Earthquake & Tsunami Emergency Support Project

ETESP

Aceh Besar Kabupaten

- Lhoknga
- Darussalam
- Baitissalam

Data Assessment and Soil Reclamation
(December 2005)

SUMMARY

S.1 Locations

Within Kabupaten Aceh Besar eight sites were subjected to a salinity survey using an EM38 device in three Kecamatan:

Lhoknga – Nusa with three transects
Darussalam – Miruk Taman with two transects, and
Baitissalam – Suleue, Blang Kreung and Lampeudaya with one transect each

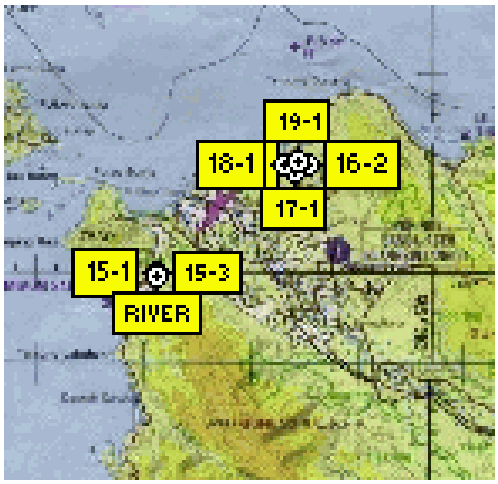
Table S.1 Coordinates of Locations

15-1	5 29 49.5	95 16 10.1	22.0	Sites 15-1&2, Nusa desa, Lkonga, Aceh Besar
15-3	5 29 47.9	95 16 10.1	7.9	Site 15-3, Nusa Desa,Lkonga, Aceh Besar
16-1	5 35 21.9	95 23 46.9	25.9	Site 16-1, Miruk Taman Desa, Darussalam, Aceh Besar
16-2	5 35 20.0	95 23 46.0	21.9	Site 16-2, Miruk Taman, Darussalam, Aceh Besar
17-1	5 34 53.3	95 23 03.9	21.9	Site 17-1, Suleue Desa, Baitissalam, Aceh Besar
18-1	5 35 12.0	95 22 32.1	28.0	Site 18-1, Blang Kreung desa, Baitissalam, Aceh Besar
19-1	5 35 30.1	95 23 16.8	35.1	Site 19-1, Lampeudaya desa, Baitissalam,Aceh Besar
RIVER	5 29 36.7	95 16 01.8	4.0	Local river in Nusa Desa, Lkonga,Aceh Besar

NB Altitudes from GPS and NOT reliable

Approximate location can be seen in Figure S.1 and some features are presented in Table S.2

Figure S.1 Locations



S.2 Site Features

At all these sites it was established that, pre-tsunami, the favoured crop was normally rainfed rice during the wet season with various Palawija during the dry season – there was no irrigation facility at any of the sites apart from on-site wells tapping the ground water, which was used for supplementary irrigation.

Table S.2 Basic Features and Location of Sites

Kecamatan	Desa	Site	Landuse	Tsunami Sediment	Land Preparation	Crop Performance
Lhoknga	Nusa	15 – 1	Palawija	10 cm, mixed with soil	N,K,P and OM	OK but poor yield
		15 – 2	Palawija	This is same field as 15-1		
		15 – 3	Palawija	10 cm, mixed with soil	N,K,P and OM	Total failure
Darussalam	Miruk Taman	16 – 1	Sawah as Palawija	3cm, mixed with soil	None noted	No crop in ground
		16 – 2	Sawah as Palawija	3cm, mixed with soil	None noted	Good
Baitissalam	Suleue	17 – 1	Abandoned	20cm, no treatment	None	Not cropped, flood
	Blang Kreung	18 – 1	Abandoned	20cm, no treatment	None	Not cropped, flood
	Lampeudaya	19 – 1	Abandoned	20cm, no treatment	None	Not cropped, flood

S.3 Salinities and Soil Depths

Data from an EM38 salinity survey carried out by BPTP was passed to ETESP in October to allow ETESP assess the situation and attempt to compile reclamation requirements and strategy to bring about soil improvement, which would lead to enabling agriculture to recover in the effected area.

Table S.3 Salinities Established by EM38 Survey and Depths of Soil

Desa	Site	Soil PSC	Overall Salinity dS/m	Soil depth to reclaim (cm)	Soil depth possible to reclaim (cm)	Notes
Nusa	15 – 1	M	2.15	60	50	Water table restricts depth
	15 – 2	M	2.15	60	50	Same site as 15-1
	15 – 3	M	2.00	30	0	Site flooded / very high water table
Miruk Taman	16 – 1	M	2.15	60	30	High water table restricts depth
	16 – 2	M/H	2.05	60	30	High water table restricts depth
Suleue	17 – 1	M	2.05	60	15	High water table restricts depth
Blang Kreung	18 – 1	M/H	4.30	30	0	Site flooded
Lampeudaya	19 – 1	M/H	2.75	30	0	Site flooded

DLw – depth of leaching water required – this is depth of water that has to pass below the reclamation target depth
PSC is the class for leaching progress and NOT the USDA PSC classification

The depth of soil to be reclaimed is based on land-use:

- if the option is palawija then 600mm (60cm) is an acceptable depth for a rooting zone for most crops, and
- 300mm (30cm) would suffice for wetland rice

However, the depth of soil that can be reclaimed is largely governed by the depth of the existing water table and, as can be seen above, the water table reduces the depth somewhat at all sites. When the site is flooded or the water table extremely high then there is no or very reduced possibility for reclamation until such time as the flood clears and the water table is reduced to depths below the expected or desired root zone.

S.4 Soil Drainage

The status of soil drainage was assessed in mid-November 2005 whilst ETESP did site visits – the information collected is summarised in Table S.4 below.

Table S.4 Drainage System Status and Irrigation System (November 2005)

Location	Site	Nov 05 Salinity (dS/m)	Soil depth to be recovered (mm)	Depth of watertable (mm)	Drainage System Status	Irrigation System in use	Soil PSC
Lhoknga, Nusa	15 – 1	3.25	600	750	None	Furrow	M
	15 – 2	3.25	600	750	None	Furrow	M
	15 – 3	2.67	300	100	None	None	M
Darussalam, Miruk Taman	16 – 1	2.35	600	300	None	None	M
	16 - 2	2.25	600	400	Furrows	Water can	M/H
Baitissalam, Suleue	17 – 1	5.00	300	300	Blocked	None	M
Baitissalam, Blang Kreung	18 – 1	4.63	300	0	Partial flood	None	M/H
Baitissalam, Lampeudaya	19 - 1	4.93	300	0	Flooded	None	M/H

S.5 Depths of Soil that can be Reclaimed and Depths of Leaching Water

The depth of soil that it is desired to reclaim is based on what is considered to optimal or acceptable rooting depths for the crop or type of crop being grown. Basically, palawija needs 60cm soil depth and rice can manage with 30cm depth.

Table S.5 Depth of Soil that can be recovered and Depths of Water to be Applied

Site	Depth of soil that can be recovered (mm)	Depth of leaching water (mm)	No of Gifts	Depth of Water Applied (mm)	Notes
15-1	500	325	10 – 11	1000 +	Established via ETESP tools
15-2	500	325	10 – 11	1000+	Site as 15-1
15-3	Cannot be reclaimed				Water table too high
16-1	150	71	4	400	Established via ETESP tools
16-2	250	113	5	500	Established via ETESP tools
17-1	150	150	4 - 5	400 - 500	Established via ETESP tools
18-1	Possibly reclaimable				Partial flood, remove flood
19-1	Cannot be reclaimed				Site flooded

NB "Cannot be reclaimed" at present until such time as flood clears and water table greatly reduced

The depth of leaching water is the depth (mm) of water that has to pass down through the full depth of soil being reclaimed; the associated depth of water that has to be applied to the surface is considerably greater as shown above.

S.6 Findings, Conclusions and Recommendations

As can be seen above in Table S.4 there is a common feature at virtually all sites and that is the non-existence of an operational soil drainage system. Soil reclamation, whether it is planned to allow nature to do this on its own via rainfall or via the intervention of applying the necessary leaching water as irrigation gifts, cannot and will not work unless any leachate produced can be removed from the site.

The areas devastated by the tsunami are all low lying, alluvial areas and all have high or relatively high water tables and water cannot drain to depth as would happen in upland sites. Most drainage that does happen in such lowland sites is via "lateral" drainage – that is the water moves sideways in the profile to some exit point that is at a lower level. This exit point is usually a man-made drain or natural stream line. Of the sites seen to date there are very few operational drains but it is obvious that some have been installed in the past, but have been neglected. Also, at many sites inappropriate irrigation systems are being used – furrow irrigation exacerbates any salinity problem.

Figure S.2 Inappropriate Irrigation + Dam Effect

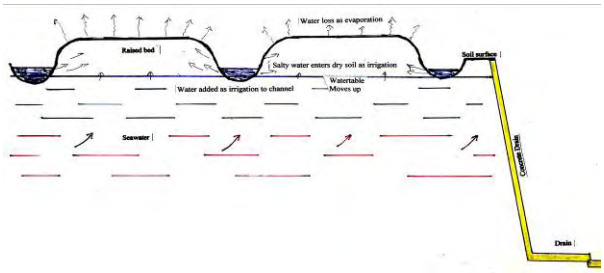
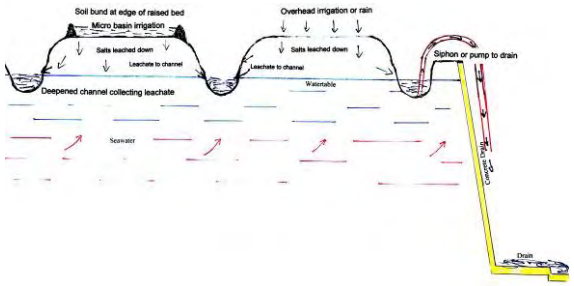


Figure S.3 Raised Beds and Siphon Drainage

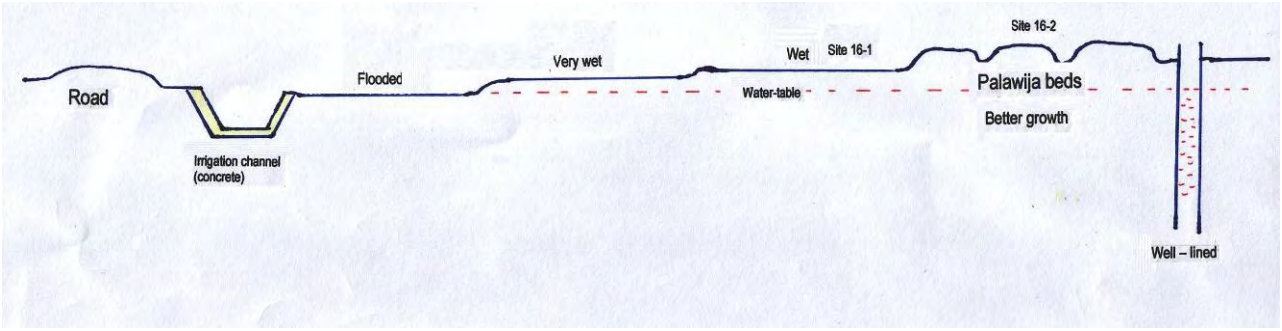


The drainage situation is made worse in several sites by structures such as road protection walls, concrete irrigation channels set into the earth and urban concrete-lined drains running along roadsides. Such constructions act as dams and prevent lateral drainage – system, such as pumps or siphons, will have to be used to ensure the dam effects can be bypassed.

There is no easy solution and each site or block of sites has to be assessed by an experienced soil scientist with relevant experience in irrigated agriculture, soil reclamation and probably with the assistance of a soil drainage engineer. But, any site can be reclaimed – it is all a matter of economics and many sites will have to be abandoned as reclamation would be far too expensive and alternative land uses must be considered.

Some farmers seem to have already started to change their cropping and husbandry and one such example is shown below where the preferred crop is wetland rice but only palawija will grow at present. The farmer is using raised beds, is applying any supplementary irrigation as an overhead application using watering cans and the original furrows would appear to be working as drainage channels.

Figure S.4 Raised Beds with Good Crop – November 2005



At this site there is better growth nearer the well, which is at the most elevated part of this farm and there was water, assumed to be leachate from the beds, sitting in the lower or down-slope parts of the existing furrows. As can be seen at this site there is an irrigation system but the farm is not within command of this system and the channel is stopping any lateral drainage.

However, some farmers following the above system have already noticed that under palawija the soil is becoming acid – this is a known problem, was reported and documented during the Aceh Design Unit project in the 1980s. Suitable tolerant crops have to be used and amendments such as OM and FYM should be applied in large quantities as OM removes the aluminium involved from circulation Furthermore, materials containing calcium can also be applied – lime, limestone and gypsum which slowly release calcium which displaces the offending aluminium.

Leaving it to nature just will not work in the present situation and there will have to be physical interventions and the main intervention will be getting soil drainage systems installed or overhauled. Once that is done, reclamation leaching can be done and this is a relatively straightforward operation as long as the necessary tools are used and the principles are understood. Once the soil has been reclaimed to salinities where suitable crops can be grown – and at this point salt tolerant varieties must still be considered – other inputs to the farmers can be considered but it is almost pointless giving farmers seed, fertiliser inputs etc until the soil is in a fit state to be cultivated.

S.7 Salinities of Water

Where possible the salinity, ECw in dS/m, of the various waters encountered were measured, the findings are shown below.

Table S.5 Water Salinities November 2005

Site	Well or ground water ECw	Water Class	Surface or flood water ECw	Water Class	Drainage Channel or River ECw	Water Class
15-1 & 15-2	0.33	C2	NA		0.61	C2
15-3	0.30	C2	3.89	C4	0.61	C2
16-1	0.30	C2	2.70	C4	NA	
16-2	0.43	C2	NA		NA	
17-1	0.56	C2	4.10	C4	ND	
18-1	NA		1.56	C3	2.69	C4
19-1	NA		4.35	C4	NA	

Classification Source: ETESP 2005b
NA – Not applicable as does not exists / Not available or not measured
ND – No data

What the above data means is that the "well" or "ground" waters are all suitable for irrigation purposes within the limitations defined in Table S.6.

Table S.6 Irrigation Water Classification

Irrigation water Salinity Hazard Class	ECw (dS/m)	Description & Notes
C1 Low salinity water	<0.25	Can be used for most crops on most soils with low chance of developing a salinity problem. Some leaching required but this would happen under normal, well managed irrigated agriculture
C2 Medium salinity class	0.25 – 0.75	Can be used if a moderate amount of leaching occurs. Crops with moderate tolerance to salinity can be cultivated without special measures for control of salinity
C3 High salinity class	0.75 – 2.25	Cannot be used on soils with restricted drainage. Even with adequate drainage special management for salinity control will be required and crops with high tolerance to salinity used.
C4 Very high salinity class	>2.25	Not suitable for irrigated agriculture under normal circumstances. Soils must be very permeable (sandy), drainage must be good, irrigation water must be supplied in excess to provide excessive leaching and only very salt tolerant crops can be grown

Classification Source: ETESP 2005b

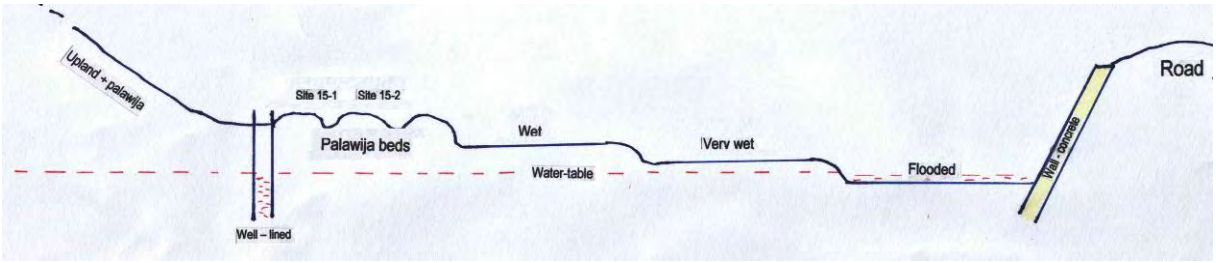
All of the water samples found on the surface, apart from Site 18-1, are far too saline to be of any use at all for irrigated agriculture and would be adding problems to the sites. It is interesting to note that at Site 18-1 the flood water would appear to be less saline than the water that is already in the drainage ditch – this suggests or indicates that desalinisation could be happening somewhere upstream of this site and the leachate is very saline, making the sample tested more saline than the surrounding flood**.** However, this salinity figure of 1.65 for flood water and the comments above should be treated with caution as only one sample was tested.

Scenario 1 Sloping land with no irrigation or drainage

The soil is considered slightly to moderately damaged with salinity levels of 2-4dS/m (Salinity Class SC1) with reclamation normally being attempted by the farmer without guidance. But, the farmers are only having limited success and that is normally only on the highest parts of their farm. The main problem with such sites is a high water table and restricted drainage. Water tables at highest part of farm are at 50-75cm with salinity of 0.25-0.50dS/m (Class C2) and the water table is usually at the surface on the lower parts of the farm.

The water on and in the land just cannot escape from the site as there is no active drainage system and the natural stream lines have been blocked, often by man-made structures such as roads and concrete irrigation channels.

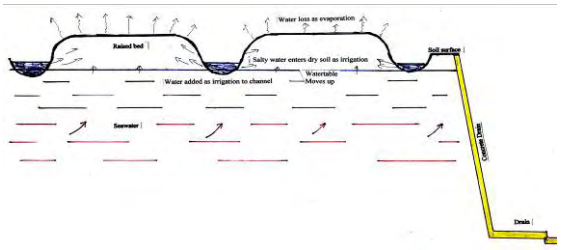
Cross Section of typical location



Problems

1. High water table which gets closer to the surface as the level of the land falls towards the natural stream lines
2. The land in the lower-slope positions is flooded since the water table is actually at the surface
3. Man-made structures, such as roads, urban and agricultural drainage ditches and irrigation channels, acting as dams and blocking the drainage
4. Inappropriate, surface flow irrigation methods are being utilised and these are perpetuating the salinity
5. No in-field or on-farm drainage and natural stream lines are no longer active

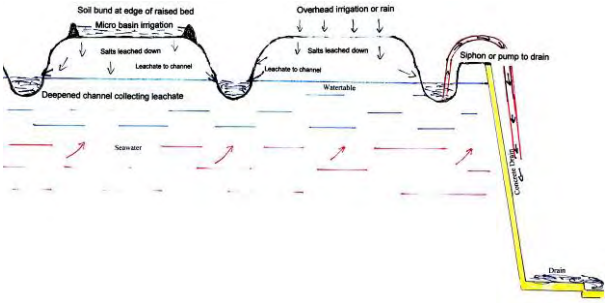
Surface Irrigation Perpetuating Salinity



Immediate actions

1. Install in-field & on-farm drainage, these can be farmer-installed with guidance and instruction
2. Clear, unblock and restore natural drainage lines and ensure they connect to the local river or drain
3. Deepen in-field furrows so they can act as drains to remove any saline leachate produced – the farmer can implement this
4. Apply irrigation as overhead and not surface-flow, this will better enable soil leaching – use watering cans or appropriate, low-cost technology with piped or pumped supply
5. Use salt tolerant varieties and, for the immediate future, only grow palawija on raised beds with overhead irrigation techniques.

Overhead Irrigation Giving Desalinisation



A palawija cycle must be built into the cropping calendar to allow annual leaching and desalinisation

Possible reclamation problems and effects

1. Engineering difficulties bypassing man-made structures requiring minor to medium civil engineering inputs
2. Increasing salinity and flooding downstream as the saline leachate is removed from the sites and drained to local rivers
3. Development of soil acidity under palawija cropping, this is a known problem with some of the soils of the region and soil pH must be monitored. Soils with this possible problem should have large amounts of organic matter (FYM, compost) added to assist remove the aluminium from the soil and hence reduce the acidity. Liming materials may also be required. These soils will revert to neutral when flooded for padi in future.
4. Farmers might show some resistance to having to grow palawija rather than padi but, with selection of high value, marketable crops income generation could be considerably enhanced

Conclusions and Recommendations

These soils can be easily and rapidly reclaimed and brought back into production with relatively low costs and most of the intervention done by the farmer.

In puts such as seed and fertilizer should not be supplied, or applied to the farm, until the salinity level is lowered via the above actions. Even then, salt tolerant varieties of crop should be utilised and, if palawija, soil pH must be monitored.

Scenario 2 Level, low lying close to the coast and still flooded with drainage

The soil is considered to be moderately to heavily damaged and still flooded. Surface water salinity of 1.5-2.0dS/m (Class 3) and surface soil salinity of 4.63dS/m (SC2). However, previous irrigation systems are now acting as drainage systems and could be utilised to drain and reclaim this land if some refurbishment was done, channels cleaned and deepened to improve the outflow of the main drains or channels into the sea plus preventing or reducing tidal effects.

Typical site previously used for padi

Problems

1. High water table and flooding by very saline water which is influenced by tidal action via the existing channel
2. Deep sediments deposited by the tsunami which, to date, have not yet been mixed in with the original soil due to flooding restricting access to the land
3. High salinity surface water and moderately salinised surface soil giving unsuitable environment for cropping
4. No current cultivation and cannot be any cultivation until the land is drained and salt tolerant seed is made available

Sites like this are on almost flat alluvial plains with no obvious high points, still totally or partially flooded, no cropping at all and covered in grasses which are being browsed by buffalo etc. and are close to the coast. But, at least one location, there was an operational drainage channel. Refer the photos below. However, local information was that this was, in fact, a previous irrigation system. The in-field water-flow in this channel was fairly fast and there was an outlet into a major channel which was obviously linked to the sea. This drain or channel was flowing - but very slowly. This drainage system was governed by tidal movement and the local estimate was that there is presently between 50-100cm of sludge, sediment and rubbish in the channel or drain.

Existing badly silted-up channel

Drainage entering main channel

Immediate Actions

Deepen and clear all existing channels on, around and above the site, ensure all sediment and garbage is removed. Much of this can be done by the farmers under supervision and within the "cash-for-work" scheme.

Cut tidal effects in the main channel by clearing the river / channel mouth and install flood gates to protect the channel. These activities will NOT be low cost and will involve major civil engineering.

Restore irrigation water supply with an upgraded distribution system. This task will not be low cost and will involve civil engineering expertise – but could be incorporated into the ETESP irrigation programme.

Use highly saline tolerant rice varieties as such sites will probably be at risk of re-salinisation from sea-water ingression.

Possible reclamation problems

Sea level continues to rise and inundation could well be an on-going problem, even if tidal gates are installed.

If highly salt tolerant varieties cannot be located locally for immediate use then they must be located and imported before any planting is done (Thailand has knowledge).

Conclusions and Recommendations

These sites can be reclaimed but at considerable cost due to relatively major civil engineering interventions.

If reclamation proves too expensive then a change of land-use is indicated and the immediately obvious use is to construct fish pods

No seed, fertilizer or other inputs should be supplied or applied until reclamation has been completed. If reclamation is not to be attempted then a change in land use has to be made or the land abandoned to agricultural cropping.

Scenario 3 Rain fed area with no active drainage though drainage installed

Level areas previously used for rain-fed rice but out-of-command of local irrigation systems and having the remnants of a soil drainage system. Soil salinity level about 4-6dS/m (SC2) and water table at 30-50cm with salinity level of 0.3-0.6ds/m (C2). Farmers have tried cropping but crops failed and sites now abandoned. Such sites can be quite badly damaged with the surface water virtually stagnant with algae etc growing and water is not passing into the existing drainage canal.

Raised bund above the soil drain

Immediate Actions

Clear the drain that passes through the site and also ensure it is cleared down-stream so that any effluent collected can be removed from the site. At the same time deepen the drain to below the rooting depth for palawija (50-60cm). Most of the on-farm work can be done by the farmers under guidance and through the "cash-for-work" scheme.
Refurbish the full length of the drain where it leaves the farmland and until any effluent that it carries can be safely and environmentally acceptably be removed from the area and into a local, natural stream line or functioning, large drain.
Establish, by digging, examining, describing and sampling soil profile pits in several locations within the site to establish if there is a restriction to drainage due to a plough pan. If there is a restriction deep plough or rip to at least 50cm depth to break or rupture any pan or restriction.
Construct palawija beds and follow Scenario 1 using palawija cropping with overhead irrigation, when required, as the cropping system until salinity is reduced.
Much of the damage to such drains is not due to tsunami effects but is due to long-term neglect and lack of maintenance of the drain.

Problems

High soil salinity that, if anything, is getting worse due to evaporation of the saline water from the surface concentrating the salts.

High water table that should not be there since there is a soil drain at the edge of the field but it is NOT collecting and removing water from the field.

Surface water all over the site gives an unacceptable, anaerobic root zone for palawija and the site is far too saline for padi. The site is so wet and stagnant that algae and other water plants are growing.
Water is not entering the existing drain and it is suspected that there might be a plough pan formed over years of puddling with oxen.

Badly damaged and blocked drain

Refurbishment will be mainly a civil engineering task and relatively expensive to implement but very necessary if not essential – not only for agriculture but also for social reasons.

Possible reclamation problems

Civil engineering inputs will have to be used to ensure that the drainage is safely disposed of and does not flood other areas and create problems downstream if the drain begins to flow carrying saline leachate.
It may not be economically possible to refurbish the full length of the drain due to expense or lack of relevant civil engineering skills and availability. Similarly, if safe disposal of the saline leachate cannot be guaranteed then the work should not proceed.
Inability to install / supply irrigation water could be a problem, but the ground-water can be used and the quality of the ground-water should improve with time as the salinity of the area is reduced. Also, the rainfall is relatively good (about 1700mm/annum) and, in the past, was good enough for rain-fed rice to be grown.

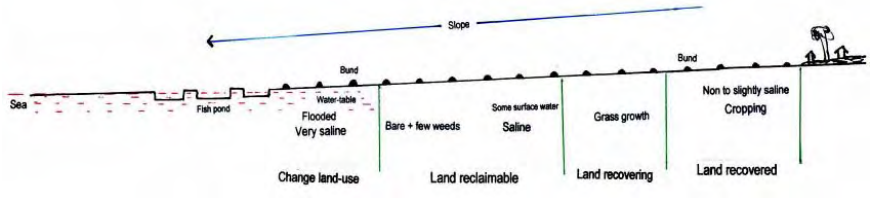
Conclusions and Recommendations

There are no insurmountable reasons as to why such sites cannot be reclaimed and brought back into production. However, the reasons for the present lack of flow from the fields to the existing drains must be established and remedial measures taken.
No seed, fertilizer or other inputs should be supplied or applied until reclamation has been completed or at least underway. After reclamation it is strongly recommended that saline tolerant varieties of crops should be ustilised to ensure there is no future crop yield reduction or failure due to any salinity build up – this is possible if the deep subsoil is also salinised to some extent and capillary rise can resalinise the topsoil.

Scenario 4 Lower slopes of irrigation schemes, close to fish ponds

This scenario is found mainly in the Pidie and Bireuen areas and is associated with the lower slope positions of irrigation schemes, near the coast and where fish ponds already exist.

Cross section from village on high ground to fish ponds and the sea



Drainage Ditch / Collector Drain

The irrigation schemes have an operational water supply system and some basic drainage channels – though what the farmers call drainage is really overflow systems that remove excess irrigation water from one irrigated field to the next field down-slope.

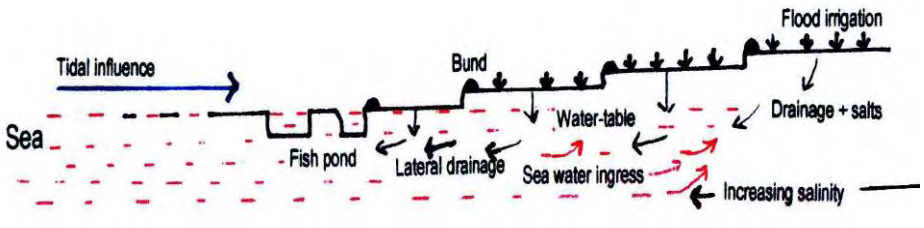
However, there is often a larger drainage channel running directly down-slope at the opposite side of the field from the inlet for the irrigation water, hence there is some drainage of the land.

Problems

There is a progression of salinity increase down-slope with the soils at the top of the slope already back in production (Scenario 5) and the soils at the lowest points being badly flooded and very saline. There are at least two possible reasons for the salinity of these lower slope sites:

- Tidal influence and sea water ingress via the water-table, and
- Accumulation of salts in the lower slopes due to the sub-surface, lateral or sideways drainage of the soils further upslope. This is a natural phenomenon and is to be expected in any irrigation scheme, in particular where there has been inadequate provision of soil drainage

Salinisation of low lying site from the sea and irrigation



Salinisation is happening from the sea plus from the land and, for the worst affected areas, there is probably no way to reclaim the land and land-use should probably be changed to construction of fish ponds.

Immediate actions

A decision has to be made as to where the land-use should be changed to construction of fish-ponds and where reclamation should be carried out. One indicator or guideline should be the severity of the flooding on the surface and, also, if there is tidal influence – that is, does the flood increase and decrease with the tide? If there is obvious tidal influence then the land-use should be changed.

Where there is no tidal influence, but the land may still be flooded, then the drainage should be increased immediately – this can be done by installing drainage ditches across the slope (on the contour) and ensuring any drainage collected is discharged into the collector drain down the edge (down-slope) of the irrigated area leading to the fish ponds and the sea.

In the areas further upslope, where the land is recovering and grasses are starting to grow, the drainage should be increased as suggested above and this will speed up the recovery process. Diagrams are presented in Scenario 5 of such drains.

Possible reclamation problems and effects

With the installation of drains there will be an immediate increase in the amount of water, mainly saline, draining off the land trying to find its way to the sea. All channels downstream and the outlet to the sea must be unrestricted or increased flooding at the shoreline will happen.

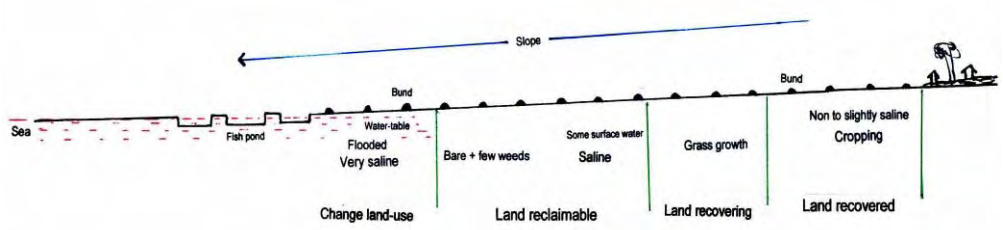
Conclusions and Recommendations

The services of an experienced soil / land drainage engineer should be used to design and oversee the installation of the suggested drains and, in the worst effected areas, no seed, fertilizer or other inputs should be supplied or applied until reclamation has been completed or at least underway.

Scenario 5 Flat to very gently sloping wetland-rice areas within irrigation

This scenario is found mainly in Bireuen plus other places where there are large, well established irrigation systems. Cropping has re-commenced in these areas and the combination of irrigation and even minimal drainage has lead to leaching of the salts and reclamation of the land. Farmers are monitoring the recovery themselves and start to cultivate when there is strong, green growth of natural grasses on their fields.

Cross section from village on high ground down-slope through padi area



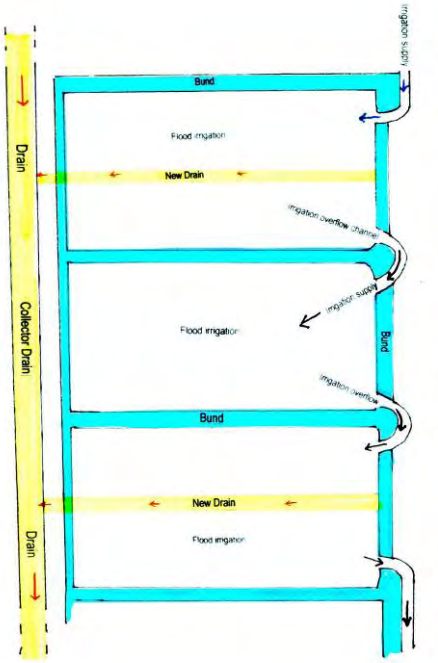
The situation of this scenario is depicted on the right hand side of the diagram where the lower captions read "land recovered" and "Land recovering".

Very little intervention is now needed on this scenario but, if there had been a more comprehensive drainage system, this land could have been back in production much sooner.

Problems

Land is this category no longer has a problem of any great significance, but there is an increase in salinity as one progresses down-slope away from the village on the high ground – this is because the first land to be leached would be the highest land and the saline leachate would have drained laterally down slope and added to the salinity of the lower slope sites. As long as there is sufficient rainfall plus continued application of irrigation water the land will continue to recover as the salts are leached out further and further down the slope.

New field and existing collector drains



Immediate actions

Consideration should be given to improving the existing drainage system to ensure there is no future build-up of salinity through normal irrigation of the land. In addition, a study of the water management and irrigation applications should be carried out to ensure that sufficient water is applied to ensure that there is an adequate "leaching fraction" being applied to ensure leaching occurs. If there were ever to be another disastrous tsunami and vast amounts of salt water were again dumped on the field the improved drainage system would speed up the recovery process.

Additional drains should be installed on the contour; right across the width of the padi fields and disgorge into the existing collector drain. The field drains should be deep enough to ensure that the bottom of the drain is below the maximum rooting depth of the crop (rice) being grown and, generally should be somewhere between 60 – 75cm deep, whilst the existing collector drains are already about 100cm deep.

Possible reclamation problems and effects

Field Drain

With the installation of drains there will be an immediate increase in the amount of water, some of it possibly saline, draining off these upper slope sites and trying to find its way down-slope to the sea. All channels downstream and the outlet to the sea must be unrestricted or increased flooding at the shoreline will happen.

Drainage Ditch / Collector Drain

Conclusions and Recommendations

Although land falling into this category is largely recovered, or recovering, improving the drainage network system can only be of benefit for the immediate and long-term future and will help ensure there is little or no build-up of salinity with continuing irrigated agriculture – however, good water management will also be important. Land in this category should receive all available inputs, especially improved seed, as soon as possible to help boost agricultural output.

Contents

CHAPTER 1 INTRODUCTION

1.1 Introduction

The Tsunami of 26 December 2004 inundated the Aceh Besar area and dumped vast amounts of sea-water plus sediments and debris on the land as well as virtually totally destroying a large proportion of the infrastructure - social and agricultural. The ADB Grant Number 0002-INO: Earthquake and Tsunami Emergency Support Project (ETESP) was set-up to assess the situation and propose remedial measures to assist the area recover from this natural disaster. Uniconsult International Limited (UCIL) was awarded Package 3 – Agriculture Component and UCIL staff mobilised in early September 2005 to commence work.

The Desalinisation and Soil Improvement Specialist was tasked with assessing the situation with respect to soil damage and designing remedial interventions to enable the reclamation of the soil and farmland to enable agriculture to resume as quickly as possible. All the Kabupaten within the immediate study area are shown in Figure 1.1 and Aceh Besar is labeled 08 in the top NW corner of the island of Sumatra surrounding Banda Aceh. Several sites from Kecamatan, with available soils and salinity data, within Aceh Besar are reported here.

Figure 1.1 NAD Kabupaten

1.2 Kecamatan

In Figure 1.2 the relevant Kecamatan have been coded:

L Kec No. 20 – Lhoknga

D Kec No. 60 – Darussalam

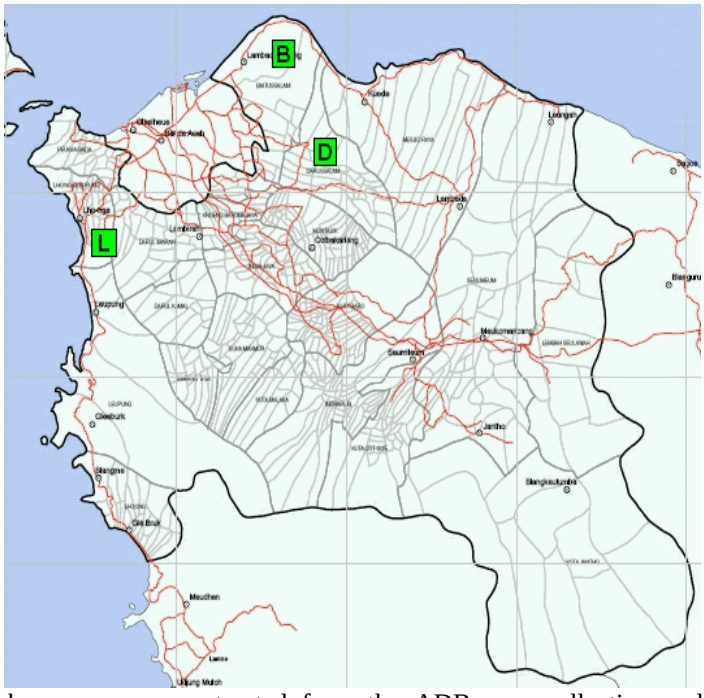
B Kec No 61 – Baitissalam

Wherever the transects were done in Lhoknga they could not be any further from the sea than 4.2km since this Kecamatan is only just over 2km deep and is very exposed to the ocean on the west coast.

The furthest one can get from the coast in Darussalam is between 12 and 17km and the village boundaries shown in Figure 1.2 suggest that the areas nearer the coast were less densely settled.

Baitissalam shows the same pattern as Darussalam with an apparent lower density of village boundaries nearer the coast with the more densely developed area between 10 and 16km from the coast.

Figure 1.2 Kabupaten Banda Aceh and Kecamatan



The above map was extracted from the ADB map collection and geo-registered in the GPS software Ozi Explorer and distance measurements were made from the on screen digital map.

1.3 Background

At the time the Inception Report was prepared very little data had been located with respect to the soils, salinity and sediment problems brought about by the tsunami. However, there was limited information and data available relating to the aerial extent and degree of damages inflicted by the tsunami – most of this data being available in the ADB GIS Mapframe system – these data has been consulted and used. Limited climatic data were reported in the Interim Report and these data have been used for further analysis and manipulation.

Other data were made available through BPTP (Balai Pengkajian Teknologi Pertanian) for use by ETESP, this included the raw data for a salinity survey done using an EP38 salinity probe. This dataset was compiled by the Soil Research Institute, Bogor 16123, Indonesia from a survey carried out by the institute and funded by the Australian Centre for International Agricultural Research (ACIAR). Transects were done in three Kecamatan at 5 locations with 8 transects being completed in total. Further data on the sites, soils, water-tables, salinity and land status were collected during a site visit by ETESP in late mid-November 2005.

1.4 Sites or Locations

The format of this report is that material, such as climate, common to all areas, Kecamatan or transects, is contained in this chapter and a separate section is devoted to each of the Kecamatan with data from each individual location. Updates on the sites and data are presented later in this report.

Table 1.1 Kecamatan Reported for Aceh Besar – EM38 survey data

No	Name	Features	Location / Desa	Transect	Days flood	Sediment (cm)	Landuse
20	Lhoknga	Very exposed to the ocean and tsunami. The village plan shows apparently dense development close to the coast in the central part of the kecamatan.	Nusa	15 – 1 15 – 2 15 – 3	5	10	Rainfed Palawija Cropping OK
60	Darussalam	Slightly sheltered by promontory of Baitassalam from the ocean and tsunami	Miruk Taman	16 – 1 16 – 2	3	3	Sawah Prepared as palawija beds
61	Baitassalam	Very exposed to the ocean and tsunami	Suleue Blang Kreung Lampeudaya	17 – 1 18 – 1 19 – 1	30	27	Sawah Not used since tsunami

The Kecamatan are presented by kecamatan number and not in alphabetical, size or perceived order of importance.

Table 1.2 Geographic Coordinates of Sites

Site	Deg N	Min N	Sec N	Deg E	Min E	Sec E	Altitude masl	Notes
15 – 1	5	29	49.5	95	16	10.1	22.0	Transects 15 – 1 and 15 – 2 on the same plot
15 – 2	5	29	49.5	95	16	10.1	22.0	
15 – 3	5	29	47.9	95	16	10.1	7.9	Perhaps 50cm lower than 15-1 and 15-2
River	5	29	36.7	95	16	1.8	4.0	River approximately 0.5km from sites and 4m lower
16 – 1	5	35	21.9	95	23	46.9	25.9	Fractionally lower than 16 – 2
16 – 2	5	35	20.0	95	23	46	21.9	
17 – 1	5	34	53.3	95	23	3.9	21.9	Partially flooded and abandoned
18 – 1	5	35	12.0	95	22	32.1	28.0	Flooded and abandoned
19 – 1	5	35	30.1	95	23	16.8	35.1	Flooded and abandoned

NB Altitudes from GPS unit and not to be taken as anything like accurate, must be found from topographical map

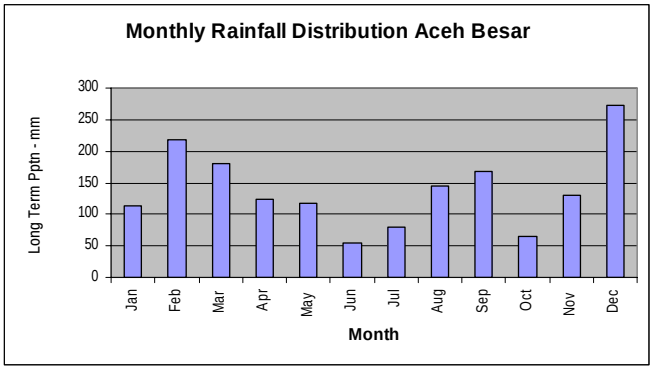
1.5 Climate

The climatic data that are available are presented more fully in Appendix A and only salient features are presented in here. The distribution is shown diagrammatically below in Figure 1.3 and as Table 1.3

1.5.1 Rainfall in Aceh Besar

The annual rainfall, or precipitation, for the area is taken as almost 1700 mm and the monthly distribution, as seen in Figure 1.3, appears to suggest there are two main peaks – February with over 200mm and December with close to 300mm and a minor peak in August September of 140 – 170mm

Figure 1.3 Rainfall Distribution in Aceh Besar



15.2 Use of Rainfall Data

The monthly rainfall data have already been built into one of the main "reclamation" tools which is an MS Excel spreadsheet (Leaching Water Requirements.XLS) for calculating the depth (mm) and volume (cubic metres per hectare) required to leach soils of various textural class with salinised horizons of various depths.

On the assumption that the data are reasonably accurate, reclamation was to be done in December, the highest rainfall month, and it rained every three days then on average with an even distribution then something like 25 – 30mm could fall every three days. But this calculation is very basic and proper computer modeling would be required to get a more accurate figure.

Table 1.3 Rainfall Distribution in Aceh Besar

Code	Kabupaten No 8 mm	Distribution %
Jan	114	7
Feb	219	13
Mar	180	11
Apr	123	7
May	117	7
Jun	54	3
Jul	80	5
Aug	145	9
Sep	169	10
Oct	65	4
Nov	131	8
Dec	273	16
Total – LT	**1668**	

Table 1.4 Recent Site Data

Name	Location / Desa	Transect	Watertable depth (cm)	Soil PSC	Drainage System	Irrigation	Landuse
Lhoknga	Nusa	15 – 1 15 – 2 15 – 3	75 75 10	M M M	None, but it obvious to see how it could be done for this block	Using furrow from ground water but does have watering cans	15-1 Palawija others not used
Darussalam	Miruk Taman	16 – 1 16 – 2	30 35 – 40	M M/H	None set up but furrows in 16-2 are draining beds	16-2, watering cans from GW	16-2 Palawija 16-1 not used
Baitassalam	Suleue	17 – 1	35	M	Yes, blocked	Rainfed area with well	Abandoned
	Blang Kreung	18 – 1	Surface flood	M/H	Yes, flowing but site flooded	None obvious	Abandoned
	Lampeudaya	19 – 1	Surface flood	M/H	None, but small earth channel might have been	None obvious	Abandoned

PSC Particle Size Class leaching progress: M = medium, H = heavy (clays)

CHAPTER 2 LHOKNGA

2.1 Introduction

Kecamatan Lhoknga is, as previously noted, located on the extreme north west coast of Sumatra and is labeled as 020 in Figure 2.1 below.

Figure 2.1 Kabupaten Aceh Besar

Only one location within the kecamatan was subjected to a salinity survey and this was in Nusa where three transects were done with the EM38 salinity device.

With the lack of suitable maps it is difficult to represent the location of the sites with any clarity but the sites all lie on the map (Figure 2.2) between site 15 – 1 and the river and are approximately 4km from the sea.

2.2 Salinity Survey

Three transects were done in Nusa and the locations are shown in Figure 2.2 – the coordinates being taken by ETESP in mid November 2005 are shown in Table 2.1.

Figure 2.2 Locations

Some salient facts about the sites are given in Table 2.2, which has been compiled form study of the original dataset – MS Word document plus the Excel spreadsheet – the available maps and a field visit by ETESP.

Table 2.1 Coordinates of Lhoknga Sites

Site	Deg N	Min N	Sec N	Deg E	Min E	Sec E	Altitude masl	Notes
15 – 1	5	29	49.5	95	16	10.1		Transects 15 – 1 and 15 – 2 on the same plot
15 – 2	5	29	49.5	95	16	10.1		
15 – 3	5	29	47.9	95	16	10.1	7.9	Perhaps 50cm lower than 15-1 and 15-2
River	5	29	36.7	95	16	1.8	4.0	River approximately 0.5km from sites

NB altitudes, taken from GPS, are not accurate and access to a topographical map is required

2.3 Site Description

This site description was compiled after the field visit by ETESP in mid November 2005.

Site 15 lies on a very gently sloping valley infill between low hills within Nusa Desa and a cross sectional diagram is shown as Figure 2.3. Transects 15–1 and 15–2 were done within the same field but ran in different directions and this field is approximately 0.5m higher than the field where 15–3 was located.

Pre-tsunami all of site 15 was favoured for padi rice that gave good yields, presently the 15-1 and 15–2 field is growing water melon but giving a poor yield whilst the 15–3 field carries no crop and is as good as abandoned. In November 2005 there was no standing water in field 15–1 or 2 but there were pools and depressions filled with water in field 15–3. Other features noted are given in Table 2.2

Figure 2.3 Cross Section of Location of Site 15

As indicated in Figure 2.3 Site 15-1 lies close to the upland which exists in this area and there is a gentle fall in level, or altitude, from 15-1 which carries reasonable Palawija, to the road which is raised and protected by a concrete wall.

This wall prevents excess water escaping from the site and, accordingly, the field next to the road is flooded, the next one has a high percentage of surface water whilst the further fields 15-3 and 15-1 & 2 are progressively higher, better drained, have greater soil depth and 15-1 does support a crop.

Figure 2.4 Difference in Level 15-1 to 15-2

This demonstrates that the main problem is soil drainage, or the lack of it, and without soil drainage soil leaching or reclamation will not be possible. There was a rudimentary channel exiting from these fields but the road / wall dammed the site. Within 400m of this site there is a river which is flowing, albeit with tidal influences, but it could carry saline leachate away from the area when tides were favourable.

Table 2.2 Soil and Site Features November 2005

Site	PSC 0-25 cm	Soil Textures	Soil ECe 0 -25 cm	PSC 25 – 50 cm	Soil ECe 25 – 50 cm	Soil Depth cm	WT Depth cm	WT EC dS/m
15-1 15-2	M	SCl to CL	1.24	M	3.25	80 - 90	75	0.33
15-3	M	Sl over SCl	2.67	M	3.77	10 - 15	10	0.30

Soil depth at 15-1/15-2 increased due to Palawija beds of about 30cm height above ground level, soil depth is being presented as soil existing above the water table and hence could act as a normal root zone for most crops. It is accepted that padi rice grows in flooded conditions but, if reclamation is planned, there has to be some soil depth above the water table.

Land preparation on field 15-1 / 15-2 seemed to have been quite thorough and the farmer did have a rotovator or small walk-behind tractor.

Irrigation at this site was rainfall supplemented by hand irrigation from the on-site well and was normally done via furrows but, it should be noted, the farmer did have watering cans available and could therefore apply irrigations as overhead or sprinkler.

2.4 Site Information from EM38 Survey

No additional soil analytical or laboratory data have yet been located for this site but soil and water salinities were measured in the field by BPTP staff during an ETESP site visit when additional data were collected in order that a more considered assessment of the situation could be presented.

2.5 Problems

These sites (15-1 to 15-3) have been seen by ETESP and the following problems have been identified:

- the main problem within most of this “block” is soil drainage and a high water-table
- soil salinity, considered a “chronic” low level problem that will not “go away” via natural rainfall leaching
- insufficient soil depth to allow full reclamation via leaching
- insufficient depth of suitable soil for the crop to exploit

Table 2.3 Transect Information from EM38 Survey

Name	Site	Days flood	Sediment (cm)	No	EM38 Points	Sediment Treatment	Landuse / Crop	Fertiliser	Noted Problems
Lhokngа	Nusa	5	10	15 – 1	11	Mixed with soil	Palawija Melon Crop OK	Urea KCl Phosphate OM	Water-logging
				15 – 2	19	Mixed with soil	Palawija Melon Crop OK	Urea KCl Phosphate OM	Water-logging
				15 – 3	7	Mixed with soil	Palawija Corn Crop OK	Urea KCl Phosphate OM	Water-logging

2.6 Soil Salinity from EM38 Survey

The raw data from a salinity survey carried out on the site were passed to ETESP for use in soil reclamation studies. The basic findings of what the data reveals are presented as simply as possible in this section without going into the theories or the processes of data-manipulation used. Table 2.4 below is a presentation showing a few facts that the data reveal, these facts are revealed by all EM38 datasets and are standard procedure.

Table 2.5 contains the actual salinities determined from the EM38 data.

- Starting in the right hand column of Table 2.4 it states "Reading OK" – this has been determined from carrying out a check of some of the ratios of the various data items and is a standard procedure with the EM38. The data can be classified as "false" if an unacceptable ratio is found and would be caused by the presence of metallic objects in the soil – such as metal poles etc.

- Similarly, another check of another ratio of some of the data items reveals if the soil salinity sits in the topsoil (referred to "inverted" in the literature) or if it has been "leached " downwards to some extent. Sites 15–1 and 15–2 show as leached, meaning that the topsoil has lower salinity than the subsoil whilst 15–3 has the most saline material at the surface in the topsoil

- The coloured coded column is the ETESP assessment of the degree of problem that the original depth of sediment presented – the key is shown as Figure 2.5. The coding is also used for salinity as shown in Table 2.5

Figure 2.5 ETESP Problem Rating Key

ECe dS/m	PROBLEM RANKING	Sediment cm
0 - 1.9	None	0 - 0.9
2 - 3.9	Negligible	1 - 1.9
4 - 5.9	Very Slight	2 - 4.9
6 - 7.9	Slight	5 - 9.9
8 - 11.9	Moderate	10 - 14.9
12 - 15.9	Moderately Big	15 - 19.9
16 - 23 9	Big	20 - 29.9
>24	Very Big	>30

Table 2.4 Assessment of the EM38 Dataset for the Site

Kabupaten	Kecamatan	Location	Site	EMv	EMh	Average	No	Cm	Days	Status	Check
Aceh Besar	Lhoknga	Nusa	15 - 1	77	75	76	11	10	5	Leached	Reading OK
			15 - 2	84	78	81	19	10	5	Leached	Reading OK
			15 - 3	78	86	82	7	10	5	Saline	Reading OK

The salinity data in Table 2.5 reveals that, based on the average values, the salinity problem is negligible for this site (colour code green) and the various determinations of salinity all fall into Salinity Class SC1 (International System) and estimates range from 2.0 – 2.5dS/m. This is the value that would be normally be aimed for when reclaiming a badly salinised site. In other words this site has no actual salinity problem and this would be supported by the field notes during the survey that cropping was proceeding normally.

Table 2.5 Salinity Measurements for the Site

Aceh Besar Kabupaten				Rhoades	ETESP Lookup			Salinity Class	
	Kecamatan	Location		ECe 0 - 90cm dS/m	ECe EMv dS/m	ECe EMh dS/m	ECe EMav dS/m	Rhoades	ETESP
	Lhoknga	Nusa	Site						
Averages	values		15 - 1	2.5	1.8	1.8	1.8	SC1	SC1
			15 - 2	2.4	2.0	1.9	1.9	SC1	SC1
			15 - 3	2.1	1.9	2.0	1.9	SC1	SC1
		Mean average		2.3	1.9	1.9	1.9	SC1	SC1
Maximums	values		15 - 1	2.6	2.5	2.2	2.3	SC1	SC1
			15 - 2	2.6	2.4	2.2	2.2	SC1	SC1
			15 - 3	2.8	2.2	2.8	2.3	SC1	SC1
		Mean maximum		2.7	2.4	2.4	2.3	SC1	SC1
Minimums	values		15 - 1	1.4	1.2	1.3	1.3	SC1	SC1
			15 - 2	1.6	1.6	1.3	1.4	SC1	SC1
			15 - 3	1.8	1.6	1.4	1.5	SC1	SC1
		Mean minimum		1.6	1.4	1.4	1.4	SC1	SC1

If the maximum values are studied it can be seen that all determinations still fall into Salinity Class SC1 with values ranging from 2.2 – 2.8 dS/m. The minimum values, as would be expected, fall into the SC1 and the group considered as having no salinity problem at all – that is they are "non-saline"

2.7 Sediment Depth

Table 2.3 notes that the sediment depths deposited on the soil at the Lhoknga site are considered to be "moderate" problem. However, as the local cultivation of this site has been successful through "mixing" the sediment with the native soil it appears that there is no longer a problem from the sediment. Similar sites with this depth of sediment (10cm) should be treated the same way and the sediment mixed in via good ploughing with the application of fertilisers and organic manures.

2.8 Conclusions & Recommendations

In summary, the data from the EM38 would appear to be reliable and there was not much of a salinity problem on this site at the time of the survey. The recent values for salinity collected by ETESP and BPTP in mid-November 2005 have been included in the summary below. An overall salinity figure for this area is taken as the average of:

- ECe for 0 – 90cm by the Rhoades equations, and
- ETESP estimate of the average salinity

Table 2.6 Overall Salinities in Lhoknga at time of EM38 Survey

Location	Site	Overall dS/m	Rhoades 0–90cm dS/m	ETESP average dS/m
Lhoknga	15 – 1	2.15	2.5	1.8
	15 – 2	2.15	2.4	1.9
	15 - 3	2.00	2.1	1.9
	Overall means	**2.10**	**2.33**	**1.87**

Although the data collected in November 2005 were limited to a few points it is worthwhile comparing what the situation was at the time of the EM38 survey and the present.

Table 2.7 Comparison of Salinities EM38 Survey and Nov 05

Location	Site	Overall EM38 dS/m	Rhoades 0–90cm EM38 dS/m	ETESP average EM38 dS/m	Rhoades 0–30cm EM38 dS/m	Rhoades 30–60cm EM38 dS/m	ETESP EMh EM38 dS/m	ETESP 0–25cm Nov 05 dS/m	ETESP 25+cm Nov 05 dS/m
Lhoknga	15 – 1	2.15	2.5	1.8	2.5	3.3	1.8	1.24	3.25
	15 – 2	2.15	2.4	1.9	2.4	3.4	1.9	1.24	3.25
	15 - 3	2.00	2.1	1.9	3.3	ND	2.0	2.67	3.77
	Overall	**2.10**	**2.33**	**1.87**	**2.7**	**3.35**	**1.9**	**1.7**	**3.4**

The salinity problem at these sites is not large but it can be considered as "chronic", that is like a low-grade illness that goes on for a long time. The salinities all fall within Salinity Class SC1, but there has been no dramatic decrease in the months since the EM38 survey despite there having been quite some significant rain fall.

The top layer of Site 15-1 (and 15-2) has fallen from 2.15 to 1.24dS/m, but this has not allowed the farmer to obtain what he considers an acceptable yield or grow the crop of his preference. The salinities of the upper subsoil (25 – 50 or 60cm) have remained virtually the same at 3.25 to 3.4dS/m.

The situation at Site 15-3 has, if anything, worsened in that the upper subsoil now has a salinity closer to 4 than the original 3.3. This has only to be expected from the conditions at the sites in that any salts leached out of the top block (15-1 and 15-2) have ended up in Site 15-3. This situation will not and can not change until such time as a functional drainage system is installed that can remove leachate from all the fields, get past the dam caused by the road and end up in the local river.

In addition, the farmer(s) must be encouraged not to apply any supplementary irrigation via surface flow or furrow methods but use the watering cans that they do have and apply irrigation as an overhead spray.

Table 2.8 Overall Salinity Classification of Lhoknga Sites

Location	**Site**	Rhoades EM38	ETESP EM38	ETESP Nov 05
Lhoknga	15 – 1	SC1	SC1	SC1
	15 – 2	SC1	SC1	SC1
	15 - 3	SC1	SC1	SC1
	Overall means	SC1	SC1	SC1

Although the salinities all fall within Salinity Class SC1 they are too high for cultivation of the preferred crops and the crops that will grow give reduced yields. Use of salt tolerant varieties could well improve yields, but a more permanent solution would be to:

- Obtain the services of an experienced soil drainage engineer and install proper soil drainage, ensuring effluent is removed from the site
- Encourage the use of raised soil beds, certainly for the immediate future, to allow better soil leaching and greater depth of soil for roots to exploit and grow Palawija crops
- Use only overhead irrigation methods, pipe supply, drip or spray (watering cans) until such time as the salinity is removed via leaching
- If necessary, even cultivate sawah on small basins constructed on top of raised beds and add any supplementary irrigation as suggested above

However, at this site the farmer already grows Palawija, not only in the raised beds on his rice land but also on the upland soils that surround the padi area. The farmer reported that he has acidity problems with the upland soils, this is a known problem with the upland soils in Aceh Province and is a problem that must be attended to if more growth of Palawija is to be encouraged. This soil acidity problem is not discussed here but is covered in ETESP background paper “Soil Acidity and Liming”.

CHAPTER 3 DARUSSALAM

3.1 Introduction

Kecamatan Darussalam is, as previously noted, located on the extreme north coast of Sumatra and is labeled as 060 in Figure 3.1 below. Only one location within the kecamatan was subjected to a salinity survey and this was in Miruk Taman where two transects were done with the EM38 salinity device.

Figure 3.1 Kabupaten Aceh Besar

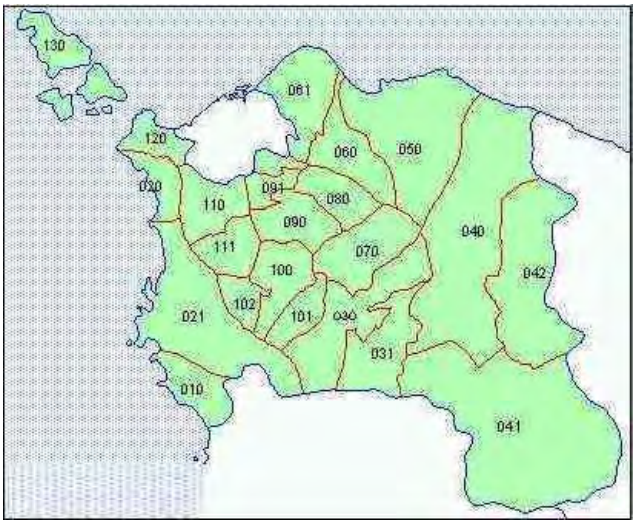
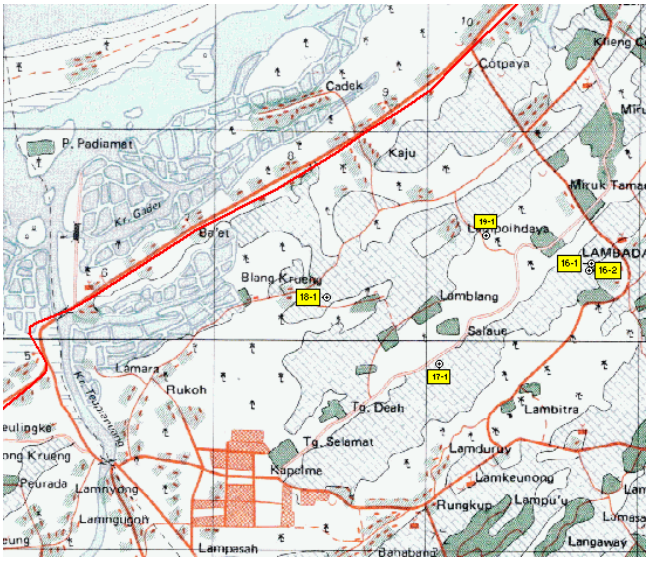


Figure 3.2 Sites in Northern Aceh Besar



Map Series 1:50,000 Sheet 042152

Coordinates of the sites were taken and an estimate of the accuracy of these can be seen in Figure 3.2 where the redder line is a GPS trace of the main coastal road heading in a north-eastwards direction.

The base map is the 1:50,000 scale topographic map, which has been geo-registered in the GPS software Ozi Explorer using; Datum WGS 72, Projection Lat/Long and Magnetic variation 12 min E

3.2 Salinity Survey

Two transects were done in Miruk Taman and, with the reservations on accuracy, these sites are labeled 16-1 and 16-2 in Figure 3.2.

Some salient facts about the sites are presented in Table 3.1, which has been compiled form study of the original dataset – MS Word document plus the Excel spreadsheet – the available maps and a field visit by ETESP..

Table 3.1 Coordinates of the Miruk Taman Sites

Site	Deg N	Min N	Sec N	Deg E	Min E	Sec E	Altitude masl	Notes
16 – 1	5	35	21.9	95	23	46.9	25.9	Fractionally lower than 16 – 2
16 – 2	5	35	20.0	95	23	46	21.9	

NB Altitudes from GPS unit and not to be taken as anything like accurate, must be found from topographical map

3.3 Site Description

This site description was compiled after a field visit by ETESP in mid November 2005.

Site 16 lies on a very gently sloping to almost flat alluvial plain within Miruk Taman with an asphalt road and a concrete irrigation channel on the lower side of the site, as indicated in Figure 3.3. Transects 16-1 and 16-2 were done in adjacent fields with 16-2 being at a slightly higher level than 16-1. There was cultivation at 16-2 but the rest of this "block" out to the road was un-cultivated and got progressively wetter until it was flooded close to the road.

The cropping cycle pre-tsunami was padi during the wet season and Palawija during the dry season – good yields were obtained. There is an irrigation supply locally running along the road but this is at a lower level than the sites which are, according, outwith the command of this system – unless pumping was used.
Currently only the "highest" part of the site is cultivated and, at the start of the wet season, this was to Palawija on raised beds, chili and greens being grown with some corn down the edge of the field. Even within the cultivated area

there was a visible difference in the status of the crop; at the highest point, near the well, the crop was better, greener and stronger looking. Near the drop to Site 16-1, the crop tended to be patchy and yellowish in places. The corn was not healthy looking at all.

Land preparation appears to have been good with remnants of OM still visible on the surface of the Palawija beds and, overall, the level of husbandry at this site was rated as quite good.

Irrigation was predominantly via rainfall supplemented by water from the on-site well and this was obviously being applied by watering cans, as there were several sitting about. The furrows appeared to be acting as minor drainage channels and, in fact, there was some water sitting in the furrows at the down-slope end.

There was a water-table at 30cm, measured in the well, and it would appear that the main problem in this block is, yet again, mainly associated with soil drainage. This has been represented in Figure 3.3 where, as one moves down-slope towards the road the land level falls and hence the water-table progressively gets closer to the surface until the field near the road is flooded. The water-table problem is exacerbated by the irrigation canal and road acting as dams and cutting off any lateral, subsurface flow or drainage. The water has to drain laterally to the nearest deep drain or river since it does not appear to be able to drain to depth, possible because of long-term build up of water-table level plus, possibly, sea-water ingress.

Figure 3.3 Cross Section of Location Site 16

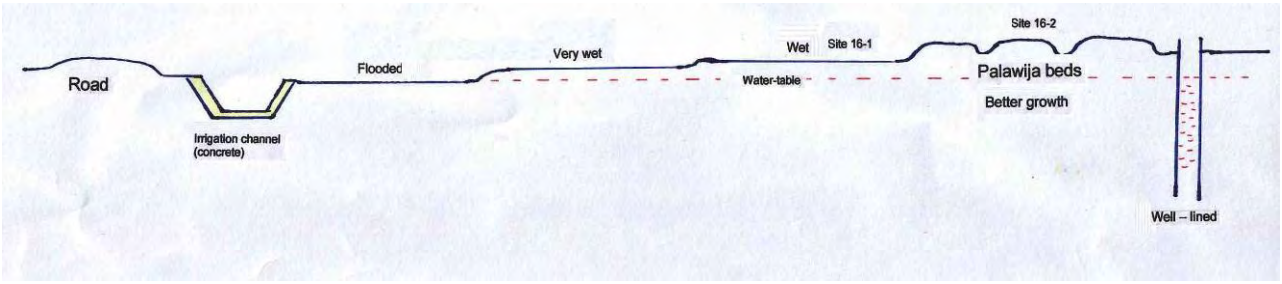


Table 3.2 Soil and Site Features November 2005

Site	PSC 0-25 cm	Soil Textures	Soil ECe 0 -25 cm	PSC 25 – 50 cm	Soil ECe 25 – 50 cm	Soil Depth cm	WT Depth cm	WT EC dS/m
16-1	M	SiCl / CL	2.36	ND	ND	25 - 30cm	30cm	0.30
16-2	M	SCl / Cl	1.75	H	2.60	60	40	0.43

PSC: M=medium and H = heavy (clays) – this is not the USDA PSC definitions but is for leaching progress

Soil depth at Site 16-2 was increased above the natural soil (40cm above the water-table) by about 15 – 20cm to 60cm due to the construction of the raised beds. This means at this site the crops growing on the raised beds had a rooting depth of about 60cm, which they could exploit for nutrients and moisture and is about the optimum that Palawija crop need. As noted above the land preparation and husbandry at this site was of an acceptable standard and considered good.

3.4 Site Information from the EM38 Survey

No additional soil analytical or laboratory data have yet been located for this site but soil and water salinities were measured in the field by BPTP staff during the ETESP site visit when additional data were collected in order that a more considered assessment of the situation could be presented.

3.5 Problems

These sites (16-1 and 16-2) have been seen by ETESP and the following problems identified:

- the main problem within most of this “block” is soil drainage and a high water-table
- soil salinity, considered a “chronic” low level problem that will not “go away” via natural rainfall leaching
- insufficient soil depth to allow full reclamation via leaching
- insufficient depth of suitable soil for the crop to exploit apart from in the raised soil beds at Site 16-2

Table 3.3 Transect Information from EM38 Survey

Name	Site	Days flood	Sediment (cm)	No	EM38 Points	Sediment Treatment	Landuse / Crop	Fertiliser	Notes
Darussalam	Miruk Taman	3	3	16 – 1	10	Mixed with soil	Sawah as Palawija beds Beds prepared No Crop sown	None noted	Water-logging
				16 – 2	10	Mixed with soil	Sawah as Palawija Salad plants Crop good	None noted	Some water-logging

3.6 Soil Salinity from EM38 Survey

The raw data from a salinity survey carried out on the site was passed to ETESP for use in soil reclamation studies. The basic findings of what the data reveals is presented as simply as possible in this section without going into the theories or the processes of data-manipulation used. Table 3.4 below is a presentation showing a few facts that the data reveal, these facts are revealed by all EM38 datasets and are standard procedure.

Table 3.3 contains the actual salinities determined from the EM38 data plus recently acquired "traditional" determination of the soil salinity from the site.

- Starting in the right hand column of Table 3.5 it states "Reading OK" – this has been determined from carrying out a check of some of the ratios of the various data items and is a standard procedure with the EM38. The data can be classified as "false" if an unacceptable ratio is found and would be caused by the presence of metallic objects in the soil – such as metal poles etc.

- Similarly, another check of another ratio of some of the data items reveals if the soil salinity sits in the topsoil (referred to "inverted" in the literature) or if it has been "leached " downwards to some extent. Sites 16–1 and 16–2 show as saline topsoil, meaning that the topsoil has higher salinity than the subsoil and, if the salinity level were found to be high, would require leaching

- The coloured coded column in Table 3.5 is the ETESP assessment of the degree of problem that the original depth of sediment presented – the key is shown as Figure 3.4. The coding is also used for salinity as shown in Table 3.5

Figure 3.4 ETESP Problem Rating Key

ECe dS/m	PROBLEM RANKING	Sediment cm
0 - 1.9	None	0 - 0.9
2 - 3.9	Negligible	1 - 1.9
4 - 5.9	Very Slight	2 - 4.9
6 - 7.9	Slight	5 - 9.9
8 - 11.9	Moderate	10 - 14.9
12 - 15.9	Moderately Big	15 - 19.9
16 - 23 9	Big	20 - 29.9
>24	Very Big	>30

Table 3.4 Assessment of the EM38 Dataset for the Site

Averages							Samples	Sediment	Flood		
Kabupaten	Kecamatan	Location	Site	EMv	EMh	Average	No	Cm	Days	Status	Check
Aceh Besar	Darussalam	Miruk Taman	16 – 1	62	97	80	10	3	3	Saline topsoil	Reading OK
			16 – 2	60	93	76	10	3	3	Saline topsoil	Reading OK

The salinity data in Table 3.5 reveals that, based on the average values, the salinity problem is negligible for the subsurface layers of this site (colour code green) and the various determinations of salinity all fall into Salinity Class SC1 (International System) and estimates range from 0.5 – 2.3dS/m. However, as indicated above in Table 3.3 the topsoil is slightly more saline and it can be seen that the 0 – 30cm depth is colour coded yellow – this is rated as a very slight salinity and still falls into salinity class SC1.

The second layer 30 – 60cm depth is virtually salt free with all values around 0.5dS/m and qualify for no colour coding, the lower horizons from 60 – 90cm depth are coded green and have values of around 2.2dS/m.

The surface layer would benefit from reclamation leaching and this is discussed further later in this report where the aim would be to reduce the top layer, and the underlying layers, to the value of the 0 – 30cm layer. However, this will only be possible on the assumption that there is sufficient soil depth and that the water-table is not at too high a level – it is suspected that the water table could be sitting at about 60cm and could be coinciding with the increased salinity at that depth.

Table 3.5 Salinity Measurements for the Site

Aceh Besar Kabupaten						Rhoades		ETESP Lookup		
				ECe 0 - 30cm	ECe 30 - 60cm	ECe 60 - 90cm	ECe 0 - 90cm	ECe EMv	ECe EMh	ECe EMav
	Kecamatan	Location	Site	dS/m	dS/m	dS/m	dS/m	dS/m	dS/m	dS/m
Averages	Darussalam	Miruk Taman	16 - 1	4.3	0.6	2.2	2.4	1.4	2.3	1.9
			16 - 2	4.1	0.5	2.2	2.3	1.4	2.2	1.8
		Mean average		4.2	0.6	2.2	2.3	1.4	2.3	1.8
Maximums	Darussalam	Miruk Taman	16 - 1	5.1	0.7	2.6	2.8	1.7	2.8	2.1
			16 - 2	4.7	0.6	2.6	2.6	1.7	2.6	2.0
		Mean maximum		4.9	0.6	2.6	2.7	1.7	2.7	2.1
Minimums	Darussalam	Miruk Taman	16 - 1	3.3	0.5	1.7	1.8	1.0	1.8	1.4
			16 - 2	3.5	0.5	1.6	1.9	1.0	1.8	1.7
		Mean Minimum		3.4	0.5	1.6	1.8	1.0	1.8	1.5

***Rhoades** (1989) = Traditional estimate of salinity from EM38, **ETESP** = project estimate.*

If the maximum values are studied it can be seen that all determinations still fall into Salinity Class SC1 with values ranging up to 5.1dS/m in the top layer (0 – 30cm) of site 16 – 1 and the top layer has approximately twice the salinity of the third layer (60 – 90cm).

The minimum values, as would be expected, all fall into the SC1 and the group considered as having no salinity problem at all – that is they are "non-saline" - apart from the 0 – 30cm layer of both sites which are coded green and have salinities of about 3.5dS/m.

3.7 Sediment Depth

Table 3.5 notes that the sediment depths deposited on the soil at the Miruk Taman site are considered a "negligible" problem. This is supported by the fact that good crops are already reportedly being cultivated on this site following "mixing" the sediment with the native soil. Similar sites with this depth of sediment (3cm) should be treated the same way and the sediment mixed in via good ploughing with the application of fertilisers and organic manures.

3.8 Conclusions & Recommendations

In summary, the data would appear to be reliable and there is not much of a salinity problem on this site although what salinity there is seems to be concentrated in the topsoil. The salinity problem is only rated as " very slight" - colour coded yellow – and it appears that normal husbandry practices have already overcome the problem and established an acceptable rooting environment for the plants being grown.

However, the existing salinity will, whether it exists at the surface (0 – 30cm) or in the subsoil (60+cm) will NOT go away or reduce if, as suspected, this area is similar to the Kuta Alam site in Banda Aceh and has nil or very poor soil drainage. The fact that there is a virtually saline free layer from 30 – 60cm suggests that perhaps the watertable, which will be saline, is sitting at about 60cm depth at least part of the time.

An overall salinity figure has been calculated from the EM38 data for this area and it is the average of the:

- ECe for 0 – 90cm by the Rhoades equations, and
- ETESP estimate of the average salinity

Table 3.6 Overall Salinities in Darussalam at the time of EM38 Survey

Location	Site	Overall soil salinity via EM38 dS/m	Rhoades 0 – 90cm EM38 dS/m	ETESP average salinity EM38 dS/m
Miruk Taman	16 – 1	2.15	2.4	1.9
	16 - 2	2.05	2.3	1.8
	Overall means	**2.10**	**2.35**	**1.85**

Although the data collected in November 2005 were limited to a few points it is worthwhile comparing what the situation was at the time of the EM38 survey and the present.

Table 3.7 Comparison of Salinities EM38 Survey and Nov 05

Location	Site	Overall salinity via EM38 dS/m	Rhoades 0–90cm EM38 dS/m	ETESP average salinity EM38 dS/m	Rhoades 0–30cm EM38 dS/m	Rhoades 30–60cm EM38 dS/m	ETESP average EMh EM38 dS/m	ETESP 0–25cm Salinity Meter Nov 05 dS/m	ETESP 25+cm Salinity Meter Nov 05 dS/m
Miruk Taman	16 – 1	2.15	2.4	1.9	4.3	0.6	2.3	2.36	ND
	16 - 2	2.05	2.3	1.8	4.1	0.5	2.2	1.75	2.6
	Overall	**2.10**	**2.35**	**1.85**	**4.2**	**0.55**	**2.25**	**2.03**	**2.6**

The salinity problem at these sites is not large but it can be considered as "chronic", that is like a low-grade illness that goes on for a long time. The present salinities all fall within Salinity Class SC1, but there has been no dramatic decrease in the months since the EM38 survey despite there having been quite some significant rainfall.

The site which is presently still flooded, Site 16-1, would not appeared to have desalinsed, unless one were to accept and use the Rhoades estimate for 0-30cm along; if that was the case then salinity could have fallen from just over 4 to 2.4dSD/m. However, if the overall and ETESP original salinities were to be accepted and used this site has actually worsened and salinity has increased for 2dSD/m to 2.4dS/m. The fact that the site has virtually been abandoned at present would seem to support the likelihood that the situation here has worsened and salts have been leached from Site 16-2 and added to this site.

However at site 16-2, where the farmer appears to be employing overhead irrigation and raised beds, the surface salinity would appear to have fallen fractionally from around 2dS/m to 1.75dS/m. At the same time the lower horizon or layer, 25+cm, now appears to have slightly higher salt content and ECe has risen from around 2 to 2.6dS/m. This is consistent with some leaching happening via the type of irrigation, plus the rainfall, being able to leach the sazlt downwards through the active root zone. The situation at this site could probably be improved further by:

- deepening the furrows and using them as drainage channels
- ensuring that the furrows slope slightly towards the road
- continuation of the furrow, or drainage channel, through Site 16-1 all the way to the road
- removing any drainage water, leachate, from the channel and into a more permanent drainage line
- any supplementary irrigation must be done using the watering cans and any surface flow irrigation avoided

Table 3.8 Overall Salinity Classes

Location	Site	Rhoades EM38	ETESP EM38	ETESP Nov 05
Miruk Taman	16 – 1	SC1	SC1	SC1
	16 - 2	SC1	SC1	SC1
	Overall means	**SC1**	**SC1**	**SC1**

Although the salinities all fall within Salinity Class SC1 they are too high for cultivation of the preferred crops and the crops that will grow give reduced yields. Use of salt tolerant varieties could well improve yields, but a more permanent solution would be to:

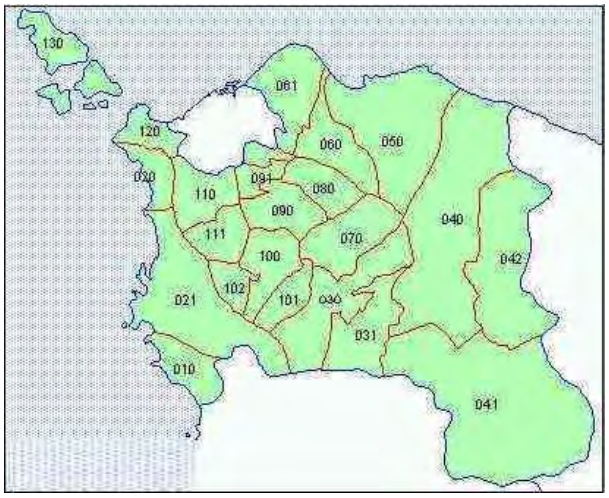
- Obtain the services of an experienced soil drainage engineer
- Install proper soil drainage, ensuring effluent is removed from the site
- Use raised soil beds, certainly for the immediate future, to allow better soil leaching & deeper root zone
- Use only overhead irrigation methods, pipe supply, drip or spray (watering cans) for the application until such time as the salinity is removed via leaching
- If necessary, even cultivate sawah on small basins constructed on top of raised beds and add any supplementary irrigation as suggested above and use only salt tolerant varieties

CHAPTER 4 BAITISSALAM

4.1 Introduction

Kecamatan Baitissalam is, as previously noted, located on the extreme north coast of Sumatra, lies sandwiched between Darussalam and Banda Aceh and labeled as 061 in Figure 4.1 below. Three locations within the kecamatan were subjected to a salinity survey done with the EM38 salinity device and details are given in the following sections.

Figure 4.1 Kabupaten Aceh Besar



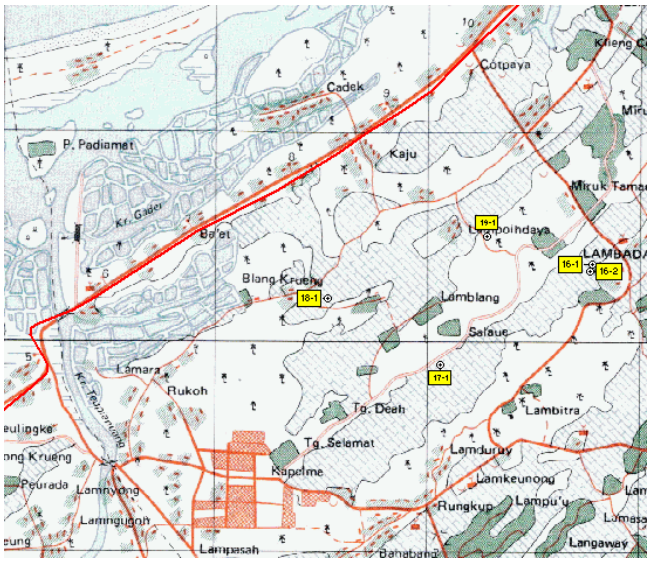
Coordinates of the sites were taken and an estimate of the accuracy of these can be seen in Figure 3.2 where the redder line is a GPS trace of the main coastal road heading in a north-eastwards direction.

The base map is the 1:50,000 scale topographic map, which has been geo-registered in the GPS software Ozi Explorer using; Datum WGS 72, Projection Lat/Long and Magnetic variation 12 min E

4.2 Salinity Survey

One transect was done at each site but the exact locations cannot be shown as no geo-referencing data were included in the dataset passed to ETESP by BPTP.

Figure 4.2 Locations in Northern Aceh Besar



Map Series 1:50,000 Sheet 042152

Some salient facts about the sites are presented in Table 4.2, which has been compiled form study of the original dataset – MS Word document plus the Excel spreadsheet – and the maps available

Table 4.1 Coordinates of Baitissalam Sites

Site	Deg N	Min N	Sec N	Deg E	Min E	Sec E	Altitude masl	Notes
17 – 1	5	34	53.3	95	23	3.9	21.9	Partially flooded and abandoned
18 – 1	5	35	12.0	95	22	32.1	28.0	Flooded and abandoned
19 – 1	5	35	30.1	95	23	16.8	35.1	Flooded and abandoned

NB Altitudes from GPS unit and not to be taken as anything like accurate, must be found from topographical map

4.3 Site Descriptions

Site 17 at Suleue is on a very gently sloping to flat alluvial plain and lies about 1 – 1.5 metres below the surfaced access road which runs within 50metres of the site. This is a rainfed area and is not within command of any local irrigation supply, though there is a well on site where the ground-water table was sitting at 35cm depth.

The site did have a drainage system with an earth channel 50 – 75cm, Figure 4.3, deep passing along the edge of the field where the site was located. However, this channel was NOT flowing and was quite badly overgrown with weeds, partially blocked by old trees plus local buffalo did use the channel for "wallowing" probably causing more blockage to the system. About 100m down-slope from the site the drainage channel was lined so there had been a properly designed, installed and, presumably, operational drainage system at one time. If the drainage channels were cleared and deepened this site could be reclaimed quite easily. The site carried a corn that had obviously failed and died. Previous history is that this site was used for sawah rice cultivation and good yields were obtained.

Figure 4.3 Damaged Drain Down-slope of Site 17

Figure 4.4 Drainage Entering Main Channel

Site 18 at Blang Kreung is an almost flat alluvial plain with no obvious high points, mainly flooded, no cropping at all, covered in grasses but there was an operational drainage channel. However, local information was that this was in fact the previous irrigation system. The water flow in this channel was fairly fast and there was an outlet into a major channel (Figure 4.4) which was obviously linked to the sea and this drain was flowing but very slowly. This drainage system was governed by tidal movement and the local estimate was that there is presently between 50-100cm of sludge, sediment and rubbish in this channel. If these channels were to be cleared and deepened the site could be reclaimed relatively easily. No active land use at all, apart from grazing buffalo, but the site apparently used to be favoured for wetland rice cultivation and good yields were obtained. In mid-December 2005 this site was being drained some 2 weeks after the previous ETESP visit when discussions were held with local people about the need for drainage.

Site 19 at Lampeudaya is an almost flat alluvial plain with no obvious high points, 70% flooded with what might be a rudimentary drainage channel. This channel is about 20cm deep, and excavated in the earth (no lining) but there was no obvious flow occurring. There was no obvious land-use apart from a few buffalo grazing the grasses that cover most of the site. Pre-tsunami , this area was favoured for wetland rice cultivation with reportedly good yields. Currently the site is virtually abandoned from an agricultural point of view.

Table 4.2 Soil and Site Features November 2005

Site	PSC 0-25 cm	Soil Textures	Soil ECe 0 -25 Cm	PSC 25 – 50 cm	Soil Text 25 – 50 cm	Soil ECe 25 – 50 cm	Soil Depth cm	WT Depth cm	WT EC dS/m
17-1	M	FsCl / CL	5.00	M	Cl	ND	35	35	0.56
18-1	M	FsL	4.63	H	Cl(h)	ND	0	0	1.56
19-1	M	FsL	4.93	H	Cl / C	ND	0	0	4.35

4.4 Site Information from EM38 Survey

No additional soil analytical or laboratory data have yet been located for this site but soil and water salinities were measured in the field by BPTP staff during the ETESP site visit when additional data were collected in order that a more considered assessment of the situation could be presented.

Table 4.3 Transect Information Baitissalam Sites

Site	Days flood	Sediment (cm)	No	EM38 Points	Sedmnt Treat	Landuse / Crop	Fertiliser	Noted Problems
Suleue	30	20	17-1	16	None	Sawah – Land not used since tsunami	None	Abandoned, Sediment Salinity, Flooding
Blang Kreung	30	30	18-1	12	None	Sawah – Land not used since tsunami	None	Abandoned, Sediment Salinity, Flooding
Lampeudaya	30	30	19-1	7	None	Sawah – Land not used since tsunami	None	Abandoned, Sediment Salinity, Flooding

4.5 Problems

The significant conditions noted for these sites are the problems of:

- water-logging, obviously indications of very high water-tables plus obvious tidal effects in some cases
- no current land use or cultivation
- deep sediments as established during the EM38 survey
- surface water, and presumably groundwater, with salinity of around 5dS/m in November 2005

It is concluded that the above problems place this land in the severely damaged category and the land has, to all intents and purposes, been abandoned possibly because it is considered that it would be extremely difficult and expensive to reclaim. However, by mid-December 2005 the first drainage ditches at Blang Kreung had been cleared and drainage had commenced.

Severely damaged land may well not be tackled in the immediate future but left "as is" for present and be looked at in the next stage of ETESP activities. Priority has to be given to getting less severely damaged land back into production first. Once the situation stabilizes after several cycles of rain and basic amenities and infrastructure, such as drainage systems, are restored to some extent the situation should be looked at again and the soil re-assessed.

4.6 Soil Salinity

The raw data from the EM38 salinity survey carried out on the site was passed to ETESP for use in soil reclamation studies. The basic findings of what the data reveals are presented as simply as possible in this section without going into the theories or the processes of data-manipulation used. Table 4.4 below is a presentation showing a few facts that the data reveal, these facts are revealed by all EM38 datasets and are standard procedure.

Table 4.5 contains the actual salinities determined from the EM38 data plus recently acquired "traditional" determination of the soil salinity from the site.

Starting in the right hand column of Table 4.4 it states "Reading OK" – this has been determined from carrying out a check of some of the ratios of the various data items and is a standard procedure with the EM38. Data can be classified as "false" if an unacceptable ratio is found and would be caused by the presence of metallic objects in the soil – such as metal poles etc.

Similarly, another check of another ratio of some of the data items reveals if the soil salinity sits in the topsoil (referred to "inverted" in the literature) or if it has been "leached " downwards to some extent. Two of the sites show as saline topsoil, meaning that the topsoil has higher salinity than the subsoil whilst the third site shows there has been some leaching. If the salinity levels of these sites are found to be high, reclamation leaching would be required

The coloured coded column in Table 4.4 is the ETESP assessment of the degree of problem that the original depth of sediment presented – the key is shown as Figure 4.3, this coding is also used for salinity in Table 4.5

Figure 4.3 ETESP Problem Rating Key

ECe dS/m	PROBLEM RANKING	Sediment cm
0 - 1.9	None	0 - 0.9
2 - 3.9	Negligible	1 - 1.9
4 - 5.9	Very Slight	2 - 4.9
6 - 7.9	Slight	5 - 9.9
8 - 11.9	Moderate	10 - 14.9
12 - 15.9	Moderately Big	15 - 19.9
16 - 23 9	Big	20 - 29.9
>24	Very Big	>30

The salinity data in Table 4.5 reveals that, based on the average values, the salinity problem is negligible for the surface (0 – 30cm) layer of the Suleue site (colour code green, with SC1) and very slight (colour code yellow, with SC2) for the Blang Kreung and Lampeudaya sites. The average determinations of salinity for the surface layers at the three sites fall between 3.3 – 5.2dS/m.

However, as indicated in Table 4.4, the topsoil is more saline than the subsoil and the pattern is very clear in sites 17-1 and 19-1 where the second layer (30–60cm) has very low salinity (no colour code) and the third layer (60–90) raised salinity again (coded green). The situation at Blang Kreung is slightly worse in that the second layer (30–60cm, colour-coded blue) is more saline than the top 30cm. It would appear as though there has already been some leaching of salts downwards and they are concentrated in the 30–60cm depth whilst the lower layer (60–90cm) is very similar to the other two sites.

The second layers (30 – 60cm depth) at sites 17 – 1 and 19 - 1 are virtually salt free with all values between 0.01 and 0.6dS/m and qualify for no colour coding, the lower horizons from 60 – 90cm depth at all sites are coded green and have values of just over 3dS/m.

The surface layer would benefit from reclamation leaching and this is discussed further later in this report where the aim would be to reduce the top layer, and the underlying layers, to salinity values of less than 2dS/m and probably to about 0.5dS/m might be possible in the 0 – 30cm layer. However, this will only be possible on the assumption that there is sufficient soil depth and that the water-table is not at too high a level – it is suspected that the water table could be sitting at about 60cm at sites 17 and 19 whilst it may well be at shallower depth at site 18 in Blang Kreung.

Table 4.4 Assessment of the EM38 Dataset for the Sites

Aceh Besar - Averages							Samples	Sediment	Flood		
Kabupaten	Kecamatan	Location	Site	EMv	EMh	Average	No	Cm	Days	Status	Check
Aceh Besar	Baitissalam	Suleue	17 - 1	83	87	85	16	20	30	Saline topsoil	Reading OK
		Blang Kreung	18 - 1	154	149	151	12	30	30	Leached	Reading OK
		Lampeudaya	19 - 1	86	122	104	7	30	30	Saline topsoil	Reading OK

If the maximum values are studied it can be seen that the determinations fall into Salinity Class SC1 for the Suleue site with values ranging from 2.3 to 3.6dS/m overall and SC2 with 4.8dS/m in the top layer (0 – 30cm). Overall, the maximum values for the Blang Kreung site fall into SC2 with values ranging from 4.3 to 6.8dS/m. It has to be noted that the "suspect" value of -0.1 for the 30 – 60cm layer has been ignored and eliminated from the data manipulations. In Lampeudaya, the soil is classified as falling somewhere between salinity classes SC1 and SC2 with values between 2.8 and 5.6 dS/m though the second layer (30 – 60cm) is virtually salt free.

Table 4.5 Salinity Measurements for the Aceh Besar Sites from EM38 Survey

						Rhoades	ETESP Lookup			Salinity Class	
Averages			ECe 0 - 30cm	ECe 30 -60cm	ECe 60 -90cm	ECe 0 - 90cm	ECe EMv	ECe EMh	ECe EMav	Rhoades	ETESP
Kecamatan	Location	Site	dS/m	dS/m	dS/m	dS/m	dS/m	dS/m	dS/m		
Baitissalam	Suleue	17 - 1	3.3	0.0	3.2	2.1	2.0	2.1	2.0	SC1	SC1
	Blang Kreung	18 - 1	4.8	6.6	3.1	4.8	3.8	3.7	3.8	SC2	SC1
	Lampeudaya	19 - 1	5.2	0.6	3.1	3.0	2.0	3.0	2.5	SC1	SC1
Maximums											
Baitissalam	Suleue	17 - 1	4.8	0.3	3.6	2.9	2.3	2.9	2.5	SC1	SC1
	Blang Kreung	18 - 1	6.8	-0.1	6.7	6.8	4.4	4.6	4.3	SC2	SC2
	Lampeudaya	19 - 1	5.6	0.3	4.1	4.8	2.7	3.4	2.8	SC2	SC1
Minimums											
Baitissalam	Suleue	17 - 1	2.8	0.0	2.5	1.8	1.6	1.7	1.7	SC1	SC1
	Blang Kreung	18 - 1	4.7	-0.1	4.8	3.1	3.1	3.2	3.4	SC1	SC1
	Lampeudaya	19 - 1	5.0	0.9	1.9	2.6	1.3	2.6	2.2	SC1	SC1

NB Value in red "suspect" and ignored in manipulations

The minimum values, as would be expected, all fall into the SC1, with only the topsoil at Lampeudaya and the topsoil plus deeper subsoil at Blang Kreung showing higher values and being colour-coded yellow.

4.7 Sediment Depth

Table 4.4 notes that the sediment depths deposited at the Miruk Taman site are considered a "big to very big" problem. The magnitude of the problem, or problems, being supported by the fact that no cropping has taken place and the above sections indicate that there are serious problems. However, the overriding problem at Sites 18-1 and 19-1 has to be the fact that the sites are still flooded almost one year after the tsunami, the flood seems to be at a level where it is very strongly influenced by tidal action and soil reclamation may never be a possibility. The fact that there are deep sediments becomes almost inconsequential. Site 17-1 is slightly different and, once the water-table is successfully lowered the sediment will have to be dealt with; and that will depend largely on the texture of the sediment:

- Consideration can be given to physically removing sands, but
- Routines would have to be developed for the ploughing and subsequent leaching of the heavier textured deposits such as silts and clays.

Recent field textures indicate that 17-1 has a covering of finer textured deposit (fine sandy clay loam) whilst the other two sites have a much sandier deposit and field texturing suggested fine sandy loam; however it must be remembered that these textures were attempted on very wet samples and may not be as accurate as normal field texturing.

The reclamation routines that need to be investigated would basically be to establish how much ploughing and mixing to what depths plus the quantities of organic manures, amendments and fertilisers that need to be applied and when to apply them in the cycle – but this would only be necessary if the flooding could ever be cleared.

4.8 Conclusions & Recommendations

In summary, the data would appear to be reliable and there is a very large salinity problem on this site although what salinity there is seems to be concentrated in the topsoil. The salinity problem is rated as "very slight" - colour coded yellow – in Blang Kreung and some reclamation leaching could be envisaged if flooding could be overcome. In Suleue and Lampeudaya it is coded "negligible" – colour coded green - and it appears that in other areas, where there is no flooding and the water-table is not too high, normal husbandry practices have already overcome the problem and established an acceptable rooting environment for the plants being grown.

However, the existing salinity will, whether it exists at the surface (0 – 30cm) or in the subsoil (60+cm) will NOT go away or reduce if, the flooding cannot be cleared and water tables reduced.

Overall salinity figures have been calculated from the EM38 data for Baitissalam as the average of:

- ECe for 0 – 90cm by the Rhoades equations, and
- ETESP estimate of the average salinity

Table 4.6 Overall Salinities in Baitissalam from the EM38 Survey

Location	Site	Overall soil salinity dS/m	Rhoades 0 – 90cm dS/m	ETESP average salinity dS/m
Suleue	17 – 1	2.05	2.1	2.0
Blang Kreung	18 - 1	4.30	4.8	3.8
Lampeudaya	19 – 1	2.75	3.0	2.5
	Overall means	**3.03**	**3.30**	**2.77**

Although the data collected in November 2005 were limited to a few points it is worthwhile comparing what the situation was at the time of the EM38 survey and the present.

Table 4.7 Comparison of Salinities EM38 Survey and Nov 05

Location	Site	Overall salinity via EM38 dS/m	Rhoades 0–90cm EM38 dS/m	ETESP average salinity EM38 dS/m	Rhoades 0–30cm EM38 dS/m	Rhoades 30–60cm EM38 dS/m	ETESP average EMh EM38 dS/m	ETESP 0–25cm Salinity Meter Nov 05 dS/m	ETESP 25+cm Salinity Meter Nov 05 dS/m
Suleue	17-1	2.05	2.1	2.0	3.3	ND	2.1	5.00	ND
Blang Kreung	18-1	4.30	4.8	3.8	4.8	6.6	3.7	4.63	ND
Lampeudaya	19-1	2.75	3.0	2.5	5.2	0.6	3.0	4.93	ND
	Overall	**3.03**	**3.30**	**2.77**	**4.43**	**3.60**	**2.93**	**4.85**	

The salinity problem at Suleue, based on the EM38 data could be described as "chronic" in that it is low level but, without serious reclamation inputs the situation will not improve. In fact, if the limited data collected in November 2005 by ETESP is reliable to some degree then the situation is worsening in that surface salinity has increased from 3.3dS/m (Rhoades figure) to 5dS/m. It is quite possible that salinity has increased since this site does have a drainage system but it is totally non-functional and any water removal from the site is going to be via evaporation on dry days and this process concentrates any salts in the soil, soil solution and flood water.

The salinity problem at Blang Kreung and Lampeudaya are insignificant when compared to the flooding and it would be superfluous to say much about salinity at these sites apart from the fact that, if anything, salinities are now higher than when the EM38 survey was carried out.

Table 4.8 Overall Salinity Classes

Location	Site	Rhoades EM38	ETESP EM38	ETESP Nov 05
Suleue	17 – 1	SC1	SC1	SC2
Blang Kreung	18 - 1	SC2	SC1	SC2
Lampeudaya	19 – 1	SC1	SC1	SC2
	Overall means	**SC1**	**SC1**	**SC2**

The site at Blang Kreung can be reclaimed and the tsunami damage may have given the pointers for this. The previous irrigation channel is now acting as a drainage channel and water flow is relatively significant in the upper parts of this channel (Figure 4.3). The main, or lower channel (Figure 4.5) could be deepened significantly by removal of silt and garbage and, if it was, flow from Site 18 would increase and at least start the reclamation process.

By mid-December 2005 following a previous ETESP visit and discussions on drainage with local people drainage ditches had been cleared and drainage of this site had started.

However, the actual padi field would require leveling before reclamation and suitable salt tolerant varieties of rice could be grown here very soon – but perhaps the irrigation supply should also be restored before full reclamation interventions start.

Figure 4.5 Main Channel Site 18

It should be noted that this main channel is now tidal and the previous flood gates at the shore line were destroyed by the tsunami.

The Suleue site can also be reclaimed and the task should be relatively straightforward here since the remnants of a drainage system still exists, but this needs to be rehabilitated. It is obvious, even in Figure 4.6 that the site is not draining and water is not leaving the field and getting into the drain on the left. Perhaps there is a plough pan that needs to be broken up to allow water to percolate.

Figure 4.6 Poor Drainage at Site 17

On this site although the salinities all originally fell within Salinity Class SC1 even this is too high for cultivation of the preferred crops using the current varieties.

The crops that will currently grow give reduced yields. If the recent data are correct and reliable then it appears that the problem is getting worse.

However, in mid-December 2005 the corner area, near where the person is standing in Figure 4.6 was being used as a germination and production of rice seedlings and very minor drainage channels had been excavated. With some guidance the farmer could get the reclamation of this land underway.

Use of salt tolerant varieties could well give a crop after even the minimum of drainage and reclamation, but a more permanent solution would be to:

- Obtain the services of an experienced soil drainage engineer to assist refurbish the existing drainage system
- Ensure that the existing drain is cleared and deepened to between 100 and 150cm, this would help remove effluent from the site
- Possibly consider deep ploughing or ripping as this site has a long history of wetland rice culture and there is little evidence of any drainage happening at present; it is suspected that there could well be a plough pan – created by long term puddling via the use of oxen
- Encourage the use of raised soil beds, certainly for the immediate future, to allow better soil leaching and greater depth of soil for roots to exploit
- Use only overhead irrigation methods, pipe supply, drip or spray (watering cans) for the application until such time as the salinity is removed via leaching
- If necessary, even cultivate sawah on small basins constructed on top of raised beds and add any supplementary irrigation as suggested above

CHAPTER 5 SOIL RECLAMATION and IMPROVEMENT

5.1 Introduction

No matter how the salts got into the soil they can be removed (at a cost) provided the reasons for the salt accumulation are understood and the appropriate remedial measures undertaken. The reasons for the salt accumulation have been addressed in Chapter 2. The process of salt removal is termed reclamation.

The general principles for the reclamation of salty soils comprise:

- the removal of salts from the soil by leaching, plus
- the removal of the saline leachate from the site
- the prevention of further accumulation of salt or sodium
- the replacement of exchangeable sodium by exchangeable calcium and

Reclamation is only feasible if leaching water is able to move downwards through the soil profile, carrying the salts below the main root zone and eventually being removed from the site as drainage and disposed of in an environmentally acceptable manner. This leaching water can be required in large quantities and, in association with the continuing percolation of water from irrigated crops, results in the deeper layers becoming waterlogged and a rise in the water-table towards the surface. In most situations natural drainage is insufficient to cope with the water flow and some sort of artificial drainage often becomes necessary at some stage in the reclamation cycle.

Reclamation (in the first instance) involves the desalinisation of a defined depth of soil (root-zone) to a particular salt content. There will be an initial phase of saline water percolating below the root-zone that eventually merges with the subsurface water table, resulting in increased salinity and movement of the water-table towards the surface. Subsequent normal irrigation continues to remove salts from the soil and the quantities of salt carried will decrease over time.

Planning for the reclamation of saline areas requires an estimate of the size of the salinity problem (how saline is the soil? – measured in dS/m) and a reliable estimate of the quantity of water necessary to reduce soil salinity to a level where crops can be economically produced.

5.2 Water Requirements for Salinity Reduction

Based on the information collected during the EM38 survey and subsequently updated by site visits by ETESP estimates have been compiled for water requirements. The basic data used to get these estimates are given in Table 5.1 along with other site features. The water requirements are given in Table 5.2 – where it is considered that the site can be reclaimed.

Table 5.1 Features of the Sites

Location	Site	Existing Salinity (dS/m)	Soil depth to be recovered (mm)	Depth of watertable (mm)	Drainage System Status	Irrigation System in use	Soil PSC
Lhoknga, Nusa	15 – 1	3.25	600	750	None	Furrow	M
	15 – 2	3.25	600	750	None	Furrow	M
	15 – 3	2.67	300	100	None	None	M
Darussalam, Miruk Taman	16 – 1	2.35	600	300	None	None	M
	16 - 2	2.25	600	400	Furrows	Water can	M/H
Baitissalam, Suleue	17 – 1	5.00	300	300	Blocked	None	M
Baitissalam, Blang Kreung	18 – 1	4.63	300	0	Partial Flood	None	M
Baitissalam, Lampeudaya	19 - 1	4.93	300	0	Flooded	None	M/H

NB: The soil PSC is the class for reclamation purposes and is NOT the USDA textural / PSC classification

Sites 15-1, 15-2, 16-1 and 16-2 are noted as being cultivated for palawija and hence a soil depth of 600mm should be reclaimed to give a suitable soil depth for the roots to exploit.. The watertable depth at these sites has been established and used in the calculations. Sites 15-3, 17, 18 and 19 are noted as being preferred as “sawah” land, though presently abandoned, and recovery of 300mm should be attempted. All of these sites have high to very high water tables and, in some cases the water table is at the surface – that is the site is flooded

All soils seen to date have been textured in the field and have had textures that place them in the “medium” or “M” to “heavy” or “H” particle size class (PSC) though a few sites do have some layering with the surface soil being lightered textured than the subsoil but these variations would have little effect on the overall PSC of the site. Hence, all have been allocated to PSC “H” for this operation.

The available data were then inserted into the tool (Leaching Water RTequirement.XLS) for determining the depths and volumes of water required for reclamation – the outputs are seen in Table 5.2.

Table 5.2 Water required for reclamation

		Add	*Add*	*Add*	*Add*	*Auto*	*Add*	*Auto*	*Add*	*Auto*	*Auto*	Leaching H_20		Irrigation H_20	
Kabupaten Aceh Besar	Site / Sample Number	**Reclamation Start Month**	Soil PSC, Texture or Type	Depth want to reclaim (mm)	INITIAL Salinity ECo dS/m	INITIAL Salinity class	TARGET / DESIRED EC dS/m	TARGET / DESIRED Salinity class	H20 table depth (mm)	Max soil depth reclaimable (mm)	Reclamation Required	Dlw (mm) DEPTH LEACHING WATER	Dlw m3/ha CUBIC METRES WATER / Ha	Dliw (mm) DEPTH IRRIGATION WATER	Dliw m3/ha CUBIC METRES / ha
Lhoknga, Nusa	15-1	Dec	M	600	3.25	SC1	0.5	SC1	750	500	Yes	325	3250	248	2483
Lhoknga, Nusa	15-2	Dec	M	600	3.25	SC1	0.5	SC1	750	500	Yes	325	3250	248	2483
Lhoknga, Nusa	15-3	Dec	M	300	2.67	SC1	0.5	SC1	100	-50	Yes	-27	-267	-20	-204
Darussalam, Miruk Taman	16-1	Dec	M	600	2.36	SC1	0.5	SC1	300	150	Yes	71	708	54	541
Darussalam, Miruk Taman	16-2	Dec	M/H	600	2.25	SC1	0.5	SC1	400	250	Yes	113	1125	86	859
Baitissalam, Suleue	17-1	Dec	M	300	5.00	SC2	0.5	SC1	300	150	Yes	150	1500	115	1146
Baitissalam, Blang Kreung	18-1	Dec	M/H	300	4.63	SC2	0.5	SC1	0	-150	Yes	-139	-1389	-106	-1061
Baitissalam, Lampeudaya	19-1	Dec	M/H	300	4.93	SC2	0.5	SC1	0	-150	Yes	-148	-1479	-113	-1130

Source: Leaching water requirement.XLS

The various outputs from Table 5.2 are discussed below with explanations where required.

Maximum soil depths that can be reclaimed:

For the palawija areas the aim was to reclaim 600mm (60cm) depth as this is a reasonable rooting depth for most of the crops that would be grown, but this has been reduced to considerably less at some sites due to the presence of a high watertable:

- Site 15-1 desired 600mm and possible is 500mm
- Site 15-2 desired 600mm and possible is 500mm
- Site 16-1 desired 600mm and possible is 300mm
- Site 16-2 desired 600mm and possible is 300mm

For the "sawah" sites a non-saline depth of 300mm (30cm) would be acceptable but the watertable depths mean that of the four sites only one, Site 17-1, could presently be reclaimed and that site only to about 150mm (15cm). The negative values in the Dlw columns of Table 5.2 occur because the sites are actually flooded and it is just not possible to reclaim a flooded site by any methodology without major engineering works. However, since site 18 had an irrigation system which is now apparently working (almost) as a drainage system there could be ways to recover and reclaim this site. If the existing "drainage" channels were deepened then it could be possible to reclaim the required 30cm of depth.

Depths of leaching water required:

The depths of leaching water that must pass down through the various soils that can be reclaimed are, in fact, all quite low since the soils are not particularly saline and great depths of soil are not being reclaimed. For the "palawija" sites in Lhoknga about 325mm of water in total would be required and at Darussalam between 70 - 110mm would be needed to recover the soils to a salinity level of 0.5dS/m. These depths of water would be reduced to about 240 and 50 – 85mm respectively of irrigation water since the balance would / should be supplied by the rainfall "bonus". It is not considered that rainfall alone would do the job properly or efficiently and it must be remembered that this is not the depths of water that have to be applied but the depth of water that must pass down through the full depth of soil being reclaimed. Refer to Table 5.3 for the depths of water that have to be applied.

Of the "sawah" sites it has already been mentioned that, under the present conditions, only Site 17-1 at Suleue could be reclaimed and that would require 150mm total leaching water to pass down through the full depth that it is desired to reclaim. But, due to the high watertable only 150mm, 15cm, depth could be reclaimed anyway.

However it must be remembered that we are talking about the volume of water that must pass down through the soil – NOT THE AMOUNT that has to be APPLIED to the surface. The number of gifts is determined in Section 5.3 below.

5.3 Leaching Progress

The other tool which has been used at this time is the spreadsheet "Leaching Progress.XLS". The normal situation would be the application of several gifts of 100mm (10cm) to achieve the target amount determined above to pass down through the depth of soil being reclaimed. Intermittent irrigation has to be used for reclamation as it has proved to be the most efficient (Refer Mobilisation Report, October 2005). What this means is that the gifts are applied about 7 days apart – this is to allow the soil surface to dry to some extent which draws the salts to the surface of any soil peds (units) or cracks that develop. At the next irrigation or gift application, these salts are dissolved and leached downwards.

Palawija:

In the case of the "palawija" sites the number of gifts and the depths of water to be applied can be seen below and have been deciphered from Table 5.4, All sites have been treated here as coming under the "M" category, even 16-2 which seems to be M/H as it gets heavier with depth and it is possible that this site could be reclaimed with 4 leachings.

Table 5.3 Depths of Water Applied and Number of Gifts

Site	Depth of soil that can be recovered (mm)	Depth of leaching water (mm)	No of Gifts	Depth of Water Applied (mm)
15-1	500	325	10 – 11	1000 - 1100
15-2	500	325	10 - 11	1000 - 1100
16-1	150	71	4	400
16-2	250	113	5	500

Table 5.4 Depths of water passing through the soil layers – Palawija

Medium	Accumulative	Volumes	Accumulative Water Passing thro layer			
Irrigation No	Water applied (mm)	Water entering soil (mm)	1 (0 - 25)	2 (25 - 50)	3 (50 - 75)	4 (75 - 100)
1	100	70	10	0	0	0
2	200	140	50	0	0	0
3	300	210	90	30	0	0
4	400	280	130	70	10	0
5	500	350	170	110	50	0
6	600	420	210	150	90	30
Totals	**2100**	**1470**				

As can be seen after 4 irrigations 70mm of water will have passed through layer 2 (25 – 50cm) and the required figure of 70mm has been reached. For the one deep soil Site 15 it takes about 10 or 11 gifts to get the required depth of soil reclaimed.

Sawah:

If reclamation is possible and attempted at the "sawah" site, 17-1, in Baitissalam then, as determined above in Table 5.4, 150mm of leaching water has to pass down through the limited depth of soil that can be reclaimed. Since it was estimated that only 15cm of soil could be reclaimed, due to very high watertable level, then the site would probably be reclaimed by four to five gifts of 100mm.

As stated above Site 18 might be recoverable if the rudimentary drainage system, that has self-installed, could be deepened to allow the flood to be removed and some depth of soil to be established above the water-table. However, even if the soil is reclaimed to some extent only a very salt-tolerant variety of rice could be considered for planting.

The badly flooded site, No 19, cannot be reclaimed and major drainage works would be required before starting.

However, it must be stressed that the above is assuming that the watertable at Site 17 is not any shallower than the currently measured 30cm, due to heavy rainfall, and that the drainage system can be made operational and remove water from the site. If the leachate merely goes into and adds to the watertable reclamation is NOT possible.

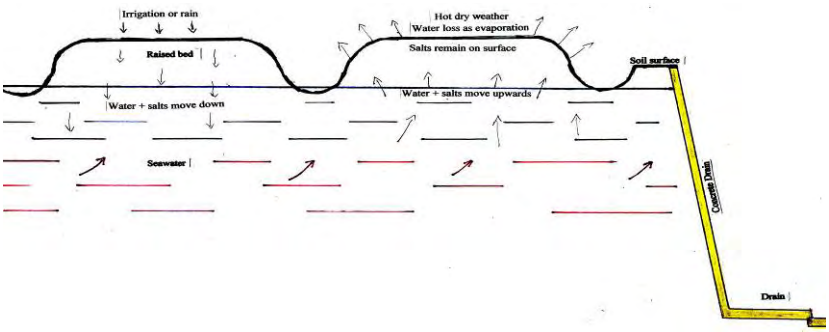
5.4 Recommendations for Soil Reclamation and Improvement

Very little can be recommended or put into operation until soil drainage systems are installed at virtually all of the sites.

It is obvious that farmers have already worked-out for them selves that they are having to change their previous cultivation techniques, rotations and crops. In most places visited, where there is some success with cropping, the farmer stated that pre-tsunami he was getting good yields and that his preferred crop was padi rice. The only successful cultivation that is happening right now is Palawija growth, that is on raised beds, and this is because the soils are just too saline for rice and the irrigation system used cannot bring about any desalinisation.

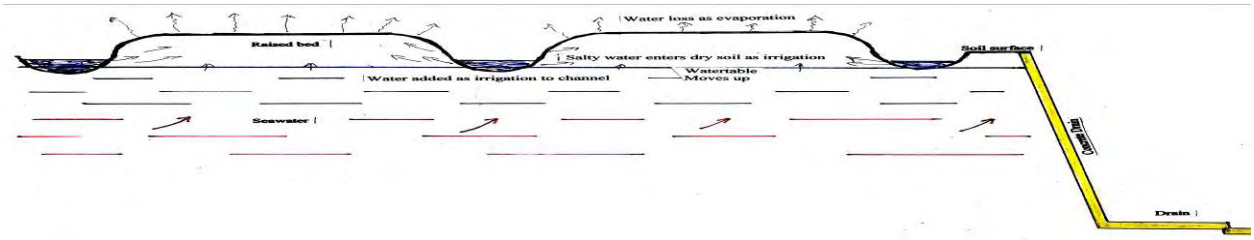
With a raised bed there is an increase in soil depth and there is the possibility of leaching occurring via rainfall and, especially, if the farmer uses watering cans to apply any supplementary irrigation as an overhead system. This is roughly outlined in Figure 5.1.

Figure 5.1 Overhead Irrigation and Leaching



However, if the farmer uses surface methods of irrigation, such as in furrows, he will not be achieving any leaching and probably making the salinity problem worse. Refer Figure 5.2

Figure 5.2 Furrow Irrigation and Re-salinisation



For the sites that are still flooded, Sites 18-1 and 19-1, even after refurbishing and upgrading the drainage systems these sites will most likely still be at severe risk from the hazard of very high water tables.

If cropping of some type has to be done in these areas one, rather expensive option would be to install a dense network of drainage channels and use the excavated soil to build large raised beds. If the beds were wide and long enough with sufficient increase in soil depth above the water then even padi might be possible.
However, an irrigation supply would have to be established from an external source and would probably have to be piped in for overhead or trickle application. These sites are at very low level, are close to the shoreline, must have tidal influence and there is almost certainly intrusion of salty sea sea-water form below. Before reclamation proceeds the following needs to be done at each site:

- Establish the actual soil depth needed and available for the crops in question to exploit – governed by the watertable depth
- Establish the depths of the various water-tables at the sites
- Check the soil texture and particle size class (PSC) of the soils at the sites
- Establish the status or presence of any soil drainage and get a system operational as the first intervention
- Establish the irrigation system and supply to be used.

APPENDIX A CLIMATE

A.1 Introduction

For the ETESP, Agriculture Component Inception Report the only rainfall data available were those quoted in Table 4.1 which contained monthly data for the year 1999 plus long term totals. The data sets were not all complete for all months or for all Kabupaten and a few "gaps" existed.

Accordingly, to try and establish a more complete data set, until such time as full meteorological data sets can hopefully be obtained, the data were manipulated to give monthly rainfall data based on the long term "total" rainfall for each Kabupaten. The hope being that by using the long term data the information just might be more reliable – but this cannot be guaranteed.

Also, in the Inception Report it was stated that rainfall was greater on the west coast than on the east – this statement, though basically accurate, did not supply much useful information. Accordingly the available data was again manipulated to try and establish "rainfall" zones which might prove useful in planning rehabilitation processes.

A.2 Monthly and Annual Rainfall

The original 1999 data plus the "manipulated" data sets are shown as Table 1.

Table 1(a) Monthly Rainfall Data - 1999

Kabupaten Code	8	16	7	15	12	1	9	10	11	5
Kabupaten Name / **Month**	Aceh Besar	Aceh Jaya	Aceh Barat	Nagan Raya	Aceh Barat Daya	Simeulue	Pidie	Bireuen	Aceh Utara	Aceh Timur
	mm	*mm*	*mm*	*mm*	*mm*	*mm*	*mm*	*mm*	*mm*	*mm*
Jan	72	242	242	384	216	40	195	195	330	246
Feb	139	180	94	159	313	75	327	97	91	387
March	114	240	299	299	254	55	126	122	85	497
April	78	140	215	286	138	65	163	123	38	170
May	74	87	307	221	280	121	85	130	-	166
June	34	61	33	33	155	70	57	69	7	129
July	51	155	147	147	206	107	30	76	-	211
Aug	92	314	314	291	185	186	123	70	-	270
Sept	107	202	202	202	488	110	333	99	-	287
Oct	41	416	416	416	210	141	140	171	-	285
Nov	83	273	273	273	98	135	98	204	-	-
Dec	173	268	268	279	231	139	129	224	-	396
Total 1999	1057	2578	2809	2990	2774	1244	1807	1541	1318	3044
Long Term Total	1668	2649	3149	3360	3303	1127	1889	1613	ND	2222

Source: *ETESP Inception report October 2005*

From Land Rehabilitation and Environment Sub-Section

Recent local advice is that the figure for Simeulue should be about 3,000 and not the above quoted 1127 or 1244mm.

Table 1(b) Monthly Rainfall Data Based on Long Term Data

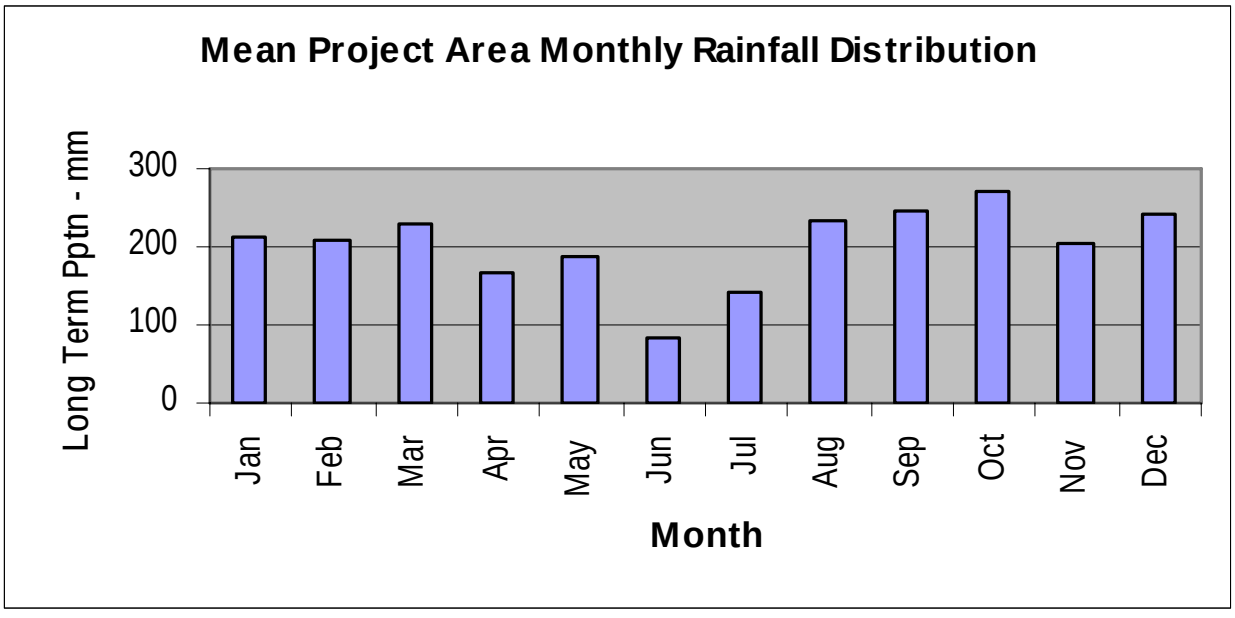
Code	8		16		7		15		12		1		9		10		11		5		Overall	
Name	Aceh Besar	Monthly as % of annual	Aceh Jaya	Monthly as % of annual	Aceh Barat	Monthly as % of annual	Nagan Raya	Monthly as % of annual	Aceh Barat Daya	Monthly as % of annual	Simeulue	Monthly as % of annual	Pidie	Monthly as % of annual	Bireuen	Monthly as % of annual	Aceh Utara	Monthly as % of annual	Aceh Timur	Monthly as % of annual	Monthly as % of annual	Overall monthly average long
Month	*mm*	*%*	*mm*	*%*	*mm*	*%*	*mm*	*%*	*mm*	*%*	*mm*	*%*	*mm*	*%*	*mm*	*%*	*mm*	*%*	*mm*	*%*	*%*	*mm*
Jan	114	7	249	9	271	9	432	13	257	8	96	3	204	11	199	12	123	9	180	8	10	212
Feb	219	13	185	7	105	3	179	5	373	11	181	6	342	18	99	6	126	9	282	13	9	209
Mar	180	11	247	9	335	11	336	10	302	9	133	4	132	7	125	8	129	9	363	16	9	228
Apr	123	7	144	5	241	8	321	10	164	5	157	5	170	9	126	8	96	7	124	6	7	167
May	117	7	89	3	344	11	248	7	333	10	292	10	89	5	133	8	101	7	121	5	7	187
Jun	54	3	63	2	37	1	37	1	185	6	169	6	60	3	70	4	55	4	94	4	3	82
Jul	80	5	159	6	165	5	165	5	245	7	258	9	31	2	78	5	76	6	154	7	6	141
Aug	145	9	323	12	352	11	327	10	220	7	449	15	129	7	71	4	127	9	197	9	9	234
Sep	169	10	208	8	226	7	227	7	581	18	265	9	348	18	101	6	140	10	209	9	10	248
Oct	65	4	427	16	466	15	467	14	250	8	340	11	146	8	175	11	145	11	208	9	11	269
Nov	131	8	281	11	306	10	307	9	117	4	326	11	103	5	208	13	107	8	146	7	8	203
Dec	273	16	275	10	300	10	314	9	275	8	335	11	135	7	229	14	141	10	143	6	11	242
Total - LT	1668		2649		3149		3360		3303		3000		1889		1613		1365		2222		Avrg	2422
Check	1668		2649		3149		3360		3303		3000		1889		1613		1365		2222		Avrg	2422

Source: Developed by manipulating data of 1999 rainfall to get % of 1999 per month then applying percentages to Long Term Total Rainfall

Total for Bireuen changed from 1100+ to 3000mm on local advice

The full spreadsheet showing the percentages per month etc is shown as Appendix 1 and rainfall distributions graphs (block diagrams) are shown in Appendix B. The overall rainfall distribution for the project area, for which data are held, is shown in Figure 1.

Figure 1 Rainfall Distribution – monthly, average for project area



A.3 Rainfall Zones

For planning soil reclamation and, later, agricultural inputs, it is very helpful – perhaps necessary – to have as much climatic data, including isohyets mapping information as possible. No such information was immediately available hence the existing rainfall data has been manipulated with the following outputs.

- A table showing rainfall zones
- A diagram showing rainfall in the various Kabupaten, and
- A simple map showing the location of these zones

Table 2 Rainfall Zones based on Long Term Precipitation

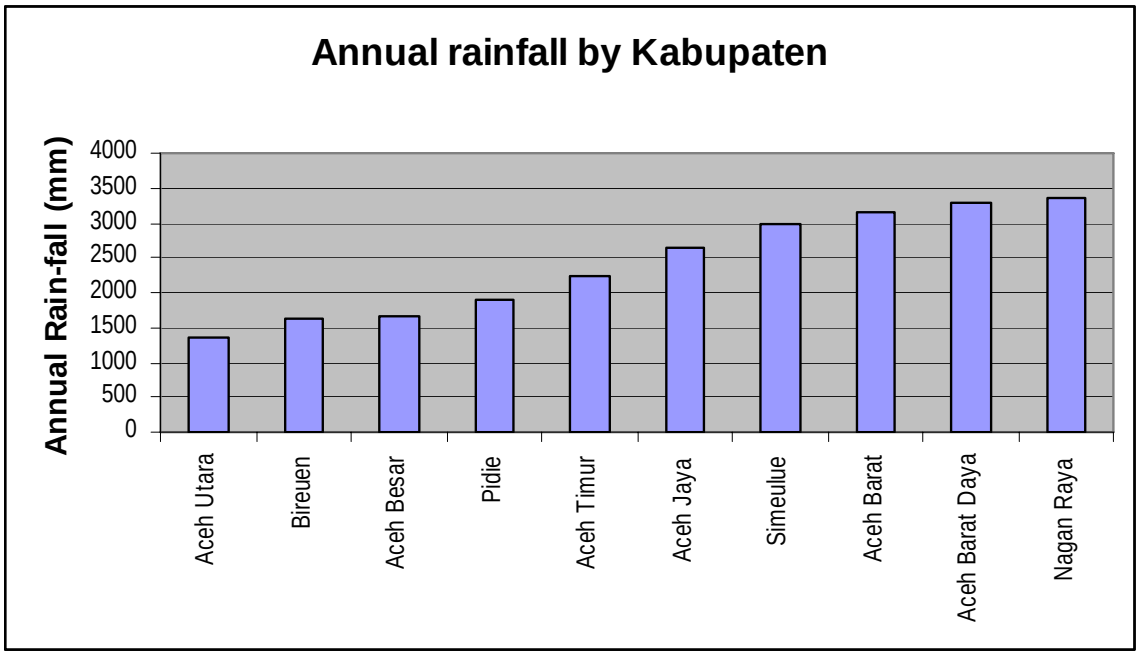
District No	Name	Location	Annual long term Pptn (mm)	Pptn in 1999	1999 as % of average
11	Aceh Utara	N	1365	1318	97
		Average	**1365**	**1318**	**97**
10	Bireuen	N	1613	1541	96
8	Aceh Besar	N	1668	1057	63
9	Pidie	N	1889	1807	96
		Average	**1723**	**1468**	**85**
5	Aceh Timur	E	2222	3044	137
16	Aceh Jaya	W	2649	2578	97
		Average	**2436**	**2811**	**117**
1	Simeulue	W	3000	ND	ND
7	Aceh Barat	W	3149	2809	89
12	Aceh Barat Daya	W	3303	2774	84
15	Nagan Raya	W	3360	2990	89
		Average	**3203**	**2858**	**87**

It can be seen in Table 2 that groupings based on latitude and or geographical position do show variations with:

- The lowest rainfall, less than 1500mm, in Aceh Utara which is at the eastern end of the N coast
- Average of around 1700mm found along the N coast
- Average of around 2400mm in the band with Aceh Jaya in the W and Aceh Timur in the E and at about the same latitude
- The lower west coast, including the island of Simeulue, having the highest – overall average of over 3200mm

With slightly more data and knowledge of actual rainfall stations it would be possible to draw crude isohyets; this has not been attempted by ETESP.

Figure 2 Long Term Precipitation by District (Kabupaten)



It appears that rainfall decreases as one comes north and the pattern appear to be governed by latitude (how far north) and not location on the north or west coast. What has, in most previous reports, been referred to as the east coast is, in fact, largely a north coast! Only Aceh Timur should really be considered as lying on the east coast.

Figure 3 Districts (Kabupaten) in the Study and Long Term Precipitation

The original data as manipulated and used for the ETESP inception report has been found to be incorrect for Simeulue; long term annual rainfall was given as just over 1,000mm per annum when it should be about 3,000mm – this information being supplied by local Dinas staff from the area.

However, the lower figure should not be totally cast aside as it is possible that the data came from a rainfall station that is in a rain shadow – but for planning purposes the higher, 3000mm, figure should be used.

A.4 Use of Rainfall Data

The monthly rainfall data have already been built into one of the main "reclamation" tools which is an MS Excel spreadsheet (Leaching Water Requirements.XLS) for calculating the depth (mm) and volume (cubic metres per hectare) required to leach soils of various textural class with salinised horizons of various depths.

ANNEX A.1 Original Data Manipulation Spreadsheet

Kabupaten Monthly Precipitation from Long Term Annual Rainfall

Code	8		16		7		15		12		1		9		10		11		5		Overall	
Name / Month	Aceh Besar	Monthly as % of annual	Aceh Jaya	Monthly as % of annual	Aceh Barat	Monthly as % of annual	Nagan Raya	Monthly as % of annual	Aceh Barat Daya	Monthly as % of annual	Simeulue	Monthly as % of annual	Pidie	Monthly as % of annual	Bireuen	Monthly as % of annual	Aceh Utara	Monthly as % of annual	Aceh Timur	Monthly as % of annual	Monthly as % of annual	Overall monthly average lor
	mm	%	mm	%	mm	%	mm	%	mm	%	mm	%	mm	%	mm	%	mm	%	mm	%	%	mm
Jan	114	7	249	9	271	9	432	13	257	8	36	3	204	11	199	12	123	9	180	8	10	206
Feb	219	13	185	7	105	3	179	5	373	11	68	6	342	18	99	6	126	9	282	13	9	198
Mar	180	11	247	9	335	11	336	10	302	9	50	4	132	7	125	8	129	9	363	16	9	220
Apr	123	7	144	5	241	8	321	10	164	5	59	5	170	9	126	8	96	7	124	6	7	157
May	117	7	89	3	344	11	248	7	333	10	110	10	89	5	133	8	101	7	121	5	7	169
Jun	54	3	63	2	37	1	37	1	185	6	63	6	60	3	70	4	55	4	94	4	3	72
Jul	80	5	159	6	165	5	165	5	245	7	97	9	31	2	78	5	76	6	154	7	6	125
Aug	145	9	323	12	352	11	327	10	220	7	169	15	129	7	71	4	127	9	197	9	9	206
Sep	169	10	208	8	226	7	227	7	581	18	100	9	348	18	101	6	140	10	209	9	10	231
Oct	65	4	427	16	466	15	467	14	250	8	128	11	146	8	175	11	145	11	208	9	11	248
Nov	131	8	281	11	306	10	307	9	117	4	122	11	103	5	208	13	107	8	146	7	8	183
Dec	273	16	275	10	300	10	314	9	275	8	126	11	135	7	229	14	141	10	143	6	11	221
Total - LT	1668		2649		3149		3360		3303		1127		1889		1613		1365		2222		Avrg	2235
Check	1668		2649		3149		3360		3303		1127		1889		1613		1365		2222		Avrg	2235

LT = Long Term data source

This sheet shows Simeulue as having an annual rainfall of about 1130mm
The above is extracted from the MS Excel spreadsheet Kabupaten Precipitation.XLS and can be supplied on request.

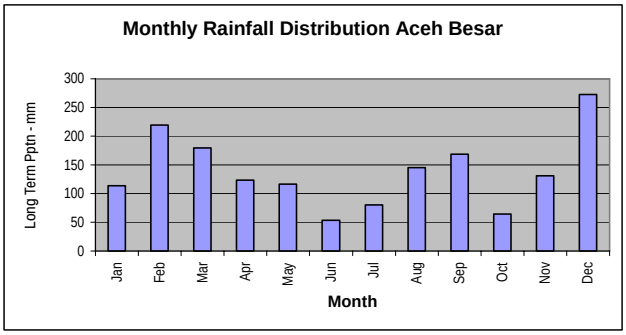
ANNEX A.2 Updated Data Manipulation Spreadsheet

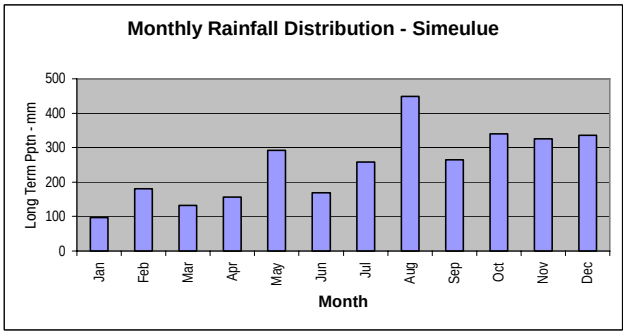
Code	8		16		7		15		12		1		9		10		11		5		Overall	
Name / Month	Aceh Besar	Monthly as % of annual	Aceh Jaya	Monthly as % of annual	Aceh Barat	Monthly as % of annual	Nagan Raya	Monthly as % of annual	Aceh Barat Daya	Monthly as % of annual	Simeulue	Monthly as % of annual	Pidie	Monthly as % of annual	Bireuen	Monthly as % of annual	Aceh Utara	Monthly as % of annual	Aceh Timur	Monthly as % of annual	Monthly as % of annual	Overall monthly average long
	mm	%	mm	%	mm	%	mm	%	mm	%	mm	%	mm	%	mm	%	mm	%	mm	%	%	mm
Jan	114	7	249	9	271	9	432	13	257	8	96	3	204	11	199	12	123	9	180	8	10	212
Feb	219	13	185	7	105	3	179	5	373	11	181	6	342	18	99	6	126	9	282	13	9	209
Mar	180	11	247	9	335	11	336	10	302	9	133	4	132	7	125	8	129	9	363	16	9	228
Apr	123	7	144	5	241	8	321	10	164	5	157	5	170	9	126	8	96	7	124	6	7	167
May	117	7	89	3	344	11	248	7	333	10	292	10	89	5	133	8	101	7	121	5	7	187
Jun	54	3	63	2	37	1	37	1	185	6	169	6	60	3	70	4	55	4	94	4	3	82
Jul	80	5	159	6	165	5	165	5	245	7	258	9	31	2	78	5	76	6	154	7	6	141
Aug	145	9	323	12	352	11	327	10	220	7	449	15	129	7	71	4	127	9	197	9	9	234
Sep	169	10	208	8	226	7	227	7	581	18	265	9	348	18	101	6	140	10	209	9	10	248
Oct	65	4	427	16	466	15	467	14	250	8	340	11	146	8	175	11	145	11	208	9	11	269
Nov	131	8	281	11	306	10	307	9	117	4	326	11	103	5	208	13	107	8	146	7	8	203
Dec	273	16	275	10	300	10	314	9	275	8	335	11	135	7	229	14	141	10	143	6	11	242
Total - LT	1668		2649		3149		3360		3303		3000		1889		1613		1365		2222		Avrg	2422
Check	1668		2649		3149		3360		3303		3000		1889		1613		1365		2222		Avrg	2422

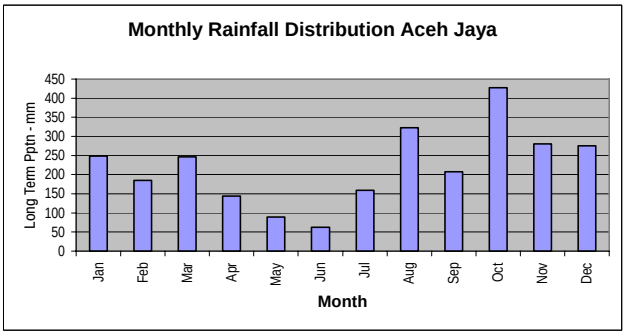
Original figure suspect and replaced with 3,000mm on local advice

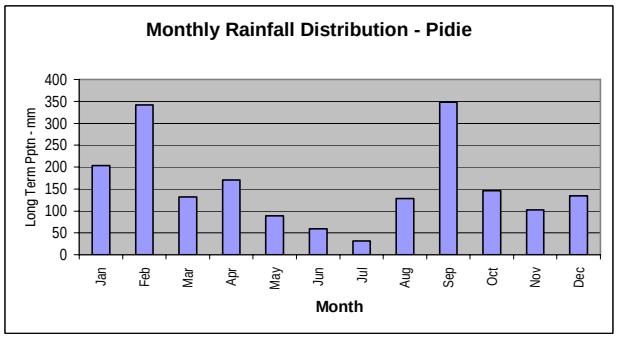
LT = Long Term data source

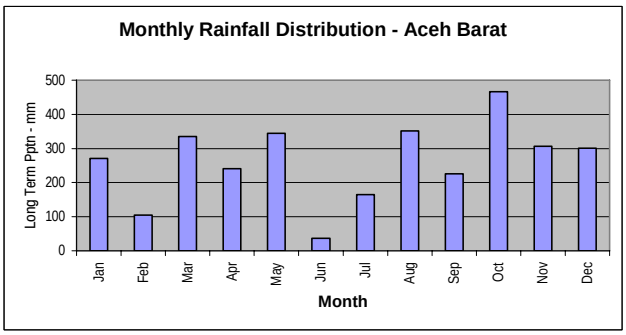
ANNEX A.3 RAINFALL DISTRIBUTION DIAGRAMS

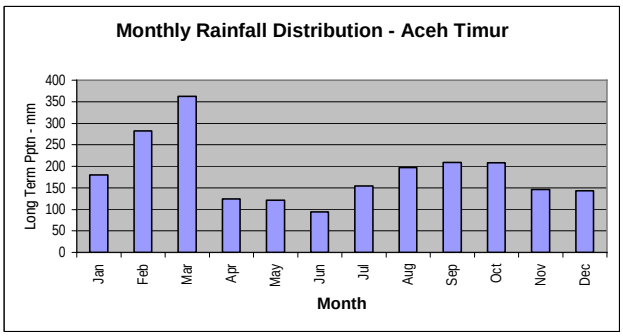


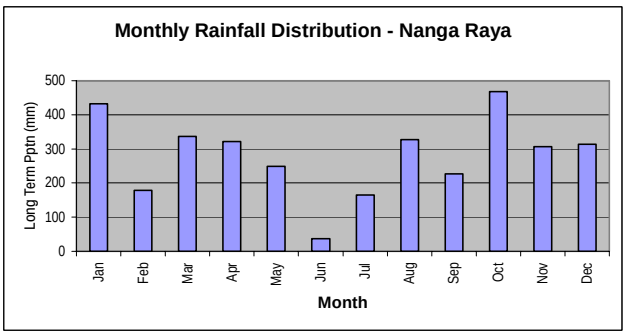


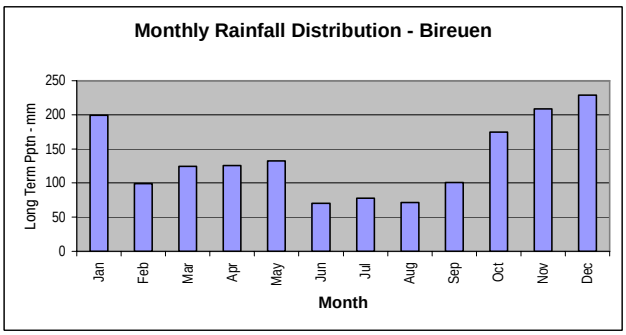


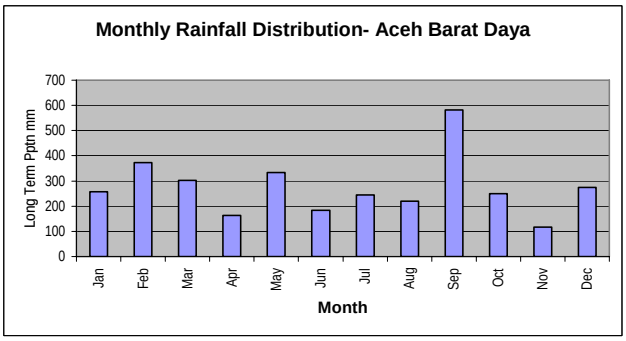


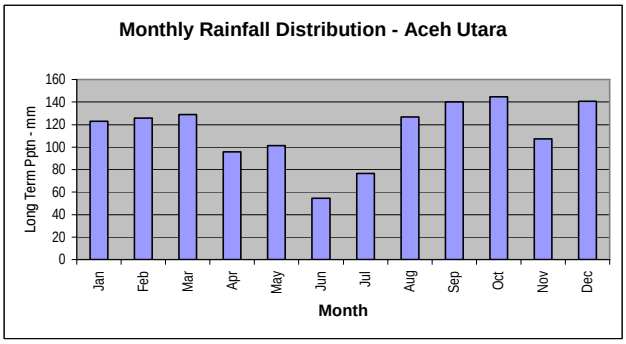












APPENDIX B DATA MANIPULATION

B.1 Introduction

There is no presentation of the theory and practices of soil reclamation given in this document. If such material is required the reader is referred to ETESP, Agricultural Component, Desalinisation and Improvement, Mobilisation Report of October 2005.

B.2 Data Availability

Data was not abundantly or obviously available but BPTP were extremely generous is rapidly supply ETESP with the dataset that they did hold. Similarly, Dr A. Rachman offered to pass on data recently collected in new surveys on the west coast as soon as the data has been compiled and collated. Both these actions have been / are greatly appreciated by ETESP.

B.3 Data Format

The BPTP data was contained in two digital files – one on MS Word and the actual EM38 measurements in MS Excel, making data transfer, manipulation and study straightforward.

The soil reclamation and improvement specialist built the data supplied into a larger, more sophisticated Excel spreadsheet titled "*EM38.XLS*" and finally extracted averages etc into a final spreadsheet ECe from "EM387.XLS"

Traditional laboratory data were supplied by BPTP as hardcopy and these data were transferred to the Excel spreadsheet "*lab data.XLS*".

B.4 Data Manipulation

All data manipulation has been done in the above spreadsheets and each spreadsheet has an "Introduction" page indicating what it does, how it works or what data inputs are required.

When data are entered into the indicated section the manipulation, for example ratings and ratios, are processed automatically.

B.4.1 Correlation of EM38 with soil ECe

Raw data for salinity surveys were made available to ETESP by BPTP and the consultant had to try and calculate a correlation between the EP38 values from the survey (EMv and EMh in mS/cm) and soil salinity or ECe in dS/m.

Rachman (personal communication) advised that a rough and ready correlation that could be tried or utilized and this is as shown below:

Table B.1 Approximate Correlation between EM 38probe and ECe

EM38 Readings in mS/cm	Salinity Class	Approximate ECe (dS/m) Values
0 - 100	SC1	2
100 - 150	SC1	2 – 4
150 - 200	SC2	4 – 6
>200	SC2 – SC3	>6

Accordingly, a spreadsheet was compiled to automatically allocate an approximate ECe value to each separate EMh, EMv and EM average reading as supplied by BPTP in their data set.

In addition, the original conversions proposed by Rhoades (1989) were applied in the same spreadsheet.

B.4.2 Rhoades Conversion / Calibration Equations

The proceedings of the EM38 workshop held in India in February 2000 were supplied by the National Soil Resources Institute (NSRI), Silsoe College, UK in answer to a request for help with this problem. The equations are rather complicated and which equation to use depends on whether EMh (Horizontal) or EMv (Vertical) is larger for each specific measurement. The spreadsheet has all the necessary checks built into it to automatically guide the user to apply the correct equation and the details are not gone into here. The introductory page to the spreadsheet (ECe from EM38.XLS) offers sufficient explanation for a relatively computer literate operator to arrive at acceptable decisions and obtain the required ECe data.

On testing the two methods it was found that most readings were relatively close irrespective of which method was applied – some minor adjustments were made to the "look-up" tables used in the spreadsheet and, based on the EMh and EMv reading, ECe values falling in the same salinity class are arrived at by either method. It was then felt that the correlation or calibration was sufficiently accurate to allow further data manipulation to proceed and that the data could be used in the "reclamation" tools referred to in Appendix. These manipulation procedures were further supported when a traditional laboratory measurement of ECe of one of the EM38 sites was compared and the results were close enough to be acceptable.

Table B.2 Comparison of ECe Determination

				Rhoades				Lookup			New Data	
Banda Aceh - Averages				ECe	ECe	ECe	ECe	ECe	ECe	ECe	ECe pre	ECe post
	mS/cm	mS/cm	mS/cm	0 - 30cm	30 -60cm	60 -90cm	0 - 90cm	EMv	EMh	EMav	Tsunami	Tsunami
Location	EMv	EMh	Avg	dS/m	dS/m	dS/m	dS/m	dS/m	dS/m	dS/m	dS/m	dS/m
Kantor BPTP	95	113	104	4.49	0.20	3.57	2.75	2.3	2.7	2.5	0.79	3.8

Table A.2.2 compares the various determinations of ECe for the site at the BPTP office in Banda Aceh and it can be seen that all the determinations fall between 2.3 – 4.49 dS/m and these readings are all in Salinity Class 1. In fact the average of the "determined" vales is 3.1 dS/m whilst the laboratory determined value is 3.8 dS/m.

The actual Rhoades equations calculate what is called ECa which is the bulk EC of the layer in question. In each case the layers used are 30cm thick. The equations are used are as follows:

When EMh > EMv

Depth range (cm)	Equation
0 – 30	ECa = 1.690(EMh) – 0.591 EMv
30 – 60	ECa = 0.554EMh – 0.595EMv
60 – 90	ECa = -0.126EMh + 1.283EMv – 0.097

When EMv>EMh

Depth range (cm)	Equation
0 – 30	ECa = 3.023EMh – 1.982EMv
30 – 60	ECa = 2.585EMh – 1.213EMv -0.204
60 – 90	ECa = 0.958EMh – 0.323EMv – 0.142

APPENDIX C Data

The outputs from the manipulated data are presented in separate sections for each of the three Kecamatan as:

- Overall averages (Table C.2)
- Average data values (Table C3)
- Maximum data values, and (Table C.4)
- Minimum data values (Table C.5)

These values are also coded to highlight the size of the problem that exists, or existed, when the surveys were conducted. In fact the salinity data may well not present the situation now as some natural leaching from the rainfall will have occurred.

The size of the problem also presented by the sediments is also coded.

The coding used in all of the data forms is as shown below as Figure C.1

Figure C.1 Problem Rating or Ranking

ECe	PROBLEM	Sediment
dS/m	RANKING	cm
0 - 1.9	None	0 - 0.9
2 - 3.9	Neglibible	1 - 1.9
4 - 5.9	Very Slight	2 - 4.9
6 - 7.9	Slight	5 - 9.9
8 - 11.9	Moderate	10 - 14.9
12 - 15.9	Moderately Big	15 - 19.9
16 - 23 9	Big	20 - 29.9
>24	Very Big	>30

Figure C.2 Overall Averages for Kabupaten Aceh Besar

							Rhoades	ETESP Lookup			Salinity Class	
							ECe	ECe	ECe	ECe		
		Samples	Sediment	Flood			0 - 90cm	EMv	EMh	EMav	Rhoades	ETESP
Kecamatan		No	Cm	Days	Status	Check	dS/m	dS/m	dS/m	dS/m		
	Lkonga	37	10	5	Leached	Reading OK	2.3	1.9	1.9	1.9	SC1	SC1
	Darussalam	20	3	3	Saline topsoil	Reading OK	2.3	1.4	2.3	1.8	SC1	SC1
	Baitissalam	35	27	30	Saline topsoil	Reading OK	3.3	2.6	2.9	2.8	SC1	SC1
	Kabupaten Means	**92**	**13**	**13**			**2.6**	**2.0**	**2.4**	**2.2**	**SC1**	**SC1**

Table C.3 Average Values of Manipulated Data

Aceh Besar Kabupaten

Aceh Besar Averages

Kabupaten	Kecamatan	Location	Site	EMv	EMh	Average	Samples No	Sediment Cm	Flood Days	Status	Check	Rhoades ECe 0 - 90cm dS/m	ETESP Lookup ECe EMv dS/m	ECe EMh dS/m	ECe EMav dS/m	Salinity Class Rhoades	ETESP
Aceh Besar	Lhoknga	Nusa	15 - 1	77	75	76	11	10	5	Leached	Reading OK	2.5	1.8	1.8	1.8	SC1	SC1
			15 - 2	84	78	81	19	10	5	Leached	Reading OK	2.4	2.0	1.9	1.9	SC1	SC1
			15 - 3	78	86	82	7	10	5	Saline topsoil	Reading OK	2.1	1.9	2.0	1.9	SC1	SC1
		Location average		80	80	80	37	10	5	Leached	Reading OK	2.3	1.9	1.9	1.9	SC1	SC1
Aceh Besar	Darussalam	Miruk Taman	16 - 1	62	97	80	10	3	3	Saline topsoil	Reading OK	2.4	1.4	2.3	1.9	SC1	SC1
			16 - 2	60	93	76	10	3		Saline topsoil	Reading OK	2.3	1.4	2.2	1.8	SC1	SC1
		Location average		61	95	78	20	3	3	Saline topsoil	Reading OK	2.3	1.4	2.3	1.8	SC1	SC1
Aceh Besar	Baitissalam	Suleue	17 - 1	83	87	85	16	20	30	Saline topsoil	Reading OK	2.1	2.0	2.1	2.0	SC1	SC1
		Location average		83	87	85	16	20	30	Saline topsoil	Reading OK	2.1	2.0	2.1	2.0	SC1	SC1
Aceh Besar	Baitissalam	Blang Kreung	18 - 1	154	149	151	12	30	30	Leached	Reading OK	4.8	3.8	3.7	3.8	SC2	SC1
		Location average		154	149	151	12	30	30	Leached	Reading OK	4.8	3.8	3.7	3.8	SC2	SC1
Aceh Besar	Baitissalam	Lampeudaya	19 - 1	86	122	104	7	30	30	Saline topsoil	Reading OK	3.0	2.0	3.0	2.5	SC1	SC1
		Location average		86	122	104	7	30	30	Saline topsoil	Reading OK	3.0	2.0	3.0	2.5	SC1	SC1

Table C.4 Maximum Values of Manipulated Data

												Rhoades	ETESP Lookup			Salinity Class	
Aceh Besar Maximum Values							Samples	Sediment	Flood			ECe	ECe	ECe	ECe		
Kabupaten	Kecamatan	Location	Site	EMv	EMh	Average	No	Cm	Days	Status	Check	0 - 90cm dS/m	EMv dS/m	EMh dS/m	EMav dS/m	Rhoades	ETESP
Aceh Besar	Lhoknga	Nusa	15 - 1	102	90	96	11	10	5	Leached	Reading OK	2.6	2.5	2.2	2.3	SC1	SC1
			15 - 2	101	90	92	19	10	5	Leached	Reading OK	2.6	2.4	2.2	2.2	SC1	SC1
			15 - 3	91	114	97	7	10	5	Leached	Reading OK	2.8	2.2	2.8	2.3	SC1	SC1
		Location average		98	98	95	12	10	5	Leached	Reading OK	2.7	2.4	2.4	2.3	SC1	SC1
Aceh Besar	Darussalam	Miruk Taman	16 - 1	73	116	88	10	3	3	Saline topsoil	Reading OK	2.8	1.7	2.8	2.1	SC1	SC1
			16 - 2	72	108	85	9	3	3	Saline topsoil	Reading OK	2.6	1.7	2.6	2.0	SC1	SC1
		Location average		73	112	86	10	3	3	Saline Topsoil	Reading OK	2.7	1.7	2.7	2.1	SC1	SC1
Aceh Besar	Baitissalam	Suleue	17 - 1	96	119	103	16	20	30	Saline topsoil	Reading OK	2.9	2.3	2.9	2.5	SC1	SC1
		Location average		96	119	103	16	20	30	Saline topsoil	Reading OK	2.9	2.3	2.9	2.5	SC1	SC1
Aceh Besar	Baitissalam	Blang Kreung	18 - 1	175	182	170	12	30	30	Leached	Reading OK	6.8	4.4	4.6	4.3	SC2	SC2
		Location average		175	182	170	12	30	30	Leached	Reading OK	6.8	4.4	4.6	4.3	SC2	SC2
Aceh Besar	Baitissalam	Lampeudaya	19 - 1	110	137	117	7	30	30	Saline topsoil	Reading OK	4.8	2.7	3.4	2.8	SC2	SC1
		Location average		110	137	117	7	30	30	Saline topsoil	Reading OK	4.8	2.7	3.4	2.8	SC2	SC1

Table C.5 Minimum Values of Manipulated Data

												Rhoades	ETESP Lookup			Salinity Class	
Aceh Besar Minimum Values							Samples	Sediment	Flood			ECe 0 - 90cm	ECe EMv	ECe EMh	ECe EMav	Rhoades	ETESP
Kabupaten	Kecamatan	Location	Site	EMv	EMh	Average	No	Cm	Days	Status	Check	dS/m	dS/m	dS/m	dS/m		
Aceh Besar	Lhoknga	Nusa	15 - 1	54	58	56	11	10	5	Saline topsoil	Reading OK	1.4	1.2	1.3	1.3	SC1	SC1
			15 - 2	66	57	62	19	10	5	Leached	Reading OK	1.6	1.6	1.3	1.4	SC1	SC1
			15 - 3	66	60	63	7	10	5	Leached	Reading OK	1.8	1.6	1.4	1.5	SC1	SC1
		Location average		62	58	60	37	10	5	Leached	Reading OK	1.6	1.4	1.4	1.4	SC1	SC1
Aceh Besar	Darussalam	Miruk Taman	16 - 1	46	74	60	10	3	3	Saline topsoil	Reading OK	1.8	1.0	1.8	1.4	SC1	SC1
			16 - 2	44	77	71	9	3	3	Saline topsoil	Reading OK	1.9	1.0	1.8	1.7	SC1	SC1
		Location average		45	76	66	19	3	3	Saline topsoil	Reading OK	1.8	1.0	1.8	1.5	SC1	SC1
Aceh Besar	Baitissalam	Suleue	17 - 1	66	72	71	16	20	30	Saline topsoil	Reading OK	1.8	1.6	1.7	1.7	SC1	SC1
		Location average		66	72	71	16	20	30	Saline topsoil	Reading OK	1.8	1.6	1.7	1.7	SC1	SC1
Aceh Besar	Baitissalam	Blang Kreung	18 - 1	125	128	136	12	30	30	Leached	Reading OK	3.1	3.1	3.2	3.4	SC1	SC1
		Location average		125	128	136	16	30	30	Leached	Reading OK	3.1	3.1	3.2	3.4	SC1	SC1
Aceh Besar	Baitissalam	Lampeudaya	19 - 1	56	108	92	7	30	30	Saline topsoil	Reading OK	2.6	1.3	2.6	2.2	SC1	SC1
		Location average		56	108	92	16	30	30	Saline topsoil	Reading OK	2.6	1.3	2.6	2.2	SC1	SC1

APPENDIX D TOOLS

The tools are spreadsheets to enable calculations to be done quickly and to allocate ratings to various soil parameters. These are all MS Excel spreadsheets and easy to use as very little data needs to be entered.

As the tools have been reported on previously (Mobilisation Report) no in-depth discussion is presented in this section.

The introduction page, showing formula and definitions is given in each case as is an example of output from the tool.

D.1 Leaching Water Requirement (LWR) Hoffman Formula

Figure D.1 Estimation of LWR – Introduction Hoffman

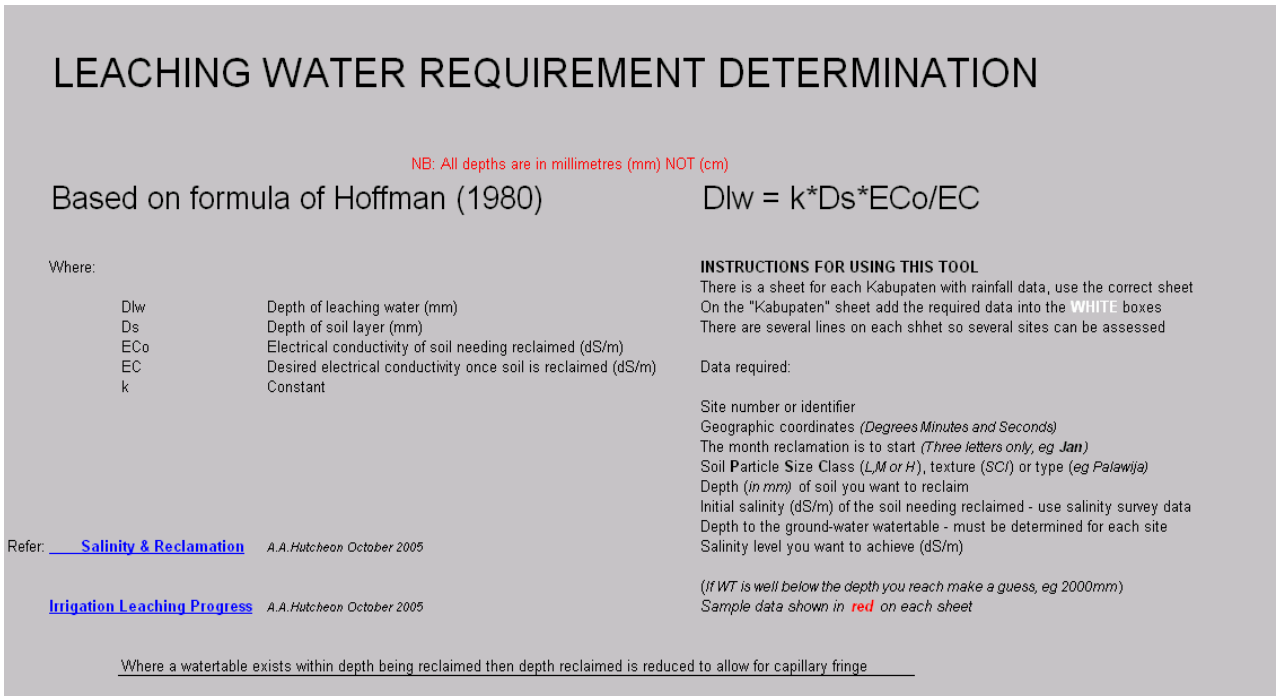


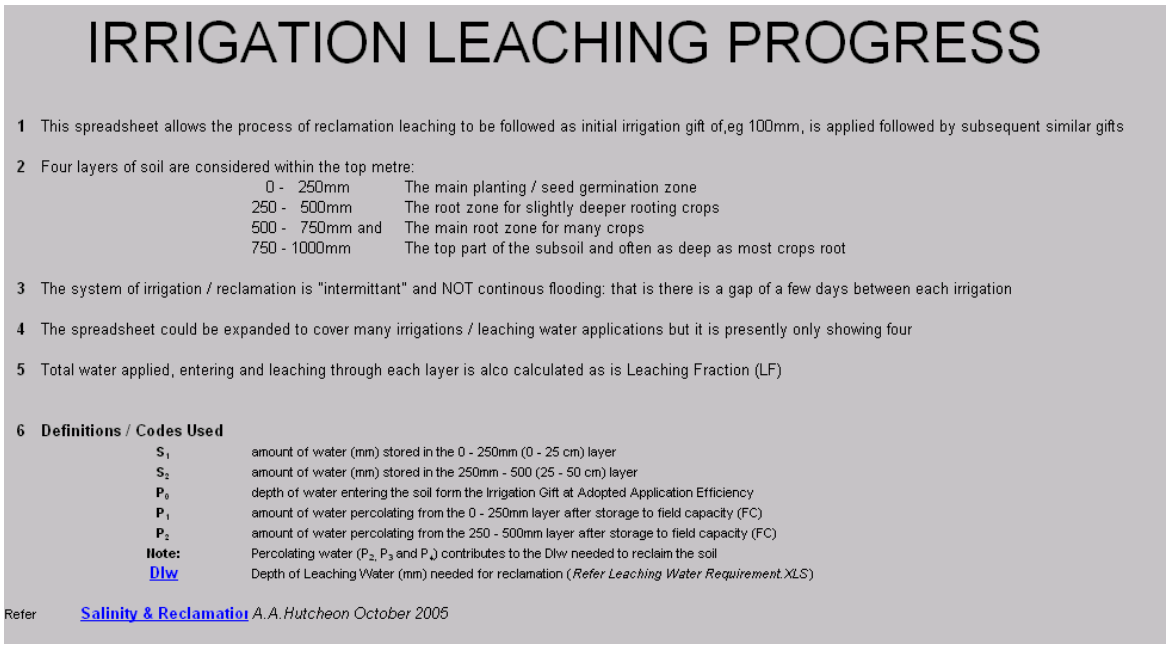
Table D.1 Data Entry Area for LWR

Enter data	*Initial*	*Initial EC*	Depth of Soil		*Desired EC*	*Desired*		Leaching Water Required	
Site / Sample Number	ECo dS/m	Salinity class	Ds (mm)	Constant "k"	EC dS/m	Salinity class	ECo/EC	Dlw (mm)	Dlw m3/ha
January									
Aceh Utara - max	100	SC6	250	0.1	4	SC2	25.0	625	6250
Aceh Utara - min	44	SC5	250	0.1	4	SC2	11.0	275	2750
Bereuen - max	6.5	SC2	250	0.1	4	SC2	1.6	41	406
Pidie - max	10	SC3	250	0.1	4	SC2	2.5	63	625
Pidie - min	5	SC2	250	0.1	4	SC2	1.3	31	313
March									
Aceh Utara - max	17	SC4	250	0.1	4	SC2	4.3	106	1063
Aceh Utara - min	7	SC2	250	0.1	4	SC2	1.8	44	438

D.2 Leaching Progress

Once the soil type and the leaching water requirements have been established the expected progress of the leaching can be determined using this tool.

Figure D.2 Leaching Progress introduction



IRRIGATION LEACHING PROGRESS

1 This spreadsheet allows the process of reclamation leaching to be followed as initial irrigation gift of,eg 100mm, is applied followed by subsequent similar gifts

2 Four layers of soil are considered within the top metre:

0 - 250mm	The main planting / seed germination zone
250 - 500mm	The root zone for slightly deeper rooting crops
500 - 750mm and	The main root zone for many crops
750 - 1000mm	The top part of the subsoil and often as deep as most crops root

3 The system of irrigation / reclamation is "intermittant" and NOT continous flooding: that is there is a gap of a few days between each irrigation

4 The spreadsheet could be expanded to cover many irrigations / leaching water applications but it is presently only showing four

5 Total water applied, entering and leaching through each layer is alco calculated as is Leaching Fraction (LF)

6 **Definitions / Codes Used**

S_1	amount of water (mm) stored in the 0 - 250mm (0 - 25 cm) layer
S_2	amount of water (mm) stored in the 250mm - 500 (25 - 50 cm) layer
P_0	depth of water entering the soil form the Irrigation Gift at Adopted Application Efficiency
P_1	amount of water percolating from the 0 - 250mm layer after storage to field capacity (FC)
P_2	amount of water percolating from the 250 - 500mm layer after storage to field capacity (FC)
Note:	Percolating water (P_2, P_3 and P_4) contributes to the Dlw needed to reclaim the soil
Dlw	Depth of Leaching Water (mm) needed for reclamation (*Refer Leaching Water Requirement.XLS*)

Refer Salinity & Reclamation *A.A.Hutcheon October 2005*

Table D.2 Leaching Progress data

Texture Group	Adopted AWHC (mm / m)	Adopted Application Efficiency (AE)	Irrigation Gift (mm)	Depth of water entering soil (mm)
L	120	0.7	100	70

FIRST IRRIGATION		Top Layer 0 - 250 mm			Second layer 250 - 500mm			
Texture Group	Depth of water infiltrating (mm)	Layer can hold (mm)	Depth (mm) water stored	Balance in layer for percolation	Layer can hold (mm)	Layer receives (mm)	Depth (mm) water stored	Balance in layer for percolation
Formula	P_0	*Calc from AWHC*	S_1	$P_1=(P_0-S_1)$	*Calc from AWHC*	P_1	S_2	$P2$
L	70	30	30	40	30	40	30	10

Notes:

For the sandy soil this first irrigation will leach salts from the top 25 cm down into the 25 - 50cm layer and start leaching into the third layer

For the medium and heavy soils there is little leaching as the soil in layer 1 has just reached field capacity hence there is little to percolate to layer

This first irrigation is a pre-planting irrigation to start flushing salts out of the planting zone

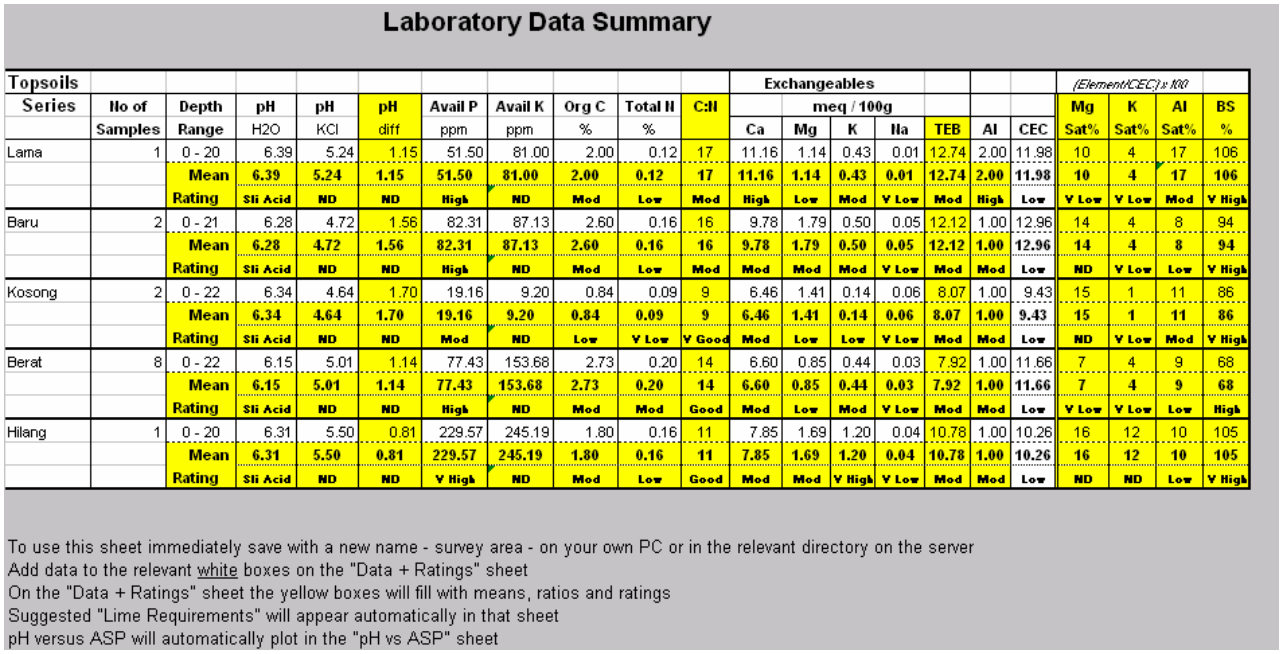
SECOND IRRIGATION		Top Layer 0 - 250 mm			Second layer 250 - 500mm			
Texture Group	Depth of water infiltrating (mm)	Layer Already holds (mm)	To reach FC need (mm)	Balance in layer for percolation	Layer Already holds (mm)	Layer receives (mm)	Depth (mm) water stored	Balance in layer for percolation
Formula	P_0	*50% of Irrig 1*	*S1*	$P_1=P_0-S_1$	*From Irrig 1*	P_1	S_2	$P2$
L	70	15	15	55	30	55	30	55

Notes:

Assumes the top layer retains 50% of water absorbed during irrigation No 1with 50% being lost via evaporation etc

Assumes second layer has not lost any of the water gained from first irrigation

Figure D.3 Laboratory Data introduction



Laboratory Data Summary

Topsoils												Exchangeables							(Element/CEC) x 100			
Series	No of	Depth	pH	pH	pH	Avail P	Avail K	Org C	Total N	C:N		meq / 100g							Mg	K	Al	BS
	Samples	Range	H2O	KCl	diff	ppm	ppm	%	%			Ca	Mg	K	Na	TEB	Al	CEC	Sat%	Sat%	Sat%	%
Lama	1	0 - 20	6.39	5.24	1.15	51.50	81.00	2.00	0.12	17		11.16	1.14	0.43	0.01	12.74	2.00	11.98	10	4	17	106
		Mean	6.39	5.24	1.15	51.50	81.00	2.00	0.12	17		11.16	1.14	0.43	0.01	12.74	2.00	11.98	10	4	17	106
		Rating	Sli Acid	ND	ND	High	ND	Mod	Low	Mod		High	Low	Mod	V Low	Mod	High	Low	V Low	V Low	Mod	V High
Baru	2	0 - 21	6.28	4.72	1.56	82.31	87.13	2.60	0.16	16		9.78	1.79	0.50	0.05	12.12	1.00	12.96	14	4	8	94
		Mean	6.28	4.72	1.56	82.31	87.13	2.60	0.16	16		9.78	1.79	0.50	0.05	12.12	1.00	12.96	14	4	8	94
		Rating	Sli Acid	ND	ND	High	ND	Mod	Low	Mod		Mod	Mod	Mod	V Low	Mod	Mod	Low	ND	V Low	Low	V High
Kosong	2	0 - 22	6.34	4.64	1.70	19.16	9.20	0.84	0.09	9		6.46	1.41	0.14	0.06	8.07	1.00	9.43	15	1	11	86
		Mean	6.34	4.64	1.70	19.16	9.20	0.84	0.09	9		6.46	1.41	0.14	0.06	8.07	1.00	9.43	15	1	11	86
		Rating	Sli Acid	ND	ND	Mod	ND	Low	V Low	V Good		Mod	Low	Low	V Low	Mod	Mod	Low	ND	V Low	Mod	V High
Berat	8	0 - 22	6.15	5.01	1.14	77.43	153.68	2.73	0.20	14		6.60	0.85	0.44	0.03	7.92	1.00	11.66	7	4	9	68
		Mean	6.15	5.01	1.14	77.43	153.68	2.73	0.20	14		6.60	0.85	0.44	0.03	7.92	1.00	11.66	7	4	9	68
		Rating	Sli Acid	ND	ND	High	ND	Mod	Mod	Good		Mod	Low	Mod	V Low	Mod	Mod	Low	V Low	V Low	Low	High
Hilang	1	0 - 20	6.31	5.50	0.81	229.57	245.19	1.80	0.16	11		7.85	1.69	1.20	0.04	10.78	1.00	10.26	16	12	10	105
		Mean	6.31	5.50	0.81	229.57	245.19	1.80	0.16	11		7.85	1.69	1.20	0.04	10.78	1.00	10.26	16	12	10	105
		Rating	Sli Acid	ND	ND	V High	ND	Mod	Low	Good		Mod	Mod	V High	V Low	Mod	Mod	Low	ND	ND	Low	V High

To use this sheet immediately save with a new name - survey area - on your own PC or in the relevant directory on the server
Add data to the relevant white boxes on the "Data + Ratings" sheet
On the "Data + Ratings" sheet the yellow boxes will fill with means, ratios and ratings
Suggested "Lime Requirements" will appear automatically in that sheet
pH versus ASP will automatically plot in the "pH vs ASP" sheet

Table D.3 Laboratory Data

												Exchangeables							(Element/CEC) x 100				Cation Ratios		Cation Ratios	
Sample	No of	Depth	pH	pH	pH	ECe	Avail P	Avail K	Org C	Total N	C:N	meq / 100g							Mg	K	Al	BS				
Site	Samples	Range	H2O	KCl	diff	dS/m	ppm	ppm	%	%		Ca	Mg	K	Na	TEB	Al	CEC	Sat%	Sat%	Sat%	%	Ca/Mg	Rating	Mg:K	Rating
Pre tsunami	Bulk	0-15	6.87	6.17	0.70	0.79	11.60	22.00	1.56	0.13	12	17.00	13.00	0.80	10.70	41.50	0.00	41.50	31	2	0	100	1.31	Ca sli deficient	16.25	K deficient
		Rating	Neutral	ND	ND	SC1	Low	ND	Mod	Low	Good	High	V High	High	V High	V High	ND	V High	ND	V Low	ND	V High				
Post tsunami	Bulk	0-15	7.10	6.90	0.20	3.80	3.70		3.05	0.11	28	26.50	13.70	4.20	36.60	81.00	0.00	81.00	17	5	0	100	1.93	Ca sli deficient	3.26	OK
		Rating	Neutral	ND	ND	SC1	V Low		High	Low	Poor	V High	V High	V High	V High	V High	ND	V High	ND	V Low	ND	V High				

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