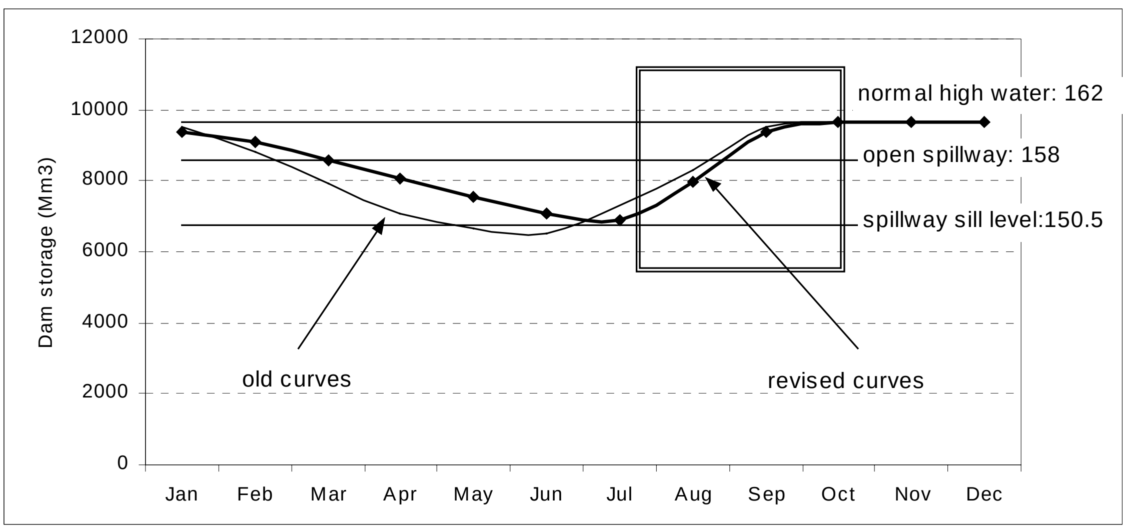
spill of 127 Mm3/day was recorded, while the water level reached 162 m. The spillway was open at the level 158.84 m (for a recommended value of 158 m).

Figure 89 displays the upper rule curves of Sirikit Dam (old and revised versions). As it is very unlikely that any high water level will occur before July, only the July-October period is relevant for this curve. It can be seen that the revised curve dictates an earlier spill than was the case before. It is also beyond the scope of this report to judge the consistency of these curves and to devise new ones but modelling should be done based on the maximisation of the stored volume, with security, and not on the maximisation of energy generation. Of course, all this makes sense only if these curves are adhered to. The releases of Sirikit dam in 2000 show that they have been anticipated with regards to the standards of the rule curve.

TABLE 16: DIFFERENT LEVELS IN SPILLWAY MANAGEMENT AND CORRESPONDING VOLUMES (SIRIKIT DAM)

	Spillway sill	Open spillway recommended	Normal retention level	Normal maximum retention level	Dam crest level
Level (MSL)	150,5	158	162	166	169
Volume (Mm3)	6,751	8,563	9,647	10,815	

FIGURE 89: UPPER RULE CURVE FOR SIRIKIT DAM



Source: EGAT (pers.com.)

11.4 Tapping the dead storage volume ?

The inter-annual regulation is very much dependent on whether the dead storage volume is treated as an absolute limit or not: in the Mae Klong basin, the two dams are provided with outlets located much under the minimum level defined by the position of the turbine inlet. This means that it is possible to use the (huge) dead storage volume in exceptional cases. With this possibility – which implies that energy generation will be suspended for a few weeks, until the run-off of the coming rainy season fills the void – flexibility is gained up to the point that no real shortage should be experienced, with the actual level of water requirement. In the Chao Phraya Basin, however, the situation is slightly different, as only the Sirikit Dam is provided with an outlet which can be operated in normal conditions (non emergency).

If energy generation ceases to govern the logic of management, then there should be little reluctance in envisaging resorting to the dead storage volume, or at least in *increasing the probability* that it should be tapped, although this case must remain an exception rather than the rule and would only a few weeks at the most.

The dead storage volume of the Sirikit Dam is 2.85 Bm^3. Considering 200 cms as a minimum supply (for Bangkok and other priority uses) during the end of the dry season, this corresponds to a volume of 0.5 Bm^3/month which can be found, during two or three months, in this reserve[117]. Resorting to the dead storage volume, however, should be done with extensive prior public information, in order to avoid that it be wrongly interpreted by the media and lead to alarming news. This would come naturally with the official recognition that the management of the two dams is to be governed by downstream use and that a special request at the highest levels should be made if EGAT was to envisage large unproductive releases in excess of this use.

[117] The case of the Mae Klong should also be mentioned. The two storage dams of the basin jointly have a dead storage of almost 10 Bm3, that is the inflow into the two dams of the Chao Phraya Basin ! In the year 1994, however, supply to irrigated areas were reduced in order to avoid lowering the water level under the threshold of energy production. The social and economic benefits drawn from agriculture are higher than the price of energy generation by the reserve capacity and such a situation should not be allowed to occur in the future.

12 Water pricing as a management policy ? [118]

As water systems evolve from a situation of open-access resource to one of conflict generating pressure, there is an increasing need to regulate water allocation and abstraction. With the disappointing results of the attempts at upgrading infrastructure or management, economic means of regulation may appear as attractive substitutes or complements. This tends to shift water, a vital natural resource, to the realm of economic goods and markets, raising fears of third-party effects. With the return of water shortages, solutions to the looming crisis must obviously be found. Four different options are commonly supported:

The first school of thought on water resources, promulgated by NGOs and social activists, considers water as a social good, the free use of which is a human right. As expressed by a scholar at Thammasat University "natural resources — such as water — are essential to all, and should not be managed by market mechanisms. Otherwise, water would not flow by gravity but by purchasing power. Commoditisation of water should not be allowed because the right to natural resources is a basic right all human beings have". This view is echoed by some farmers, who inquire why they would "have to pay for the water that Mother earth and the forest give us" (The Nation, 2000 June 11).

A second viewpoint is spearheaded by international donors, notably the Asian Development Bank (ADB), together with some segments of the public administration who, willingly or not, seem to have rallied to the cause. They have voiced support in favour of the introduction of economic incentives and demand management. Water saving must come from water pricing (users will inevitably be encouraged to reducing their consumption), and improved management. Conflicts between users, in particular different economic sectors, are eventually best regulated by market-based mechanisms.

A third attitude, favoured by most of the Thai public sector, supports an administrative solution rather than one based on demand management. New laws aim at giving more control power to the various administrative bodies concerned by water issues, orientations quite in evidence in the two drafts of the "Water Law" which have been elaborated in the past years (Christensen and Boon-Long, 1994). Emphasis is also placed on co-ordination between agencies and on the idea of basin agencies. The possibility of creating a Ministry of Water has also been debated for a few years.

Finally, the somewhat "traditional" concept put forth by technical bodies (and consultants) which holds that the problem of water shortage can be solved by increasing supply through further water resource developments[119]. These efforts include new dams and transbasin water transfers from the Salaween and Mekong rivers. This solution faces growing opposition

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[118] This issue is developed at length in Molle (2001).

[119] The Metropolitan Water Authority's website bears a motto which suggests that agencies can have mixed feelings: "Tap water is not a commodity but something obtained from the management of natural resources, therefore it is a treasure which ownership right must be extended to all people".

from environmental activists and is loosing its attractiveness for donors because of the increasing costs of tapping an additional m^3 of water. However, it tends to be preferred by some governmental agencies for well known reasons, ranging from an engineer-oriented culture, to political and financial direct or indirect benefits (Christensen and Boon-Long, 1994; Repetto, 1986).

While discussions on the opportunity of a water charge are an old story, these conflicting views have been recently put in relief. The issue came in the limelight further to the announcement that the granting of ADB funds to the country would be conditional on its subscribing to, and applying, the overall principle of water pricing. The public debate is clearly confused by the different nature of the economic tools envisaged and of the arguments which can be raised in favour or against these policies. This appears clearly in newspaper articles, interviews and NGO literature. Officers from the Royal Irrigation Department (RID), the National Water Resources Committee (NWRC), the Ministry of Agriculture or from international agencies (in particular ADB) come out with conflicting statements and show positions which evolve over time. The debate is also obscured by the fact that several measures are proposed, with different but overlapping objectives and justifications:

1. The first proposal is to elicit *water-saving* behaviour by charging a usage fee. By raising the costs of a given resource, it is widely believed that users tend to reduce their consumption.

2. A second approach is a *cost recovery* justification. As supplying water is costly (in most cases to the government coffers), it is justified to pass part or all of costs to the concerned users, rather than to the entire population, as is the case with electricity or urban water supply. Cost recovery may include capital cost recovery (sunken costs of project implementation) and/or operation and maintenance (O & M), or recurrent service costs.

3. A third possibility reflects the preoccupation of macro-economists concerned with *allocating water* to the most profitable uses, those which produce a higher added value per cubic meter of water input. Whoever can pay the most for a cubic meter of water is the one who will obtain the highest added value from it, and vice versa. Introducing market-based mechanisms and letting the market's invisible hand reallocate water is believed to lead to a “maximisation of the social benefit” produced. Through this implicit competition, the first objective of water saving is also indirectly attained.

The issue of water saving has been dealt with in § 9.1, where it was shown that the rationale for implementing measures aimed at saving water was weak and flawed. The objectives of cost-recovery and reallocation, and their justification and applicability in the Thai context, are briefly analysed in what follows.

12.1 Water charge, taxation and cost recovery

There is wide consensus that introducing market-based mechanisms to improve resource allocation, or even levying fees related to water use, makes little sense in an open system, where there is little pressure on the access to the concerned resource (Smith *et al.* 1997; World Bank, 1993). Firstly, there appears to be little scope for water scarcity issues during the rainy season. Although some episodic dry spells are commonly experienced, irrigated schemes have no difficulties in supplementing crops with the required water supply. In fact, water inflow is mostly coming from rainfall or uncontrolled (i.e. not captured by reservoirs) natural sideflows in the river basins, upstream of the irrigated areas. Overall, rather than supplying water, water management is often geared towards limiting excess flows and flooding. In other words, water saving is not an issue[120].

It has long and widely been recognised that volumetric water pricing is incompatible with irrigation water distributed by gravity over tens of thousands of farms, because there is no way to measure the amounts of water used (Moore, 1989). A second alternative is to adopt the wholesaling of water to groups of users (typically those served by a same lateral). This leads us, beyond individual users, to the much more complex socio-technical question of water allocation and management at the delta and basin levels. This point will be addressed later. The remaining alternative is to price water using proxies such as the area of land and the kind of crop. This totally deals away with the argument that water pricing would allow water saving (as the tax would not embody any incentive to use less water) and is tantamount to establishing a taxation, within a perspective of *cost recovery*.

12.1.1 Defining the charge: theoretical and pragmatic approaches

There are several academic ways to work out an "optimal" taxation, depending on the approach and criteria adopted. The cost of water can be derived from the cost of supply (investment recovery), to which can be successively added: the O&M cost of supply (full supply cost), the opportunity cost in other alternative uses, the economic, environmental and social externalities. Another way to proceed is to assess the economic value of water. This value should ideally be at least equal to the marginal value of product for industrial and agricultural goods, and based on the "willingness to pay" for domestic use.

This economic value is as a rule much higher than observed water fees. One reason is that full economic prices are almost invariably too high to ensure the economic reproducibility of the concerned activity. Even in the United States, Postel (1992) reports that 4 million ha of the West are supplied "at greatly subsidised prices" by The Federal Bureau of Reclamation (see also Anderson and Snyder, 1997). Irrigators of the California's huge Central Valley Project have repaid only 4% of its capital cost. The second reason is that sectoral clout is often able to preserve a low pricing of water, either for socio-economic reasons (rural poverty alleviation, competitiveness) or for political reasons (vote-catching). A last reason is that these calculations are far from being standardised and that there is, in particular, little agreement on how to define and calculate opportunity costs and externalities.

In the real world, things are settled in a much more pragmatic way. A first and overriding consideration is that charges be in accordance with what *users are able to pay*. Few

[120] For agriculture. Nevertheless, water saving is a relevant issue at the level of the basin, especially with regards to the fit between dam releases and demand, and to responsiveness to hydrological change.

governments would take the economic and political risks to define fees at deleterious levels only for the sake of conforming to some theoretical abstraction. A second point is that an additional tax is to be considered *within the wider overall context of national taxation*. Asserting that farmers in the Central Plain have never paid for the irrigation system or for water use may be acceptable literally and in a narrow sense: if we consider, however, the revenues siphoned off from rice cultivation by the State through the mechanism of the rice premium between 1952 and 1984, it becomes clear that rice-farmers have indirectly paid back more than it can ever be dreamt to levy through a water fee. Indirect taxation through the control of market prices, or export taxes, often significantly accrues to the government revenue, as for example in Egypt or in Vietnam.

This point also serves to question the rationale used by ADB to support cost recovery.[121] Subsidies to the farm sector eventually maintain the price of food low, indirectly benefiting the whole non-farming population, and allowing lower wages and higher international competitiveness. This shows that things are more complex than what simplistic arithmetic might suggest[122]. The cost-recovery argument is also based on the alleged evidence that O&M costs correspond to a "huge drain on the national budget" (Halcrow, 2001). This argument also needs to be brought down to earth, as the potential gains from cost sharing represent 0.16% of the Thai national income[123]. It would probably not be difficult to find other "huge drains" with much less economic and social impact on the Thai population.

The crux of the matter for developing countries is to maintain a relative balance between the agricultural and the non-agricultural sectors, so that the transfer of labour from the former to the latter follow a pull process rather than a push one. In other words, the issue is one of maintaining the respective basic profitability/reproduction of the two sectors during this transfer process, in order to avoid major social and political disruptions. State investments, subsidies and taxation are “connected vessels” (what is added here will have to be discounted there) all aiming at sustaining, by and large, this balance, be it in accordance with economic orthodoxy or not. In addition to the delicate trade-off between farming sustainability and urban food price control, considerations of food security also contribute to turning the matter more social and political than purely economic[124]. All in all, a naive and insistent

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[121] “Thai taxpayers are paying Baht 35 billion a year to run RID. If this is worthwhile to the farmers then why should the taxpayers have to pay for RID?” (Halcrow, 2000).

[122] Schiff and Valdés (1992) show how governments are caught up in a web of contradictory goals, including protecting farmers, protecting consumers from high food prices, raising revenues through taxation and ensuring the competitiveness of economic sectors in the world market. Thailand appears in their study as a country where agriculture has been heavily taxed. This may serve to show that in the overall 'communicating vessels' game agriculture has been on the giving end rather than on the receiving one, which implies that the 'free water' subside can be seen as a small compensation for this situation.

[123] O&M costs are estimated at 11 billion US$. If we assume, optimistically, that cost sharing will cover up to 50% of this amount (all the main infrastructures and headworks are to be operated and maintained by RID), this gives 5.5 billions $ to be compared with a national income of 3,317 billion baht.

[124] The fact that funding agencies have never applied sanctions to countries for their non compliance to covenants stipulating cost-recovery may be regarded as an implicit recognition of the fact that the real world does not easily lend itself to paper principles (see Carruthers and Morrisson, 1996).

emphasis on theoretical concepts appears to be of little use and depending on the situation, constraints and objectives, it becomes “quite legitimate and even optimal in some sense to have the market clearing price different from its marginal price” (Sampath, 1992).

Subsidies, seen from such an angle, are a necessary preventive/corrective measure, but all the difficulty of policy makers is to distinguish the point beyond which they may turn prejudicial : they may become the expression of an undue sectoral privilege (obtained by a lobby) and/or insulate some economic activities from a more competitive context which would otherwise produce efficiency gains (regarding our present concern, for water saving) or call for alternatives (but the costs affixed to moving from one crop to another often poses a problem).

This is well exemplified by the case of Thailand. The decreasing profitability of rice and the crises experienced in the 70s have called for the abolition of the rice premium, and other taxes, such as the land tax, have not been raised for decades and are now almost insignificant. The charge on groundwater, too, which lends itself with more facility to control and volumetric taxation and mostly concerns industries in BMA, has remained stagnant and under-priced. Reasons for this have been a combination of several factors: 1) the fear of political and social consequences[125]; 2) the concern about maintaining the relative profitability of agricultural and manufacturing activities in a competitive regional context[126]; 3) the attempt to achieve a transition from the former to the latter without too sharp imbalances; and 4) the political clout of both the Federation of Thai Industries and farmers[127].

Even if we adopt the wise line of defining pragmatic water charges (a “second best choice..”), there are other drastic obstacles to its definition in medium and large scale gravity schemes. The quality of the access to water in most large scale schemes of Thailand is so varied that it is very hazardous to define a single fee per area unit under such circumstances. Big differences exist between head and tail-enders and this variability cannot be assessed once and for all: the access to water depends upon the overall amount of water distributed in the different canals, itself a yearly vagary. In addition, farmers commonly tap several water sources. Some may use canal water for 80% of their needs and a well for the remaining 20%; for others, sometimes only separated by a few meters, these percentages will be inverted. This may be true one year, but not the following, when the first farmer will use exclusively canal water by gravity (no cost), while the second will use the same water but will have to pump it from the ditch to his plot, because it is 30 cm higher128. A fixed fee per (cropped) area would obviously entail injustice, inequity, and widespread disputes on the

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[125] cf. the Minister of Agriculture’s declaration in January 1999: “The complete stoppage of farm subsidies would cause political and economic chaos in Thailand because farmers form the largest part of the population”.

[126] This also applies to internal and intra-region competition. After the pollution scandal of a pulp factory in the Northeasten region, an official appeared reluctant to get tough with factories and was quoted to say “if we punish them, who will want to invest here ?”

[127] Recently the federation opposed a gradual rise of the groundwater price (from 3.5 to 8.5 baht/m3, in an attempt to catch up with a m3 of tap water at 12.5 baht), stating that a price of 5 baht would “already lead to hardship” (Bangkok Post, 2000, June 28).

[128] For more details on the complexity and variability of water use at the plot level, see Molle et al. (1998)

level of taxation attached to each plot. A variable and adjustable fee would be just as unworkable, given the fluctuating variety of situations and the lack of simple quantitative measurement. In addition, it is also likely that farmers will use shortcomings in water supply or depressed rice prices as a pretext no to pay the tax. All this would occur because uncertainty and shortages are not equally distributed, not even stable, which, again shows that a water charge cannot be designed independently of questions of service quality.

What precedes chiefly applies to the upper part of the delta, but also to irrigated areas of the middle basin and to the Mae Klong Project. Things are more homogenous in the lower delta. In the conservation area, all farmers withdraw water from nearby canals with pumping devices. Keeping in mind that water is not accessed without costs, it is nevertheless easier to apply some kind of taxation based on plot area and crop type. Other users include over 40 golf courses, sugar mills, industries, real estates, etc. which, in some instances, pay a symbolic fee to RID.

12.1.2 Water charge and risk

Interestingly, it is not the amount of money that rural people earn in local factories, or migrants in Bangkok, which they readily cite as the advantage of their new activity but, rather, the regularity and certainty of their wage. It is equally meaningful in that respect that, when asked about the eventuality of a water tax, farmers do not display sharp concern on the issue but – almost invariably – either straightaway shift to asking back why the government is not instead guaranteeing the price of rice or, alternatively, appear not to oppose considering the issue *if* this means reliable deliveries (Bangkok Post, 2000 July 1; TDRI, ; Molle *et al.* 2000)[129]. This duly emphasises that the principle of a water charge in itself is acceptable (although, nothing is discussed yet on how much the charge could be), but only if the basic economic arithmetic of crop production is stable enough. Scott (1976) has shown how fixed taxes are deleterious to peasant economies because they translate into indebtedness in case of failure (be it crop failure or very low sale prices).

The lesson to draw from farmers' opinions is that the two mains sources of uncertainty (rice price and, for many farmers, water supply) are deterrents to any efficient use of economic incentives to impact on water use. In the current situation, it is to be feared that any significant taxation would not only have no impact on farm water use, but also deleterious effects on economic sustainability by increasing vulnerability to risk and, consequently, raising indebtedness.

12.1.3 Conclusion on cost-recovery arguments

Gathering a few key arguments from the two preceding sections, it appears that 1) there is a significant gap between theoretical economic values of water and farmers' ability to pay; 2) that it is extremely hazardous to define a fee based on the area irrigated in the situations in which the quality of access to water is extremely heterogeneous; 3) that a fee high enough to

[129] "I don't mind paying for water service if the government can guarantee delivering us water all year round", a farmer was reported saying (Bangkok Post, 2000, June 11).

offset collection costs would, in the actual context of fluctuating rice prices, raise the economic risk attached to farming; 4) that it is incorrect to state that farmers have never paid for infrastructures or water delivery, as cost-recovery was achieved by the State through export taxation; 5) that the 'huge drain' of O&M costs to the government coffers only amounts to 0.16% of the national income; 6) that an additional tax is to be considered *within the wider overall context of national taxation,* where taxes, subsidies and State investments eventually define the reproducibility of economic activities and shape the patterns of shift from the agricultural sector to non-agricultural sectors.

Such essential aspects of social and economic policies therefore not only address macro-economic efficiency but also the control of socio-economic disparities, regional poverty alleviation, competitiveness in the wider economy and include considerations of food security. This, therefore, makes things more complex that just an issue of “farmers must pay”. Several declarations from officials emphasise that “small-scale and poor farmers” are not to be charged, but without proper definition of such categories, speculations are set free.

12.2 Reallocation of water resources through market mechanisms

The third objective mentioned earlier is the concern to (re)allocate water to more productive uses. This can be attempted by differentials in the level of taxation, or by the establishment of a water market, an issue addressed in this section. The main advantage of water markets – a mechanism which defines users’ rights and allow them to trade them, either temporarily or permanently - over water pricing is that they may allow flexibility and adaptability to respond to temporal and spatial changes in supply and demand, and may reallocate water from low-value to high-value uses.

Although it emphasises the (theoretical) potential of water markets in achieving increased overall economic efficiency, the literature also recognises that such markets are often marred with a high occurrence of market failures and externalities (Smith *et al.* 1997; Perry *et al.* 1997; Meinzen-Dick and Rosegrant,1997). Even proponents of market-based mechanisms often admit that “tradable property rights does not imply free markets in water” and favour a system of “*managed trade*, with institutions in place to protect against third-party effects” (Meinzen-Dick and Rosegrant,1997).

It is recognised that water markets demand a background of legal consistency, administrative accountability and low enforcement which are rarely found in developing countries (Sampath, 1992), where, on the contrary, “capability in both management and regulation is limited and the social and environmental risks of getting wrong are considerable” (Morris, 1996). In fact, in the Thai context, few venture to make proposals which go that far[130], but this eventuality

[130] There are isolated examples of consultants not short of extravagant recommendations such as a system in which all farmers in Thailand would “each season, depending on how much water was in storage ” receive “shares” and would exchange them on a market, a system “currently being tried in New Zealand” (TDRI, 1990). More recently, TDRI (2001) returned to working on adapting a theoretical framework on water markets to Thailand. What appears to be a vision at best suitable for small scale basins is readily proposed as a policy for

seems to pervade the debate as NGO leaders express concern "that small-scale farmers will be deprived of water because bigger farms will have the ability to buy it" (Bangkok Post, 2000 June 11). Nevertheless, analysing to what extent Thailand relates to or differs from countries where such policies have been attempted, or where water trading is observed, is not devoid of interest. Several and varied examples drawn from a number of contrasting contexts have been raised and discussed in the literature. Some of their commonalities are first emphasised here.

12.2.1 Context for establishing water markets

Classical examples from the United States, Australia, Spain or Chile, generally have in common a strong legal background and law enforcement capability. They also come from contexts where users are well identified, homogeneous and in relatively low number. Water abstraction is measurable and most of the time done by pumping devices. Distribution facilities are modern and allow a good control of possible water transfers. This stands in sheer contrast with the context of Asian wet-rice small-scale farming, where irrigation is done by gravity and the simple identification of the users is hardly feasible.

Other classical references, *a priori* closer to the Thai context, come from South Asia. In irrigated areas of Pakistan, India or Bangladesh, groundwater markets have emerged along with the development of private tube-wells, spurred by insufficient and/or unreliable superficial water supplies. It appears that these markets are more germane to the leasing of irrigation equipment than to water marketing (as water does not belong to the pump owner). To recognise this fact leads to considering these contracts as so many examples of arrangements devised by farmers and other operators to allow a degree of reallocation of production factors and economies of scale. In that, they differ from other arrangements not by their nature (no one is surprised to find tractor or land rental contracts and should not be so to find pump leasing) but, if anything, by the fact that they mediate the transfer of scarce common-pool resources to individuals. In the upper part of the Chao Phraya Delta, for example, there is an estimated total of 30.000 wells. Cases of farmers paying neighbours to supply their plot too are commonplace and did not raise particular interest from anyone; nor was it felt necessary to consider them as water markets. There is little scope for and benefit to expect from any formalisation of these diverse arrangements which are already very flexible.

Another kind of water transaction, this one more akin to the idea of marketing, is that of superficial water in irrigation scheme. Examples from the Asian context also centre on arrangements found in schemes managed through the *warabandi* system, or other forms of rigid allocation principles. This is no surprise, although seldom emphasised, because such systems implicitly define a *right* to water. In the *warabandi*, this right is generally defined by a frequency (lowered in case of shortage) and fixed duration of water supply. This right may be more or less reliable, in particular the discharge in the tertiary canal may differ significantly from the nominal theoretical value (Strosser, 1997), but this does not prevent some farmers

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Thailand without due consideration to the constraints of the real world (in particular technical in large scale projects, but also institutional and political).

to cede their right to others. What *warabandi* also implicitly has, is an “automatic” way to share deficit over all users. This provide a great strength in that the uncertainty of supply affixed to the fluctuation in the available water is more or less accounted for. In that, it can be related to run-of-the-river systems, which often have proportional dividing weirs to achieve the same objective, like in Bali, Nepal or Chile.

These examples suggest that exchanges or sale of superficial water are likely to appear endogenously wherever conditions make them possible. Conversely, the absence of such arrangements in the Thai context of large irrigation schemes is clearly indicative of their irrelevance in the local conditions. The simple reason for this is that there are no such pre-defined water turns, as found in the *warabandi* system, nor any other form of definition of *what* could be traded. Water is supplied under a continuous flow regime and there is, by and large, no right beyond that of who gets the water first, be it by pumping or not.

12.2.2 Context and impact of water re-allocation

The concept of water market implies possible reallocation of water both within the agricultural sector and from agricultural activities to non-agricultural ones.

Within the agricultural sector, giving more water to those who produce crops with higher value added would be tantamount to strengthening areas which are favoured with locational or land-resources advantages, or with greater capital endowment, and can afford to grow these crops, at the expense of those which grow rice or sugar cane and are not in a position to shift away from them. In the delta, this would be exemplified by orchard growers and aquaculture farmers who would secure their access to water thanks to their higher purchasing power. While there is some economic justification for this, there is a risk that the alleged principle to give “due attention to the poor” remains purely cosmetic under such logic[131].

Cases of reallocation of water away from agriculture to other sectors are scarce and limited to some experiences in the United States and Australia. A few comments can nevertheless be done on the applicability of the principle to the context considered here. The idea is basically that “if an irrigator can earn more by selling water to a nearby city than by spreading it on alfafa, cotton, or wheat, transferring that water from farm to city use is economically beneficial” (Postel, 1999a). Two distinct cases must be considered. The first one is an occasional reallocation, while the second is a permanent one.

Occasional re-allocation is difficult to achieve because it not only requires accurate definition of individual rights but also a very high degree of control on water and transportation facilities required to transfer water from one user to the other. This appears clearly in the case of the “drought bank” set up in 1991 in California, where networks of canals and pumping stations

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[131] It must be noted that these differences are actually already implicitly incorporated in the current centralised allocation policy. The 250,000 ha of raised bed systems in the lower Mae Klong area are given priority over other crops in case of water shortage, although the rationale for that is more the high immobilisation of capital in the orchards of the area than the fact that the value added per hectare is higher.

allowed the reallocation of water among a few (30) big contractors (see Wahl, 1993; Teerink and Nakashima, 1993). The assertion that "if the price of rice is low, [Thai] farmers would be happy to cede their right to industrialists" (Wongbandit, 1997), just runs counter to the most simple evidence. Industrialists or cities are served first and would do nothing with more water attributed to them when the price of rice is low, let alone the evidence that the physical constraints of the distribution network make such a reallocation impossible. How would the "rights" of a group of farmers in, say, Kamphaeng Phet (middle basin) be transferred to a given golf court or factory in the suburbs of Bangkok?

The question of permanent reallocation is beset with the same juridical difficulties but is less demanding in terms of physical flexibility : should a given group of users collectively agree to give up its right to a volume V of water, then this volume would be simply made available within the system for other users. Obviously, with regards to Thailand, this is only a mind game, as the first daunting step would be to identify the million of users, alternatively pool them in consistent collective entities, to find an accepted criteria to attribute a right to them (say a volume V), and to define how this right varies with the water stock !

Notwithstanding these difficulties, if we follow this line of reasoning we may accept that golf courts, recreational areas and factories gain preferential access to water resources because they can afford to pay more for it. That such an example of "the maximisation of benefits for the society" is compatible with equity and poverty alleviation is not straightforward. The theory works as long as the reallocation of factors occurs between activities that constitute alternatives for investments and between users who also have a range of opportunities and compete in a perfect market. In other words, this holds for the logic of capitalistic investment, which constitutes the underpinnings and driving force of the proposed economic mechanisms. The small peasant distinguishes himself by a lack of choice or, rather, by an alternative which is quitting, willingly or not, the farm sector.[132] If farmers who are unduly exposed to the competition of sectors with a much higher profitability[133] were eventually led to let their land fallow (or to sell it to big farmers) they could ultimately swell the ranks of the unemployed and slum population in the capital. It is hard to see how the overall benefit of the society would be maximised by such a scenario, despite the fact that macro indicators would deceivingly suggest an overall gain. Political consequences of the reallocation of water away from agriculture are potentially high. Price (1994) noted that [in South Asia] "the cost of foregone agricultural production, multiplier effects regionally, and the resulting social problem of large pockets of poor rural residents are possible results that are politically unacceptable to governments and present little incentive to promote open water markets". The impact of the diversion of water out-of agriculture is a complex issue (Rosegrant and Ringler, 1998) but

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[132] Similarly, it is often inferred from the observations that some farmers, in particular contexts (such as Pakistan), are led to pay high amounts of money for secure water, that "farmers are *willing* to pay" (Postel, 1972; World Bank, 1993). A less optimistic view would be to assume that many of these farmers do so because they have no choice and because survival, indeed, entails a high "willingness-to-pay"… This would be consistent with observations that these informal markets are sometimes not competitive, and the prices charged higher than theoretically expected.

[133] Only very capital and labour intensive agricultural production (aquaculture, horticulture) can provide farmers with incomes which can stand comparison with non-agricultural ones.

in developing countries with large agricultural sectors and percentage of rural poor there is often little room for manoeuvre[134].

This takes us back to what has been said earlier regarding the trade-off faced by developing countries: if conditions for a pull driven shift from agriculture to other sectors are not met, then the odds are that free market mechanisms will compound inequalities, and deprive farmers of their access to water without ensuring descent alternatives to them.

Despite all these drastic difficulties, and staying in the virtual world of theory, the often emphasised advantage of a water market system, beyond the macro-economic gains, is that by being granted rights, farmers, either pushed or pulled to sell them, would at least get some compensation for relinquish their right to water. This may be seen as a clear gain from the current prevailing inequity of the centralised system. Where farmers have well-established customary or legal rights to the use of water, reallocation allow them to receive some compensation and not just being stripped of their water by other users. However, because rights can by no means be individual due to the high number of irrigators, decisions on the relinquishment of rights would have to be made collectively, which in most cases would be highly problematic[135]. All in all, it is also legitimate to wonder whether the actual system of indirect subsidising (free water[136]) is not easier to sustain than the daunting task of creating marketable rights which will eventually have to be relinquished. In the first case there is an indirect support to farmers' endeavour to maintain farming (*now)* as a sustainable economic activity, while in the second case farmers would pay a water charge and get (later) a 'bonus' to jump out of the boat…[137]

In the Chao Phraya delta, in contravention to common wisdom that casts farmers as the main *guzzlers* and beneficiaries of water, farmers have few rights to water, or rather, their right is mostly confined to the "leftover water." In case of shortages, water is centrally and unilaterally allocated to other uses and they are the ones to be prejudiced. If there were a

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[134] This is not peculiar to developing countries. In the Western USA, Frederik (1998) reports that "when farmers want to sell water to cities, irrigation districts resist, fearing the loss of agricultural jobs that accompany rural water use", while Wahl (1993) acknowledges that "most agricultural water districts have viewed the potential for water transfers only very tentatively out of concern over the security of their water rights and potentially adverse effects on the districts and local communities".

[135] Because of the heterogeneity of farmers and of their respective strategies, it will be impossible to cope with the fact that those with other activities and/or poorer access to water will be inclined to sell the groups rights and the other not.

[136] The point here is that, at the moment, this 'subside' goes to all users (with no difference between those, in the southern part of the delta, who always get water, and the others who seldom do) and every year (regardless of whether the supply is normal or reduced).

[137] There is an understandable concern on the economists' part to see factor prices reflecting their marginal use, as a way to avoid market distorsions and outright subsidisation. Whereas in most markets a change in input prices is readily passed on to the consumers (if the electricity charge to a given factory is raised, then, by and large, this surcharge translates in a similar hike of the sale price), this does not happen for commodities tightly linked to export markets. In the case of rice, the farm price elasticity relative to the world market price is 0.8 (Sombat Saehae, pers. com.). It follows that farm gate prices are predominantly driven by the world market and that internal balancing mechanisms to reflect changes in factor prices are critically constrained.

market, with user rights formally defined, their share could be bought by other users. Put another way, they would be compensated for their non-growing a crop, something they may be compelled to in the future [as experiences from Israel, United States, India or China indicate (Postel, 1992); in all cases agriculture's share was decreased to the benefit of cities].

There is some irony in the evidence that if the Thai legal system had been based on prior-appropriation rights, like in the western US, the delta would have been granted senior rights on water since the sixties or earlier and Bangkok would now be trying to buy these rights from farmers. *In such a case, farmers would at present not be asked to pay but, on the contrary, courted to accept money as a compensation!*

12.3 Water charge and water management

Several segments of the preceding sections have hinted at the crucial linkage between the establishment of water fees (let alone water markets) and the notion of quality of service or control over supply which comes together (in other words, some type of perceived *right*). The declaration of farmers mentioned earlier are consonant to Postel' s claim that "irrigators have shown time and again that they are willing and able to pay more for water that is reliable and over which they can exercise control"[138]. In irrigation, water has little value if its quality in terms of timeliness is not specified.

While, to use the parallel/opposition with domestic water, a few users are more or less ensured to receive water all year long (those located along main waterways in the lower part of the delta, as mentioned earlier), for the great majority of farmers this is by no means the case. Levying a yearly fee is contingent upon ensuring a corresponding service. A part of RID's officers foot-dragging in considering the issue is probably linked to the fact that establishing a water charge may eventually backfire, in that farmers will be given "the legal standing to bargain forcefully with the water conveyance bureaucracy for timely and efficient service" (Rosegrant and Binswanger, 1994).

The difficulties mentioned earlier attached to individual pricing and to the estimation of the quality of service received by each farmer, plus the impossibility to establish rights or fair fees without improving the control on supply, often points towards an intermediate solution: water rights, or at least estimated amounts of water, could be allocated to groups of users, for example to those farmers who are served by a same lateral (thus lowering the exigency on service improvement by ensuring only the inflow to laterals), while a collective fee could be levied (transferring the burden of its definition and collection to the groups).

What would be expected is that binding farmers together by granting them a collective right could be a way to "force" them to act collectively in order to (a) achieve greater efficiency/equity within the command area of their canal; (b) to constitute a bargaining power to obtain from RID the water supply they are entitled to; (c) to internally solve the problem of

[138] This point might also well contain a fallacy: farmers who do not get water may be willing to pay to have it; those who do probably not. The implicit promise behind the question is that it will be possible to give them water, which is not be the case because supply is short of demand.

differentiated qualities of access to water and define individual charges accordingly; (d) to instil some formalised notion of water right which could later be conducive to some form of tradability; (e) to constitute autonomous bodies which could later take over a part of the managerial tasks attributed to RID and could further federate at the Project or basin level; (f) to foster, in return, a corresponding improved performance on RID's (and EGAT's) part. The potential benefits are so sweeping that one may be tempted to gloss over the prerequisites to such moves.

We must first investigate what is meant by "improved performance", what are the constraints experienced by these agencies, those which may lie beyond their reach, and those which offer significant margin for progress. At the other extremity, it must be analysed whether farmers are able or willing to respond as expected. The other sections of this report, together with the companion report on institutional and social aspects (Report 2) give ample details on the difficulties existing at both ends.

In practical terms, it still remains to define how the set of drastic changes needed can be brought into the system with the acceptation and participation of both farmers and agencies. The costs of establishing such a policy, defining sound hydraulic units, involving farmers in the conception phase, co-ordinating uses at the basin level and reducing political interference, controlling and applying penalties on unauthorised abstraction, etc. are obviously huge. These changes must also be phased, as an eventual success will be conditional on their concomitant establishment.

All the measures brought up and discussed in what precedes translate in crucial exigencies addressed to the Thai institutional and political setting. Management rules, rights and control must be defined at all levels of the river basin, which challenges the actual definition of roles. The current institutional deadlock includes the sheer inadequacy of current laws with the problems experienced; the confused definition and scattered attribution of roles and power to the different ministries and strata of the government; and a context of political interventionism and laxity in law enforcement (see more details in Molle, 2001).

12.4 Conclusion: scope for economic regulations in water management

Despite its peculiarities, there is little doubt that the problem of water allocation demands regulation and interventions, against the view held by some NGOs that concepts and practices inherited from a situation of open-access resource should continue to prevail. Demographic and economic changes in Thailand will not, in the short run, allow free and non co-ordinated access to water to last as a sustainable solution. Admittedly, however, "water is far too important to its users to be the basis for socioeconomic experiments" (Perry *et al.* 1997). In this regard, the stance that "markets should be given a chance", only because centralised administration has shown its limits, appears a bit short.

The analysis of the current debate revealed a certain degree of confusion in the objectives and weaknesses in the justifications put forward. The idea that shortages are due to poor efficiency is the most misleading and enduring misconception. The litany: "water is consistently undervalued, and as a result is chronically overused" (Postel, 1992) applies in general to urban tap water, for which convincing experiences of seepage control and regulation through pricing exist, but is often loosely and abusively extrapolated to other sectors. It is our contention that Thai farmers' responsiveness to water scarcity is not crippled by a supposed lack of awareness attached to the non-pricing of water. There is a pervasive feeling that the rhetoric of water saving may obscure the fact that, in reality, closed systems have (already) significantly responded to water scarcity, in particular by developing conjunctive use and pumping capacities, and that in contravention to common wisdom, most farmers pump water in the dry season and do not engage in wasteful practices. In any case, the efficiency at the macro level can be considered rather high and gains from reforms may not be as high as expected.

Establishing a water fee for rice farmers in the actual context seems doomed to failure: it cannot be affixed to volumetric use and will at best have no effect on water use efficiency; it will soon be beset with defaulting because the service of supplying water with relative certainty is unlikely to be ensured; and it will stir farmers' exigencies in a technical and institutional setting which cannot, under the present conditions, respond to them. It cannot be justified without wider considerations on global fiscal policy, on inter-sectoral balances and regional competitiveness.

It appears that conditions for the development of water markets are just opposite to those prevailing in the delta: no possible volumetric metering, a very high number of small farms with differentiated and fluctuating levels of access to water, often committed to wet rice cultivation with severe environmental and market constraints to diversification, weak legal and institutional environments, and significant political meddling. Regulation through economic means is unlikely to bear fruits, at least in the foreseeable future. The impact and the relevance of confronting farmers with users from other economic sectors with higher capital and productivity is also questionable. The key question is whether farmers who would give up farming would do it willingly, on account of alternatives offered to them, or whether they would be thrown into bankruptcy, distress and poverty.

Water pricing, as a fixed tax, is consistent with a context of relative stability of income (rice prices) and production (reliability of water supply). It must therefore be addressed within a wider perspective including most particularly rice pricing and marketing, water planning, allocation and reliability, farmers' participation. More generally, we must recognise the virtuous linkages existing between structural, managerial, institutional and financial approaches (Small, 1997). Reforms addressing a single aspect of the system are all the more likely to fail or to turn counter-productive. Although the wholesaling of water is still extremely rare (Moore, 1989), it may appear as a viable solution if considered within a comprehensive reform framework. However, prudence, gradual reforming, testing in pilot areas and in-depth awareness-building, training, negotiation and discussions with all stakeholders, including politicians, are needed. We will return to these points at the end of the following section. The reader is also referred to Molle (2001b) for further discussion.

13 Rethinking the water allocation planning process

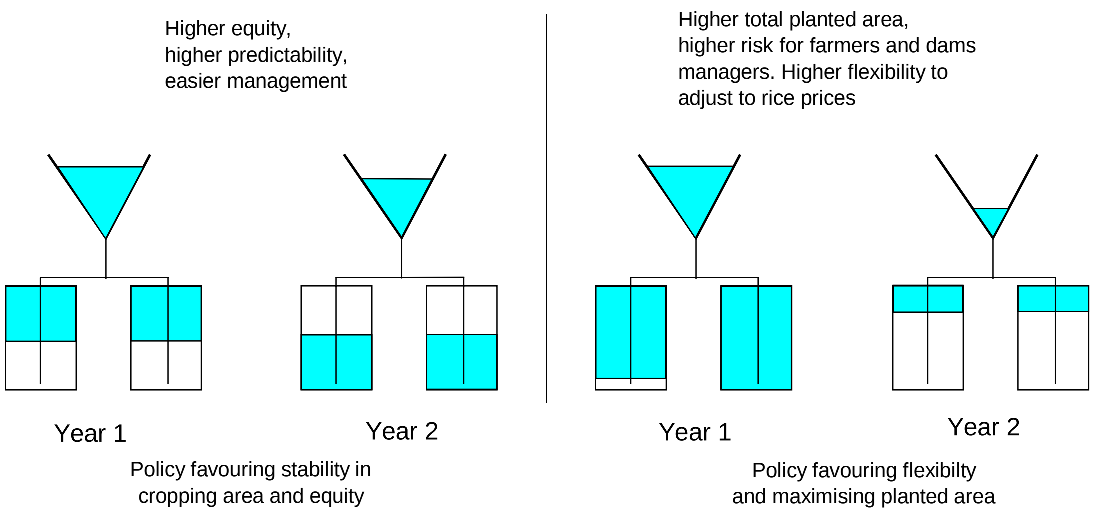
Based on the discrepancies observed between the formal and the effective management (Chapter 5), this section explores alternatives and complementary procedures which could lead to greater equity and greater control over the allocation process.

13.1 Seasonal water allocation: stability vs. efficiency

A first point to be considered here is whether the amount of water allocated each year will be based on the available stock (just keeping a security volume, still to be estimated), or if it is attempted to design a more stable (and more predictable) delivery, using the regulation capacity of the dams.

This poses a great difficulty to planners. Suppose, as shown in Figure 90 (left), that the volume to be allocated each year is fixed, or does not vary that much. We may therefore plan which areas will receive water each year and try to achieve a long term equity. In the most simple case, water is enough for half of the total area and the Project is divided in two parts which will receive water alternately. On the contrary (right), if the amount of water allocated each year is highly variable, like in the present situation, where it varies between 2 and 10 Bm3, then it is hard to plan which area is likely to get water or not. If the year is very dry, for example, part of the area which was supposed to get water will not be supplied. In the opposite case, areas which were not supposed to get water for being "out of turn" will eventually be supplied. After a few years, there is no way to prevent the head-enders will eventually be the ones to be highly benefited.
This difficulty was clearly the main factor which undermined the rotational policy adopted in the 1980s in the Chao Phraya Delta, according to which half of each Project would be allocated water one year out of two.

FIGURE 90: TRADE-OFF IN RESERVOIR-BASED IRRIGATION SCHEMES MANAGEMENT



Let us examine the trade-off between allocating a constant amount of water and one based on the available water stock (Figure 90). In the latter case, we *maximise* the total planted area over the years but we have to cope with high year to year *fluctuations*: this entails great difficulties in setting a spatial pattern of allocation respectful of basic equity requirements. In the first case, the total planted area over the years will be reduced (because the higher average water level in the dams will entail higher evaporation loss and spill), but it will be easier to plan a more equitable and predictable allocation of resources.

If we chose to fix a target volume TV in the case of the Chao Phraya Delta, we can use historical data to simulate what would have been the evolution of the two dams. If we fix a low value (for example 5 BM3, while the *average* potential is above 6 Bm3), then the dams will tend to store more water (better regulation), but also to spill with higher frequency and to evaporate more. The simulation is carried out assuming that the chosen Target Volume TV is supplied each dry-season[139], except of course if the volume available on the first of January (VA) is insufficient (TV < VA-FV, where (FV) is a floor security stock) ; in that case the target release TV for that year is taken as (VA-FV). However, this volume TV is not allowed to go under a certain threshold MT: this minimum target corresponds to the (minimum) incompressible requirements during the dry season, taken as 2.5 Bm3 for a default value on account of the lowest historical value observed (1.9 Bm3 in 1994, but with damage because of salinity intrusion).

Table 17 provides average values of seasonal allocation, and spill, evaporation, and energy generation for different targets TV. It shows that, as expected, spill significantly increases with low target values, but that variations in both evaporation loss and energy generation are very small. While low targets can be achieved in most years, the rate of "target achievement" is only 64% for TV=7,000 Mm3 and 40% for TV=8,000 Mm3. Conversely, the efficiency index, that is the ratio of the overall average seasonal supply to the historical value is 98% for 8,000 Mm3, but only 79% for 5,000 Mm3. If we want to decrease risk by imposing 3 instead of 2.5 Bm3 as a floor value, we can also see that the efficiency is only altered by 1%. This is because in most years the available water is higher than 9 Bm3, which explains why the floor value has little impact for the series of data considered (the floor value would have more impact for high targets, or for a policy aimed at maximising the cropping area without, or with little, consideration to the regulation capacity of the dams[140]).

Figure 91 shows this logic on a graph: when the seasonal target is low, it is all the more likely to be achieved, but the overall performance will be lower. Stability and certainty extol a price in terms of overall supply. Conversely, when targets are high, they will often have to be reduced but more water will be allocated on average. Figure 92 shows the succession of seasonal allocation for a Target of 6,000 Mm3, as compared with historical data. Only in 4 years would the Target not be achieved; only in one year would the floor target MT be

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[139] The calendar is following the historical one; daily deliveries are proportional to the ratio of the target TV to the seasonal historical release. Supply during the rainy season (last 6 months) is unchanged because it is assumed that this complement irrigation is given priority, whatever the policy adopted for the dry-season. Historical over-release of water for some reason (power plant outage, etc), are therefore kept as historical real-world constraints and decisions.

[140] Basically, the current prevailing policy.

reached. Figure 93 provides additional insight on the positive impact of uniform target setting on security: the amount of water available at the end of the dry-season is always much over historical values.

TABLE 17: EVOLUTION OF THE AVERAGE SEASONAL WATER ALLOCATION FOR DIFFERENT TARGETS (MM3)

Target Volume	Average seasonal release	Average seasonal evaporation	Average seasonal Spill	Energy Index	Target achievement	Nb of years with floor target	Efficiency index relative to the real situation*
FV=2500 Mm3 MT=2500 Mm3							
5000	4956	677	1066	15,2	96	0	79
5500	5336	666	733	15,1	84	1	85
6000	5608	657	507	14,9	80	1	89
6500	5823	650	346	14,8	72	1	93
7000	6004	641	225	14,6	64	2	96
7500	6090	633	165	14,6	48	2	97
8000	6144	629	119		40	2	98
FV=2000 Mm3 MT=2500 Mm3							
6000	5649	655	470	14,9	80	1	90
7000	6051	637	184	14,6	64	2	96
FV=3000 Mm3 MT=2500 Mm3							
6000	5561	660	550	15,0	72	1	89
7000	5946	644	271	14,7	60	2	95

* Total amount of water released over 25 years in the simulated case/total historical release

Although some traditional systems have devised sophisticated ways to equitably allocate water among users regardless of the available stock, it is widely observed that in large public schemes the rule is to base allocation on the available water stock. Negotiations tend to centre on how much water is to be left unused in order to minimise the risk for further seasons.

It is doubtful that in the actual Thai setting there is much scope to enforce a more balanced policy, between the respective optima of equity and efficiency. The above considerations, however, should draw our attention both on the impact of adopting an efficiency-oriented policy and on the necessity to better define the risk attached to a given floor value (FV).

FIGURE 91: CHANGE IN TARGET ACHIEVEMENT AND EFFICIENCY INDEX FOR DIFFERENT SEASONAL TARGETS

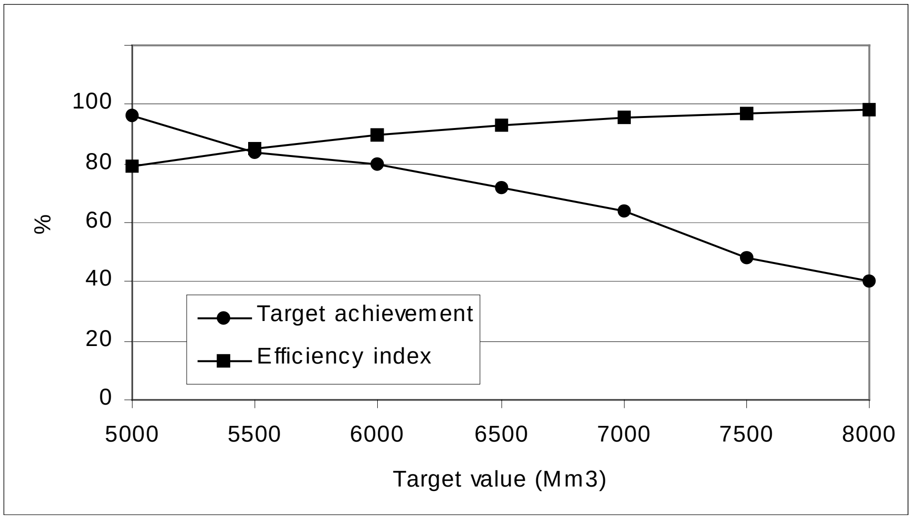


FIGURE 92: YEARLY DRY-SEASON RELEASES FOR A TARGET OF 6,000 MM3, COMPARED WITH HISTORICAL DATA

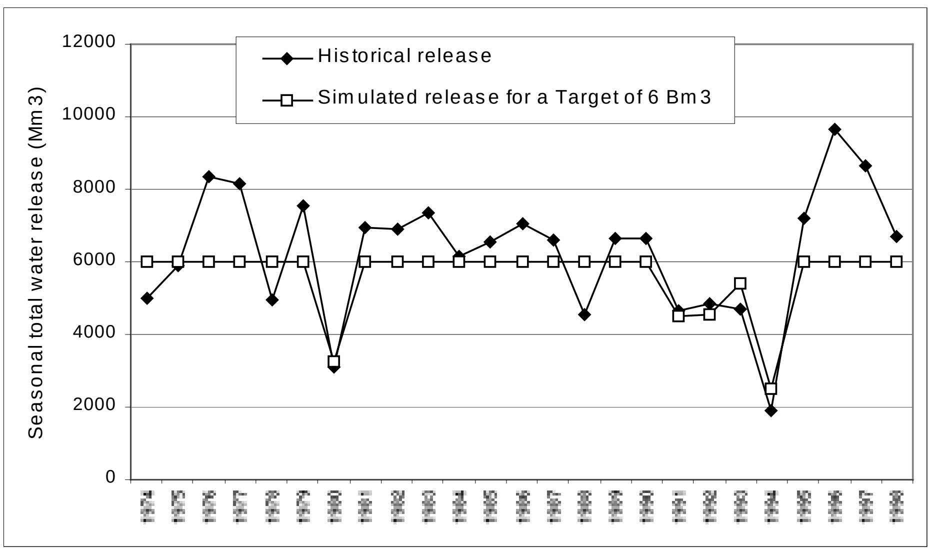
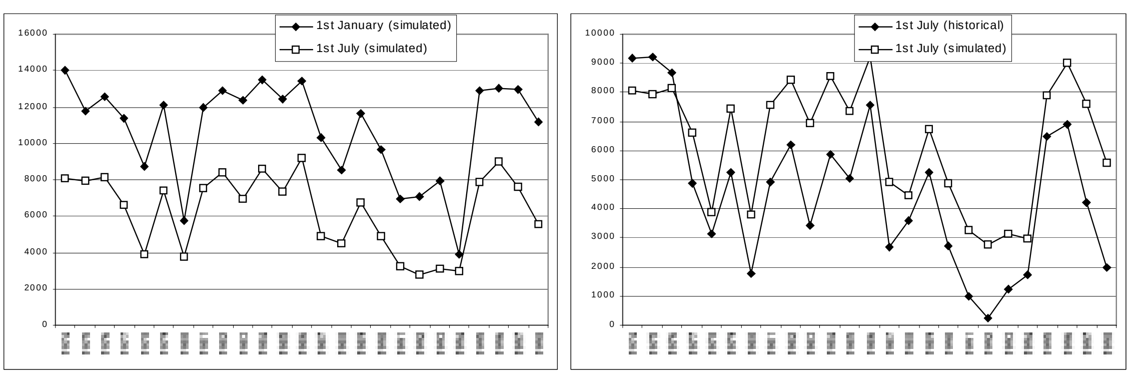


FIGURE 93: SOME RESULTS OF THE SIMULATION FOR FV=2500 MM3 MT=2500 MM3



13.2 Guidelines for the definition of seasonal volumetric targets

The first and foremost question of an efficiency-oriented allocation process is to decide how much water will be released during the 6 months of the dry season (or, in other words, how much water should be left at the end of the dry-season[141]). This decision will translate into a certain risk for the ensuing years. This risk is of course difficult to assess but it can be related to the amount of water available in the dams on the first of July: the lower this amount, the higher the risk.

A first uncertainty about the future is how much water will have to be used in the following wet season. On average, monthly sideflows are higher than corresponding monthly requirements and most of the inflow in the dams can be stored. Statistically, however, "dry" months occur frequently and dam water must be released to supplement both rainfall and sideflows. In all cases the dams water balance in the rainy season will be positive but the net stock gain, 4.7 Bm3 in a median year, may be as low as 1.5 Bm3 one year out of ten. In the next dry season, however, dams release will have to amount *at least* to a floor value of 2.5 Bm3 (out of which only 0.6 Bm3 will be provided nine years out of 10 by dry-season inflow into the dams). Therefore, there is a risk of having an overall yearly deficit of at least 0.4 Bm3, or much more as it is very difficult in practice to keep effective releases at such a low floor value.

Risk will be lowered if :

a) dams releases in the wet season are decreased (better responsiveness to hydrologic events, no releases decided only for energy generation), therefore improving the net gain of the wet season water balance;

b) if the carry-over stock kept at the end of the dry-season (floor value FV) is increased. If we chose an allocation policy favouring the stability of seasonal allocation, then the available stock remaining at the end of the dry-season will in general be higher than FV and the risk lower. If we chose, every year, to use all the available water minus the FV volume, the risk will be higher and linked to the value of FV chosen. We have seen in the preceding section how this trade-off between stability/equity and efficiency can be quantified.

On the other hand, risk will increase in the future because of,

a) the expected decrease in dam inflow (decreasing net gain in the WS, declining contribution of run-off in the DS)

b) the growth of incompressible water requirements, most especially in the DS[142] (BMA).

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[141] These two questions are not totally equivalent because of the uncertainty on the dry-season dams inflow (1.2 Bm3 net inflow on average) and sideflows in the basin; however, these flows are limited and the stock at the end of the dry-season can be derived rather accurately from the stock on the 1st of January and the seasonal target.

[142] Except in the month of January, when excess water is released from the flood-prone area. In the WS, these requirements will most often be met by natural sideflows but, as noted earlier, this will not be the case in all months.

If the efficiency-oriented policy is adopted, the question will be how to chose FV. It appears that at the moment there is still no agreed upon value which should not be trespassed. It therefore gives way to conflicting interpretations between the farmers/politicians, who tend to see immediate benefit, and Project managers, who are afraid of the major disrupting consequences of a possible drastic shortage or of a dam emptying.

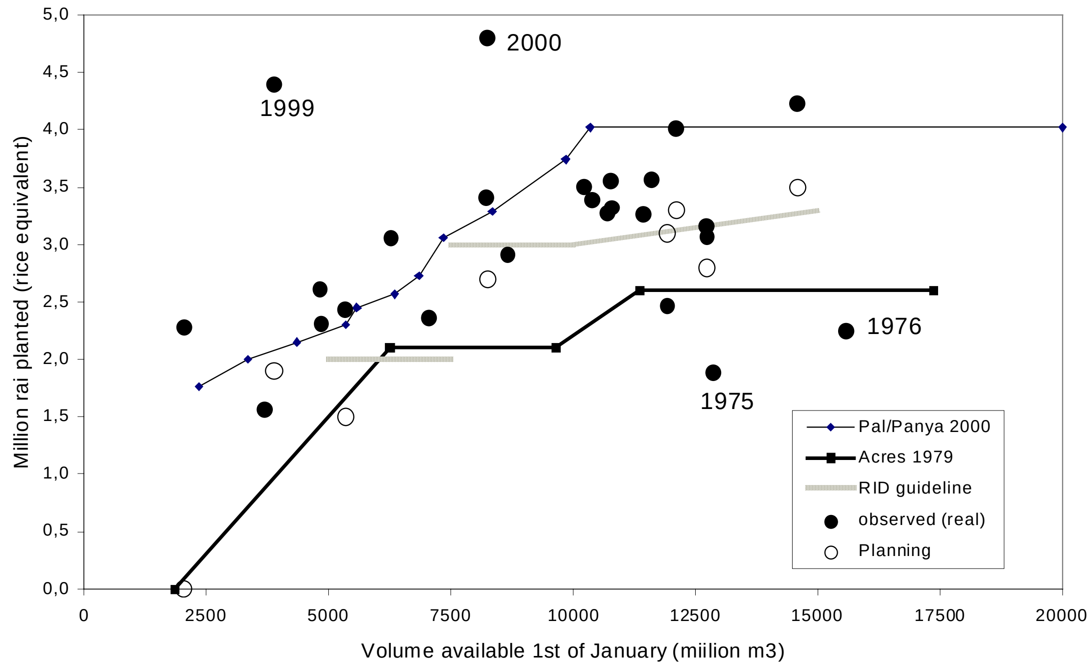
How this volume TV translates into cropping area once released is another “quiz”. As the relationship is poorly known, it is difficult to estimate a realistic target area TA: consequently it is difficult to follow a decision-making allocation process based on cropping areas. We have indicated earlier why real cropping areas are invariably higher than target areas for both macro and micro level reasons. Macro-level factors include: extension of cropping calendars both before and after the theoretical date of dry-season cropping; no accurate consideration of the water provided by the Tha Chin and Bang Pakong rivers (gravity and pumping), of the water stored in the channels of the lower delta at the end of the rainy season, and of some inflow provided by the drainage water of the flood plain in January; no consideration of wells and of the use of short term varieties (3 months); unknown contribution of rainfall. At the micro-level, the amount of water use per rai is also variable, depending on how dry the plot is at land preparation, the type of soil, the length of irrigation canals upstream of the plot, on farmer’s practices and whether he pumps or not, etc.

Figure 94 shows the theoretical relationships between the available water and cropping areas, as estimated by Acres (1979) and, more recently, by Pal & Panya (2000). The difference between the two curves is an instructive indication of the initial under-evaluation of the cropping area; the figure also shows the observed historical values. The years 1975 and 1976, with cropping areas much under the potential, are indicative of an early development of dry-season cropping. The years 1999 and 2000, on the other hand, have yielded extremely high cropping areas. This reflects, among other factors, a sharpening of the trend to advance cropping calendars (therefore an increasing part of the rice area is started before the 1st of January), a better registration of triple cropping and possibly an increase in the use of 3 month cycle rice varieties. Discrepancies also account for errors in reporting and for the fact that the water eventually released during the dry season may differ from the “sustainable” values assumed in the models.

It is interesting to note that the standards above, and also the RID guidelines given in § 5.2.1, look like compromises between the efficiency-oriented policy (TV (or TA) are attuned to the available volume) and security concerns (the floor value increases with the available volume[143]).

[143] but is always at least equal to 1 Bm3 + dams inflow and sideflows contribution.

FIGURE 94: GUIDELINES FOR SEASONAL ALLOCATION, AND OBSERVED VALUES



We must now attempt to derive some management rules from the different pieces of analysis presented in this report. For an efficiency-oriented policy, we can adopt the following rationale:

1) Under the current conditions and the expected decrease of dam inflows and sideflows in the dry season, it is advisable to consider the minimum value observed in the last 25 years[144] (0.45 Bm3, rounded up to 0.5 Bm3) as the contribution of run-off.

2) Given that the incompressible requirements in the dry-season are estimated at 2.5 Bm3, we must be prepared for a deficit of at least 2 Bm3 in the dry-season water balance.

3) Considering an ensuing wet season with a net storage gain of only 1.5 Bm3, the yearly deficit will be at least 0.5 Bm3. As a prevention against 3 consecutive dry years, we must have at least 3 x 0.5 = 1.5 Bm3 stored at the end of the dry season, rounded up to <u>2 Bm3</u> to allow for some security.

4) The floor value FV of active storage at the end of the dry-season must therefore be <u>2 Bm3</u>. The active storage was closed to 1 Bm3 along the 1991-1994 period and the crisis would have been much less severe if it has not been allowed to drop under 2 Bm3 in 1991 and 1992[145].

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[144] The percentile of probability 0.9 is 1.1 Bm3 (0.6 Bm3 for net dams inflow and 0.5 Bm3 for sideflows), but these flows occur generally late in the season and tend to decline.

[145] By reducing the dam releases which remained higher than 4 Bm3.

5) This means that the Target Volume can be derived from the available volume on the 1st of January (AV) by $TV = AV – FV + 0.5_{(inflow)} = AV – 1.5$
but only if AV is greater than 4 Bm3, as the target cannot be less than the incompressible requirements (2.5 Bm3)

Should AV be less than 4 Bm3, then severe restrictions would have to be implemented, with probable damage by salinity intrusion, to curtail releases and maintain them under the 2.5 Bm3 threshold.

6) In case of very high values of AV (higher then 11-12 Bm3), TV can be adjusted down from the value given by the formula. In particular, if rice prices are low, it might be wise not to allow the full potential water to be released but to build up some stock for the following years.

7) These rules do not drastically stray from RID guidelines. However, they stress that the *respect of the floor value FV is paramount to limit the probability of a crisis*. If this limit is compromised, such as in 1991-1994 period, then the risk is higher. In such a light, and based on the propensity of seasonal effective releases to exceed planned by values by 15 %, it might be wise to raise FV up to 2.5 Bm3.

8) These rules must not be regarded as carved in stone for eternity. The terms of the basin water balance evolve and the rules must be adapted accordingly.

Three main changes are occurring and must be taken into account:

- While the water abstraction by BMA during the 5 months (Feb-June) in which mostly dam water is used is assessed at 0.6 Bm3, this value is expected to rise to 1.5 Bm3 in 2010[146]. This means that with incompressible requirements at 3.4 Bm3, the yearly deficit might increase to 1.4 Bm3, entailing a theoretical FV of 3 x 1.4 Bm3 = 4.2 Bm3, if we want to be guaranteed against three consecutive dry years. This shows how the rise of BMA impacts on FV, if we want to keep a constant level of risk.

  One must be cautioned against the temptation to infer that yearly dry-season releases will have to be reduced accordingly (by 1.2 Bm3 in our example). In fact this will happen only the first year, in which FV is raised, but not in the following ones[147]. However, the amount water allocated to agriculture will be cut by this amount every year, as it is reallocated to the urban sector.

- This worrying trend will be compounded by the decline in the net dam inflows (see chapter 1). For a decrease of 1 Bm3, the potential yearly deficit will be increased by the same token, raising the risk.

[146] For a growth of 5% per year (or 1.2 Bm3 for a growth of 3%).

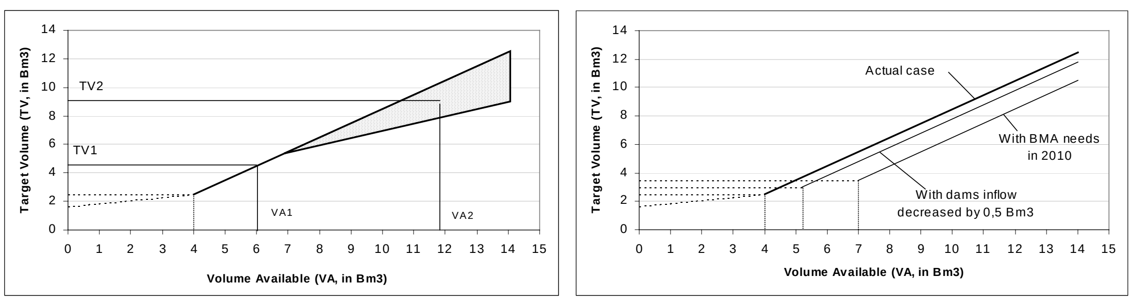
[147] By raising the carry-over stock, however, evaporation and spill frequency will also be raised, incurring in higher losses. These changes are nevertheless minor.

- These trends can (must) be compensated by a betterment of the average net gain in the wet-season dam balance: *average water releases must be reduced in greater amount than the proper decline in dams inflow*. This can be achieved, as mentioned several times, both by avoiding using the dams for energy generation in excess of what downstream users request, and by a better responsiveness to hydrologic events.

The guidelines are represented in Figure 95 (left). The grey triangle indicates an approximate area of decision, as an available volume VA greater than say 7 Bm3 might not be entirely released if policy dictates that rice production should be controlled or the water stock built up. For VA under 4 Bm3, a crisis is declared and special policies must be set to curve DS release under 2.5 Bm3.

The figure (right) also shows how the rules will be altered by the growth of BMA (5% growth over 10 years) or the decrease in dam inflows (-0.5 Bm3). These changes, especially the first one, shift the minimum point to the right because of the increase in incompressible requirements in the dry-season (case 1) and/or in the exigency of security carry-over stocks (both cases).

FIGURE 95: EFFICIENCY-ORIENTED GUIDELINES FOR THE DETERMINATION OF THE TARGET VOLUME



The magnitude of the DS incompressible needs is a key parameter and rules will be affected as they go up. In 1979, a low was reached in the month of August, with a reasonable 4.6 Bm3 available. What was not expected is a WS dam inflow as low as 5 Bm3. Because of generous extra supply for energy generation (at that time 22% of Thai energy had to be produced by hydroelectricity), more than 2 Bm3 were lost to the sea during the wet season. When the rainy season ended without fulfilling the expectation of a late betterment, “it was too late”: only 3.5 Bm3 remained available on the first of January 1980, making the year 1979 the only year with a negative dam storage balance in the wet season (see Annexe 17). The failure to reduce the supply of the next dry-season (3 Bm3), probably mostly because of the impossibility to curtail energy generation, led to an almost zero stock (0.5 Bm3) at the end of the dry season. This episode illustrates the lack of preparedness to confront such a low run-off in the wet season and the lack of flexibility in energy generation, making it difficult to reduce DS releases. It can be seen that EGAT was trapped and had to face a crisis because it could not easily stop turbines, a constraint which would decrease in the following decade, removing a main potential cause of crisis. Such a low run-off will be observed again in 1993 (4.7) and will be tackled by a drastic reduction of water releases down to 1.9 Bm3 in the 1994 DS. In 1998, too, a low WS run-off (4.2) was observed but there was a failure to control DS releases until late March. As mentioned earlier this led to a short crisis which was rapidly overcome by abundant early rainfall.

An interesting option would be to decrease the constraint of security by allowing the dead storage volume of the Sirikit Dam to be used in some instances, for example in the case of three dry-years with only 1.5 Bm3 net storage gain in the wet season (our criteria used earlier).

It must be stressed again that the above rationale is based on the simple examination of the percentiles of the terms of water balances applied to a 6 month DS and a 6 month WS. It focuses on mid to long term trends without paying attention to yearly fluctuations. The use of the percentiles does not fully capture the stochastic nature of the system, nor does it formally lend itself to exact balances.

However, it is our contention that it allows a concrete understanding of the interplay between the two season, of how risk can be controlled and how it will evolve with the different terms of the water balance. Classical models also have their limitations (see earlier comments) and the results are not always easy to interpret. It could be argued that some elements of the reasoning are not properly sized: for example, the estimate at 1.5 Bm3 of the net gain in the wet season ensured 9 years out of ten might be adjusted. This will have a slight (conservative) influence on the rules proposed but does not alter the logic of the reasoning. In addition, the rules proposed are consistent with the analysis of the 1991-1994 crisis, which would have been largely averted by their application.

Another limitation of this approach is that it implicitly follows the idea that DS cropping starts in January (or February), despite the considerable effort displayed earlier to show that this idea was both flawed and counter-producive, and should be abandoned in favour of a more desegregated and flexible vision.

How can these rules be adapted to take into consideration the spread of “straddling” cropping calendars both before and after the six months considered ? In fact the difficulty may only be apparent at this stage and shift further to the question of spatial allocation. What is under consideration so far is how much water can be extracted safely from the dams during the six driest months, not who will be using this water and where. How this volume TV will be allocated to the different sub-areas, and how it will translate – in combination with other sources of water used within or outside this period – into a final cropping area must now be scrutinised.

13.3 Spatial allocation and scheduling

The allocation of TV over time and space, or in other words the setting of a schedule defining the (weekly) discharges into the main waterways, must be considered together with some main principles and constraints identified earlier in Part I.

1) Calendars must be allowed to expand over a longer time span, leading to greater efficiency in water use (lower consumption for early or late planting), and with rotations allowing water to reach larger areas.

2) Significant imbalances of water use within the delta must be corrected in order to increase equity. This point raises three issues:

- Basic spatial equity: for example, triple cropping should not be encouraged by continuous supplies if other areas have not been served yet. The West of the delta should not be favoured at the expense of the East, etc.

- To achieve a greater equity, higher control of cropping areas and tighter scheduling must be implemented. This can only reasonably be done with a multi-level participatory management;

- The allocation process must address the question of how to maintain equity when yearly release targets are extremely variable.

From the evidence of both the significant imbalances in water allocation over the past 25 years (§ 3.3) and their impact on farm livelihood and sustainability (Chapter 7), there is an obvious necessity to reconsider the spatial pattern of allocation in order to achieve greater equity. In particular, it is time to reconsider the fate of part of the flood-prone area, which has been widely disregarded in the past for several reasons alluded to earlier (§ 4.2.4).

3) The allocation process must also take into consideration an important varying factor. The beginning of the dry-season cropping in the West Bank will depend on the recession of the flood water, from October (in "dry" years) to late December (if excess water has entered the plots). In the first case (more common), the crop will rely on the water remaining at the end of the WS and on the water released by the "boxes" of the flood prone area which will be partly diverted to the area from mid-December onward (see Molle *et al.* 1998). In the latter case, crop water requirements will be shifted into the following year and will overlap with those of the upper delta, decreasing the available water for this sub-area.

Gaining equity in allocation of water resources can be feasible in two different degrees:

- *Basic rebalancing (top-down re-allocation)*: this can be achieved by a closer consideration of the *supply/potential area* ratios obtained for the different main canals over the December-June period. In practical terms, this would also imply fixing calendars more rigidly, in order to curtail the expansion of triple cropping, favoured by a situation where supply is never really interrupted[148]. Yangmanee, Maharat, Chong Kae, Kok Katiem and Roeng Rang Projects should see their share increased.

- *Thorough rebalancing (bottom-up re-allocation)*: this could be achieved if a Chao Phraya Basin Organisation was set to control water allocation in the different parts of the basin and to conduct a participatory process with concerned stakeholders in order to: 1) define an overall policy of water allocation; 2) define the plan to be implemented each year; 3) contribute to its enforcement by monitoring the situation and controlling free riding. This is

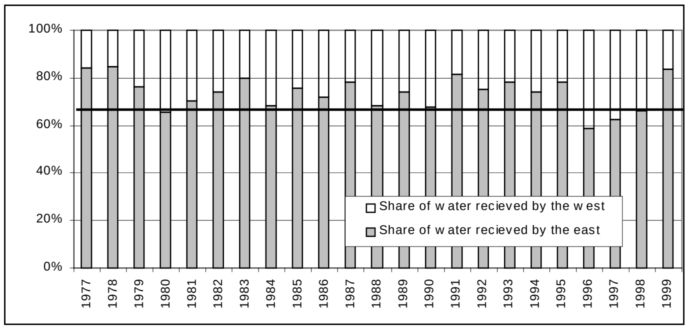
[148] The pretext of "*upaphok boriphok*" (consumption) water allows some flexibility but is often a way to refer to unplanned additional supplies.

contingent upon a process of identification and empowerment of representatives of users and could lead to defining "rights" for different sub-areas of the basin.

We are here concerned with the first option, while the second will be scrutinised in the following section.

Figure 96 reminds us of the unequal allocation between the Western and Eastern banks of the Chao Phraya in the upper delta. The horizontal line shows the estimated proportion of land provided with on-farm facilities (able to grow DS rice) on both sides and the respective shares of water allocated each year, emphasising the imbalance[149].

FIGURE 96: ALLOCATION OF WATER BETWEEN THE WESTERN AND EASTERN SIDE OF THE UPPER DELTA



Re-balancing water allocation and recognising the beneficial trend to shift calendars forward could lead to the following policy guidelines:

1. The Western area (Tha Bote, Pollathep, Don Chedi, Pho Phaya, Samchook, Borommathad) should have water allocated in continuation of the wet-season, allowing an early start of the DS cropping (November). Sub-areas with possible specific problems can be attributed a different calendar. The eastern part of Samchook Project, for example, could start later if sugar cane harvesting is a constraint[150]. The lower part of Don Chedi Project may also be flooded and receive water later[151]. Samchook and Yangmanee Projects, as well as the eastern Upper Delta, could then be supplied as the demand in the western part declines.

2. Calendars must be announced in advance and it must be made sure that supply will not extend beyond the date when the first DS crop has been harvested. In case of very high amounts of water available, the cut can be more moderate, allowing some farmers to

[149] The real imbalance is significantly sharper as the Western not only benefits from more groundwater but also starts DS cropping before January in some areas (with water thus not considered in the balance).

[150] Defining different calendars is less problematic in areas with land consolidation. Higher land with DS HYV can be separated from lower lands with WS traditional rice through improvements in the drainage system (avoiding seepage from the former to the latter).

[151] In addition this area will in the future be increasingly supplied with water coming from the Mae Klong basin, through the drainage system.

grow a third crop[152], but in theory water should never be enough to serve the whole area. This means than triple cropping (except when achieved based on groundwater or other ancillary sources) is a hallmark of inequity and should not exist within a system of allocation respectful of equity (this being said regardless of whether one judges triple cropping desirable or not).

3. In case of flood in the preceding WS, calculation must take into account the growing requirement from the (lower) West Bank due to the shift in calendars[153].

4. Spreading water deliveries over time will allow to partly bypass the physical limits of the system to distribute large water supplies. In case the total available water is insufficient (the most common case), then a device must be designed in order to decide how to allocate, each year, the limited resource while ensuring an acceptable equity in the long run. There are theoretical solutions to this problem but it is hard to imagine one which could realistically be adopted in the prevailing context of experience-based routine and political intervention.

   However here lies a critical aspect of equity in water distribution. At present, if there is little water, only head enders will grow a second crop. If supplies are abundant, these will grow a third crop while end-enders will grow their first DS crop. This can be changed only through some more rigid scheduling but this option is also conditional upon critical improvement of the physical infrastructures and of the social/institutional setting.

   In this respect, it is instructive to note the semi-failure of the rotational system established in the 1980s. It proved particularly vulnerable to the 1991-94 dry spell, in which it turned meaningless and impracticable, prompting its abandonment. It could be revitalised and adapted. For example, each Project could be divided in sub hydraulic units which would get water in turn, the number of them depending on the available water each year and each unit re-entering the “queue” after being serviced. Again, it is unlikely that the overall situation may allow such degree of flexibility to be implemented.

In summary, it is believed that the prevailing physical and institutional conditions do not allow a complete overhauling of the allocation procedures (see Report No. 2). Nonetheless, the measures concerning the:

6) De-aggregation of DS cropping-calendars and the formal (and official) recognition of the interest of shifting part of them (western part) ahead in time (November);

7) a growing effective concern to incorporate more equity in the total amount allocated to different sub-areas (more to the East);

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[152] It is considered more difficult to plan a (partial) third crop in an equitable way. Therefore head-enders, who in addition have the highest density of tube-wells, are likely to conserve some advantage.

[153] This requires that managers be supplied with real-time information on the cropping area in the lower delta and take into consideration real calendars, the variation of water use with the time of crop-establishments (as shown in § 9.3), the water coming from wells and adjacent rivers, the water remaining in the channels of the lower delta after the dry-season.

8) the recognition that a growing part of the flood-prone area is now fit to accommodate HYV in the dry-season and should also be considered,

can be implemented with no delay. They can be associated with new rules for dam management.

13.4 Water basin organisations and institutional reforms

Regaining control of water use within the basin and setting a bottom-up allocation process is not believed to be feasible by the mere improvement of some components of the system. This is consistent with a global participatory process to be carried out under the umbrella of a Water Basin Organisation (WBO). It is beyond the objective of this report to investigate adequate institutional settings but the recent proposals made by consultants will be briefly recalled here[154] (WRCS, 2000).

Water resource management is to be taken over by a three tiered institutional system aimed at separating policy, resource management and bulk water services, which includes:

1) A *regulator, standard setter and auditor*, all responsibilities which could be attributed to the National Water Resources Committee (NWRC);
2) A *resource manager*, which could derived from a strengthened Office of the National Water Resources Committee (ONWRC), and would serve as umbrella for a set of Basin Management Offices (e.g CPBO for Chao Phraya Basin), further divided in sub-basin management offices;
3) An *operator/provider* level, which would be taken over by the existing line agencies (EGAT, RID, etc).

The current draft on the water law does not define a clear mandate for a national water resource manager (ONWRC is designated but not provided with the adequate functions and power). It refers to "River Basin Committees" but defines them as co-ordinating bodies and does not give them attributions for defining water permits or for handling water management, in particular in times of shortage. With an unconvincing Water Bill draft stalled in a bureaucratic process [in any case, it is also judged inappropriate to allow integrated water management (WRCS, 2000)], there are currently attempts to set pilot projects and prototypes of water basin organisations in a few basins (Pasak, Lower-Ping, etc).

13.5 Steps towards a decentralised allocation system

Our concern here is how the Chao Phraya Basin Organisation (CPBO) could be instrumental in achieving the goals of efficiency and equity exposed earlier. In other words, how farmers could be effectively brought into the decision and management process. This takes us to imagine a few scenarios in which the potentially powerful linkages between water pricing (by

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[154] Despite the fact that there seems to be no consensus on this issue, judging from the differences between this proposal and that of Binnie's report (1997), both funded by the World Bank.

group), institutional reforms and water management improvement could be activated (Small and Carruthers, 1991).

As noted earlier, the rationale to establish a water fee is poorly supported by considerations of efficiency, or even cost recovery, and only gains relevance when considered as one piece of a wider jigsaw which includes institutional change, scheme modernisation and turnover. What follows provides a few options on how to proceed and comments on possible misconceptions.

13.5.1 Step 1: Regaining (some) control on water allocation

The ASPL ADB loan does consider the phased establishment of Water User Groups (WUGs) at the tertiary and secondary levels, followed by two years of joint management of lateral canals with RID, and two years of joint management of the scheme (Project). This is in agreement with the conventional approach to build a pyramid starting with the basis, trying to consolidate it and then building upper levels. Such an approach is not consistent with the current level of control upon water resources at the basin level and the odds are high that newly formed WUGs would undergo the fate of their predecessors. It is widely recognised that WUGs can only be successful if they get from their association some benefit that they would not get otherwise. This is generally couched in terms of increased, more predictable and more stable water supply.

It is believed that, before indulging in setting user groups, it is necessary to strengthen the capacity of RID to establish a more rigid schedule. We have shown earlier that this may not be satisfactorily achieved without re-gaining control over water use in the basin, in particular the middle basin. This, in turn, is strongly related to the setting of a new legal framework and a WBO. Therefore, doubt remains on whether specific moves can be done successfully without this proper background.

Assuming that some degree of improvement, albeit limited, can be achieved by structural measures [automation and a MIS (Management Information System)], these measures must be made effective as a first step. Instead of starting by establishing “contracts” of water distribution at lower levels, it is necessary to first strengthen the “top of the pyramid”, *as greater control at the lower levels is conditional upon greater control at the upper level.*

In parallel, the establishment of a CPBO (even in a transient form, not fully backed by legal dispositions because of the lack of proper legislation) must allow a stricter monitoring of who is really using water, the definition of who is entitled to do so and the formal registration of these users. In particular, this should halt, at least temporarily, the un-coordinated and/or illegal[155] expansion of irrigated areas. There is a clear inconsistency between the already water-stressed status of the basin irrigation areas and the fact that new areas are being constructed whatever new resource is made available (Anukularmphai, 2000). For example

[155] According to the law riparian farmers have the right to water as long as it does not create prejudice to downstream users already established. In the current dry-season context, the third-party effect cannot be negated (just as the water received by the delta is depleted by the growing share of water abstracted in the medium delta).

during the first year (2000) of the operation of Pasak dam, RID could benefit of an additional supply of 50 cms to be diverted to the lower East Bank at Rama VI dam. This relieved the situation but will be short-lived as new irrigated areas downstream of the dam (150,000 rai) will be soon have to be supplied by the dam.

In other cases, like in the Phitsanulok Project, the rationale is to stabilise the wet season crop through irrigation but any benefit in the dry season is eventually achieved at the expense of a same area of land downstream in the delta. This does not even mean a zero-sum benefit because this is achieved at the cost of duplicating investments in infrastructures. The same can be said about the development of DEDP supported pumping projects along the rivers.

In the case of the expansion of ditches and water supply in areas located along the eastern and western boundaries (80,000 rai) of the delta, the rationale is to compensate local farmers for degraded drainage conditions and to allow water supply on the ground of equity concerns. This leads to the development of double-cropping outside the formal irrigated area.

All these situations have in common the concern to either expand the benefit of irrigation to more riparian users (on the basis that their right to water is not different from that of other users) or to the Provinces which have accepted the disruptions of a new dam and demand some benefit in exchange. While it is hard to go against such a logic, and to counter the political forces which are driving it, it is also apparent that it constitutes an economic non-sense. Indeed the same limited and declining water resource is allocated to several successive areas equipped with public funded infrastructures only partly valorised. In addition, this is strongly detrimental to any effort to define allocations or rights, as new users constantly come into play. Benefits may be spread in space, but scarcity and uncertainty also are by the same token.

In parallel with the reform of the irrigation sector, emphasis should be placed on the control of underground water in BMA. This must include raising the price of underground water to the level of tap water but this is contingent on two other measures: 1) the strengthening of monitoring and law enforcement capacity, a task which should be passed from DMR to MWA (TDRI, 1990), in order to avoid an increase in illegal pumping; 2) the development of tap water networks, in order to compensate for the phasing out of underground water use (more superficial water will have to be dedicated to the industrial sector).

13.5.2 Step 2: Introducing participatory decision-making in macro-allocation

Such a step of regaining (partial) control over the basin level being achieved, it is possible to define relevant hydraulic sub-units in each Project, in general the areas served by a same secondary canal, or by a given reach of a main canal. Farmers in the different sub-units of each Project would then be asked to form Water User Associations (WUA) and to elect a board and a head. Membership should be made compulsory. The WUAs' heads would then act as farmers' representative to the RID Project's level. Their task would be to define a policy for the allocation of water at the main canal and Project levels and to set practical procedures for each dry-season. A pre-requisite to this, of course, is that RID be in a position to guarantee a given scheduled inflow at the head of each main canal branching off the Chao Phraya at Chai Nat. In a first phase, it is suggested that RID (or the country water manager, if already set up) keep the decision on how much water is to be allocated to each main canal in the Delta.

Corresponding weekly schedules being fixed, the representative from the WUAs of the different Projects supplied by the main canal (for example 4 for CPK canal, 3 for Makham-Uthong canal, etc)[156] would be involved, with other stakeholders and officials, in the definition of how much water is to be attributed to each Project and, in subsequent local meetings, on how each Project quota will be further shared among the sub-units (levels 3, 5 and 5). Methods to effectively distribute water should also be defined by farmers' representatives and RID staff (rotation, continuous flow, etc). This would set users' participation high enough in the levels of the hydraulico-administrative structure to better control supply and be aware of the factors which work against their receiving their share.

Comment 1: it is desirable that distribution patterns be made in a way to ensure full supply level (FSL) in the canals, as this allows gravitational inflow and minimises farmers' costs. Several structural improvements must be done but they do not appear as pre-requisites as farmers have gained important pumping capacity.

Comment 2: contrary to general blueprints often put forward, we don't believe that focusing on the tertiary level be of any benefit. Farmers do not need to be formally organised at this level and are likely to continue using the current social patterns of interaction. Even at the lateral level it is not clear what "managing (jointly) the lateral canal" means, as field observations show that in many cases farmers already manage the lateral by themselves (for example they often manipulate cross regulators and even head regulators by themselves; see Report II). Rather than managing the flow *within* the lateral, something which is already being done, the fulcrum point is the inflow at the head regulator of the lateral. This inflow, in turn, depends, both at the level of planning/allocation and at the operational level, on what happens at the higher levels: the Project, the Delta, the basin. This means that if WUAs at the lateral level are not represented since the beginning at the Project level, and very quickly at the delta level, there will be little matter to "jointly manage" and the reform will fail to effectively integrate farmers in the management process.

In such a step, farmers are led to understand that the amount of water that will be attributed to them is a product of their involvement in the negotiation. They will also be aware of who gets what and of former inequalities between Projects and will be motivated to contribute to monitoring supply. It is expected that, in the long time, some kind of socially optimal allocation result from such users' participation. The role of RID is to ensure that proposals are consistent with hydraulic functioning and other physical constraints of the network.

It cannot be overemphasised, however, that structural measures are unlikely to allow a full control of water distribution in the delta. The problem of water abstraction in the middle delta, in particular, will not be satisfactorily be solved without an institutional and legal reform, with the establishment of a CPBO.

13.5.3 Step 3: linking service and farmers' financial participation

With a sense of responsibility and right building up at the WUA level, together with some concrete assurance that RID is in a position to achieve the schedules agreed upon, it would

[156] It is debatable whether WUA's head should first only discuss the distribution of a quota allocated to their Project or directly be involved at the main canal level.

then be opportune to introduce a higher degree of participation by linking the quality of the service and the maintenance of part of the system to some financial contribution.

We see a water fee, as already alluded to, mainly as a binding element of an increasingly contractual relationship between users and suppliers, only secondarily as a cost-recovery device and very marginally as a way to induce water savings. Consultants to the ADB have suggested that such a fee be used to constitute an Incremental Repair and Improvement (IRI) Fund for Irrigation, which would further be used to improve O&M, through actions to be decided by the farmers concerned (the law does not allow the collected money to go back to the State revenue). The IRI fund should be managed by WUAs at the Project level, where the requested actions will be examined under different criteria (relevance, percentage of cost sharing proposed, etc).

Comment 1: If such a local control of the fund and of its use is laudable, it ignores the fact that many maintenance works, especially of ditches and drains at the tertiary level, are already achieved by farmers and by local administrations (Molle *et al.* 1998). With the recent decentralisation process and the emergence of TAOs, local budgets are increased and much of the farmers' demand already centres on such operations. This dramatically lessens the interest that farmers would have to build up and contribute to the IRI fund, given that they already have (and have had for some years) some other mechanism to cope with such needs.

What may also be overestimated is the uniformity of farmers' awareness of the individual and collective costs of the accumulating negative impact of the scheme deterioration. Such a deterioration is very relative (RID's maintenance, at least in the central region, can be considered quite good if compared with other countries), its impact is offset by the use of pumps in case of poor delivery, and ditches are already taken care of when really needed. There is no evidence of drastic impact of degradation on performance at the moment, in part because of the loose method of supply adopted.

Comment 2 : Nothing is said, so far, on the level of the fee to be collected, apart from the fact that such a decision will have to be locally agreed upon (ADB's consultant propose a tentative 120 baht/rai). It is wise, upon consideration of the frozen 5 baht/rai of the 1943 irrigation Act, and following the convincing arguments provided by Small and Carruthers (1991), to adopt a fee indexed on the price of rice, rather than a nominal amount which must be frequently actualised.

The water fee being set at the WUA's level, it makes possible to link it with the approximate volume to be received by the sub-unit. This is also tantamount to shifting the burden of recovering the fee to the association and to devise its own internally negotiated mechanisms to inflict penalties on defaulters. The definition of who will pay, on which basis (area, crop, etc), and how much, should be left to the WUAs. The attribution of water in the following years could be made conditional on achieving a certain level of fee collection. On the other hand, the collected money should be partly used for local maintenance but also to pay field staff (contracted directly by WUAs) and part of RID's staff salaries. As payment will obviously depend on the capacity of RID to deliver the WUA's quota, a two-way "virtuous" binding process could be initiated.

WUAs would also be expected to be instrumental in solving the problem of the distribution of water within the sub-unit. This point, easily glossed over in a report, may be the source of severe difficulties: the growing involvement of farmers in the decision-making process may also come along with a higher claim for water of those farmers of a given sub-unit who were formerly disadvantaged (in general because of their geographic location or topography). If, on one hand, it is a desired outcome of the envisaged institutional changes to bring about more equity by letting all users voicing their right, there is, on the other hand, no certainty as whether local communities will be able to solve this problem without major conflicts.

One must also recall that in most cases the water allocated to a given WUA will not be sufficient to supply all the plots of the sub-unit area. This makes necessary the setting of some social agreement on how this factor deemed to generate inequalities can be locally dealt with. The situation is compounded by the fact that the volume of water considered is likely to change from one year to the other, generating the same difficulties than those described for dam management in § 13.1). In addition, only a moderate optimism can be derived from the reflections on the social structure presented in the Report n°2.

In other words, if the units are supplied each year with varied amounts of water, this will create severe social difficulties for the sharing of water; if they are fully supplied (thus, with lower frequency), this will be tantamount to raise demand. More equity will be achieved but at the cost of a hike in demand, leading to scarcity being spread more evenly over the basin.

13.5.4 Step 4: participation at the basin level and the emergence of water rights

With farmers' participation strengthened at the Project and main canal levels, there is scope for the election of representatives at the Project level who would participate to upper-levels decision making within the Chao Phraya Basin Organisation. They would be partners in the more complex process of allocating water within the basin, including the medium and lower parts.

In the long run, such a process may lead to a gradual consensual definition of rights attached to the different Projects. With the volumetric pricing to the WUAs equated to the wholesaling of water there might be scope for a degree of negotiations to cede this "right", either temporarily or permanently (e.g "sale" of 20% of the right because of the decline of agriculture in a given area). This remains a very remote perspective and more speculation at this stage is not opportune. Suffice it to say that if such potentially tradable rights are to be defined it might not totally be a disadvantage to farmers, as often claimed, because they would at least get a financial compensation in the ineluctable process of transfer of water from agricultural use to non-agricultural use (see Molle, 2000).

Comment: it must be recognised that while water basins are an unavoidable concept for converging hydraulic networks, they are a hydrologic nonsense in diverging networks, as observed in deltas. This explains why the Tha Chin and Chao Phraya River basins, as initially defined in the slicing of the 25 main basins of Thailand, are not helpful units[157]. Rather, the delta, together with the reach between Nakhon Sawan and Chai Nat, should be considered as one "basin" – or unit – in which the artificial distribution of water further defines relevant hydraulic sub-units.

[157] This is strikingly exemplified by the rather hazardous boundary between the two basins drawn across the West Bank.

14 Conclusions

The Chao Phraya River Basin (one third of Thailand but 70% of the GNP) is now facing unprecedented challenges regarding the status of its water resources. Existing water storage facilities are insufficient to fully realise the potential for production in the dry-season and new water resource development projects are facing financial and environmental constraints. The growing abstraction of both surface and underground water is not properly monitored and the concerned agencies are not empowered with sufficient technical, human and legal means to control these challenges. This translates into high externalities (pollution and land subsidence) and patterns of water distribution characterised by uncertainty and a low level of equity. Despite the transient respite brought about by the 1997 economic crisis, projections for the mid-term show dramatic developments which confirm that a drastic reaction is needed if the worse crisis is to be averted. In other words, what is at stake is the proper management of the transition from a status of a common-pool resource in sparsely populated agricultural areas to one of collective management in a more complex world, respectful of basic equity and efficiency standards.

14.1 Diagnosing the system and avoiding misconceptions

This report has first analysed the current situation regarding water allocation in the dry-season and attempted to understand evolutions and to identify bottlenecks.

A water accounting exercise at the basin first gave a clear vision of the nature and magnitude of water flow in the delta during the dry season. It demonstrated that the overall basin efficiency, in accordance with the nature of closed basins, is very high (between 80 and 88%, depending on the hypothesises considered) and that management practices observed in the last decade do not leave much scope to achieve spectacular savings.

A prospective analysis of the supply and demand in the basin has indicated that the amount of water available for dry-season agriculture is bound to decline drastically over the next two decades. This far-reaching trend results from both the decline of the inflow in the Bhumipol and Sirikit Dams (due to growing abstraction and climatic change in the upper basin) and from the growth of urban areas, particularly Bangkok Metropolitan Area (BMA). This forecasted evolution will materialise more rapidly if the growth rate of BMA and of water use in the north are high, but it was shown that in all instances the decline was bound to be much higher than any gain or savings which could be made by improving the current situation. In other words, it appeared beyond doubt that however desirable these improvements may be, supply will have to be augmented in the mid-run (it was not the objective of this report to discuss such options (dams, trans-basin diversion schemes,...) and our focus was on how to gain in equity and efficiency under the current conditions of supply).

It was first shown that dry-season cropping had significantly changed in many respects over the last quarter century. It first increased in magnitude, expanded in both the middle basin and the delta, but spatial patterns of allocation showed a significant inequity between the western and the eastern parts of the upper delta, and more generally between projects. The total cropping intensity over the 1977-99 period was estimated at 1.45 but was as high as 1.63 in the last 5 years. Several historical constraints have been removed to allow the growth of DS cropping:

1. some canals were dredged or recalibrated, allowing larger flows;
2. farmers offset the difficulty to have gravity inflow into their canals or ditches by acquiring an impressive individual and mobile pumping capacity;
3. secondary water sources were developed or tapped (wells, ponds, drains);
4. shorter rice varieties (as short as 90 days) have become common;
5. transplanting, and its constraints in timing and scheduling, gave way to a more flexible technique (wet broadcasting); harvesting is now widely mechanised, easing calendar and labour force constraints;
6. on-farm development gradually expanded (farmers' investments);
7. calendars were de-regulated to adapt to fluctuating conditions of supply (western upper delta) and of the flood regime (west bank). The analysis of the year 1998 showed a very complex spatial pattern in the spreading of cropping areas.

The current method of water allocation was investigated and found to be supply-driven, guided by experience rather than by clear-cut technical parameters, somewhat flexible rather than rigidly pre-determined. It focuses on allocation at macro level, with little control on the day-to-day fluctuations experienced at lower levels but with a concern not to stray too much from the weekly planning, as a way to ensure that the total water released at the end of June did not differ from the overall target by more than 15%. Adjustments in the planned schedule are sometimes necessary to respond to imbalances between the planned and the actual crop progress or to climatic events.

The main point under consideration was how the targets (volume and cropping areas) were defined, based on the available water volume at the beginning of the dry-season. Insufficient security carry-over stocks at the end of the dry season make the system vulnerable to exceptionally dry wet-seasons, when the net gain in stored water can be as low as 1.5 Bm3 (hence the 1980 and 1994 crises).

Attributing the responsibility of water shortage to poor efficiency is the most widespread and misleading misconception. Should irrigation gain 10% in efficiency, this would not diffuse any crisis but only raise by the same amount the area that would be irrigated (as supply is to remain under the overall potential demand, especially in dry years). Shortages and crises are not due to a hypothetical low efficiency but to the allocation policy and its impact on dam water stocks when risk has been mis-evaluated. The lack of strong technical criteria in managing dams and in allocating water to irrigation, and the way they are being challenged by political interventions and farmers' uncontrolled planting[158], are conducive to recurrent

[158] The hopelessness of officials is apparent in public declarations: The Deputy Agriculture Minister reported in early 1998 that "plantations in Nakhon Sawan, Tak and Kamphaeng Phet had increased to more than 670,000 rai

shortages and incur escalating risk. This does not dismiss the fact that efficiency gains are desirable in that they allow the benefits of water use to be spread to a larger number of users, but it draws our attention to the inconsistency of the commonly stated relationship between efficiency and water shortage.

An attempt was made to estimate the amount of water released by the dams and further lost to the sea (in excess of what is necessary to control salinity). This is a controversial question as EGAT is often accused of using huge amounts of water only for the sake of energy generation, which depletes the water stocks available for agriculture. The total average yearly loss was found to be quite considerable, amounting to 2.9 Bm3, or 30% of the average inflow in the two dams. However most of the years with high "losses" were early years in which a significant share of the Thai energy generation system was based on hydroelectricity. In the 1990s, on the other hand, as the Chao Phraya system gradually "closed" and water resources came under stricter scrutiny, such losses were found under 1 Bm3/year, with the exception of 1996, which stands as an horrendous counter-example and serves to stress that regulative measures are needed in order to avoid such occurrences.

Water scarcity cannot be reduced to a declining index discussed in reports and discussions. Extensive farm surveys in three villages with contrasting access to water in the dry-season were conducted to show the impact of such access on the sustainability of farming systems in the delta. Despite a relative re-balancing of average incomes thanks to animal breeding and non-agricultural work opportunities, this strengthens the necessity to give due attention to existing allocation imbalances, in particular to give more consideration to those areas which grow deep water rice in the wet season but have adequate on-farm development to also grow a crop in the dry season.

It is commonplace to stress the increasing conflicting *competition* for water within the basin, but the term *competition* may be misleading, as allocation among users is decided by a centralised bureaucratic process. Competition would occur if users' water shares were subject to weighed reductions in case of shortage, and if these weighing coefficients were a matter of debate and negotiation. Rather, it appears that the different uses are ranked by priority and that the possibility to reduce allocation for 1) Bangkok, 2) salinity intrusion, and 3) pollution dilution is very limited. Regarding Bangkok, for example, restrictions have been attempted during 1999 and were to correspond to approximately a 20% decrease. In fact, it is agriculture which bears the brunt of the pressure on water resources: not only has its share – defined as the *remaining* available water – decreased over the years, but this decrease also entails this remaining part is increasingly subject to interannual variability. These facts are obscured by the dominant common wisdom that agriculture is indirectly responsible for shortages because of its alleged low efficiency of use.

It was shown that the formal overall efficiency of irrigation was rather high (around 60%) and that, in addition, losses by percolation benefit 100,000 ha of home gardens, replete shallow

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from a target of 190,000" (Bangkok Post, 1999, January 13), while the RID Director admits that "things are out of control", with 330,000 rai under cultivation, against a limit set at 90,000 rai (The Nation; 1999 Jan 8). "Our major concern is that we have no effective measures to control the use of water by rice growers. The only thing we can do is ask for their cooperation to cut down rice cultivation".

aquifers and are eventually reused through pumping in BMA. If we look at the delta as a whole and disregard the inevitable loss of water by evaporation in the waterways, it appears that the only possible losses are those volumes dumped to the sea in excess of what is necessary to control salinity intrusion. These volumes are very limited in the dry-season, meaning that the Chao Phraya system is a closed system with a very high macro-efficiency. Contrary to common wisdom, even the efficiency at the plot level is higher than usually stated, as most farmers have to pump to access water and therefore already receive the incentive not to waste it.

In light of these different issues, it appeared that the objective to achieve *water savings* through some kind of water pricing is at best illusory, as farmers in the dry-season eventually use only the water which is left, do it rather efficiently, often indirectly pay for that, and have already experienced water scarcity.

14.2 Recognising changing conditions in the delta: adapting policy and management

Analysing large and complex hydrosystems which include intensive human activities, in particular large scale irrigation schemes, demands that due attention be given to the dynamic aspects of the system, or how elements within and outside the systems shape its transformations. This entails that rules or habits which were relevant in a given context often become irrelevant in a new context and hamper the functioning of the system as long as they are not recognised as obsolete and replaced. Many changes have occurred since the development of dry-season cropping in the 1970s, among which:

- *Power generation structure*: while the total power generation capacity has skyrocketed, the share of hydro-electricity has declined from 40% in 1970 to 6-8% at present, seriously affecting multi-purpose dam management;
- *Rice farming techniques*: introduction of wet-broadcasting, short-term varieties, triple cropping;
- *Farm equipment:* mechanisation of harvest, dramatic development of individual and mobile pumping capacities;
- *Land development:* improvement in the drainage system; expansion of on-farm facilities; gates to allow the closure of drains;
- *Farming systems and rural communities*: pluri-activity, rural industrialisation; out-migration; decentralisation; rural community's empowerment;
- *Water demand:* declining supply, growing demand, in particular of incompressible needs (BMA).

These changes shape the way technical and institutional innovations must be devised in order to respond to the new challenges posed. The improvements proposed are summarised in Figure 97. In brief, it is believed that **efficiency**, **equity**, and **security** can be raised through a number of measures including:

- Reduce water requirements (smarter definition of calendars, deaggregated in time and partly advanced to reduce water requirements);

- Reduce releases in the wet season in order to increase stocks for the dry season (higher responsiveness to hydrological events; MIS, automation, etc);

- Reduce the amount of water lost to the sea (dam management to be governed exclusively by downstream requirements; forced outages dealt with other power sources; peak requirements dealt with gas turbine plants);

- Reduce carried-over security stocks (by allowing the tapping of the dead storage of Sirikit Dam in exceptional cases);

- Reduce the risk of shortages and crises by enforcing the proposed standards of seasonal allocation targets;

- Reduce underground water use in BMA, despite this being at the expense of surface water; support water treatment and recycling;

- Reinforce the overall sustainability of farming systems by reducing inequity in water allocation (balance east/west, give consideration to the fringe of the flood-prone areas);

- Bring users into the allocation decision-making process. Participatory management *after* regaining control over water distribution; bulk water pricing at the WUA level *after* making their participation in allocation decisions effective and regaining control on water distribution;

- Envisage further water resource developments, as all measures will be quantitatively insufficient in the mid term.

As emphasised earlier, the gains in efficiency – water saving – which can be obtained through the adoption of the measures proposed are necessarily of limited magnitude. This is because managers, uses and users have adapted to the growing water scarcity which has accompanied the closure of the basin. *As a consequence, this study has repeatedly underlined the evidence that possible gains are more on the side of equity and security than on efficiency in use proper*. However, in the current situation no small gain can be neglected and we may tentatively estimate the margins for progress[159] (it must be remembered, for the sake of comparison, that the yearly annual dam inflow is approximately 10 Bm3).

- Curtailing dam releases in the wet season[160], and/or improving responsiveness to hydrological events: 0.7 Bm3
- Shifting cropping calendars to early and late in the dry season[161]: 0.4 Bm3

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[159] These figures must be taken as mere orders of magnitude

[160] The difference between the historical average value considered in the balance (3.8 Bm3) and the value for the last 10 years. This is also approximately the loss indicated by the analysis of dam releases.

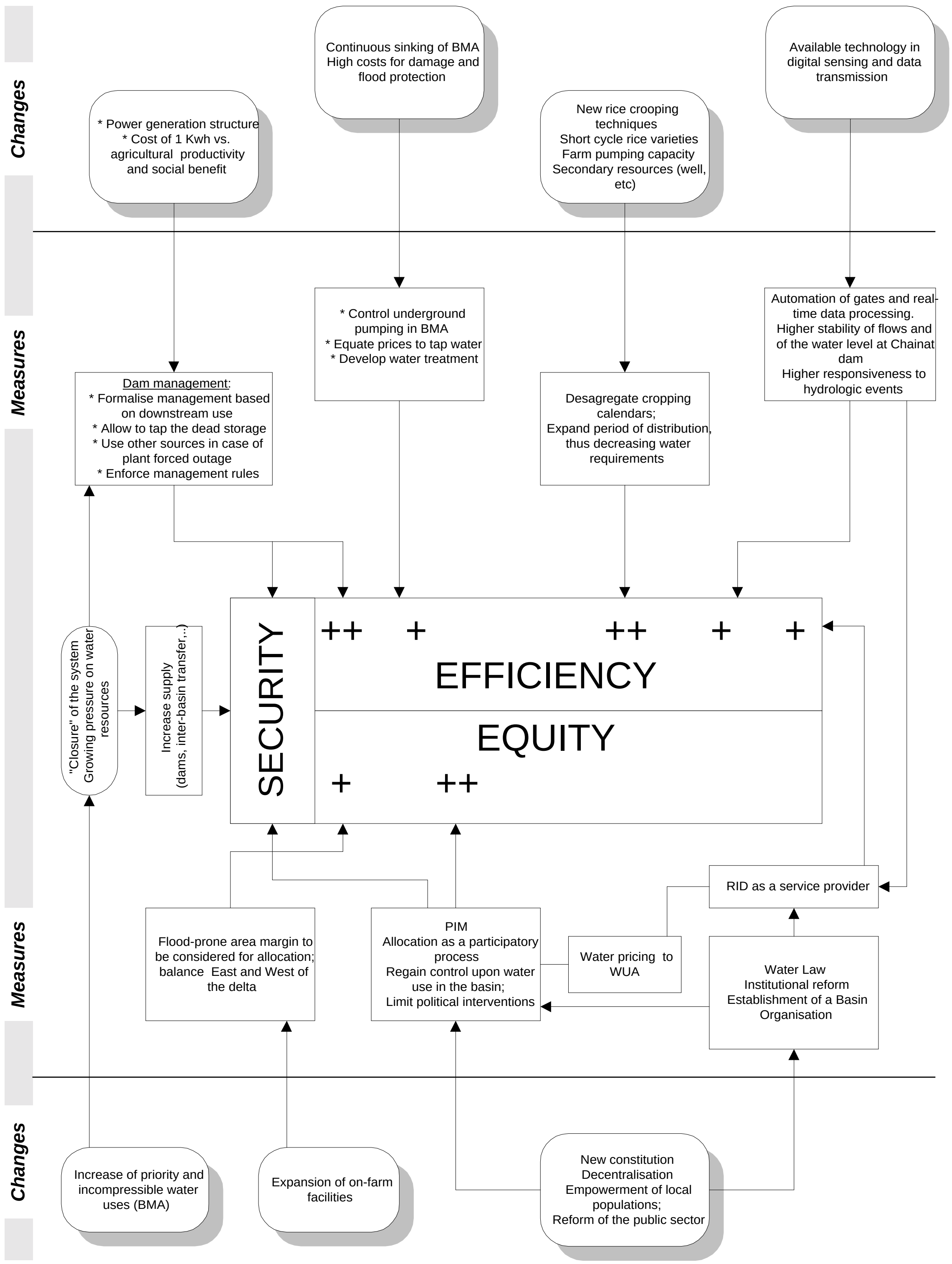
[161] Gains of 30% in water consumption on 30% of the crops, or 9% of an average diverted amount of water of 4.5 Bm3.

- Not allowing dam releases over downstream requirements: avoids isolated years with high releases;
- Modify the upper-rule curve: at most 0.1-0.5 Bm3, in some rare years only
- Tapping the dead storage volume in exceptional years: lessens or zeroes risks (also allows the lowering of the bottom security values: 0.5 Bm^3 every 7 years[162])
- Participatory management and allocation process: increase in equity (small gains in efficiency if stricter scheduling can be enforced)
- Water pricing (non volumetric): small gains or neutral

Overall, it seems reasonable to estimate potential gains at 1 Bm3, which can chiefly be achieved – at least partly – through the first two measures. Reducing risk and increasing equity are achieved by other measures. Such a gain corresponds roughly to 10% of the yearly dam inflow, or 20% of the water diverted in the dry-season to agriculture, which is still considerable. Even a more realistic target of half this value is not to be neglected.

[162] Lowering the security stock in the end of the dry season only increases supply when the dam spills (1 year/7). In other years only the net inflow accrues to the dam stock, regardless of the floor value considered (taken as constant).

FIGURE 97: SCHEMATIC REPRESENTATIONS OF MAIN PROPOSALS AND MAIN CHANGES IN THE SYSTEM



14.3 Scenarios for the reform of the Chao Phraya hydro-system

In summary, it can be shown that limited, although desirable, gains can be achieved in terms of efficiency, and that most of the changes needed (redefining cropping calendars, information management system, limiting EGAT's authority on dams, etc) can be reasonably implemented under present circumstances. However, *the different possible measures will not radically revert the current water shortage status of the Chao Phraya Basin.*

More significant gains can be made in terms of equity of allocation, re-balancing the apportionment of water to the different sub-areas, enforcing stricter scheduling, in particular to curtail triple cropping and spread the benefit of dry-season cropping. However, it must be stressed that the costs and difficulties of establishing a full multi-level participatory allocation process are extremely high, therefore making the continuation of a socially accepted inequity a most likely (if not preferable) option. The extent to which this inequity is accepted is conditioned by short term factors (e.g. the price of rice), mid-term factors (most prominently by the capacity of the national economy as a whole to offer alternatives to those who cannot fully intensify agriculture), and long-term factors (e.g. cultural features).

A third concern is that of the stability, or security of the hydrosystem. This is, in fact, the most salient concern for outsiders, as reflected by the popular fear of water shortage and the evidence of a supply-side short of demand. Punctual crises are not directly due to a lack of water but to the failure to make water releases in accordance with available stocks. The gap between supply and demand is critically compounded by: 1) the uncontrolled planting of farmers who then call for more releases; 2) the expansion of the irrigated area (middle basin, delta fringes). Water crises can be totally averted if carry-over stocks in the dams are respected and if the dead storage volume is allowed to be tapped in exceptional situations. However, the growing frequency[163] of shortages – driven by undue water releases – *can be best interpreted as an expression of the refusal by the farming sector to see its share declining*. As the leftover water – as shown earlier – tends to decline and as pressure on water increases, *the mismatch is dealt with by eliciting releases – through political channels – beyond what risk standards command*. While measures to avert crises are available, their application is challenged by political interventions and by the worrying growth of users. (In addition to declining volumes available for dry-season cropping, the share of the delta proper has been depleted by soaring water diversion in the middle delta). The solution of this problem therefore appears as a political issue, including both the control of political meddling (which also reflects a demand from farmers) and the registration and control of both users and uses. This obviously takes us one step beyond mere *ad hoc* improvements, to the wider and more complex issue of institutional change, with its administrative, political and cultural dimensions.

[163] Historical data are not long enough to give to this term statistical meaning but the likelihood of crises (the 1990s had to undergo a four year dry period (1991-1994) and another crisis in 1999), is obviously on the rise.

Overall, it is clear that efficiency concerns are poorly addressed by and offer little justification to proposals of water pricing or water markets, and that there is limited scope to achieve large water savings. Regarding equity considerations, it is not clear that imbalances are sufficient to justify costly and complex institutional reforms which success is not at all ensured. The current vulnerability of the overall system can only be done away if growing water scarcity is fully passed on and expressed at the farm level (less water for more users). This has strong political implications and it can be hypothesised that an increased need for water would translate into unrest in rural areas, and therefore in more political interventions and more support for water resource development. The current alternative to this vicious circle is to bend security standards, while continuing to allow an expanding and loosely controlled use of water (although these two fundamental points could be partly tackled rather than be left unattended). As Allan (1999) has said; "regional politicians have a powerful intuition that economic principles and the allocative measures which follow logically from them must be avoided at all costs…Government are more likely to rely on the exhaustion of the resource to be the evidence that persuades water using communities that patterns of water use have to change".

If no more water is tapped into the system, would an inevitable agricultural decline result? An optimistic (pull) scenario is that this situation would be paralleled by a sustained growth of non-agricultural sectors; therefore the demise of agriculture would have less socio-economic consequences and more intensification would take place in the most suitable areas. A pessimistic (push) scenario is one of an agrarian crisis in which rural stagnation could not be avoided. It is all the more likely that such a situation would create the political conditions for more water resource development (trans-basin transfers and more dams for storage). Reality might well be something in between, combining more productive use of water (diversification), reduction of rice cropping areas, and a degree of water resource development.

The overarching conclusion of the study is that water scarcity, efficiency, equity and security (or reliability) are interwoven aspects of the Chao Phraya River hydrosystem. All aspects can be partly improved in the present situation. A more sweeping reform, however, needs drastic and simultaneous changes and there is, at present, no strong evidence that the potential gains and the political awareness/will needed are equal to the costs and difficulties of the tasks to be achieved. This is not a plea for playing a waiting-game but a caution against over-enthusiastic single-minded technically or ideologically oriented reforms.

Because of the current lack of political support to achieving sweeping reforms, it was found more adequate to separate the recommendations to be made in two sets. All the different measures aimed at improving water allocation, distribution and security discussed earlier, and the necessary phasing in of some measures, can be summarised in two scenarios. The first is a “low” scenario, which produces significant but partial benefits, and does not rest on the pre-requisite of a large-scale institutional reform covered by a new water law. It combines structural improvements and innovations in management.

The second scenario, on the contrary, assumes that the current institutional gridlock is overcome and that a proper Chao Phraya Basin Organisation, with legal and political backing, allows the empowerment of users and their active participation in the main decision processes: allocation of water within the delta and at the different lower levels; along with scheduling and maintenance. Water pricing can be introduced as a “virtuous” binding element between users and suppliers, if conditions for defining contractual services (and in the long term, rights) are fulfilled. While this scenario is presented as desirable, with its different components, the difficulties involved in the steps to be taken cannot be overemphasised. Therefore, it should be considered as a direction to be taken, within a specific cultural and historical, societal context, rather than a series of technical measures awaiting to be put in practice (for more cautionary stances, see Molle, 2001b and Molle, forthcoming). The two following tables summarise the set of structural and non-structural measures which can be implemented under the two scenarios considered.

Scenario 1 (centralised)		
Measures	*Actions*	*Benefits*
Structural measures		
1. Improve responsiveness to hydrological events (rainfall, sideflows)	Real-time recording of rainfall and river flows. Management of Information System	Reduce dam releases in the wet season: save water Support decision-making
2. Stabilise the water level at Chai Nat Dam	Automation of main regulators; computerised response	Stabilisation of inflow to the main canals: more reliable supply
3. Raise water levels in main canals and laterals (dry season)	Add regulators and weirs at appropriate locations, recalibrate canals and freeboard	Allow higher peak discharges and more gravity inflow (reduce pumping costs of farmers)
4. Expand water treatment in BMA and reduce leakage	Invest in water treatment units and control of leakage	Increased re-use of water; better environment; water savings.
5. (Increase water supply)	(transbasin diversion; dams)	(Increase supply into the Chao Phraya Basin)
Non-structural measures		
Formalise RID's priority over the 2 dams management	Set rules preventing release of water in excess of downstream requitements	Avoid water releases only aimed at generating energy (loss to the sea); save water for productive use
Set standards for the definition of targets in the dry-season	Set targets in order to keep a minimum volume of 2 Bm3 at the end of June (but adjust the value when conditions change)	Reduce risk of shortages
Make the use of Sirikit Dam dead storage a feasible and "normal" option	Raise public awareness about the large amount of water available and introduce the idea to use it in exceptional years	Allow to decrease the security carry-over stocks which is bound to increase dramatically with BMA's requirements
Redefine cropping calendars	De-aggregate the delta in sub-areas and define calendars running all year round	Capitalise on field wetness in the late rainy season, decrease average water requirements/rai, expand dry-season period and benefit
Increase spatial equity in allocation	Allocate more water to disadvantaged Projects, curtail triple cropping by stricter scheduling	Improve the overall sustainability of farming in the delta; improve equity in access to water; reconsider newly improved areas in the flood-prone area
Control underground water use in BMA	Raise underground tariffs to that of tap water; expand tap water facilities; tougher monitoring and control of registered and unregistered wells	Control the sinking of BMA, decrease flood risk and flood damage (but must increase the share of superficial water allocated to the capital)
Reinforce the administrative co-ordination for River Basin management	Establish a transitory Basin Organisation with main stakeholders (*even with no full backing because of the lack of legislation*)	Increase control over water use in the basin; better assess and control demand and possible allocation
	Register (at least identify) users and try to control new ones	Limit political interventions. Stop the expansion of irrigated areas
Non-agricultural users paying for water	Financial incentives to water treatment and other water saving initiatives (though the Basin org.)	Better water quality ; water recycling and saving

Scenario 2 (decentralised)

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Scenario 1

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Measures	*Actions*	*Benefits*
Structural measures		
Automation and computerised processing of real time data	The main gates in the system must be automated and respond to changes in water levels, anticipating the impact of hydrological conditions in the middle basin	Stabilisation of the water level and intakes at Chai Nat Dam. Regaining control over water flows
Non-structural measures		
Set WUAs at the lateral and main canal levels **Define stricter scheduling** **Associate farmers to management and maintenance of secondary/ tertiaries**	Hydraulic Units have representatives at the Project level; Allocation among main canals of the Project is decided jointly by RID and representatives (but the shares of the main canals may still be centrally defined) Levy a water fee, to be used locally for maintenance and to hire field staff	Distribution of water among farmers decided collectively: greater equity Pressure on RID to ensure the distribution of water as scheduled Part of the costs borne by farmers; higher sense of 'ownership'
Setting of a Chao Phraya River Basin Organisation **(institutional clarification of the water sector)** **Organise farmers at the Project and basin levels** **Cost sharing**	Legal empowerment and political backing. Centralise data. Register users and deliver permits. Define control and penalties. Representatives of farmers and other users within the Basin Agency. Participation in decision-making regarding macro-level allocation. Increase the share of RID's budget paid by users' fee (salaries)	Unify policy making under a strong body with representatives from stakeholders Centralise data and information for better monitoring and decision-making Enforce policy Ensure participatory decision on water allocation; create conditions for a future formalisation of rights (and compensa-tion for users not served) "virtuous binding" between performance and salary. Better service. Farmers as "clients"

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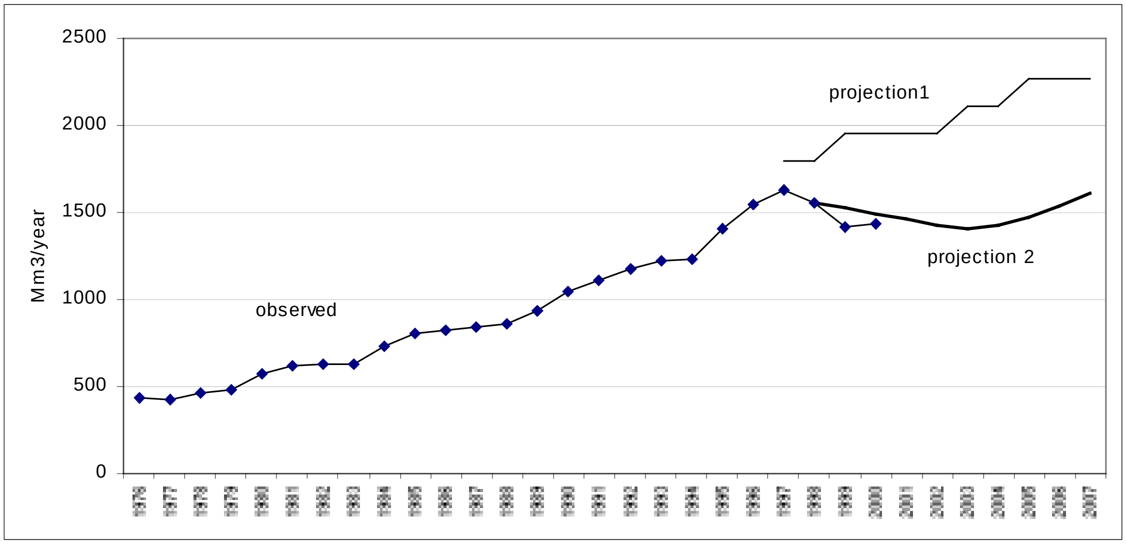
16 Annexes

ANNEXE 1: EVOLUTION AND PROJECTIONS OF SUPERFICIAL WATER USE IN BMA



Source: MWA (Projection 1 is pre-crisis, Projection is post-crisis)

ANNEXE 2: NUMERIC ASSUMPTIONS (FOR A GROWTH OF 5%), IN BM3

year	year	A	B	C	D	E	F	G	H	I	J
2515	1972	11,5	1,5	0	0,12	0,27	0,4	7,1	1,7	7,7	0,5
2518	1975	11,2	1,4	0	0,16	0,31	0,5	6,7	1,7	7,4	0,5
2523	1980	11,0	1,4	0	0,24	0,36	0,6	6,5	1,8	7,2	0,5
2528	1985	10,7	1,4	0	0,33	0,46	0,8	6,1	1,8	6,9	0,5
2533	1990	10,3	1,3	0	0,43	0,55	1,0	5,6	1,8	6,5	0,5
2538	1995	9,9	1,3	0,08	0,58	0,55	1,2	5,0	1,9	6,1	0,5
2543	2000	9,5	1,2	0,16	0,62	0,55	1,3	4,6	1,9	5,7	0,5
2548	2005	9,30	1,1	0,22	1,1	0,40	1,7	3,9	1,7	5,5	0,5
2553	2010	9,10	1,0	0,3	1,6	0,27	2,2	3,2	1,6	5,3	0,5
2558	2015	8,90	1,0	0,58	1,9	0,27	2,8	2,7	1,9	5,1	0,5
2563	2020	8,70	1,0	0,58	2,7	0,27	3,5	1,7	1,8	4,9	0,5
2568	2025	8,50	1,0	0,58	3,6	0,27	4,5	0,6	1,8	4,7	0,5

A: 2 dams net inflow
B: DS dams net inflow
C: Contribution from Mae Klong
D: MWA, superficial water
E: MWA, underground water
F: MWA, total water use
G: for agriculture (with loss)
H: Total supply in DS
I: available for Dry season (considering an average dams release of 3.8 Bm3 in the Wet Season)
J: for control of salinity intrusion
Values before the year 2000: (B) estimated; (E) estimated; (D) MWA data

Data on DEDP pumps are not always consistent; often, it is not specified which crops are grown, differences between wet and dry seasons, the percentage of stations in operation, etc. The following table is drawn from a DEDP report. Irrigable areas are deduced from the water volume (itself probably calculated based on energy consumption) through a 1000 m3/rai standard. This shows that irrigated crops are not always rice. To transform the area in rice equivalent, these values must be multiplied by 1500/1000.

Year	Mcm/year				Irrigable area (rai)					(rai)
	Lower Ping	mid Nan	Lower nan	TOT	Lower Ping	mid Nan	Lower nan	TOT		Equiv Rice
1979		7		7		7010		7010	1023	4780
1980		15		15		14360		14360	1022	9787
1981		32		32		31400		31400	1022	21400
1982		38	13	51		36750	12310	49060	1031	33713
1983	11	60	23	94	11420	59050	21790	92260	1023	62913
1984	15	66	49	130	15140	64250	47740	127130	1020	86460
1985	15	69	51	135	15140	67250	49390	131780	1023	89840
1986	19	74	52	145	19650	72700	50840	143190	1015	96887
1987	19	99	54	172	19650	97140	52840	169630	1016	114880
1988	25	104	60	189	24910	102050	58120	185080	1023	126227
1989	27	110	65	202	27110	107530	63320	197960	1020	134627
1990	31	115	68	214	31160	112930	66270	210360	1017	142667
1991	43	131	95	269	44260	128410	93070	265740	1012	179333

Other data (ESCAP, 1991), (DEP, 1998), give the number of stations as follows:

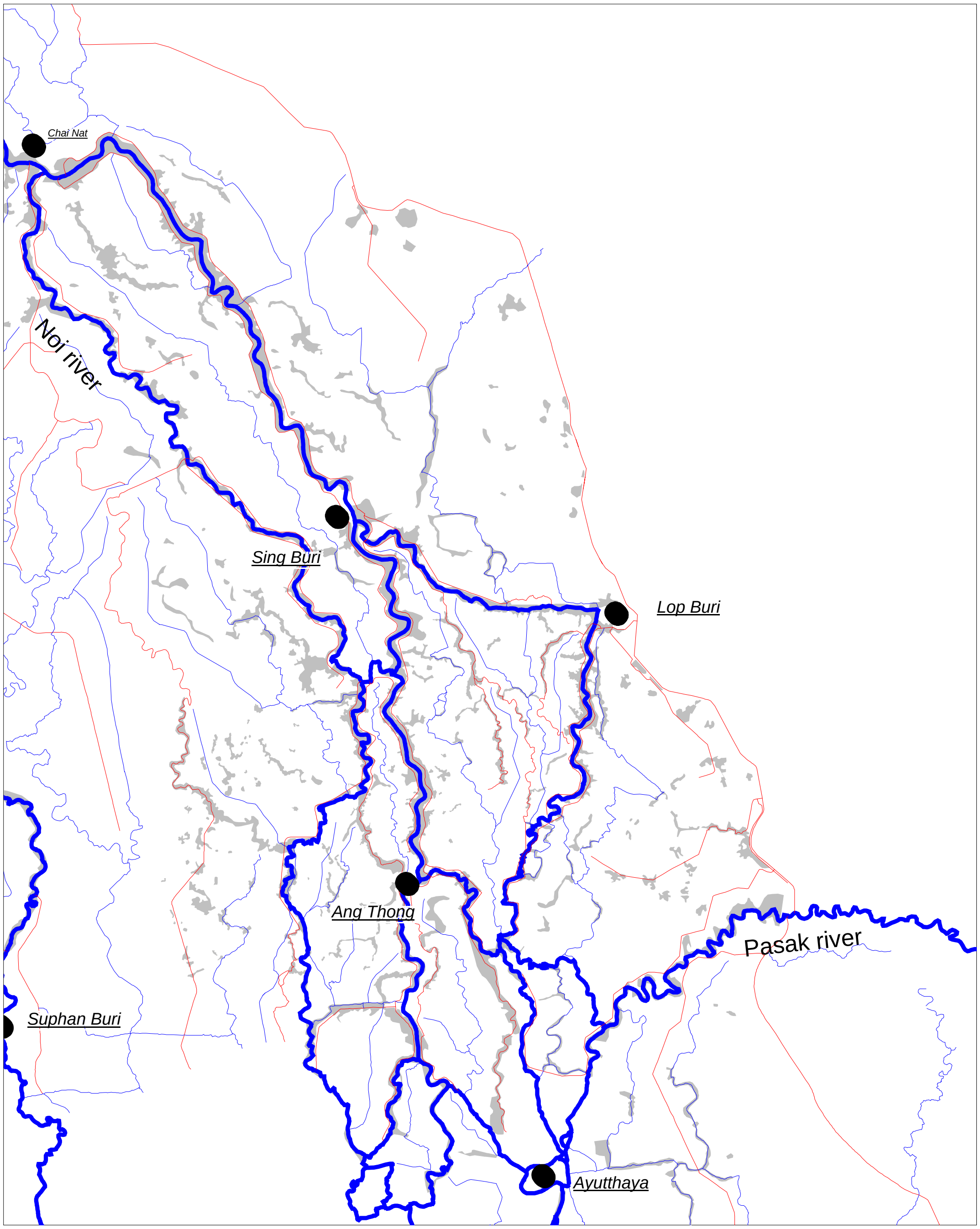
	Number of stations		Irrigated area (rai)	
	1991	1998	1991	1998
Middle/Lower Nan	156	159	295000	282040
Lower PING	46	69	109000	116830

and Binnies (1997) provides numbers on irrigated areas in the wet and dry seasons 1995/96.

	DS			WS		DS (%WS)	
	All irrig	rice	Rice equiv	All irrig	rice	All irrig	rice
	TOTAL (RID+DEP)						
Nan lower	**1,091,541**	**740,031**	**932,578**	**2,355,590**	**1,848,579**	**46**	**40**
Ping Lower	**298,494**	**113,023**	**226,313**	**1,018,550**	**702,800**	**29**	**16**
	RID						
Nan lower	844753	515219	698975	2067730	1632720	41	32
Ping Lower	269248	95694	204217	756430	521937	36	18
	DEP						
Nan lower	246788	224812	233602	287860	215859	86	104
Ping Lower	29246	17329	22095	262120	180863	11	10

The chart is drawn with the 1979/91 data above; for 1992-1999 a constant increase of the irrigable area up to 400,000 rai is considered, then corrected by the ratio irrigated area/irrigable area of the delta.

ANNEXE 4: TREE AREAS (BACKYARDS)



The tree areas in the western and upper parts have not been mapped. Small areas, including tress on dikes (etc) do not appear too. This map has been made based on satellite images

ANNEXE 5: ASSESSMENT OF THE WATER BODY OF WATERWAYS

	upper delta	lower delta	length (km)	average width (m)	area (ha)
rivers	800	320	1120	150	9600
canal1	1315	45	1335	10	1335
canal2	1649	266	1915	2	383
drain1	1255	142	1397	10	1397
drain2	1469	203	1672	5	836
channel1	0	2789	2789	15	4184
channel2	0	2581	2581	7	1807
channel3	0	8164	8164	2	1633
Total	64,88	14,510	20,973		**29,574**

Canals are irrigation canals in the upper delta, as opposed to channels (excavated waterways of the lower delta).

An evaporation of 1,000 mm during the dry-season gives a loss of approximately 0.3 Bm3.

ANNEXE 6: CALCULATION OF THE EFFECTIVE RAINFALL

Rice

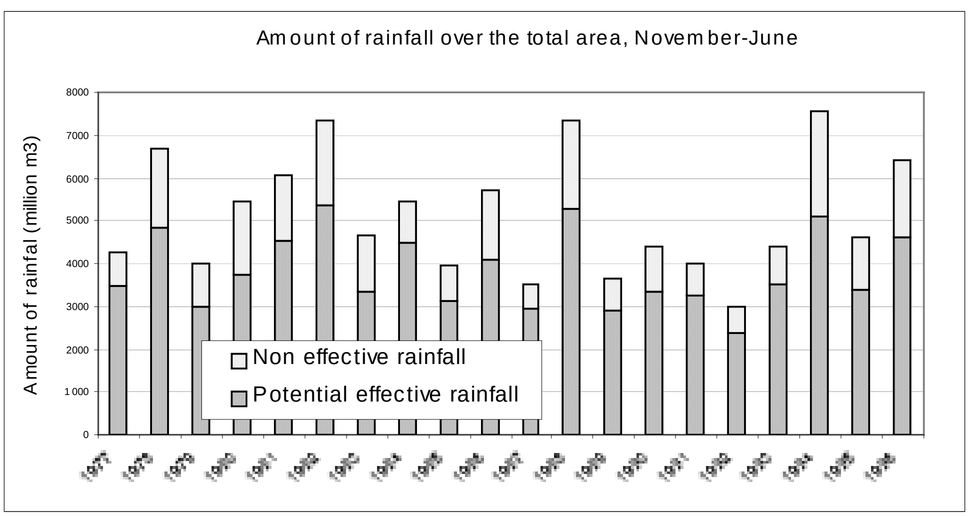
Jan-April	Eff = 1 + 0.55 * Rain	if rain < 59 then Eff = Rain
May-Jun	Eff = 7 + 0.45 * Rain	if rain < 54 then Eff = Rain
Jul	Eff = 15 + 0.75 * Rain	if rain < 60 then Eff = Rain
Aug	Eff = 22 + 0.56 * Rain	if rain < 50 then Eff = Rain
Sep	Eff = 6 + 0.38 * Rain	if rain < 42 then Eff = Rain
Oct	Eff = 5 + 0.25 * Rain	if rain < 30 then Eff = Rain
Nov-Dec	Eff = 1 + 0.55 * Rain	if rain < 59 then Eff = Rain

Sugarcane

Jan-April	Eff = 38 + 0.78 * Rain	if rain < 29 then Eff = Rain
May-Jun	Eff = 9 + 0.66 * Rain	if rain < 25 then Eff = Rain
Jul	Eff = 9.1 + 0.65 * Rain	if rain < 26 then Eff = Rain
Aug	Eff = 9 + 0.64 * Rain	if rain < 25 then Eff = Rain
Sep	Eff = 12.8 + 0.42 * Rain	if rain < 22 then Eff = Rain
Oct	Eff = 13.14 + 0.27 * Rain	if rain < 18 then Eff = Rain
Nov-Dec	Eff = 6.38 + 0.78 * Rain	if rain < 29 then Eff = Rain

Source: Vorawut (pers. com.)

ANNEXE 7: EFFECTIVE AND NON-EFFECTIVE RAINFALL (PER YEAR)



ANNEXE 8: CORRECTIONS FOR WATER BALANCE BY BLOCK

Block	Correction for domestic use	Calendar correction 1970s and 1980s	Calendar correction 1990s
SUPHAN tract	0,90	0,05	0,15
NOI tract	0,90	0,03	0,10
CH-PSK	0,90	0,00	0,10
West bank	0,80	0,13	0,13
East Bank	0,80	0,19	0,19
MK-Uth	0,85	0,01	0,06
Maharat	0,85	0,06	0,09
Borommathad	0,95	0,00	0,03
Chanasutr	0,95	0,00	0,01
Yangmanee	0,95	0,00	0,13
Man/CK	0,90	0,06	0,09
RR-KK	0,90	0,06	0,09
Polathep	0,95	0,00	0,06
Thabote2	0,95	0,00	0,03
Samchook	0,95	0,00	0,04
Phophya	0,90	0,03	0,03

Estimate of calendar corrections

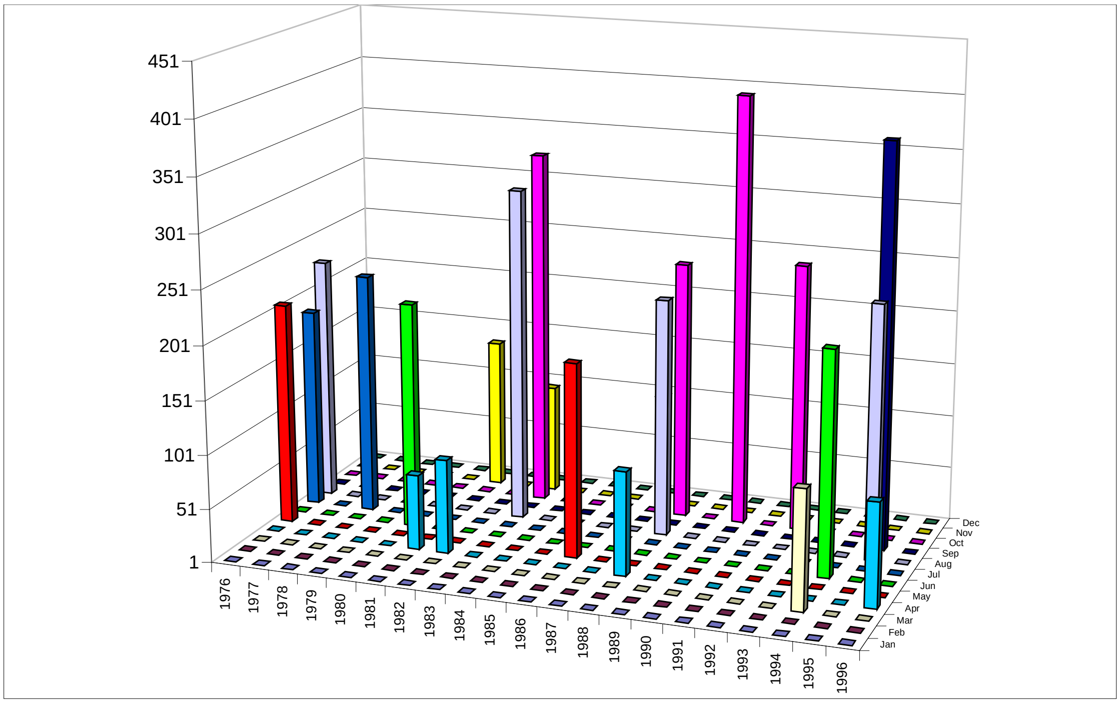
	West	East	MK-Uth	Maharat	Boro	Chana	Yangm	Man/CK	RR-KK	Polatep	Thab2	Samchk	Pophya	delta	delta
	0,13	0,19	0,01	0,06	0,00	0,00	0,00	0,06	0,06	0,00	0,00	0,00	0,03	0,03	0,15
	0,13	0,19	0,06	0,09	0,03	0,01	0,13	0,09	0,09	0,06	0,03	0,04	0,03	0,09	0,17
1970s-1980s															
% start November	25	50													35
% start December	25		10										20		12
% start May				10				10	10					5	
1990s															
% start November	25	50	10		5					10	5	5		5	38
% start December	25		20		10	5				15	10	15	25	10	18
% start May				15			20	15	15					10	
	0,40	0,30	0,05	0,00	0,05	0,00	0,00	0,00	0,05	0,05	0,00	0,05	0,15	0,00	0,20
	0,40	0,30	0,20	0,05	0,10	0,05	0,00	0,05	0,10	0,20	0,15	0,10	0,20	0,15	0,35

Corrections of delta inflow for water balances

Year	Buffer	Mae Klong	Wells	Chao Phraya	Year	Buffer	Mae Klong	Wells	Chao Phraya
1982	0,10	0,20	0,05	0,10	1992	0,10	0,30	0,20	0,10
1983	0,10	0,20	0,05	0,10	1993	0,10	0,30	0,30	0,10
1984	0,10	0,20	0,10	0,10	1994	0,10	0,30	0,30	0,10
1985	0,10	0,20	0,10	0,10	1995	0,10	0,50	0,30	0,10
1986	0,10	0,20	0,10	0,10	1996	0,10	0,50	0,30	0,10
1987	0,10	0,20	0,10	0,10	1997	0,10	0,50	0,30	0,10
1988	0,10	0,30	0,10	0,10	1998	0,10	0,50	0,30	0,10
1989	0,10	0,30	0,10	0,10	1999	0,10	0,50	0,30	0,10
1990	0,10	0,30	0,10	0,10	2000	0,10	0,50	0,30	0,10
1991	0,10	0,30	0,20	0,10					

ANNEXE 9: EXCEPTIONAL RAINFALL IN THE DELTA

Only the monthly rainfall with values higher than 1.4*average *and* higher than 70 mm in the DS and 100 mm in the WS are shown.

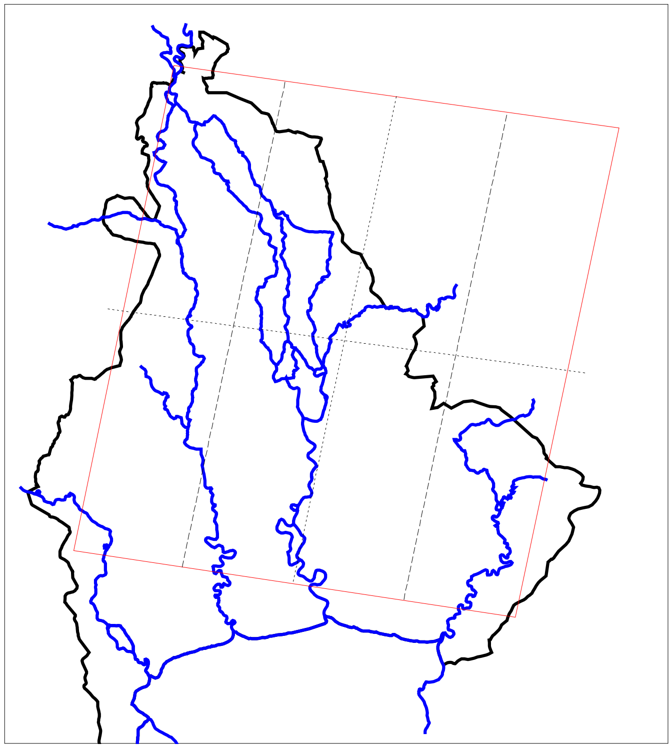


ANNEXE 10: CROPPING INTENSITY INDEX, BY PROJECT

Cropping intensity index, by Project

PROJECT	Average rice intensity Rds/Rws	Average rice intensity (Rds+FC)/Rws	Average Crop intensity (Rds+all)/(Rws+all-FC)	Average rice intensity last 5 years	Average Crop intensity last 5 years
Borommathat	1,38	1,40	1,42	1,68	1,71
Chanasutr	1,43	1,44	1,52	1,61	1,70
Chong Kae	1,15	1,19	1,19	1,44	1,45
Don jedee	1,51	1,53	1,56	1,78	1,82
Khok Katiem	1,15	1,19	1,19	1,28	1,29
Maharat	1,15	1,19	1,19	1,37	1,39
Manorom	1,30	1,31	1,32	1,64	1,65
Pho Phaya	1,72	1,73	1,74	2,06	2,06
Pollathep	1,51	1,51	1,52	1,84	1,84
Roeng Rang	1,07	1,12	1,13	1,20	1,27
Samchuk	1,57	1,59	1,65	1,79	1,84
Thabote	1,59	1,60	1,61	1,92	1,93
Yangmanee	1,16	1,17	1,22	1,25	1,35
Nakhon Luang	1,02	1,03	1,03	1,10	1,12
Pasak Tai	1,15	1,15	1,21	1,20	1,30
Phak Hai	1,10	1,10	1,12	1,36	1,40
Bangbal	1,06	1,07	1,07	1,09	1,10
Chao Ched Bang Yeeho	1,87	1,88	1,89	2,01	2,01
Khlong Dan	1,41	1,41	1,55	1,60	1,67
Phra Ong Chai Ya Nuc	1,71	1,71	1,72	1,73	1,76
Phrapimol	1,68	1,71	1,74	1,66	1,73
Phrayabanlue	1,71	1,73	1,74	1,75	1,78
Rangsit Nua	1,45	1,45	1,65	1,57	1,80
Rangsit Tai	1,50	1,50	1,53	1,59	1,62

ANNEXE 11: COVERAGE OF SATELLITE IMAGES USED



List of Satellite images used

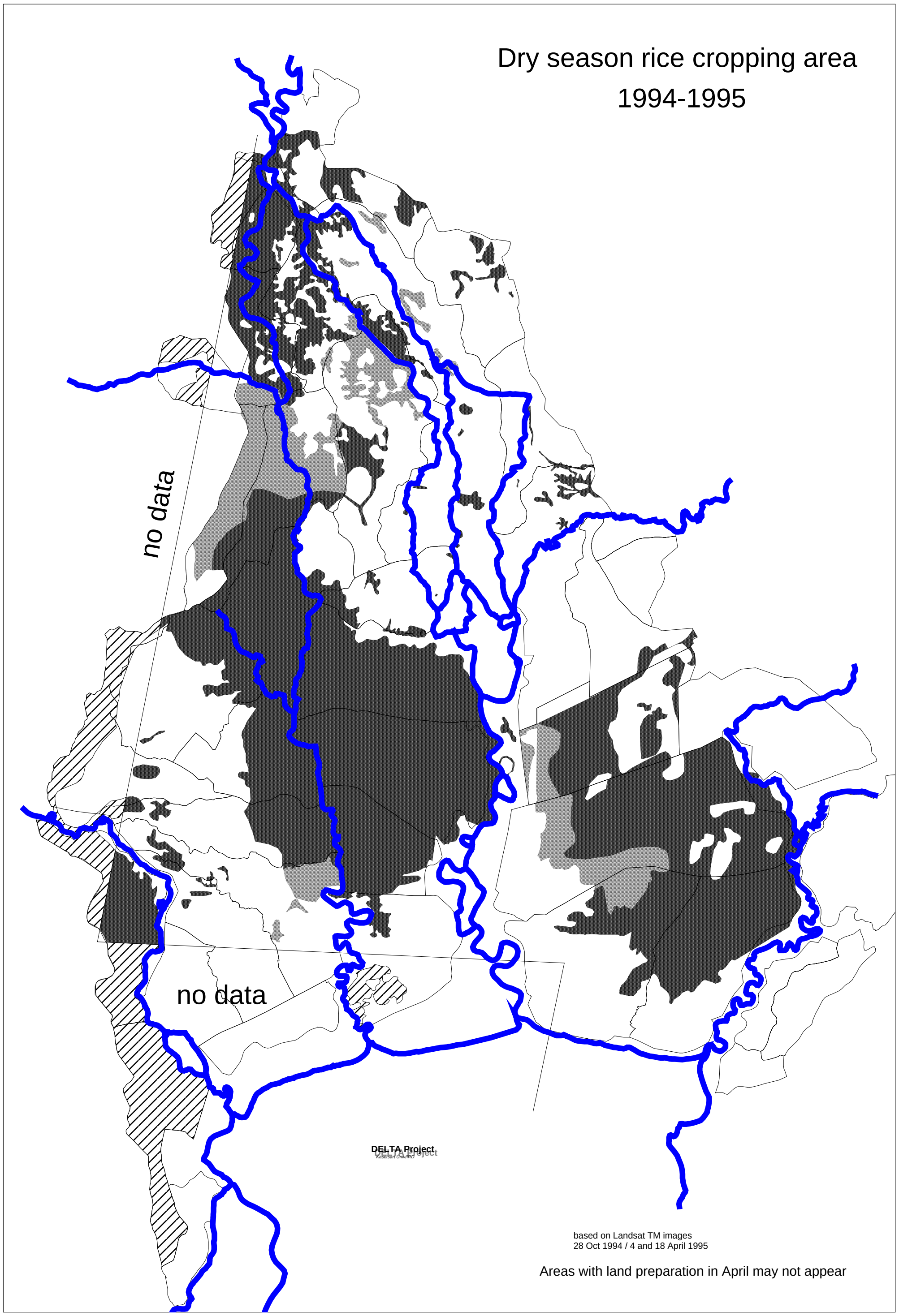
TM-Satellite WRS (path-row)	Quadrant	Date
129-050	1	20-déc-97
129-050	3,4	05-janv-98
129-050	4	11-avr-98
129-051	1	05-janv-98
129-051	1	10-mars-98
129-051	1	11-avr-98
129-051	3	11-avr-98

ANNEXE 12: TRIPLE-CROPPING (IN RAI, PER PROJECT); SOURCE RID

Triple-cropping (in rai, per Project); source RID

Year	**1998**		**1999**	
	crop 2	**crop 3**	**crop 2**	**crop 3**
Pholathep	91 015	63 590	86 222	51 140
Samchook	210 742	56 152	203 800	74 883
Don Chedee	89 640	11 994	96 010	7 857
Phophraya	245 090	153 580	253 311	no-data
Borommathad	248 404	73 742	192 721	44 490
Phak hai	42 367	27 100	62 238	43 110
Chaoched - Bangyeehon	289 395	153 580	311 905	271 395
Prapimon	155 760	155 860	155 830	155 630
Phrayabanlue	288 120	285 505	285 505	285 505
Pasicharoen	20 690		14 781	13 481
Thabote	151 169		141 987	67 669
Channasutr	254 288		88 061	17 544
Manorom	158 401		70 470	58 065
Rangsit Tai	195 200		237 455	102 600
Klong Dan	80 310		81 310	13 420

ANNEXE 13: CROPPING AREA IN THE 1994-95 DRY-SEASON



ANNEXE 14: DRILLING FOR AGRICULTURAL DRAUGHT-RELIEF – SHALLOW WELLS 1994

Uttaradit	3300	Pichit	6347
Kamphaeng Phet	8500	Pitsanulok	7000
Nakhon sawan	2900	Uthai Thani	2800
Chai Nat	5500	Singburi	5172
Ang Thong	3000	Lop Buri	2000
Suphan Buri	3000		

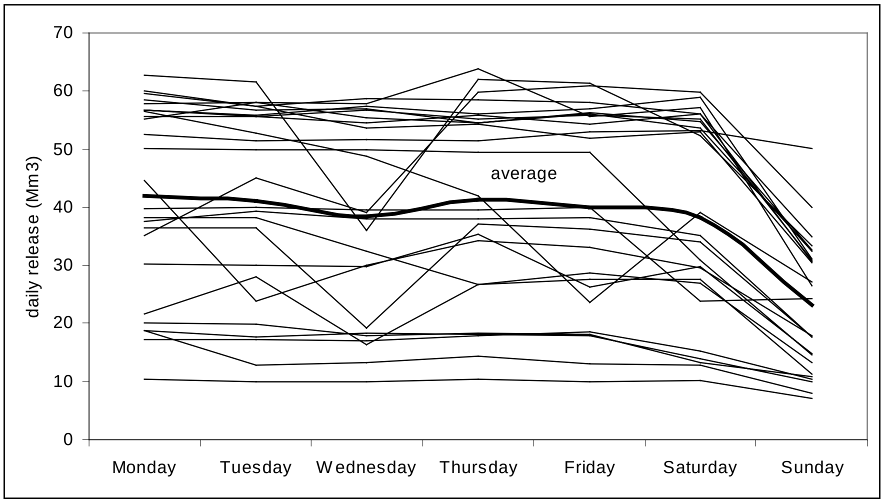
(governmental programmes)

ANNEXE 15: PERCENTILE OF THE TOTAL INFLOW IN THE TWO DAMS, BY SEASON AND BY YEAR

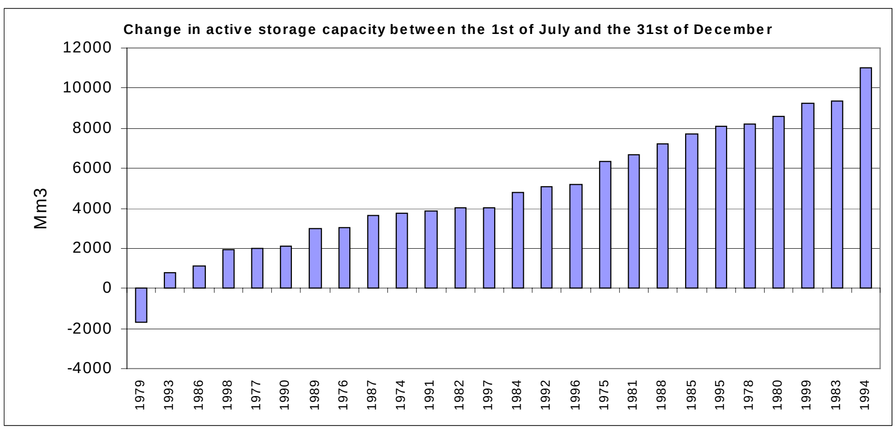
Quantile	Total dams inflow			Total dams inflow 3 years				Dams release (1972-00)		
	DS	WS	Tot	DS	WS	Tot		DS	WS	Tot
0	585	4222	5166	2667	17844	20511	1,32	1894	801	3531
0,1	1022	5952	7091	3768	20754	25380	1,19	4073	1670	5518
0,25	1165	6662	8346	4364	22520	27387	1,09	4656	2479	8326
0,33	1424	7840	9093	4588	23354	27855	1,02	5125	2874	8709
0,5	1602	8790	10643	4867	27128	31928	1,00	6533	3718	9855
0,66	1816	9711	11178	5027	29522	34308	1,02	6774	4551	11094
0,75	1878	10661	12442	5396	30957	35793	0,96	7081	4980	12061
0,9	2314	13687	15255	5888	32774	38809	0,85	8218	6044	14148
1	2568	14753	17321	6424	38564	44393	0,85	9643	8159	14824
Moyenne	1591	9040	10631	4811	27070	31882	1,00	6020	3825	9845

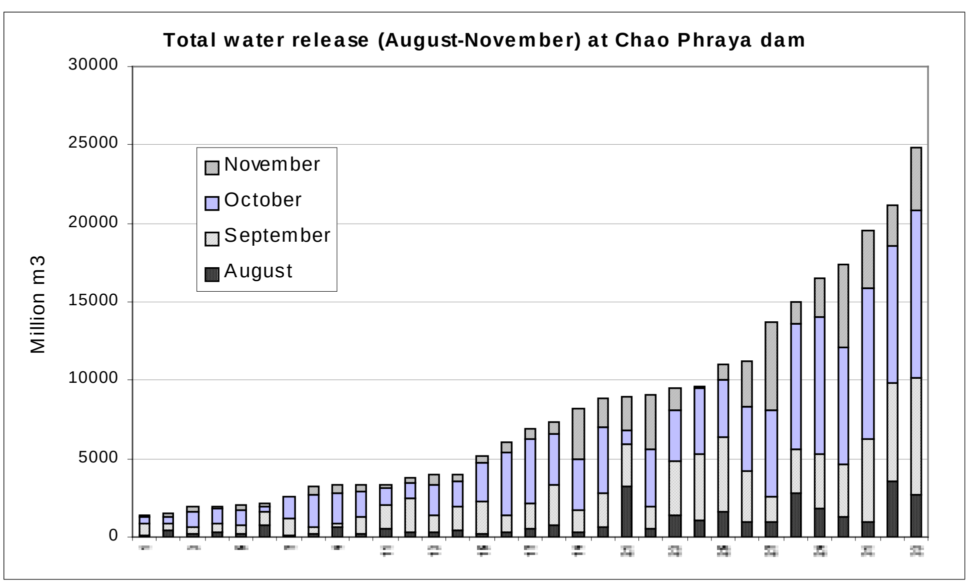
Quantile	Diversion including Naresuan				Dams balance	Release at Chai Nat Dam			Sideflows
	1973-00		**1981-00**						
	DS	WS	DS	WS	WS	WS	DS73-	DS81-	WS
0	1835	4661	1835	4661	-1704	1624	831	831	3313
0,1	2462	6046	2201	5947	1958	2766	1014	997	6961
0,25	3313	6651	3502	6350	3482	3593	1482	1328	7675
0,33	3917	6769	3998	6615	3889	3900	1587	1504	8539
0,5	4632	8152	4985	6835	5146	6963	1943	1832	12891
0,66	5238	8473	5280	7436	7299	11175	2440	2345	16767
0,75	5427	9226	5427	8200	8113	12847	2584	2667	18139
0,9	5926	10365	5919	9140	9262	18737	3745	3700	22443
1	6107	11851	6067	10685	11012	26216	4487	4211	28061
Moyenne	4386	7982	4462	7247	4960	9202	2185	2095	13530

ANNEXE 16: DAILY WATER RELEASE DURING THE 26 WEEKS OF THE 1998 DRY-SEASON (TWO DAMS)

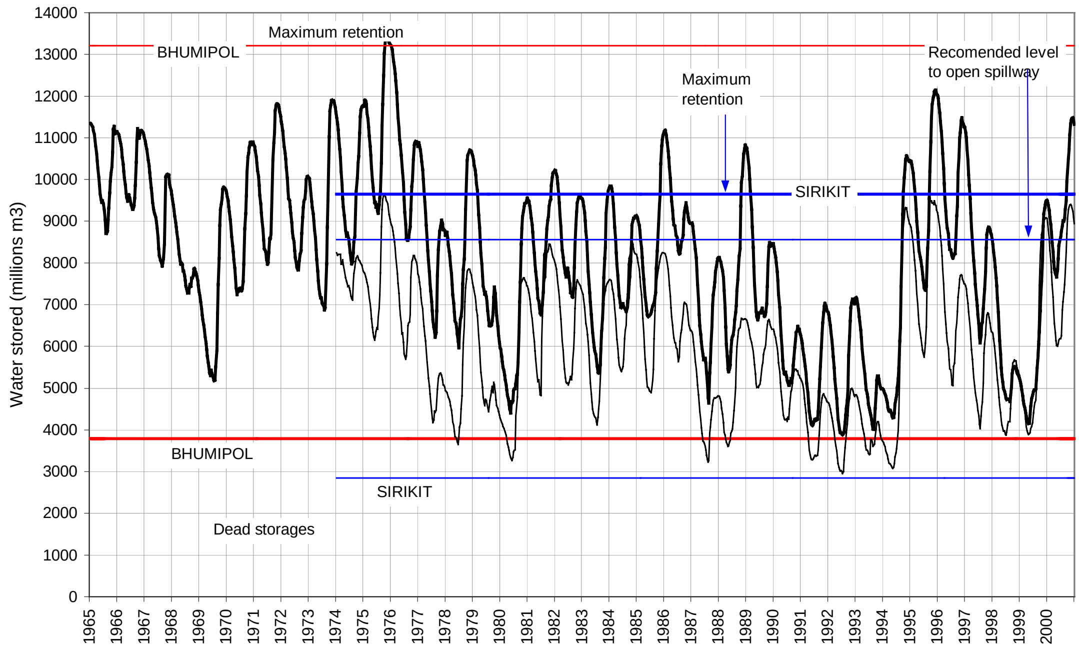


ANNEXE 17: NET DAMS BALANCE DURING THE RAINY SEASON (CLASSIFIED VALUES)

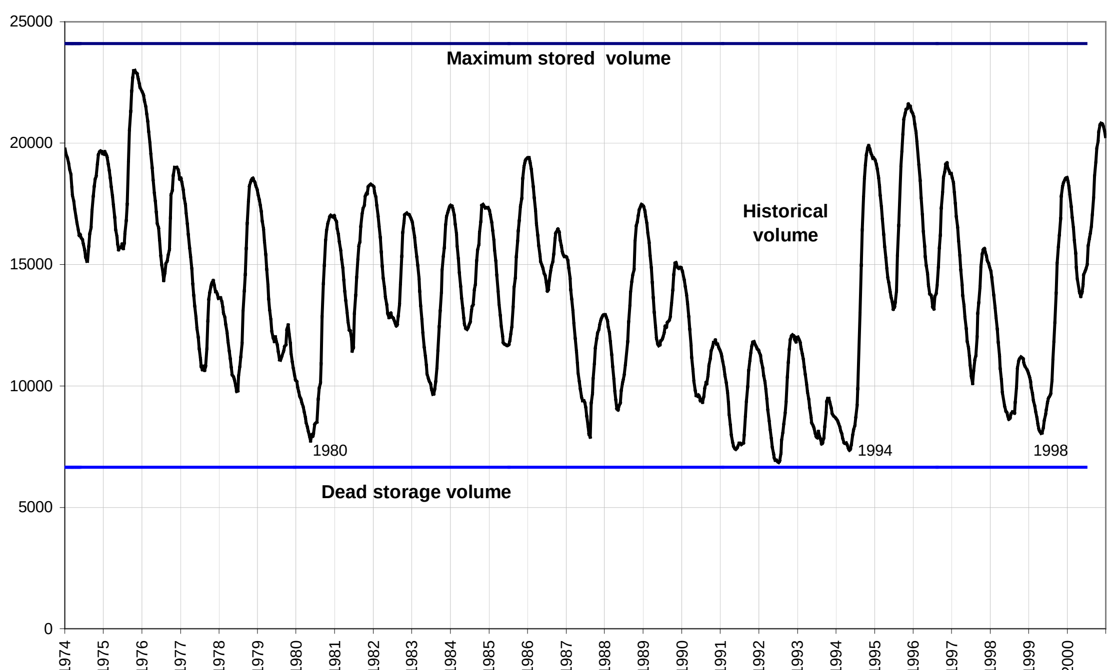




ANNEXE 18: HISTORICAL EVOLUTION OF THE WATER STOCKS OF BHUMIPOL AND SIRIKIT DAMS



Combined stored water volume



ANNEXE 19: PRIORITY TASKS FOR THE CPBC (WRCS, 2000)

1 Resource data, information systems and river basin planning

a) Data, information and systems

- A comprehensive assessment of the current status and trends of Chao Phraya Basin water resources and their use.
- A water data needs analysis covering both existing and new data systems needed for good IWRM in the CPB. This analysis should cover processing, storage, archiving and accessibility of data, and recommendations must be consistent with national standards.
- A registry of water users and uses, including definition of the procedures for creating and maintaining this registry.
- Development of a hydrologic model, appropriate to the needs of the new basin organisation for its first 5 years.
- A review of reservoir operation procedures, using the above model and other relevant information.

b) River basin planning

- Agreement on a water management vision for the basin, within the scope of the national water strategies,
- The definition of strategies to reach that vision and to allow implementation of the appropriate component projects recommended by the line agencies and the tributary basin sub-committees.
- The preparation of a prioritised action plan to address major water resource management issues arising from the strategic planning process.
- Recommendation of the vision, strategies and action plan, together with supported component development projects to the NWRC.

2 Increasing the capacity and skills of the CPBC, its Office and subsidiary organisations

- Domestic and sub-regional study tours to consider river basin planning developments, and incorporating the findings of these tours an updated action plan.
- International study tours to cover all aspects of contemporary IWRM.
- Seminars and short courses to increase the knowledge and understanding of IWRM among selected staff of the ONWRC, CPBC, Office and tributary basin sub-committees.

3 Increasing the community awareness and involvement in IWRM

- Review contemporary international experience in community awareness and participation.
- Develop options appropriate to the CPB and pilot these within the Pasak tributary basin.
- Design a program for Chao Phraya Basin-wide implementation.

4 Develop organisational strategic planning

Hold a series of workshops and other events to build organisational systems, culture and values necessary for effective water resource planning and regulatory activities