8. CHAPTER VIII: CONCLUSION

8.1. Introduction

The issues that the this research is concerned with, the aims and objectives, the methodologies, tests of hypotheses and the achieved results have been discussed in detailed in the previous chapters. In this Chapter, the results and discussions are summarized in point form, together with conclusions on the main research objectives.

8.2. Sedimentation Rates

1- Stratigraphic dates based on records of ^{137}Cs fallout in sediment column indicate that the rate of supply of ^{210}Pb to Bera Lake has been relatively constant and affirmed the applicability of the CRS model in provide a chronology of the Bera Lake sediments.

2- The assumptions necessary for application of the CIC model were not met in this study.

3- The ^{210}Pb fluxes and sediment distribution are remarkably controlled by hydrological circulation and basin morphology. The estimated maximum ^{210}Pb flux and sedimentation rates were 159±2 Bq cm^{-2} y^{-1} and 2.56 cm y^{-1}, respectively in the semi-closed area at north of Bera Lake.

4- Although the low fallout ^{137}Cs inventory in tropical regions as shown by this and previous studies, the achieved results stress the ability of ^{137}Cs for soil redistribution studies and as a confirmation time marker in sedimentation studies in tropical areas.

5- The well-resolved ^{137}Cs peaks were recorded at similar depths of 40 cm in master Cores 2, 5, and 8, and indicate the 1963 maximum ^{137}Cs fallout due to atmospheric bomb testing. This firmly emphasizes the accuracy of ^{210}Pb dating using the CRS model in the present study.

6- The chronology of four individual stratigraphic layers showed that Layers 1, 2, 3, and 4, were deposited in Bera Lake before 1950, from 1950 to 1970, from 1970 to 1993, and in 1994, respectively.

7- The means pre-1950 sedimentation rates in master Cores 2, 8, and 5, calculated at 0.06±0.02, 0.05±0.01, and 0.14±0.26 g cm^{-2} y^{-1}, respectively. This suggests a uniform accumulation rate in the south and middle of Bera Lake and an increase northward along the main stream.

8- Layer 2 has been deposited in the south, middle and north of Bera Lake at rates of 0.35±0.34, 0.28±0.36, and 0.21±0.34 g cm^{-2} y^{-1}, respectively.

9- Two vivid peaks in sediment flux were observed in Layer 2 and distinctively occurred in 1954±2 and 1962±2 with maximum rates of 1.88 and 2.74 g cm^{-2} y^{-1} in Cores 7, and 5, respectively. The first peak was induced by a non-documented natural event whilst the second one was caused by timber extraction during the first Malaysia National Plan.

10- Severe erosion-induced deposits in Bera Lake accumulated with an influx of white sandy mud sediments in Layer 3 prior to, and post, maximum deforestation phases. These were deposited in the south, middle and north of

Bera Lake at mean rates of 0.48±0.48, 0.54±1.2 and 0.17±0.12 g cm^{-2} y^{-1}, respectively.

11- Different contributions of FELDA projects, in terms of sediment supply were recorded in different sections of Bera Lake. The fifth FELDA land development phase, however, was recognized as the main contributor to the deposition of the white sandy mud layer.

12- Sedimentation of the organic-rich sediments of Layer 4 in all parts of Bera Lake has involved an average rate of sediment flux of 0.2±0.1 g cm^{-2} y^{-1} (1.03 cm y^{-1}) since 1994, with high organic waste production associated with the mature oil palm plantations.

13- A clear sediment flux recorded at depths of 2 to 4 cm with maximum sedimentation rates of 0.32 and 0.29 g cm^{-2} y^{-1} in Cores 2 and 8, signaled a huge flood in 2007, when 1,200 mm of rain was precipitated in 11 days. This natural event was also remarkably verified by the highest reworked ^{137}Cs value at the top of the Bera Lake sediment columns.

14- Mean sedimentation rates based on the stratigraphic dates of fallout ^{137}Cs horizons in Cores 2, 3, and 8 reveal a close similarity with mean sedimentation rates determined with a slope regression model where *In* $^{210}Pb_{ex}$ was plotted against depth.

15- The mean sedimentation rate in the wetlands and open waters based on fallout of ^{137}Cs and the proportional conversion model was 1.02 cm y^{-1}; a value which shows significant similarity with the sedimentation rate at Bera Lake of 1.11 cm y^{-1} which was calculated using trap efficiency and sediment discharge values.

8.3. Soil Redistribution

1- The ^{137}Cs technique and the proportional model as a conversion method were recognized as suitable methodology for the estimation of soil redistribution in Malaysian land development schemes where there has been only a single cycle of deforestation followed by cultivation. All assumptions such as the exact date of tillage and soil disturbance occasions were met in this model.

2- A strong positive correlation (r=0.74, p<0.05) was recognized between ^{137}Cs inventories and porosity values of soil samples. Conversely, a significant negative correlation (r=-0.75, p<0.05) was seen between ^{137}Cs inventories and bulk density values of soil samples.

3- A strong depth-wise negative correlations (r=-0.92; p<0.05) between the ^{137}Cs inventories and TOC contents was found in reference samples.

4- FELDA land development districts with specific elapsed times from the start of clearing of the original rainforest, and rates of erosion, provided an opportunity to create a soil erosion map of the catchment area.

5- Mean soil erosion rates of 917±345, 117±36, and 70±35, t h^{-1} y^{-1}, were determined in areas of cleared land, developing oil palm and rubber plantations, and developed oil palm and rubber plantations, respectively.

6- The means erosion rate during the first, second, third, and fourth FELDA land development projects based on their dates of starting tillage were estimated at 0.58±0.15, 0.47±0.17, 0.71±0.41, and 1.10±0.10 cm y^{-1}, respectively.

7- Mean medium-term soil erosion rates of 7.4±2.1, 1.6±0.23, and 1.13±0.31, cm y^{-1}, have been determined in areas of cleared land, developing oil palm and rubber plantations, and developed oil palm and rubber plantations, respectively.

8- The annual soil erosion from source areas was calculated to be 4.5 million tones which could potentially cover the entire wetlands and open waters at a rate of 6 mm per year.

9- It is concluded that the eroded soils have accumulated in the wetlands and open waters within Bera Lake at a rate of 1.025 cm y^{-1} since 1995.

10- Site preparation by burning is one of the land development phases that have caused a significant increase in soil loss from the Bera Lake catchment. Loss of aggregation from the destruction of organic matter binding mineral soil particles decreases pore volume and impedes flow of air and water through the soil.

11- The prepared erosion map can be used as a base map for future soil conservation and management practices in the Bera Lake catchment area and as a guideline for decision makers to adopt the appropriate policy and approach for sustainable land use schemes at any re-plantation districts.

12- This research firmly recommends using the ^{137}Cs technique and erosion mapping method for other similar catchments in Malaysia.

13- Comparison of soil erosion rates in the Bera Lake catchment in the present study with the ^{137}Cs technique with those employing the USLE equation in other studies show that the USLE equation under-estimates the rates of soil erosion.

8.4. Sediment Quality Assessment

1- Natural or background values of the 6 major and 12 trace metals for fresh water natural lakes in Malaysia were first introduced in this study. These values can be used for ecological risk assessments at other fresh water lakes in Malaysia.

2- This study recommends analyzing concentrations of Pb, As, Ni, Cu, Zn, and Cr, and then normalizing them by Al, for further sediment quality assessments at any catchment in order to estimate effects of land use change.

3- This research introduced Fe, Mn, Zn, Cd, V, Co, and Ca as excellent indicators of eutrophication in lakes where their catchment area have experienced deforestation or afforestation.

4- The highest concentrations of major elements recorded were those of Al and Fe with values of 15.4, and 3.9 %, respectively. The highest concentrations of trace metals were V and As with values of 157, and 160, mg kg^{-1}, respectively.

5- A northward increase in concentrations of Fe, K, V, Mn, Co, As, Cd, and Sr is seen in the Bera Lake sediment profiles. Under the same conditions, however, the concentrations of Cr, Ni, Cu, Zn, and Pb levels significantly declined.

6- Statistical analyses revealed two major metal populations bonded to terrestrial and organic-rich sediments. The first group with moderate to significant similarity included Li, Al, Pb, Cu, Cr, Na, Mg, Sr, and K. The second group which is associated with deposition of organic-rich sediments included Fe, Mn, As, Zn, Cu, Ni, Co, Ca and Cd.

7- Sediment quality guidelines indicated severe pollution of the Bera Lake deposits by As metalloid, and in the northern part by Fe. Furthermore, the Bera Lake sediment profiles are moderately polluted by Cu, Cr, and Ni.

8- The overall evidence clearly demonstrates the importance role of land use changes by FELDA from 1972 in the physico-chemical contamination of the sediments at Bera Lake.

9- The effects of FELDA land development projects were remarkably manifested in the values of ecological risk indices. They showed that the white sandy mud (Layer 3) is moderate to considerable contamination mostly by lithogenic metals, while the organic-rich deposits (Layer 4) are moderately to considerable pollution by organic-bond elements particularly As, Fe, Zn, and Mn.

10- Four moderate to significant enrichment peaks in metal concentration as documented by ^{210}Pb dates using the CRS model, are in excellent agreement with heavy metal fluxes and ecological risk enhancements in the white sandy mud and organic-rich layers during and after FELDA projects.

11- A significant correlation exists between the exchangeable cation ratio and heavy metals enrichment. The pre-1970 mean exchangeable cation ratio at Bera Lake, which was 5.02±0.33, faced a dramatic increase to 10.85, and 9.90, during the first and second FELDA projects, respectively.

12- Organic-rich deposits in the top layer of the Bera Lake sediment column serve as a sanctuary for microorganisms that absorb inorganic heavy metals, especially Fe, Mn, As, Zn, Cu, Ni, Co, and Cd, and transform them to organic forms.

13- The Mn/Fe ratio as an indicator of redox condition revealed a decreasing trend upwards which coincided with increasing eutrophication and acidic condition in the Bera Lake sediment column.

14- Overall sediment and water quality assessment revealed that bottom-dwelling decomposing bacteria begin to die, whereas leaf litter, dead plant and animal materials begin to be accumulated. Aquatic life is threatened by some toxic metals especially As, Fe, and Cr, whose values exceed severe effective levels (SEL).

8.5. Nutrient Contents in Bera Lake Sediment

1- It is concluded that the nutrient cycle in the Bera Lake catchment is dominantly controlled by the type of land use especially during, and after, the FELDA and local land development projects since 1960.

2- The mean TOC value decreases in the order of 2.4±1.14, 1.33±0.31, 1.22±0.62, and 1.09±0.2%, respectively, in natural forest, young oil palm/rubber lands, mature oil palm/rubber plantations, and cleared lands.

3- The mean TN value decreases in the order of 1.6±0.05, 0.13±0.02, 0.13±0.7, and 0.11±0.02%, in natural forest, young oil palm/rubber lands, mature oil palm/rubber plantations, and cleared lands, respectively.

4- A strong negative correlation (r=-0.82, p<0.05) between ^{137}Cs content and TOC was obtained in soil samples collected from cleared land.

5- The burning of felled trees plays the most important role in disturbing the nutrient cycle and self-regulating of developed and developing oil palm soil in the Bera Lake sediment profiles.

6- Total concentration of nutrients in the sediment profiles in the main open water and north of Bera Lake decreased in the order of TOC>K>TN>S>Mg>Ca.

7- It has been concluded that there is an upward trend in eutrophication and increase of C/N ratio in the Bera Lake sediment column with maximum values in the topmost organic-rich layer.

8- Nutrient fluxes that have been documented with ^{210}Pb dating and CRS model resultant dates as well as validated by ^{137}Cs horizons where TOC and TN have increased significantly in white sandy mud and organic-rich deposits are in agreement with major land clearing by FELDA.

9- The unique fate of nutrients which have been released from the source areas during and after FELDA projects has been revealed in this research. Bera Lake significantly recycles nutrients and stores them in the uppermost layer of the sediment column as organic-rich deposits.

10- Hieratical cluster analysis clearly revealed a strong similarity between nutrients (TOC, TN) contents and Fe, Mn, Zn, As, Ni, Cd, Ca, and V concentrations in the Bera Lake sediment columns. In other words, nutrients as well as Fe and Mn oxides are responsible for enriching harmful metals.

11- Clear eutrophication especially in the north of the basin, indicates that Bera Lake is on the verge of considerable ecological risk when algae bloom, reduction of dissolved oxygen, high levels of NO_3^-, and reduction of fish population are expected.

9. CHAPTER IX: SUGESSTIONS and RECOMMENDATIONS

9.1. Introduction

There is a long history of study on management plans for sustainable land and water resources in Malaysia with the first interim national forestry policy formulated in 1952. This national forestry policy which is currently being implemented in all States in Peninsular Malaysia was revised in 1992 to take into account the latest developments in forestry, in particular, the involvement of local communities in forest development and conservation of biological diversity (Kamaruzaman, 2003).

The IWRM and IRBM are concepts that have been supported in Malaysia for more than a decade as a result of rising water demands, deteriorating water quality in rivers, and environmental challenges in the form of floods, droughts and climate change (Sharip et al., 2010).

The Third National Agricultural Policy (1998–2010) focuses on agricultural programmes which aim at high productivity while ensuring conservation and utilization of natural resources on a sustainable basis. Introduction of integrated agriculture with the main emphasis on agroforestry, mixed farming, rehabilitation of marginal land, recycling of organic waste, mulching, cover cropping, composting, organic farming, and soil and water conservation are some of the measures taken to support sustainable agriculture in Malaysia (Ahmad, 2001).

Malaysia has enacted the following legislations related to land use and environment protection: (i) Land Conservation Act 1960 which relates to the conservation of hill land and the protection of soil from erosion, (ii) Environmental Quality Act 1974 which relates to the prevention, abatement, control of pollution and enhancement of the environment and for the purposes connected therewith, and (iii) National Forestry Act, 1984 which provides for the administration, management and conservation of forests and forestry development within the states of Malaysia and for related purposes (Ahmad, 2001).

In November 1994, Malaysia became a contracting party to the Convention on Wetlands of International Importance (RAMSAR) Convention. The AWB initiated an integrated management project at Bera Lake with DWNP being the lead management agency (Chong, 2007). This project commenced in June 1996, with the aim of conserving the biodiversity of Tasek Bera and its catchment area. The project ended in June 1999 with the publications of several reports, including those on anthropology (Surut, 1988), faunal and floral studies by the Forest Research Institute of Malaysia (1997), Giesen (1998) and an ecological and geological report by Wüst and Bustin (2001). Although Phillips and Bustin (1998) carried out a preliminary investigation into the peat deposits and the geological evolution of the northern area of Tasek Bera, the most detailed and complementary studies about coalification in Bera Lake and Wetlands was that by Wüst et al., (2002, 2003, 2004 and 2008). From 1998, the Bera Lake area receives routine monitoring and enforcement attention from personnel of the fisheries, forestry and wildlife departments, while channel clearance (organic matters) is contracted out annually to local residents by the Drainage and Irrigation Department. In terms of management activities, the RAMSAR Site District Site Officer has recently conducted a study on the biodiversity of Bera Lake.

The Bera Lake catchment includes natural forest (RAMSAR site) and buffer zone, and the wetlands and open waters which have been highlighted in this research as a territory of multidisciplinary importance. The main drawback that has been recognized in previous national and local studies is the lack of detailed soil and sediment management plans. Available reports have never presented management practices for soil erosion control at land development projects as well as sediment transport and sedimentation mitigation in wetlands and open waters. The majority of land development projects before 1994 and the third National Agricultural Policy (1998–2010) by government agencies or by local stockholders have been carried out without such management practices.

9.2. Soil and Sediment Management Plan

Previous Chapters have presented the results of detailed investigations of soil and nutrient redistribution in the catchment of, and eutrophication and sedimentation at Bera Lake. Management issues involving the catchment as well as the open waters and wetlands of Bera Lake have been revealed through reviews of published literature and current research achievements.

Land development projects have been recognized as unavoidable activities that have continuously encroached into areas of natural rainforest since 1960. The re-planting of the oil palm plantations in the Bera Lake catchment has been anticipated as there is a limit (25 years) to the time-span and effective duration of oil palm plantations. Eutrophication and clear changes in sedimentation regimes at Bera Lake are the impacts of management issues within the catchment area over the last four decades. A broad and integrated management practice is proposed for each of these management issues (Fig. 9.1). Specific management actions, including on-ground works and targeted scientific investigations, are recommended to meet each of the management objectives. It is to be noted that in the overall management plan proposed in Figure 9.1, emphasis is on the management issues relevant to one of the main objectives of this research project, i.e. soil and sediment redistribution in the Bera Lake catchment, wetlands and open waters. Suggestions and recommendations are supported by several international publications (Darabaris, 2008; Erickson et al., 1999) Malaysian Management Plans (Ismail, 2005; Turner & Gillbanks, 2003; Ahmad, 2001; Sharip & Yusop, 2007) as well as the results of this present study.

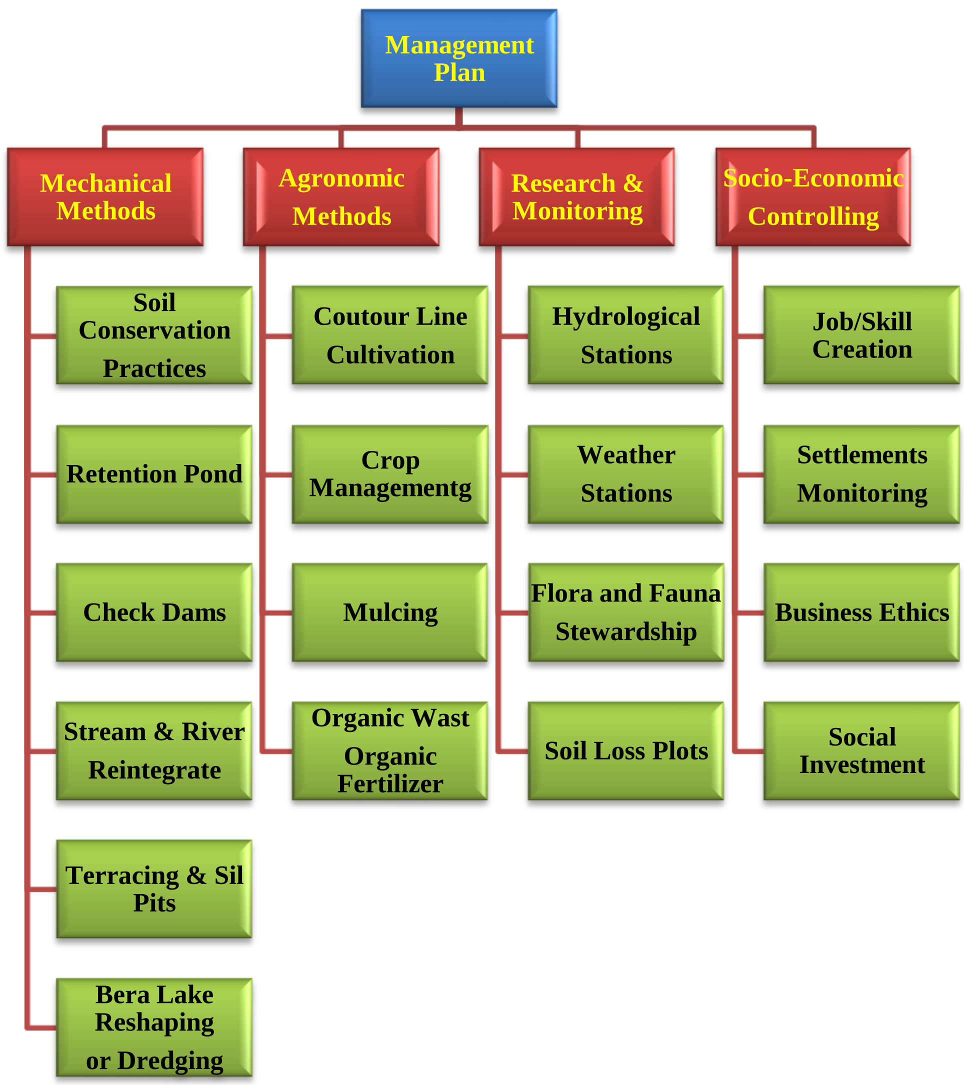

Figure 9.1: A comprehensive management plan, suggested for Bera Lake catchment

9.2.1. Mechanical methods

9.2.1.1. Soil Conservation

Soil conservation practice is one of the main important management measures that are strongly recommended for the Bera Lake catchment. An erosion risk (*ER*) map (Fig 9.2) has been prepared based on the soil erosion rate map (Fig. 6.8) which was mapped using fallout ^{137}Cs radionuclide. The soil erosion risk zoning was carried out using zoning values described in published papers in Malaysia (ECD, 2002a; Yusof, 1999) as well as the results of this present study. Published papers for instance, have classified soil erosion exceeding 150 t ha^{-1} y^{-1} as having high erosion risk, though the application of fallout ^{137}Cs radionuclide shows two main ranges of soil erosion between 600 to 1000, and exceeding 1000, t ha^{-1} y^{-1} at study area. Soil erosion risk in the Bera Lake catchment was thus separated into five zones, i.e., 1) Very low erosion risk with $ER<50$, 2) Low erosion risk with $50 \leq ER \leq 150$, 3) Moderate erosion risk with $150 \leq ER \leq 600$, 4) High erosion risk with $600 \leq ER \leq 1000$, and 5) Extreme high erosion risk with ER >1000, t ha^{-1} y^{-1}.

The soil erosion risk map demarcates several districts where different scales of on-ground management practices are needed. Cleared land fall under the critical erosion risk and indicate the serious management issues in the Bera Lake catchment. Similar soil conservation strategies, however, cannot be recommended for newly cleared land as their land use schemes are not similar to those where there is annual cultivation. Cover crops, mulching, terracing, and no-tillage farming are applicable strategies that can be used to mitigate erosion risk in the polygons of Figure 9.1. This map is a key management plan for complementary soil conservation scenarios. Current areas of critical erosion risk have been mostly created by local residents who have received limited education about environmental protection methods. Land use stewardship by government agencies is therefore, a vital step to prevent illegal land development as well as conserve water and soil resources.

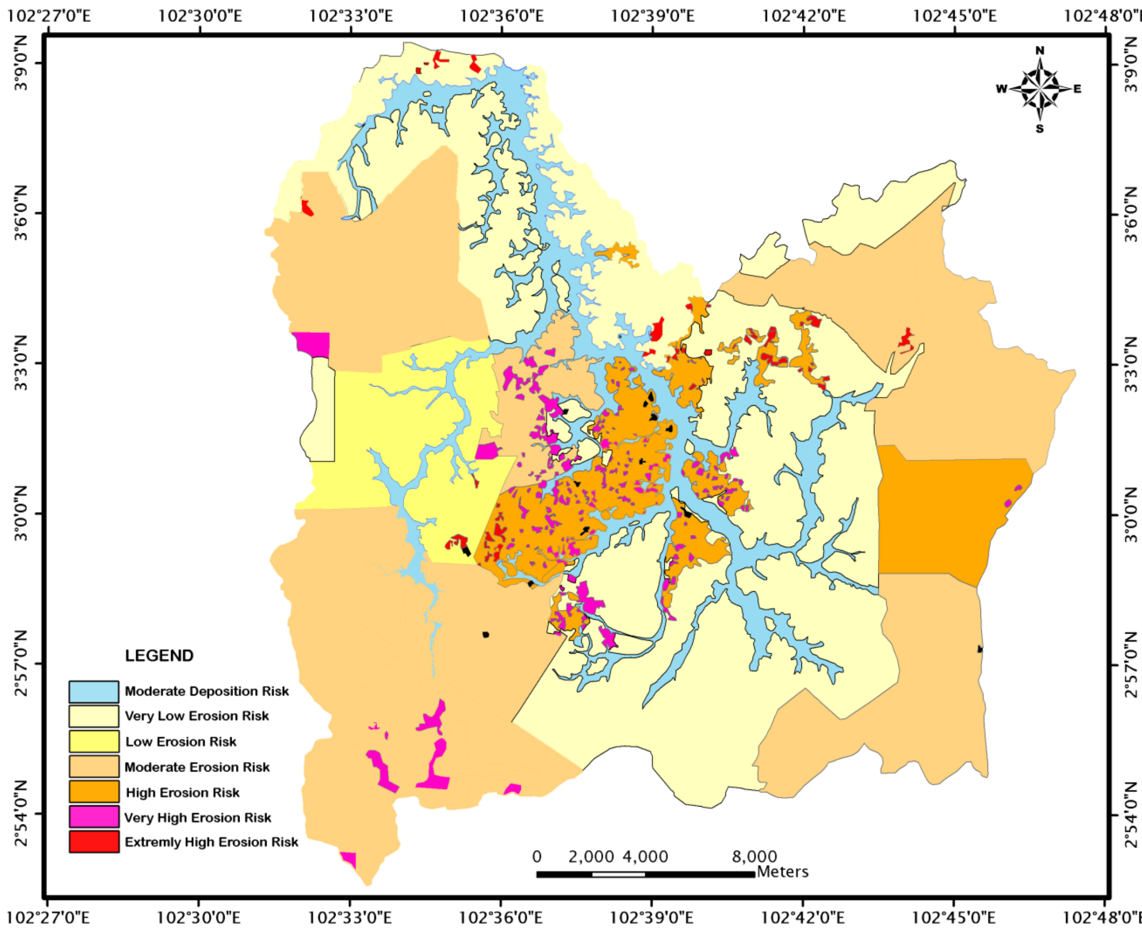

Figure 9.1: Soil erosion risk depicts priority management risk practices in study area

9.2.1.2. Construction of Retention Pond

A retention basin can be used to manage storm water runoff in order to prevent flooding and downstream erosion as well as improve water quality in an adjacent river, stream, lake or bay. It is an artificial lake with vegetation around the perimeter, and includes a permanent pool of water in its design (ASCE, 1998). Retention Ponds are increasingly being used in the agricultural sector and are often fairly small, typically less than 0.4 (ha). Such hydrological structures are recommended to be constructed along breaks in slope of the main stream in the Bera Lake sub-catchments (Fig. 9.3) where divergent currents terminate in the swamp forests.

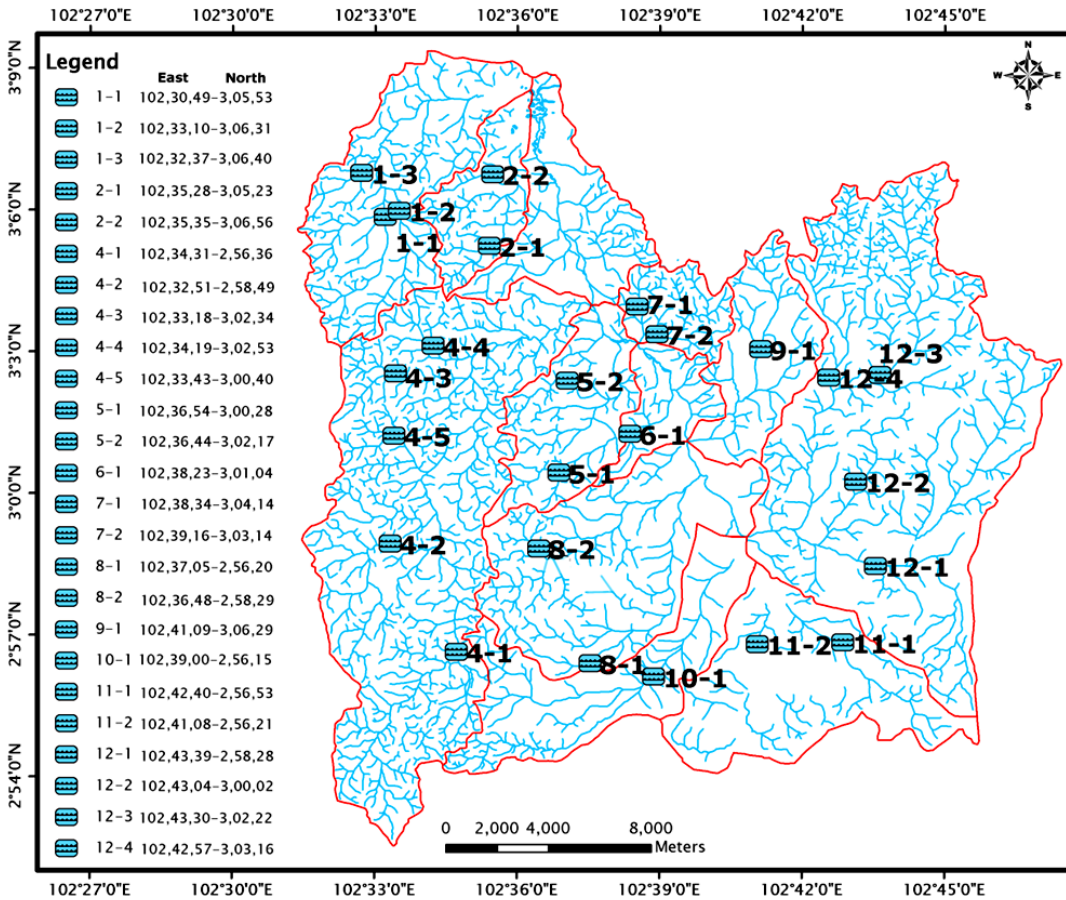

Figure 9.3: Suggested retention ponds at Bera Lake sub-catchments

Managing and controlling floods, sediments, pollution, and nutrient discharge into the sub-catchments is part of the sediment management plan which can be achieved with the construction of retention ponds. Their design and dimensions need to be determined by further hydrological studies in order to compute real water and sediment discharges from the individual sub-catchments.

9.2.1.3. Check Dams

Check dams are another recommended management practice for the Bera Lake catchment. Their primary benefits are to reduce scour and channel erosion by reducing flow velocity and encouraging settlement of sediment. The secondary purposes are preventing pollution, removing pollutants, and allowing recovery of nutrients and fertilizers. A check dam is a small device constructed of rock, gravel bags, sandbags, fibre rolls, or other proprietary product placed across a natural or man-made channel or drainage ditch (USEPA, 1992). Check dams are effective in small channels with a contributing drainage area of 0.8 to 4 (ha). Their design is dictated by runoff, slope, available materials, and management practices purposes. A detailed study needs to be carried out prior to the selection of the actual sites for construction of check dams in BLC.

9.2.1.4. Stream Reintegrate

Water-way management is identified as another necessary practice in the Bera Lake catchment. Field observations have highlighted the need to clear water-ways in the study area from deposited sediments (Fig. 9.4) and organic particles. The current situation of streams in the area, especially those in oil palm estates, is that they cannot handle runoffs causing overbank erosion and the loss of nutrients. Forested buffer strips (ODNR, 2000) can be another solution for stream management in Bera Lake. This is a multipurpose management practice which is suitable in study area. The cultivation of fruit trees in a buffer zone along most streams in the BLC is another multi-beneficiary management practice recommended for local residents. Construction of water-way, especially at junctions of streams can reduce over bank erosion.

Figure 9.4: Reduction in water way capacity due to sedimentation

The present situation of water-ways is that they are not suitable for runoff, resulting in retrogressive erosion at streams banks (Fig. 9.5). Slope pipe drains are another solution to control soil erosion in the study area. These pipes can convey concentrated runoff from bare soil especially those is developed land districts. Permanent culvert crossings furthermore, are a larger scale management practice as compared with slope pipes. Culverts can bypass maximum amounts of water from natural and artificial lands to properly control runoff.

Figure 9.5: Retrogressive bank erosion at BLC

9.2.1.5. Terracing and Silt Pits

Terracing can be highlighted as a proper safeguard for oil palm plantations that involve steep ground slopes, i.e. slopes exceeding 22 degree (Turner & Gillbanks, 2003). For slopes exceeding 10 or 15 degrees, terracing is highly recommended. If steep land is planted without proper preparation, as through planting were on flat land, then there will be very adverse results, both economic and environmental. Terracing is a good solution to stop excess water running freely away and serves the dual purpose of erosion control and water conservation. Terracing can also incorporate silt traps as non-continuous excavations along the contour; a continuous excavated section left every few meters to stop water actually running along them. The excavated earth is used to erect continues earth bank (Turner& Gillbanks, 2003). For planting terraces, the distance between each terrace would be the nominal limiting distance between palms, e.g. for 143 palms ha^{-1} this would be 9 meter (Fig. 9.6).

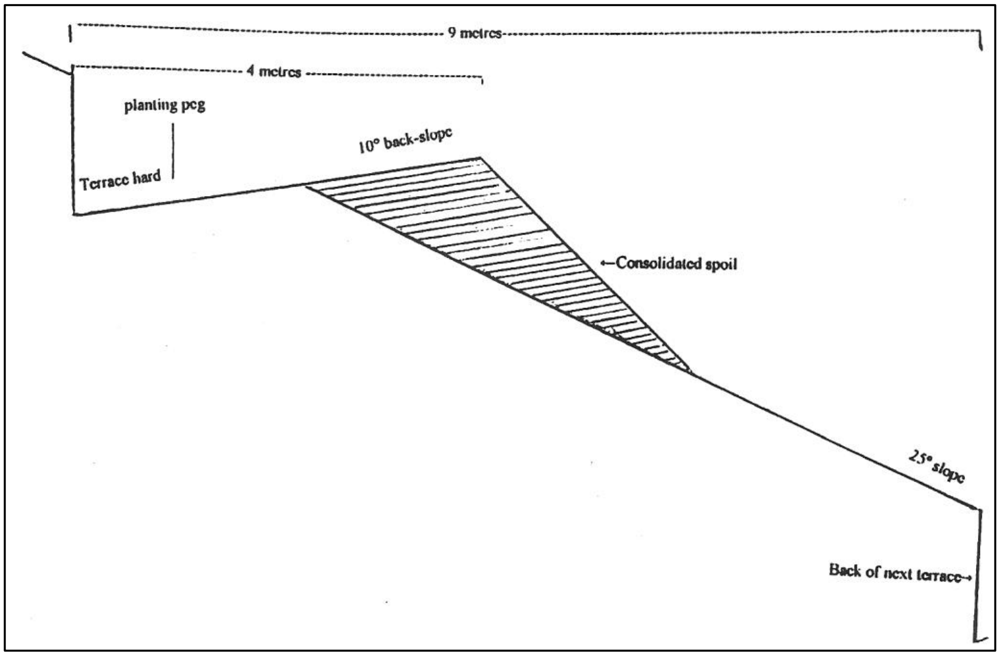

Figure 9.6: Diagram of planting terrace construction (after Turner& Gillbanks, 2003)

In the study area, ground slopes exceeding 10 degrees are mostly observed in sub-catchments 1, 4, 6, 7, 9, 11, and 12 (Fig. 4.4). The management practice of terracing is thus strongly recommended in the replanting of oil palm replantation at the BLC, together with the construction of silt traps to control soil and nutrients loss.

9.2.2. Agronomic Methods

9.2.2.1. Contour Line Cultivation

Contour cultivation refers to all tillage practices or mechanical activities as planting and tillage, which are carried out along the contours of an area. In low rainfall regions the primary purpose of contour cultivation is to conserve rain water by allowing it to infiltrate into the soil as much as possible. In humid regions, however, its basic purpose is to reduce soils erosion and/or soil loss by retarding overland flow. In this farming system the furrows between the ridges made on the contours will hold the runoff water and infiltrate it into the soil and in this way, reduce both runoff and soil erosion. Contour farming gives a better result in fields of relatively uniform slope and is not practical in fields having irregular topographical features. The use of grassed water-ways in conjunction with a contour farming system will be essential in reducing the development of gulleys. Contour cultivation is most efficient for reducing runoff and soil erosion from gentle slopes. Intense rain storms on steeper slopes allow the water to accumulate behind the ridges until it overflows and runs downhill.

Contour line cultivation is a recommended management practice to mitigate soil erosion as well as conserve water and nutrients in the cultivated land at Bera Lake catchment. This method should be used during replanting of oil palm and rubber plantations in the area.

9.2.2.2. Crop Management

Agro forestry, mixed farming, and cover crops are three effective measures (Table 9.1) in crop management practice in order to save water and soil resources and maximize income (Ahmad, 2001). Among the agro forestry systems that have been developed in Malaysia are direct inter-row integration, block planting, perimeter or border planting, and hedge planting system. The choice of timber species is important as it should be fast growing, light branching, deep rooting, self pruning, resistant to drought, diseases and pests, having soil improvement characteristics and having a high survival rate under adverse condition. In Malaysia, Teak (*Tectona grandis*) and Sentang (*Azadirachta excelsa*) have been identified as suitable timber species for commercial production (Ahmad, 2001).

Table 9.1: Agro forestry system, The Third National Agriculture Policy (Ahmad, 2001)

Main Crop	Viable Projects	Undergoing Research
Rubber	Rubber + Cash Crops Rubber + Sheep Rubber + Poultry Rubber + Apiculture Rubber + Mushroom	Rubber + Fruit Trees Rubber + Rattan Rubber + Timber Trees Rubber + Medicinal Plants Rubber + Bamboo
Oil Palm	Oil Palm + Cash Crops Oil Palm + Sheep Oil Palm + Cattle	Oil Palm + Timber Trees Oil Palm + Rattan Oil Palm + Medicinal Plants
Timber Species	Timber Species. + Cash Crop Timber Species + Tobacco Timber Species + Cash crops + Medicinal Plants	Timber Species + Fruit Trees Timber Species + Medicinal Plants Timber Species + Cash Crops + Medicinal Plants Timber Species. + Apiculture Timber Species + Animal Rearing

Crop management is an inevitable practice in the Bera Lake catchment especially in areas of developing oil palm and rubber where the plantations are immature and the soil surface is still exposed to physical and chemical weathering agents. Mature oil palm and rubber plantations in the study area (Fig. 9.7) can be evaluated on their potential for integration into buffalo, cattle, sheep and goat rearing. This practice can reduce stress on the rain forest (RAMSAR site) in terms of the food requirements for local residents. The cattle furthermore, can provide organic fertilizer and contribute to complete carbon and nitrogen cycles in cultivated land. FELDA can also develop a systematic scheme of multi-farming in the developed land in order to reduce food demands from the natural resources.

Figure 9.7: Feasibility of mature oil palm integrate into cattle feeding

9.2.2.3. Mulching

According to the conservation practice standard code 484 (NRCS, 2011), mulching implies the application of plant residue or other suitable materials produced off site, to the land surface. This management practice serves multi benefits to conserve soil moisture, reduce energy use associated with irrigation, moderate soil temperature, provide erosion control, suppress weed growth, facilitate the establishment of vegetative cover, improve soil quality, and reduce airborne particulates. This practice is strongly recommended in The Third Malaysia National Agriculture Policy especially for oil palm plantations and growing of vegetables. Potential annual biomass productivity in the Bera Lake catchment was estimated 1.5 million tons. Effective management of the biomass especially in the mature oil palm plantations and wetlands will provide a great opportunity for producing mulch for soil, water, and nutrient resources conservation in study area.

9.2.2.4. Organic Waste and Organic Fertilizer

Burning and waste disposal are two management issues in developed lands as the Bera Lake buffer zone. The high biomass productivity of tropical rainforests and forested lands also introduces organic waste as an issue in the Bera Lake catchment. In oil palm estates, dead fronds are aligned along rows of planted palms. The use of empty fruit bunches as mulch is also a popular practice. Most empty fruit bunches, however, were previously burnt to produce ash as a substitute for potash. It has recently been found that empty fruit bunches when used as mulch on planted oil palm seedlings, can hasten maturity to within 20 months as compared with 30 months for seedlings without empty fruit bunch mulch. The optimum rate of empty fruit bunch as mulching is 25 ton ha^{-1} for newly transplanted seedlings (Ahmad, 2001).

Field observations were confirmed by the application of organic waste as a management practice in mature oil palm plantations. Figure 9.8*a* and *b* shows application of empty fruit bunches to control soil redistribution from sheet and gully erosions, respectively. Remaining trunks and bunches have been used as a soil cover especially in newly opened lands at sub-catchments 6 and 8. Systematic disposal and application of organic wastes by government agencies and locals is thus one of the strong recommendations for effective nutrient recycling as well as water and soil conservation in the study area.

Figure 9.8: Application of empty fruit bunches for soil redistribution controlling

9.2.3. Research and Monitoring

Literature reviews and results of the current research project have emphasized the need for continued research programmes and monitoring of natural resources. The multidisciplinary importance of the Bera Lake catchment also highlights the need for a comprehensive research and monitoring program. The Director of the RAMSAR site is presently monitoring biological aspects of the study area as well as the water quality at 5 stations.

The present research has answered the main idea the RAMSAR site in terms of the dramatic drop in populations of the birds and fishes at Bera Lake. Several distinct layers of the Bera Lake sediments are polluted by heavy metals and in toxic conditions for aquatic life. The Bera Lake catchment nevertheless, includes developed land and natural habitats that are suffering from management issues which need a broad research and monitoring program. This study firmly recommends the following topics for research and monitoring programmes as their objectives are based on gaps in the present data as well as importance of the study area.

1. Hydrological Stations: Measurement is fundamental to assessing water resources and understanding the processes involved in the hydrologic cycle. The Bera Lake catchment needs the construction of two permanent gauges with auto-recording and remote control, at the entrance and outlet of the main open water in order to identify long-term variations in water and sediment discharge, water quality, water balance and fluctuations. Temporary hydrological gauges are also recommended for each sub-catchment in order to identify seasonal and long-term water and sediment discharge. These proposed hydrological stations will provide significant data for determining the agricultural water balance, predicting flood, designing irrigation schemes and managing agricultural productivity. They will also provide valuable information on geomorphological changes, such as erosion or sedimentation, assessing the impacts of natural and anthropogenic environmental change on water resources, and assessing contaminant transport risk and establishing environmental policy guidelines.

2. Soil loss plots: Literature reviews show that on-ground soil loss measurements in the Bera Lake catchment have never been performed and the application of fallout ^{137}Cs radionuclide in present study is the first attempt. Construction of soil loss plots in the study area is thus strongly recommended in order to estimate real soil erosion and run-off especially from cleared and under developing lands. Their design and monitoring, however, will need a comprehensive study in order to formulate an appropriate model.

3. Weather stations: Currently, the Fort Iskandar weather station is responsible for climate information on the Bera Lake catchment. Available records of this station

are, however, not complete and reliable for proper scientific studies. A large catchment as the Bera Lake (with an area of ~ 600km^2) which is located between two main mountain ranges requires a more comprehensive weather stations with facilities for wireless equipment. The construction of weather stations especially at the RAMSAR site and FELDA administration sites for recording long-term weather data for management purposes is recommended strongly.

4. Flora and Fauna Stewardship: The literature review has revealed valuable information about the biological aspects of the study area. The flora and fauna diversity at Bera Lake is being investigated by staff at the RAMSAR site and by University of Malaya biologists. These studies mostly involve the main open water, but a comprehensive management plan will require a complete program of flora and fauna stewardship in the whole of the catchment area. Field observations and conversation with local residents has revealed the importance of the natural flora and fauna to the local economy. The wild species and livestock are therefore, an active parts of the Bera Lake catchment and will require a complete management program for conservation of the natural resources.

9.2.4. Socio-Economic Controlling

The fourth angle of a comprehensive management plan that has been recognized is socio-economic monitoring (Darabaris, 2008). The settlements and their socio-economic issues are directly affecting the natural resources in the Bera Lake catchment. Jobs and skill creation, business ethics and social investments are the main topics of this monitoring. The Bera Lake catchment is the sanctuary of a group of indigenous people (Semelai). This community today numbers about 4,000; some 1,500 of whom live in the Bera Lake catchment (Chong, 2007). As with other indigenous people, the Semelais have a strong affinity with their natural surroundings. Over generations, they have adapted to survival in the area through utilizing the natural resources. They use the plants and flowers around Bera Lake for medicinal purposes, as prophylactics, as intoxicants and as aphrodisiacs (DANCED, 1998). Their economy entirely depends upon the natural resources in the Bera Lake catchment. Some of the indigenous people work in the FELDA plantations as laborers. The main management practice in socio-economic monitoring is the need for special education programmes that will improve the agricultural skills as well as business ethics of the indigenous people (Sharip et al., 2007). Educated indigenous people will definitely conserve and harvest the natural resources properly. FELDA can also play an important role by improving the skills of staff to conserve soil and water resources, especially in the buffer zone (cultivated lands). These management practices will provide a guarantee to reduce the adverse environmental impacts of re-planting oil palm plantations.