

Earthquake & Tsunami Emergency Support Project

ETESP

Banda Aceh Kota

Kuta Alam



BPTP Demonstration Plots

Data Assessment and Soil Reclamation

(November 2005)

Summary

S.1 Introduction

The BPTP, palawija demonstration plots in Kuta Alam, Banda Aceh were subject of a post-tsunami salinity survey using an EM38 device. 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). The raw dataset collected during that survey was passed to ETESP in October 2005 to assist ETESP assess the soil condition.

Figure S.1 The site 30 days after the tsunami



Figure S.2 The site in October 2005



When the appearance of the site immediately after the tsunami and in October 2005 is compared it can be seen that considerable success has been achieved in that a site covered in saline sea deposits had been recovered to the state where a crop was growing. However, the crop was not quite as good as it could be and further investigations were made as to why.

S.2 Site, Soil and Salinity

The site was virtually flat, had – by laboratory particle size analysis - light textured soils of loamy sand to sandy loam (though field texturing suggested heavier soils of sandy clay loam or medium texture), a water table at 32cm below the soil surface and the crops growing on raised beds and irrigated, when required, by surface flow via an irrigation channel running below the bed and, often, within the water-table depth. The depth of the soil in which the plants were growing was considered inadequate in supplying sufficient soil depth for the roots of the crops to exploit fully for nutrients and, in dry periods, moisture.

The recently completed soil analysis passed to ETESP indicated that the soils were:

- neutral in reaction – pH before tsunami 6.87 and post tsunami 7.10
- well supplied with exchangeable Calcium, Magnesium and Potassium (all rated as Very High)
- had very high levels of exchangeable sodium before and after the tsunami, with the “after” figure showing an three fold increase over the before tsunami
- inherent fertility was overall low with the C:N ratio falling from good to poor after the tsunami and available-P from low to very low
- fertility potential (based on CEC) would appear to be good

In October crops of eggplant, green beans and cauliflower were growing – with the egg plant showing the strongest growth with flowers visible and fruiting underway.

The water-table was apparent to casual inspection as there was water sitting in the irrigation channels and this was at the same level as the water in the onsite wells, which were used for irrigation. Patches of white salt effervescence could be seen on the soil surface in several places indicating current salinisation processes were occurring.

Analysis of the raw EM38 data revealed that most of the salinity was subsurface and not of a significantly high level – Salinity Class SC1 with an EC value of approximately 4 dS/m. Up-to-date laboratory analysis in the BPTP on-site soil laboratory gave a salinity value of just under 4dS/m using traditional laboratory methods on the soil extract; pH determinations indicated the soils were neutral.

Overall average salinity figures for the site have been estimated as below.

- ECe for 0 – 90cm by the Rhoades equations (dS/m)
- ETESP estimate of the average salinity (dS/m), and
- BPTP recent figure measured in the laboratory

Table S.1 Soil Salinity

Site	Data from Overall soil salinity	EM38 Rhoades 0 – 90cm	Survey ETESP average salinity	2005 BPTP Laboratory Traditional measurement
	(dS/m)	(dS/m)	(dS/m)	dS/m)
Kuta Alam, 20 – 1	3.02	2.75	2.5	3.8
Kuta Alam, 20 - 2	3.27	3.52	2.5	3.8
Site averages	3.15	3.14	2.5	3.8

In short, this site was not badly salinised and would be considered acceptable after routine reclamation purposes in that it could support growth of a crop with tolerance to salinity. However, the evidence and facts indicated that there would have been continual re-salinisation going on due to the shallow soil depth above the water table and the particular irrigation system being employed. Surface flow irrigation systems have very low efficiency at removing salts from soils, do so in a very patchy manner and only work if there is deep soil with free drainage – none of these conditions exist on this site.

S.3 Recommendations

S.3.1. This site does not require “reclamation” in the sense that there is a large salinity problem that must be rectified. However, there are several factors that do need to be improved through relatively simple, non-expensive inputs to rectify the situation.

S.3.2. Increase the depth of the soil in the beds above natural ground level and above the water table, increase the nutrient supplies via application of fertilisers and OM

S.3.3. Decrease the level of the groundwater table. This would be a two stage operation:

- a) Excavating the present irrigation channel to greater depth (the excavated soil can be added to increase the depth of the bed), and
- b) Siphoning or pumping the water that drains from the beds into the deeper channel into the deep (1.2metr), concrete drain that runs parallel to the main road outside the BPTP office complex. This way, any saline water would be safely removed from the site and would end up in the river and then the sea.

Once the new deeper channels are established the soil in the beds will start to drain into them and, if the channels are then emptied as suggested, the groundwater table throughout the site will slowly start to fall to the advantage of the whole site.

S.3.4. Change the irrigation system. As explained in Chapter 2 the present irrigation system used perpetuates the problem and may well be making the situation worse. It is recommended that either of the two systems suggested below are utilised:

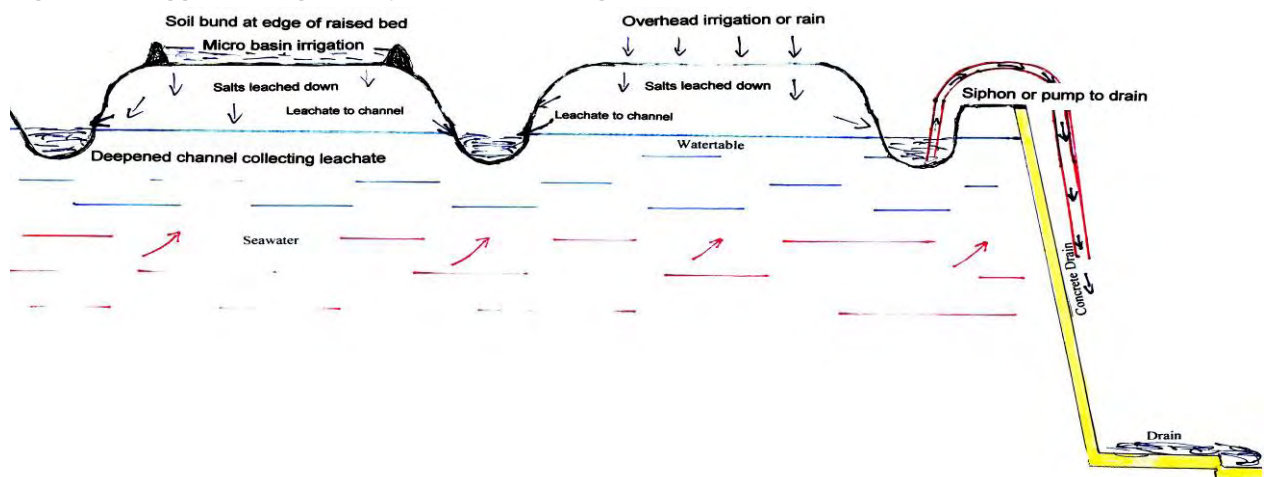
- (I) Sprinkler / spray or drip irrigation: The simplest forms of this would be
 - Utilization of hand held watering cans, or
 - Use of a raised pipe system with the outlet a simple shower head
- (II) Small basin flood irrigation
 - Once the beds have been raised by adding more soil, redesign them so that basins can be constructed on top of each bed – the edges would be as used by farmers and be constructed of soil, which would grass over in time, and protect them from erosion. The mini bunds would only need to be 10 – 15cm high, just enough to hold a normal depth of irrigation water.

All the above factors are discussed at more length in the following pages, processes are explained in sufficient detail, with the use of simple diagrams and tables, to allow the non-soils-expert understand.

If the above were all done it would ensure continual leaching of salts from the soil and even allow the use of the groundwater to continue as the main source of irrigation water since there is a relatively large “bonus” of rainfall to give regular leaching with “purer” less saline water.

S.4 Reclamation, Water Requirements and Possible Problems

However, it must be emphasized that the ground water-table is too high and any salts being leached from the soil are going into the groundwater then being re-applied to the soil in the irrigation water. The leachate must be removed from the site in a drainage system.

Figure S.3 Suggested Irrigation System with Drainage

To carry out reclamation to achieve close to pre-tsunami salinities would require that 52mm of water passes down through the profile to a depth of 50 cm and be removed from the site as drainage water.

This reclamation procedure could be completed with just 2 - 3 irrigations of 100mm of irrigation each, probably applied about one week apart, but after a drainage system is installed. That is to have 52mm pass down through the profile about 300mm need to be applied to the surface.

As there is a known soil acidification problem with local soils when they are used for palawija instead of sawah, there should be continual (research) monitoring of the soil pH throughout the season. The soil acidity problem was recognized and reported during the Aceh Design Unit project in the late 1980s and is associated with aluminium. Amelioration and careful selection of acid tolerant varieties will ensure that soil acidity does not become a problem due to changing from sawah to palawija.

Amelioration consists of applying large quantities of OM or FYM and, if necessary application of calcium bearing compounds such as lime, crushed limestone or gypsum. But it should be established if this is really necessary before any application is made.

Further information on soil acidity and aluminium can be found in the ETESP background paper 'Soil Acidity & Aluminium'.

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1 INTRODUCTION

1.1 Introduction

The Tsunami of 26 December 2004 inundated the Banda Aceh 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 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 Banda Aceh is labeled 71 at the very top of the island of Sumatra and it is a site from this area that is reported here.

Figure 1.1 NAD Kabupaten



1.2 Background

At the time the Inception Report was prepared very little data had been located with respect to the soils 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 – this 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 plus some traditional soil analysis. 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). Two transects were done on the site:

- One in the crop area, and
- One in the irrigation channel at the side of the raised crop beds

1.3 Locations

Within the Banda Aceh Kabupaten the only location for which tsunami related soil data have been located was the site of the BPTP office in Kuta Alam and the location of that site can be seen in Figure 1.2. The original data did not include GPS coordinates and the site has been located on the map below from recently taken coordinates and downloaded to the map which was extracted from the ADB map collection and geo-registered in the GPS software Ozi Explorer. Measurements from the on screen digital map put the site at just on 4km from the sea.

Figure 1.2 shows that Kuta Alam shares an exposed section of the coastline with Meuraksa, Kut Raja (not named on the map though the boundary can clearly be seen) and Syiah Kuala. Accordingly the situation as reported for Kut Alam is most likely to be very similar in these other two areas for similar locations and land-use.

Figure 1.2 Kota Banda Aceh and BPTP Plots



1.4 Site

The demonstration plots were subjected to a salinity survey and these data were all passed to ETESP and it is that data, along with a few simple field observations, that have been used to compile this report.

The site comprises raised beds for Palawija cropping and are part of the BPTP demonstration plots. Irrigation is by application of water from on-site wells accessing the ground water. The water is applied in the furrows that run below and parallel to the raised beds, plus it would appear that some water is also, or has been, applied to the top on the bed as in places very small edge bunds could be seen.

In October 2005 the crops being grown on site were:

- Eggplant
- Cauliflower, and
- Green beans

Table 1.1 Site History since the Tsunami

Site history since tsunami	One month after the tsunami site was cultivated for chili but the plants become dwarfed and died.
Tsunami	A second planting was of onion (yellowing leaf) and eggplant (good)
Tsunami sediment depth	3 days flooding during tsunami
Tsunami sediment treatment	10 - 15 cm
Crop	Removed from the onions, left on surface and mixed with soil on the egg plant area
Variety	Onion and Eggplant
Date sown	Local (onion), Bluesky (eggplant)
	July 27 th 2005 Egg plant

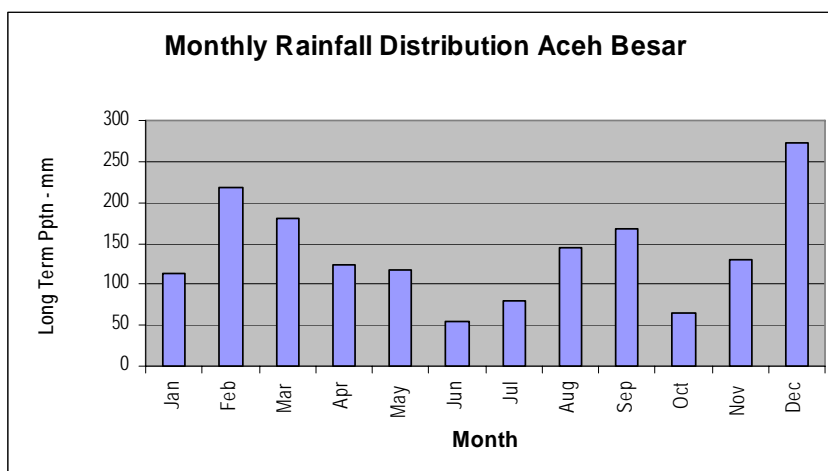
The site is virtually flat and uncultivated areas have a covering of local grasses etc which have re-grown without any interventions, apart from clearance of debris and excessive sediment deposits.

1.5 Climate

The climatic data that are available is presented more fully in Appendix A and only salient features are presented in this section.

There are no specific data to hand for Banda Aceh but since the city is surrounded by Kabupaten Aceh Besar the rainfall data from that area can probably be taken as reasonably representative for Banda Aceh.

Figure 1.3 Rainfall Distribution in Aceh Besar



1.5.1 Rainfall in Banda Aceh

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.

1.5.2 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.

Table 1.2 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	

2 SITE

2.1 Introduction

As noted in Section 1.3 above the site under discussion, and being taken as representative for Banda Aceh, is the demonstration plots at the office of BPTP in Jalan Nyak Hakam, Kuta Alam, Banda Aceh. The site was subject of a salinity survey carried out using an EM38 probe. In all some 37 readings from the EM38 were taken in two traverses:

- Traverse1 being noted as within the onion plot, and
- Traverse 2 noted as being in the drainage water – it is assumed that the determinations were done in the channel at the side of and below the raised beds

The salinity data are discussed in Section 2.5.5.

Soil samples were also collected for routine, traditional laboratory determination of fertility (nutrients), fertility potential and salinity. In the case of this site soil samples also existed from before the tsunami to allow a comparison or the “pre” and “post”-tsunami situation. These are discussed below in Section 2.2.

2.2 Soil Analyses

Bulk soil samples from the palawija plot, taken before and after the tsunami, were analysed in the laboratory at BPTP using traditional laboratory techniques and the following determinations carried out:

- Soil pH using a pH meter
- Soil salinity (ECe) on the soil extract using a salinity meter
- Available-P using the Bray 1 method
- Exchangeable cations calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) extracting with ammonium acetate solution at pH7
- Total nitrogen (N%) and Organic Matter (C %)
- Particle size class or texture was also determined

2.2.1 Laboratory Data

The results of the chemical analyses were added to the “tool” *lab data.xls* which calculates the “rating” for the nutrient or element in the soil. The output from that tool is shown as Table 2.1.

Table 2.1 Soil Analyses and Ratings

Sample Site	Depth Range	pH H ₂ O	pH KCl	ECe dS/m	Avail P ppm	Org C %	Total N %	C:N	Exchangeable (me / 100g)				meq / 100g	meq / 100g
									Ca	Mg	K	Na	TEB	CEC
Pre tsunami	0- 15	6.87	6.17	0.79	11.60	1.56	0.13	12	17.00	13.00	0.80	10.70	41.50	41.50
	Rating	Neutral	ND	SC1	Low	Mod	Low	Good	High	V High	High	V High	V High	V High
Post tsunami	0- 15	7.10	6.90	3.80	3.70	3.05	0.11	28	26.50	13.70	4.20	36.60	81.00	81.00
	Rating	Neutral	ND	SC1	V Low	High	Low	Poor	V High	V High	V High	V High	V High	V High

Source: BPTP data and Lab Data.XLS

The texture of the samples were determined using the normal textural triangle – the pre-tsunami sample being a sandy loam (M PSC – particle size class) and the post tsunami sample being a loamy sand (L PSC).

2.2.2 Laboratory Data Interpretation

(a) Soil pH

With pH (H₂O) range of 6.87 – 7.10 the rating was / is “neutral” before and after the tsunami, with a very slight increase of 0.23 pH unit after the inundation which is considered negligible. At this time there is no indication from these figures of soil acidification.

(b) Inherent Fertility

Inherent fertility is shown by the values of available-P, organic matter, total exchangeable bases (TEB), total nitrogen and the C:N ratio. Basing the rating on available-P and the C:N ratio this soil would be rated as having had low fertility before and low to very low fertility after the inundation. The main problems here are that the available-P fell from 11.6 ppm (low) to 3.7 ppm (very low) and the C:N ration went from 12 (good) to 28 (poor) due to a massive input of organic

matter from 1.56% Org-C (moderate) to 3.05% Org-C (high) without an increase in the total nitrogen. Total-N before was 0.13% (low) and was 0.11% (low) afterwards. However, the total exchangeable bases (TEB) increased by about 100% from 41.5me/100g to 81me/100g and this would allocate a very high fertility rating. At this point the situation is confused.

The exchangeable cations held on the soil complex are all rated high to very high before and after the tsunami. Calcium (Ca) increased from 17.0me/100g to 25.5me/100g. Magnesium (Mg) did not alter much and is rated very high (13.0 before and 13.7me/100g after). Potassium (K) increased dramatically from 0.8me/100g (high) to 4.2me/100g (very high) – an increase of over five-fold. Sodium (Na) was very high before and very high after with an increase of about 240% rising from 10.7me/100g to 36.6me/100g. These figures plus the TEB values indicate good inherent fertility.

However, although not shown in Table 2.1, the tool used also displays ratings based the ratios of various exchangeable cations, the Ca:Mg ratio and the Mg:K ratio. Based on FAO data some ratios show imbalances between the cations as an excess of one can cause an apparent deficiency of the other.

Table 2.2 Cation Ratios and Various Saturation Percentages

Sample Site	Mg Sat%	K Sat%	Al Sat%	BS %	Ca/Mg	Rating	Mg/K	Rating
Pre tsunami	31	2	0	100	1.31	Ca slightly deficient	16.25	K deficient
	ND	V Low	ND	V High				
Post tsunami	17	5	0	100	1.93	Ca slightly deficient	3.26	OK
	ND	V Low	ND	V High				

The calcium:magnesium (Ca:Mg) ratio appears to indicate that there is so much magnesium that the calcium could be considered slightly deficient – this is before and after the tsunami. The magnesium: potassium (Mg/K) ratio indicates that before the tsunami that potassium was deficient (when the level stood at 0.08me/100g) but after the tsunami when potassium rose to 4.2me/100g there was no apparent deficiency. In both these ratio ratings (Ca:Mg and Mg:K) the “culprit” appears to be excessive magnesium (Mg).

If independently, directly measured data for CEC had been available then some of the above ratios could or would have been different. Similarly, data on the presence or lack of exchangeable aluminium (Al) could have influenced the situation but it is most unlikely that in such a wet, flooded soil aluminium toxicity could have existed or would have been a problem.

This site clearly requires addition of phosphate and nitrogen fertilisers and the balances or imbalances between the others further investigated and rectified. One of the first things that should be done by BPTP staff is to carefully document exactly what fertilisers have or have-not been added to this site – before and after the tsunami.

(c) Fertility potential

Fertility potential is a measure or rating of just how well the soil in question would retain nutrients that are added during normal fertilization and cultivation. It is expressed by the cation exchange capacity (CEC). The data supplied by BPTP did not contain CEC values so what has been done is to use the sum of the cations to try and get a measure. Hence the values for TEB and CEC in Table 2.1 are the same thing. The soil texture determined by the BPTP laboratory is not particularly heavy – that is, there is a high percentage of sand in the soil. Sandy soils do not normally have high CEC values and FAO 42 – 1979 quote approximate figures of 10 -15me/100g for the non expanding type clays and 90 – 110me/100g for the expanding lattice type (hence it is concluded that the fertility potential is coming from the CEC of the organic materials and not from the 10 – 15% of clay that soils have, according to the laboratory. However, if the soil can hold added nutrients and not allow them to be washed out too easily the source of that potential (CEC) is not too important in the short term – but in the long term the CEC will reduce as the organic material decomposes.

(d) Texture or Particle Size Class

The textures or particle size class (PSC) determined based on the laboratory analyses indicate that both the samples tested were very to extremely sandy with the pre-tsunami sample being sandy loam (SL or PSC M) and the post inundation sample being a loamy sand (LS or PSC L).

Rapid field texturing by the ETESP soil scientist failed to find such light textured soils on the surface on the site. Also, the cation exchange capacities (CEC) as presented in Table 2.1 above do not correlate with the soils being light textured. The ETESP determination of soil texture places this soil in the heavy particle size class (PSC H) as textures were noted as being silty clay loam to clay loam (SiCL – CL). These heavier textures will be utilised in the “tools” in the “reclamation section later in the report.

2.3 Crops

The Palawija crops being grown or that had been grown include:

- (1) Eggplant (2) Cucumber (3) Green beans and (4) Cauliflower

Notes on the crops and performances at the time of the EM38 survey are shown in Table 1.1 whilst notes made in late October 2005 by ETESP are:

Beans	– growing, leaves discoloured with yellowish “splotches” – nutrient deficiency or salinity effect
Cauliflower	- growing, very weak hearts developing and leaves rather a “pale” green colour – nutrient deficiency
Egg plant	- growing quite well with flowers and fruits forming, this crop is relatively salt tolerant and suitable

2.4 Conditions

The following conditions were determined from the original survey data plus recent observations:

- The site had largely been recovered from the flood with sediment mixed in and local vegetation, grasses etc, growing normally
- Obviously high water table throughout the site
- Obvious salt efflorescence on the surface of the soil of the demonstration plots
- Salinity survey data plus pre-tsunami information to hand

2.5 Problems

The soil reclamation and improvement specialist made a very rapid examination of the site, finding the following problems. The problems are detailed in the following sections and remedial interventions are given in Chapter 3.

Table 2.2 Observed Problems

Problem	Size of problem	Associated with
Very high water table	Very large and the major cause of the other problems	Poor drainage and possibly Sea water intrusion
Salt efflorescence on the surface	Not large	Tsunami damage but being perpetuated by the irrigation system in use
Lack of sufficient soil depth for crops being grown	Massive	High water table and poor drainage
Inappropriate husbandry	Very large	Continuing salinisation of the soils due to irrigation system in use

2.5.1 High Water Table

The water table throughout the BPTP compound is very high and in late October 2005 was at 32cm below the ground surface. The figure of 32cm was measured at where there was free standing water in any channels within the agricultural area and in several wells scattered over the site.

Figure 2.1 Irrigation Channel and Water-table

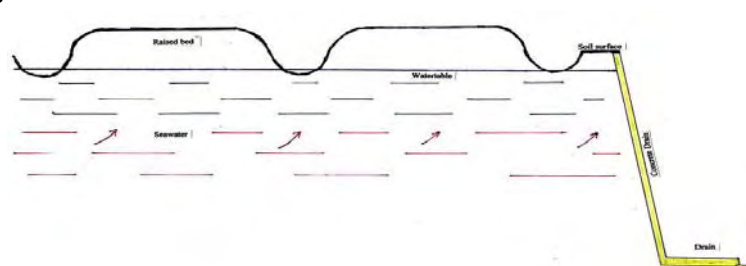


The crops were being grown on raised beds of approximately 18cm above natural ground level – this means that, at maximum, there was a soil depth of only 50cm (32 + 18) for the crop rooting system to exploit.

Reference to Table 2.2 shows just how inadequate this depth of soil is for most of the common Palawija crops. Most crops in the list have a maximum rooting depth of well over 100cm and for many the main zone for uptake of nutrients and moisture is from 40 – 60 or 70cm.

To improve the soil and get better outputs the water table has to be lowered. It should be noted that the situation is actually made worse by the drain running along the main road outside the office complex. Also, there is suspected sea-water ingress from below continually recharging the water table.

Figure 2.2 Water Table



The concrete wall of the roadside drain acts as a sub-surface dam and prevents natural, lateral flow drainage.

Any drainage pipes originally linking the soil to the drain have obviously been blocked for a long time as no evidence could be seen of any flow into the drain from the plots.

2.5.2 Salt Efflorescence

In several places there was salt efflorescence visible on the soil surface – that is there were patches of white and these patches are salts!

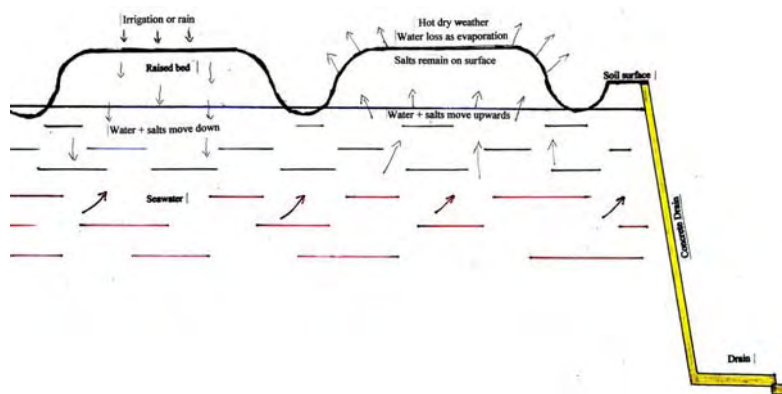
Unfortunately, the irrigation system that is being employed is quite inappropriate for the situation and needs to be changed; otherwise the salinity will just be an on-going problem. The following diagrams help demonstrate what is happening.

No matter how the water in the water-table gets there, from percolation of rainfall, from irrigation or from sea water ingress it just cannot escape and drain away.

Most likely there is continual arrival of more water from below due to sea-water ingress and the soil cannot drain to the main drain at the edge of the road because the concrete sides of this drain act as a sub-surface dam – if there were any drain holes to allow groundwater to escape into the drain they have long-since been blocked. Hence the water-table is there and will only reduce if water evaporates from the soil surface. However, if water does migrate upwards and evaporate it takes any salt with it and, when the water evaporates, the salts are left behind.

Similarly, if irrigation water is applied as an overhead irrigation (sprinkler or spray), or if it rains, the water dissolves the salts on the surface and, at first, the water will move downwards in the soil profile – but when it meets the water-table the downward movement ceases and the salty water stays near the top of the water-table. If evaporation then occurs, as it does when the soil dries out, the salts return to the surface of the soil. These situations are depicted in Figure 2.2.

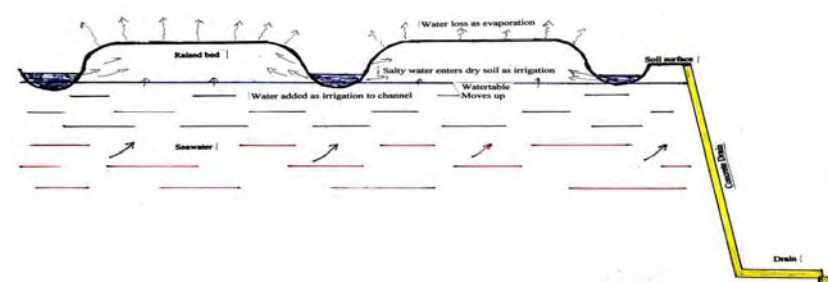
Figure 2.4 Effect of Rain or Overhead Irrigation



If irrigation water is applied as a surface flow system, as is currently done at the BPTP site, the water enters the furrow or channel and creeps into the dry soil above it through “capillary” rise – this is a natural phenomenon that happens in soils. The water then does become available to the roots of the plants in the raised beds – however, the water “creeping” into the soil will dissolve any salts it encounters and move them upwards in the soil profile. This is happening and this form of husbandry is adding to the salinity problem and there is no way that full reclamation can work using this system of irrigation.

If, however, the water-table could be reduced (lowered) and the crop left to survive on rainwater alone, or overhead application, the salinity level could reduce and the situation normalized.

Figure 2.5 Effect of Surface Irrigation



In such situations, where normal drainage is just not possible, some beds can be sacrificed for use as “dry drainage”. The principle is that if an area is left un-irrigated, and possibly protected from precipitation, groundwater will migrate to the dry area through sub-surface “lateral flow” and take the salts with it. When the water evaporates the salts are left behind and the water table will have been reduced to some extent and some salts will have been taken out of circulation.

2.5.3 Soil Depth

Reference to Table 2.3 below shows how marginal the soil depth on this site is for successful growth of the crops in use. In most instances the minimum soil depth that the crop requires is just not available – this is the depth that the crop roots enter and exploit in their search for nutrients and soil moisture. The root depths mentioned in the previous sentence are the minimum depths at which the plant searches for food and water – the optimum depth is greater than this and good crops with high percentage of expected yields cannot be expected from beds of 30 – 40 cm depth with a water table at 32cm.

Table 2.3 Requirements and Tolerances for Common Palawija Crops

Crop	Max Root Depth	Min Root Depth	Main H2O + Nutrient uptake zone	Main root pattern / concentration	Min Depth of Water Table	Tolerance to short floods	Tolerance to Salinity
	(cm)	(cm)	(cm)		(cm)		
Beans	100 - 150	60 - 90	40 - 50			M	M
Cauliflower	60	40 - 50	40 - 50	Extensive Shallow		M	M
Cucumber	>120	30 - 60	50 - 70	Dense		L	L
Onion		30 - 60		Shallow	30 - 60	L	L
Soya Bean	180	60 - 90	60 - 130		30 - 60		M
Tomato	150	60 - 90	70 - 150		50 - 70	M	M
Veg (general)	>60	60 - 90	30 - 60		Shallow	L	L

Source: Bookers Tropical Soil Manual

Study of the two right hand column of table 2.2 also reveals that:

- tolerance of the Palawija crops is only moderate to low to short periods of flooding, and
- tolerance to salinity is also moderate to low

Local information is that this site, like much of Banda Aceh, can be subjected to floods at high tides so there is a risk of flooding, but serious damage should not occur as the floods are reportedly not long-lasting. Similarly, the salinity of the site is actually at a level which would not be considered a problem for crop growth – but appropriate husbandry would need to be used.

2.5.4 Inappropriate Husbandry

Basically we are talking about the layout of the beds and the irrigation system.

The major problems are:

- Insufficient soil depth – that is soil that plant roots can and will access in the search for nutrients and moisture
- Very high water-table
- Nil site drainage, and
- An inappropriate system of water application for irrigation.

These problems, plus the slight salinity of the site, are addressed in Chapter 3.

2.5.5 Soil Salinity

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 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 2.4 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 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
- 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 2.6. The coding presented Figure 2.6 is also used for salinity as shown in Table 2.4

Figure 2.6 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	Ver Big	>30

Table 2.4 Assessment of the EM38 Dataset for the Site

Banda Aceh - Average Data

Kabupaten	Kecamatan	Location	Site	mS/cm	mS/cm	mS/cm	Samples No	Sediment Cm	Flood Days	EMh/EMv	Status	Check
				EMv	EMh	Avg						
Banda Aceh	Kuta Alam	BPTP	20 - 1	95	113	104	21	13	3	1.19	Saline topsoil	Reading OK
			20 - 2	111	95	103	16	13	3	0.86	Leached	Reading OK

The salinity data in Table 2.5 reveals that, based on the average values, the salinity problem is negligible for this site and the various determinations of salinity all fall into Salinity Class SC1 (International System) and estimates range from 2.3 – 3.8dS/m. This is the value that would be aimed for when reclaiming a badly salinised site.

Table 2.5 Salinity Measurements for the Site

Averages	Rhoades	Lookup			Salinity Class			New Data		New Data	
	Ece 0 - 90cm	Ece? EMv	Ece? EMh	Ece? EMav	Rhoades	ETESP	Lab	Ece pre Tsunami dS/m	Ece post Tsunami dS/m	pH H ₂ O post Tsunami	pH H ₂ O pre Tsunami
Site	dS/m	dS/m	dS/m	dS/m							
20 - 1	2.75	2.3	2.7	2.5	SC1	SC1	SC1	0.79	3.8	6.87	7.1
20 - 2	3.52	2.7	2.3	2.5	SC1	SC1	SC1				

Maximum	Rhoades	Lookup			Salinity Class		
	Ece 0 - 90cm	Ece? EMv	Ece? EMh	Ece? EMav	Rhoades	ETESP	Lab
Site	dS/m	dS/m	dS/m	dS/m			
20 - 1	5.42	4.3	4.2	4.2	SC2	SC2	SC1
20 - 2	5.61	4.6	3.7	4.1	SC2	SC1	SC1

Minimum	Rhoades	Lookup			Salinity Class		
	Ece 0 - 90cm	Ece? EMv	Ece? EMh	Ece? EMav	Rhoades	ETESP	Lab
Site	dS/m	dS/m	dS/m	dS/m			
20 - 1	2.16	1.5	2.1	1.8	SC1	SC1	SC1
20 - 2	2.77	2.0	1.5	1.9	SC1	SC1	SC1

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

If the maximum values are studied it can be seen that most determinations fall into Salinity Class SC2 with values of 4.1 – 5.61 dS/m and one value falls in SC1 at 3.7 dS/m. The SC2 values are highlighted in yellow and are rated as being a very small problem. The minimum values, as would be expected, fall into the “non-saline” class or SC1.

In summary, the data would appear to be reliable and there is not much of a salinity problem on this site – however, the existing salinity will NOT go away or reduce unless changes to the systems of irrigation and husbandry being applied are instigated and the drainage problem is tackled. The recommendations are presented in Chapter 3.

Overall soil salinity figures have been calculated for these sites from:

- Ece for 0 – 90cm by the Rhoades equations (dS/m)
- ETESP estimate of the average salinity (dS/m), and
- BPTP recent figure measured in the laboratory

Table 2.6 Overall Salinities in Kuta Alam

Site	Overall soil salinity (dS/m)	Rhoades 0 – 90cm (dS/m)	ETESP average salinity (dS/m)	BPTP Laboratory Traditional measurement dS/m)
Kuta Alam, 20 - 1	3.02	2.75	2.5	3.8
Kuta Alam, 20 - 2	3.27	3.52	2.5	3.8
Site averages	3.15	3.14	2.5	3.8

3 SOIL RECLAMATION and IMPROVEMENT

3.1 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 to some extent 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 by leaching plus the removal of the saline leachate from the site
- the replacement of exchangeable sodium by exchangeable calcium and
- the prevention of further accumulation of salt or sodium.

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 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.

3.2 The BTP Site

3.2.1 Present Situation

Existing Salinity:	3.8 dS/m or SC 1	- Could be reduced to 1 or 2 dS/m
Irrigation system:	Furrow	- Not suitable for reclamation - perpetuating the existing salinity and the situation could worsen
Drainage system:	Non-existent	- Drainage must be installed and made to work - Presently there are surface water drains only
Soil depth:	Insufficient	- should be increased to at least 50 – 60cm above the existing or lowered water table

3.2.2 Salinity Reduction

The salinity of the Palawija plots before the tsunami flood was very low at 0.79dS/m and this only rose to 3.8dS/cm as a result of the inundation and sedimentation (refer Table 2.4). Both of these salinities fall into the internationally accepted Salinity Class SC1 and, under most circumstances, once a soil gets to a salinity of 4dS/m or less the soil is considered reclaimed from a salinisation point of view and further reclamation leaching is not considered since normal irrigation with good water management should continue to lower the level.

No Exchangeable Sodium Percentage (ESP) or Sodium Adsorption Ratio (SAR) measurements have apparently been carried out for the site and probably they are not required. But, it should be recalled (Table 2.1) that exchangeable sodium (Na) was rated as very high on the soil exchange complex before (10.7me/100g) and after (36.6me/100g) the tsunami. This means that sodicity could build up to “undesired” levels and the balance of the various nutrients (cations) needs to be monitored – in particular calcium (Ca) already being noted as possibly slightly deficient. Perhaps some simple experimentation adding differing sources of calcium (for example gypsum CaSO_4) to the soil during operations should be considered.

However, the salinity level alone does not give the full story for this site. In Chapter 2 it was pointed out that the ground-water-table was found to be very high – 32cm below the soil surface and, also, the plots were being irrigated using a furrow irrigation system that utilised the groundwater whilst there was no operational soil drainage system.

This means that salts in the soil are being added to all the time and salinity could well be increasing as water is drawn up into the “crop bed” from the irrigation channel and, when the water evaporates from the surface and / or is used up via transpiration by the crop, the salts are left behind in the soil.

To enable the crops that are being grown to flourish to their maximum all these salts have to be removed from the soil and from the site. Using one of the “tools” developed by the ETESP team the amount of water that has to pass down through the soil and be removed from the site to achieve the pre-tsunami level of salinisation was calculated and the results are shown as Table 3.1. For this determination it can be seen that starting salinities of between 3.8 and 4dS/m were used with a target salinity of between 0.5 – 1dS/m.

Table 3.1 Water required for reclamation

Kabupaten	Site / Sample Number	Coordinates N			Coordinates E			Add	Add	Add	Add	Auto	Add	Auto		Auto	Leaching H ₂ O Needed		Irrigation H ₂ O Needed	
		Degrees N	Minutes N	Seconds N	Degrees E	Minutes E	Seconds E	Reclamation Start Month	Soil PSC, Texture or Type	Depth want to reclaim (mm)	INITIAL Salinity EC dS/m	INITIAL Salinity class	TARGET / DESIRED EC dS/m	TARGET / DESIRED Salinity class	H2O table depth (mm)	Max soil depth reclaimable (mm)	DIW (mm) DEPTH LEACHING WATER	DIW m3/ha CUBIC METRES WATER / ha	DIW (mm) DEPTH IRRIGATION WATER	DIW m3/ha CUBIC METRES / ha
Banda Aceh	20 - 1	5	33	40.8	95	20	33.5	Nov	H	500	4	SC2	1	SC1	320	170	68	680	52	524
Banda Aceh	20 - 2	5	33	37.8	95	20	41.5	Nov	H	500	3.8	SC1	0.5	SC1	320	170	129	1292	100	996

Source: Leaching water requirement.XLS

The data above shows that to achieve a salinity of 1dS/m over a planned for-depth of 50cm (500mm) only 68mm of water has to pass down through the planned for depth of 50cm, when the bonus received from rainfall is included this means that slightly less irrigation has to be applied (only 52mm). To achieve a level of half of this salinity would take twice as much water, as indicated in Site / Sample Number 20 – 2 in Table 3.1.

But, with such a high water-table it would not be possible to reclaim the soil to 50cm (500mm) depth since continual “capillary rise” from the water table would continue to add some salt. In column 11 the depth that it was planned to reclaim 500m (50cm) but the “auto” column number 17 shows that probably only 170mm (17cm) will be leached – this is because of the water table sitting at 320mm (32cm) depth. What has to be done is make the soil in the beds deeper by increasing the height of the soil above the natural ground level and, more importantly, at the same time reducing the ground-water-table to at least 50 – 75 mm below the soil surface.

3.2.3 Leaching Progress

The other tool which was applied at this time is the spreadsheet “Leaching Progress.XLS”. The normal situation would be that perhaps one would have to apply several irrigation gifts of 100mm (10cm) to achieve the target amount determined in section 3.2.2 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 irrigation 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 these salts are dissolved and leached downwards.

In the case of the BPTP site in fact only three gifts would be required as can be deciphered from Table 3.2 below, in fact as the full 50cm cannot be reclaimed the depth that can be reclaimed will probably only require 2 gifts. The low number of gifts are required because only a very shallow depth of soil can be reclaimed, due to the available soil depth and high water-table.

Table 3.2 Leaching Progress

PSC = H Irrigation No	Accumulative Water applied (mm)	Volumes Water entering soil (mm)	Accumulative Water Passing thro layer			
			1 0 – 25cm	2 25 – 50cm	3 50 – 75cm	4 75 – 100cm
1	100	70	20	0	0	0
2	200	140	65	15	0	0
3	300	210	110	60	10	0
Totals	300	210	110	60	10	0

Of the 70mm of water entering the soil at the first irrigation 50mm are absorbed by the soil bringing it up to field capacity (FC) leaving 20mm to leach downwards into layer 2. At the second irrigation the soil is assumed to be at 50% of field capacity so from the irrigation it needs less to return to FC leaving more water to leach downwards these permutations and calculations are shown in Table 3.2.

Table 3.3 Full Leaching Progress Worksheet

Texture Group	Adopted AWHC (mm / m)	Adopted Application Efficiency (AE)	Irrigation Gift (mm)	Depth of water entering soil (mm)				
H	200	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
<i>Formula</i>	P_1	<i>Calc from AWHC</i>	S_1	$P_1 - (P_1 - S_1)$	<i>Calc from AWHC</i>	P_1	S_1	P_2
H	70	50	50	20	50	20	20	0
Notes:								
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 2.								
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
<i>Formula</i>	P_0	<i>50% of irrig 1</i>	S_1	$P_1 - P_0 - S_1$	<i>From irrig 1</i>	P_1	S_1	P_2
H	70	25	25	45	20	45	50	15
Notes:								
Assumes the top layer retains 50% of water absorbed during irrigation No 1 with 50% being lost via evaporation etc								
Assumes second layer has not lost any of the water gained from first irrigation								
THIRD 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
<i>Formula</i>	P_0	<i>50% of irrig 2</i>	S_1	$P_1 - P_0 - S_1$	<i>From irrig 2</i>	P_1	S_1	P_2
H	70	25	25	45	50	45	50	45

It must be stressed that, at present, the above routines just would NOT WORK on the site because of the high water-table and total lack of drainage system. Once the channels are made deeper, the soil bed thicker and the water removed from the channels into a drainage system, reclamation would work. However, the reclamation would only be long-lasting if the saline water leaching out of the bottom of the profile was continually removed from the site and not allowed to enter the shallow ground-water-table.

3.3 Recommendations for Soil Reclamation and Improvement

3.3.1 Introduction

This site does not require "reclamation" in the sense that there is a large salinity problem that must be rectified before normal, pre-tsunami or better crop growth can be restored. However, there are several factors that do need to be improved through relatively simple, non-expensive inputs to rectify the situation.

3.3.2 Soil Depth

Increase the depth of the soil above natural ground level in the beds. This can be done by excavating the present irrigation channels to greater depth and adding this excavated soil to the bed surface – adding organic manure with phosphate and nitrogen would also be most advantageous in that it would help improve the subsoil being brought to the surface. The added and existing soil should be thoroughly mixed by tilling – mechanical or hand – to ensure mixing of the various materials.

3.3.3 Lowering the Water-table

This would be a two stage operation:

1. Excavating the present irrigation channel, and
2. Siphoning or pumping the water that drains from the beds into the “deeper” channels into the deep (1.2metre), concrete drain that runs parallel to the main road outside the BPTP office complex. This way, any saline water would be safely removed from the site and would end up in the river then the sea.

Once the new deeper channels are established, the soil in the beds will start to drain into them and, if the channels are then emptied as suggested, the groundwater table throughout the site will slowly start to fall to the advantage of the whole site. Whenever, there is heavy rain the water-table will creep upwards again but, by ensuring the channels are kept well excavated and emptied of drainage water regularly, the continual salinisation of the soil from the groundwater should be kept well under control.

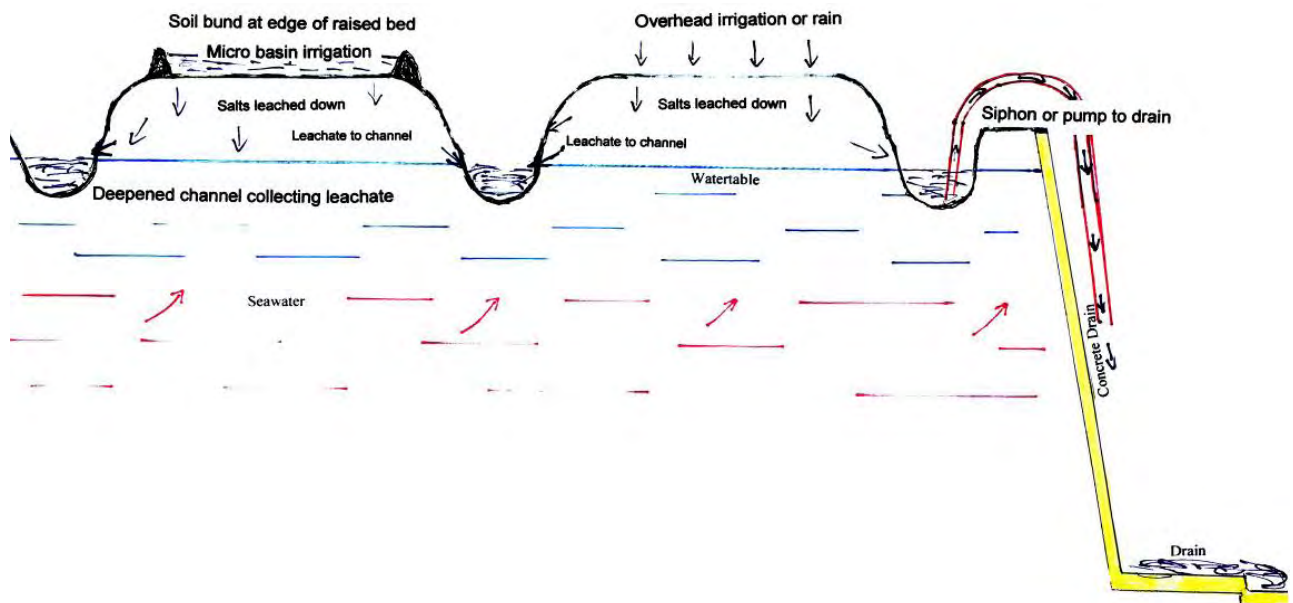
The water table problem exists not only in Kuta Alam but at every site in Aceh Besar that ETESP has visited and is a major problem that must be addressed and addressed soon if agriculture is to recover and improve.

3.3.4 Change the Irrigation System

As explained in Chapter 2 the present irrigation system used perpetuates the problem and may well be making the situation worse. It is recommended that either of the two systems suggested below are utilised:

1. Sprinkler / spray or drop irrigation: The simplest forms of this would be
 - Utilisation of hand held watering cans, or
 - Use of a raised pipe system with the outlet a simple shower head
2. Small basin flood irrigation
 - Once the beds have been raised by adding more soil redesign them so that basins can be constructed on top of each bed – the edges would be as used by farmers and be constructed of soil, which would grass over in time, and protect them from erosion. The mini bunds would only need to be 10 – 15cm high, just enough to hold a normal depth of irrigation water.

Figure 3.1 Outline of Suggested System



If the above were done it would ensure continual leaching of salts from the soil and even allow the use of the groundwater to continue as the main source of irrigation water since there is a relatively large “bonus” of rainfall to give regular leaching with “purer” less saline water.

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

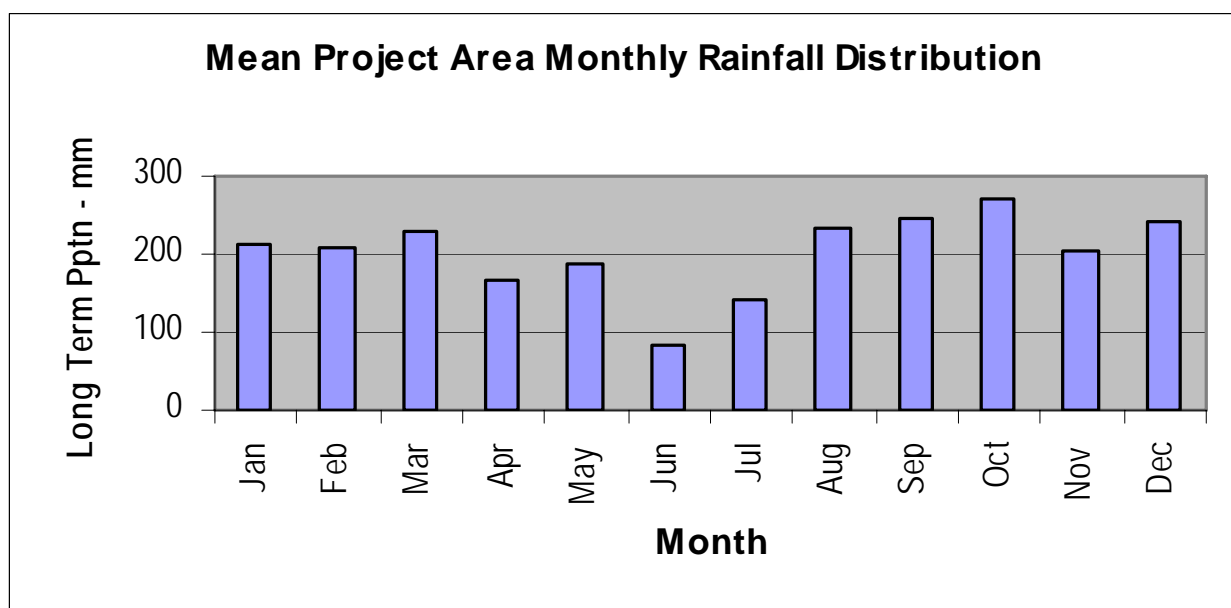
Recent local advice is that the figure for Simeulue should be about 3,000 and not the above quoted 1127 or 1244mm.

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

Code Name	8	16	7	15	12	1	9	10	11	5	Overall
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

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

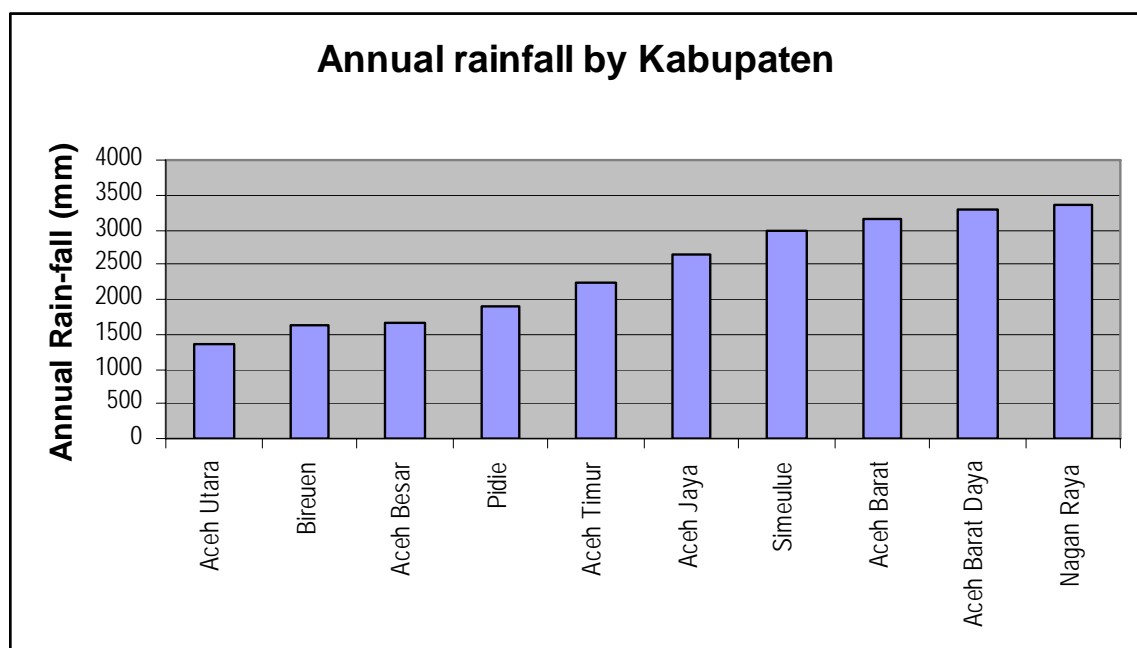
District No	Name	Location	Annual long term Pptn (mm)	Pptn in 1999	1999 as % of average
11	Aceh Utara	N	1365	1318	97
		Average	1365	1318	97
10	Bireuen	N	1613	1541	96
8	Aceh Besar	N	1668	1057	63
9	Pidie	N	1889	1807	96
		Average	1723	1468	85
5	Aceh Timur	E	2222	3044	137
16	Aceh Jaya	W	2649	2578	97
		Average	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	Aceh Besar		Aceh Jaya		Aceh Barat		Nagan Raya		Aceh Barat Daya		Simeulue		Pidie		Bireuen		Aceh Utara		Aceh Timur		Overall monthly average for	
Month	Monthly as % of annual		Monthly as % of annual		Monthly as % of annual		Monthly as % of annual		Monthly as % of annual		Monthly as % of annual		Monthly as % of annual		Monthly as % of annual		Monthly as % of annual		Monthly as % of annual		Overall monthly average for	
	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																						

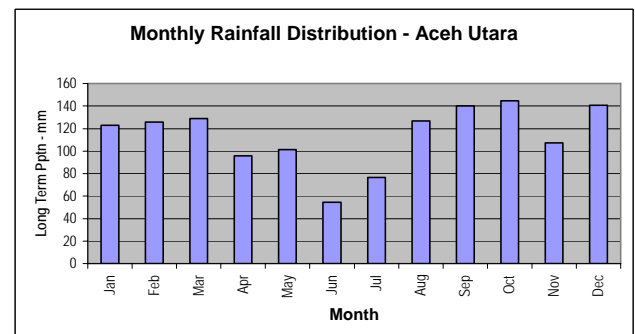
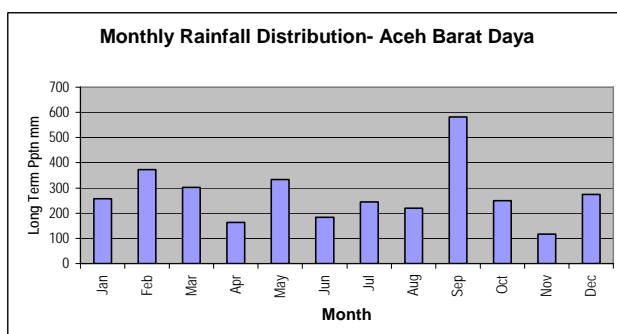
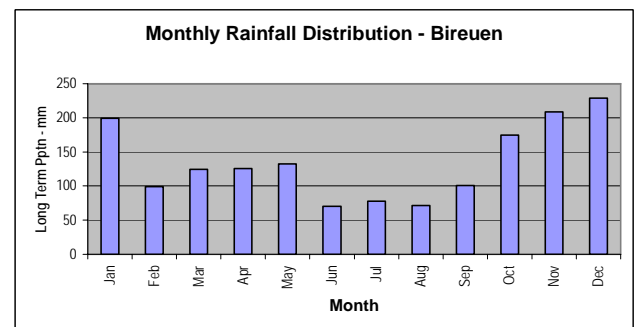
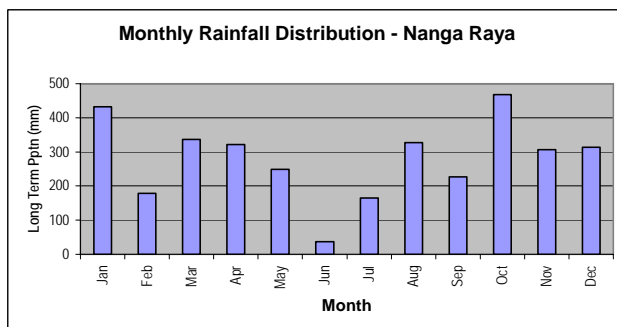
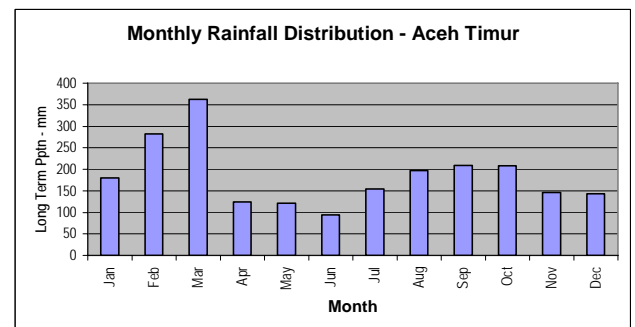
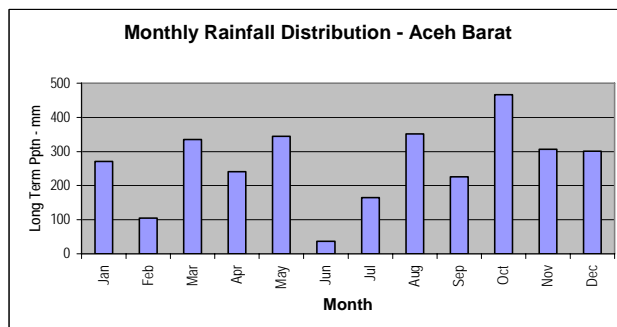
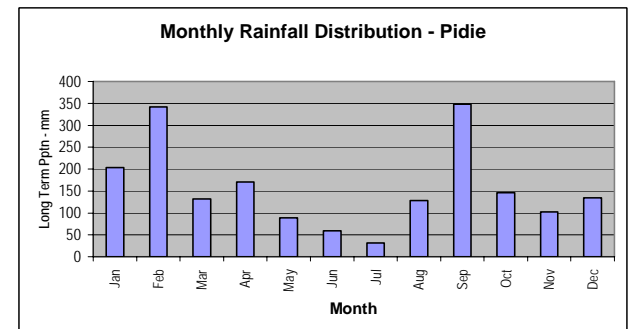
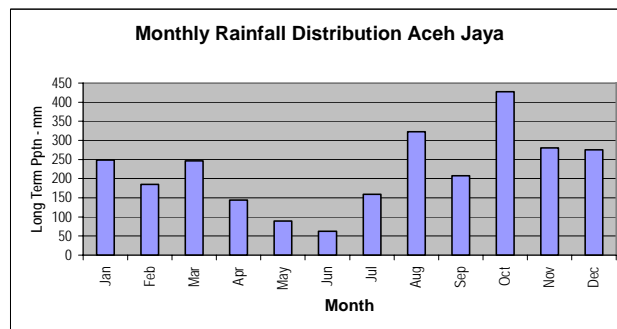
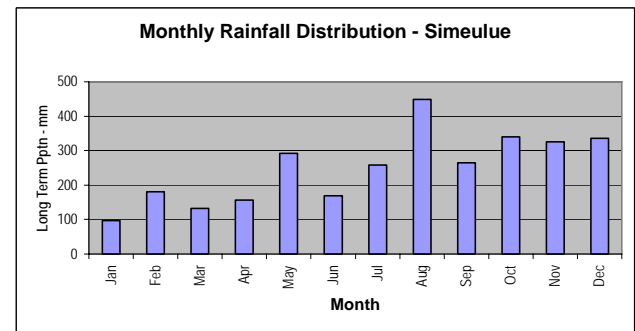
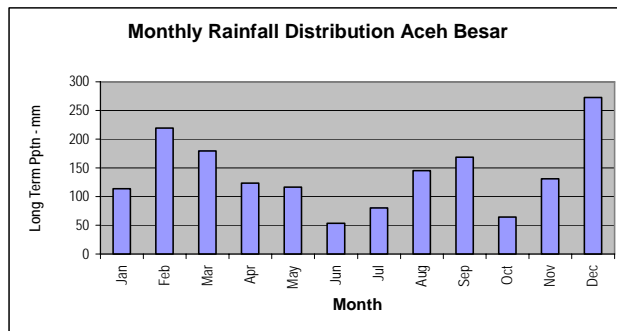
This sheet shows Simeulue as having an annual rainfall of about 1130mm

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 Name	8		16		7		15		12		1		9		10		11		5		Overall	
	Aceh Besar		Aceh Jaya		Aceh Barat		Nagan Raya		Aceh Barat Daya		Simeulue		Pidie		Bireuen		Aceh Utara		Aceh Timur			
Month	Monthly as % of annual		Monthly as % of annual		Monthly as % of annual		Monthly as % of annual		Monthly as % of annual		Monthly as % of annual		Monthly as % of annual		Monthly as % of annual		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

Banda Aceh - Averages				Rhoades				Lookup			New Data	
				ECe 0 - 30cm	ECe 30 -60cm	ECe 60 -90cm	ECe 0 - 90cm	ECe EMv	ECe EMh	ECe EMav	ECe pre Tsunami	ECe post Tsunami
Location	mS/cm EMv	mS/cm EMh	mS/cm 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 C.3)
- 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			
							0 - 90cm	EMv	EMh	EMav	Rhoades	ETESP	
Kecamatan		Samples	Sediment	Flood	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	
Baitussalam		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 Kabupaten												Rhoades ECe 0 - 90cm dS/m	ETESP Lookup			Salinity Class		
													ECe EMv dS/m	ECe EMh dS/m	ECe EMav dS/m	Rhoades	ETESP	
Kabupaten	Kecamatan	Location	Site	EMv	EMh	Average	Samples No	Sediment Cm	Flood Days	Status	Check							
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	
Location average			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	
				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	
Location average			16 - 2	60	93	76	10	3		Saline topsoil	Reading OK	2.3	1.4	2.2	1.8	SC1	SC1	
				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												ECe 0 - 90cm	ECe EMv	ECe EMh	ECe EMav	Rhoades	ETESP	
Kabupaten	Kecamatan	Location	Site	EMv	EMh	Average	Samples No	Sediment Cm	Flood Days	Status	Check	dS/m	dS/m	dS/m	dS/m			
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	
Location average			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	
					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	
											ECe 0 - 90cm dS/m	ECe EMv dS/m	ECe EMh dS/m	ECe EMav dS/m	Rhoades	ETESP	
Kabupaten	Kecamatan	Location	Site	EMv	EMh	Average	Samples No	Sediment Cm	Flood Days	Status	Check						
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
Location average			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
			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
Location average			16 - 2	44	77	71	9	3	3	Saline topsoil	Reading OK	1.9	1.0	1.8	1.7	SC1	SC1
			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 REFERENCES

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