IMPACTS OF LAND USE ON WATER QUALITY OF SIMILAJAU NATIONAL PARK, BINTULU, SARAWAK:
A CASE FOR INTEGRATED WATER RESOURCE MANAGEMENT

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Abstract

Water is considered as one of the most important components of the ecosystem. The conditions of the water resource within and flows through the drainage systems of the Similajau National Park determine the long-term ecological integrity of the Park. The appropriate planning approach and desired management interventions must be designed and aligned towards the maintenance of environment water quality requirement for sustainability of the overall ecosystem functions.

A study was undertaken from the month of May to August 2001 to characterize the watershed geomorphology and hydrology of the Sebubung and Seroba Watersheds, and assessment of water quality of the two rivers namely Sebubung River and Seroba River. The rivers flow through the Park prior to discharging their waters into the South China Sea. The upstream and the headwaters of the two rivers lie outside the Park, one within the newly established oil palm plantation and the other logged over area, respectively.

Thirty water samples were collected and analyzed for Total Suspended Solids (TSS), Suspended Solids, Total Coliform, Fecal Coliform, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Nutrients (Ammonical Nitrogen and Phosphate). In-situ measurements for Dissolved Oxygen (DO), Temperature, pH, Total Dissolved Solids (TDS), Salinity, Oxidation Reduction Potential (ORP), and Turbidity were conducted at eight sampling points, five along Sebubung River and three along Seroba River.

This study indicates that the TSS, Turbidity, BOD, and COD of the water of Sebubung River whose upstream zone and head waters currently under active establishment stage of conversion to oil-palm plantation, exhibited higher mean values relative to the water of Seroba River. Mean TSS and Turbidity under low flow recorded at sampling points WSB1 158.67 mg/L, WSB3 188.67 mg/L, WSB5 52.0 mg/L, and WSB6 72.0 mg/L. However, comparative analysis between water quality of Sebubung River and Seroba River indicated that only turbidity and TSS were significantly different at 95% confident level.
Abstrak

Air dianggap salah satu daripada komponen ekosistem yang penting. Keadaan sumber air yang terdapat dan mengalir melalui system-sistem sungai di Taman Negara Similajau menentukan dalam jangka panjang integriti ekologinya. Pendekatan perancangan yang sesuai dan tindakan pengurusan yang tepat mestilah direka bentuk dan selari dengan pengekalan kualiti air alam sekitar untuk kemapanan keseluruhan fungsi ekosistem.


Kajian ini menunjukkan bahawa Junlah Pepejal Terampai (TSS), Kekeruhan, Permintaan Oksigen Biologikal (BOD) dan Permintaan Oksigen Kemikal (COD) bagi air Sungai Sebubung dimana zon hulu dan punca air sedang secara aktif diperingkat penubuhan dan pertukaran kepada ladang kelapa sawit, memperlihatkan nilai-nilai min lebih tinggi berbanding air Sungai Seroba. Min Junlah Pepejal Terampai (TSS) dan Kekeruhan pada aliran rendah direkodkan di tapak sample WSB1 15.87 mg/L, WSB3 18.87 mg/L, WSB5 52.0 mg/L, dan WSB6 72.0 mg/L. Walau bagaimanapun, analisis perbandingan antara kualiti air Sungai Sebubung dan Sungai Seroba menunjukkan hanya Kekeruhan dan Junlah Pepejal Terampai mempunyai perbezaan yang bererti pada paras 95% tahap kepastian.
CHAPTER ONE

1.0. INTRODUCTION AND BACKGROUND

1.1. Totally Protected Areas of Sarawak

The State of Sarawak has designated one million hectares or about ten percent of its total land area as Totally Protect Areas, comprising national parks, wildlife sanctuaries, and nature reserves. Totally Protected Areas are constituted for the preservation of unique geological, historical, cultural heritage, conservation of natural habitats and bio-diversity, as research and educational sites, protection of natural water sources, and recreations. To date about 0.3 million hectares of the designated areas have been constituted and 0.7 million hectares are the various stages of constitution processes (Anon, 2000a).

Currently, there are 14 constituted national parks with the total area of about 0.17 million hectares. The predominant management and development strategies formulated related to the national parks centered around the provision and development of administrative facilities or park offices, enhancement of tourism attraction and amenities, and to limited extent field research studies. Protection and enforcement activities focus on minimizing the impacts of tourist visitation and activities and illegal hunting and encroachment. Such management strategies ignore the impacts of the adjacent land or total landscape changes on the integrity of the parks and the threat on their existing functions related bio-diversity conservation and protection of unique natural features that serve as the tourist attraction to the parks. One of those features is the water-bodies such as rivers, waterfalls, and creeks.

1.2. Water Resource Management In Malaysian National Parks

A national park depicts a resource management entity, with general and specific objectives dictated by the spatial and temporal economic, social and environmental needs of the biophysical or political system. Essentially, a national park consists of mix of natural resources with varied physical and biochemical attributes and differs in terms of quantity and quality. These patterns have given rise to the dynamics of the bio-geographical setting of a national park and define its uniqueness that justifies its creation or establishment.

Water resource is among one of the major resources that constitute the resource mix of a national park especially in the equatorial humid region such as Malaysia. The water-bodies such as rivers, streams, creeks and lakes serve as the significant tourism attractions in their pristine forms. In the undisturbed state the water resource provides important habitats for varied species of wildlife that dwell within them. Water resource also serves as the most critical component of the environment and life support system.
Considering the prime contribution of water resource it is imperative that equitable attention should be made towards its effective management. However, much of the management interventions are solely directed in addressing the tourism aspects of the water resource development manifested by the level of financial commitment for water based recreational infrastructures and facilities. Environmental consideration of management interventions is still lacking and to certain extent reactive in nature. Occurrences of severe soil erosion and landslips nearby recreation spots may trigger immediate visual assessment and implementation of physical mitigation measures. But such actions are temporary and long-term mitigation plan is absent. Comprehensive assessment and monitoring of physical, biological, and chemical condition of water resource is still yet to be desired. Management of the park's resources is predominantly fragmented and resource specific. Connectivity of aquatic and terrestrial resources and integrative function of the water resource in landscape processes in form of watersheds and river systems is still ignored.

Analysis of management plans of Bako National Park (NPWO, 1998) and Mulu National Park (NPWO, 1992) revealed that management prescriptions are limited to impacts of development of administrative headquarters, trails and access road construction on the state of water resource. Thus the recent assessment of park management plan called for extension of areas of the national parks that would lead to incorporation of complete watershed within the national parks (Tisen, 1999). Incorporation of the whole watershed within the realm of the national park is the prerequisite for the protection and effective management of water quality and hydrologic regime of the river systems therein.

1.3. Motivation for the Study

The landscapes of the State of Sarawak are undergoing fast and extensive land use changes. These accelerated land use changes are justified by the need for resource exploitation such as timber to generate income to fuel the economic growth and transformation. Official documents offered revealing statistics of the significant contribution of logging and timber industry to the Sarawak's economy (Anon, 2000b). Logging and timber sector have been the number one provider of State's income and second to petroleum and petroleum products in term of foreign exchange earnings. Logging inadvertently paved the way for the proliferation of agriculture due to the provision of access to the hinterland in the form of hauling routes or logging roads. Of late, notably in the mid eighties and nineties large tracts of the once forestlands had been converted to large-scale mono-crop agriculture holdings especially oil palm plantations.

Land use change of within the dissected hilly topography and at the headwaters or upper zone of the watersheds coupled with high rainfall intensity have led to imminent occurrence of accelerated of surface run off, soil erosion and the resultant deterioration of water quality. Interestingly, the extraction of timber and subsequent land conversion are sometimes within same watersheds as the national park or at the upstream. Thus, the very integrity of the national park is at stake and...
symbolizes the irony of ecological and biodiversity conservation as enshrined in the management plan of the park.

The study also serves to portray the integrative function of the watershed in the landscape or bioregional processes and the cause-effect relationship as exemplified by the upstream and downstream linkages through water or water bodies as media of physical and chemical transports. Choice of watersheds and a national park as study units and logging and oil palm cultivation as land use change provide excellent venue for spatial and comparative analysis of land use impacts on water quality (Gumal, MT and Ahmad, S. (1995).

The long-term park management objectives of environmental conservation and sustainable provision recreational opportunities hinges upon the state of water resource within the park and in the adjacent lands. Thus characterization of the water quality and the level of physical and chemical impairment of the water bodies would provide the base line information for management intervention at park level and inputs for regional integrated water resource and land use planning.

1.4. Research Needs

The need to undertake the study lies upon the state of environmental conditions emerging from within and outside the Park physical environments and the level of effectiveness of the current management both in its technical perspective and approach. Environmental issues and aspects evolve as the Similajau National Park geographically lies within the middle and downstream of the watersheds, and becomes the recipient of environmental stresses and perturbations, the products of upstream anthropogenic activities. There has been and still on going extensive forest conversion and landscape modification taking place in the immediate upstream areas of the watersheds bordering the Park. There are strong linkages and iterative environmental interfaces between the adjacent areas and the ecosystem of the Park.

There are eminent and anticipated effects and impacts of vegetative cover removal and landscape modifications that threaten the ecological integrity of the Park, notably Park’s hydrology, water quality and aquatic ecosystem. Hydrologic and water quality parameters such as water yield, stream flow velocity, soil loading, nutrient loading, pH, temperature, dissolved oxygen, and biological oxygen demand may already experienced certain level of change with possible ecological impairment.

1.5. Selection of the Study Area

Delimitation of the case study area was undertaken with the aid of the analog locality maps, logging progress maps and agriculture plantation maps of the Forest Department Sarawak and satellite imagery of the Similajau Basin taken in the year 2000. The data gathered from the analog maps and the satellite imagery indicated that the upper catchments of the Sebubung and Seroba Rivers, respectively, the
former is under active transformation to oil palm plantations and the later had been
duly under logging until the year 2000. The logging activities were just adjacent to
the northeast portion of the Similajau National Park, where as agriculture
conversion is in progress adjacent to the southwest of the national park. Thus the
catchments provided excellent areas for comparative assessment of impacts of
differing land use on the state of water quality of the two rivers. The existence of
the national park, logging and agriculture within the same landscape serves to
potray the impacts of conflicting land use and weaknesses of the current land use
planning and environmental management in Sarawak.

1.6. Selection of Sampling Points

The location of the sampling points were determined by examination of GIS/Arc
Info layers comprising the two catchments, logging roads, rivers and streams,
vegetation types and landuse. Ground thruthing were conducted to evaluate the
ground conditions with respect to stream morphometry, flows, and the proximate
position relative to the total catchment stream networks and area. The selected
locations of the sampling points took consideration of the ease of field sampling
works or accessibility and the representative of the catchment attributes of land use,
topography, stream order, and soil type.

Ground thru thing was guided by the locality maps and progress logging maps of
the Forest Department Sarawak. The distribution of sampling points are as shown
in Table1A and Figure 1

Table 1A. Distribution of sampling points along Sebubung and Seroba Rivers

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<td>--------------</td>
</tr>
<tr>
<td>1</td>
<td>WSB1</td>
</tr>
<tr>
<td>2</td>
<td>WSB2</td>
</tr>
<tr>
<td>3</td>
<td>WSB3</td>
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<td>4</td>
<td>WSB4</td>
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<tr>
<td>5</td>
<td>WSB5</td>
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The location and number of the sampling points would capture effects of the
varying land use and the spatial orientation of the water quality condition attributed
to the geographic aspects of the two watersheds.

1.7. Choice of Land Use Impacts Parameters

Selection of appropriate environmental impact parameters was based on the
expected contributory relational cause - effects function of water quality and
landuse. It was postulated from background literature reviews that the following
water quality parameters are relevant as determinants of land use impacts namely
logging and agriculture on the immediate or ambient water bodies. Table 1B shows
the water quality parameters measured during the study.
Figure 1: Location of Sampling Points
Table 1B. List of Water Quality Parameters Measured.

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<th>Parameter</th>
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<td>TSS</td>
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<td>Turbidity</td>
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<td>NTU</td>
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<td>Dissolved Oxygen</td>
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<td>Biological Oxygen demand</td>
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<td>Mg/liter</td>
</tr>
<tr>
<td>Acidity / Alkalinity</td>
<td>PH</td>
<td>pH</td>
</tr>
<tr>
<td>Temperature</td>
<td>Temp</td>
<td>°C (degree centigrade)</td>
</tr>
<tr>
<td>Ammonical Nitrogen</td>
<td>(NH) N</td>
<td>Mg/liter</td>
</tr>
<tr>
<td>Phosphate</td>
<td>Phos</td>
<td>Mg/liter</td>
</tr>
</tbody>
</table>

Logging and agriculture such as plantation development involved vegetation and soil mass removal. Vegetation removal resulted in increased surface run-off and elevated rainfall energy that consequently acted on the soil mass on the top horizon that triggered surface or sheet erosion. Soil material transportation would ensue along the slopes towards the lower elevation and deposited or finally entered the water bodies such as rivers or streams. Within the water bodies the soil material in motion are known as suspended load or the bed load. Soil material transportation rate is the function of grain size and stream flow such as discharge volume and velocity. Deposition of soil material would start with the decreasing flow velocity and river channel gradient.

Soil and sediments physical, biological and chemical composition within the water bodies either in motion or duly deposited would characterize the physical, biological and chemical conditions of the water column. The reactive processes following transportation and sedimentation also tend to change the natural condition or attributes of the water.

The selected water quality parameters would suffice to characterize the water quality impacts of the respective land use namely logging and agriculture and by inductive assessment processes would indicate the resultant impacts on the ecological integrity of the Similajau National Park.
CHAPTER TWO

2.0. LITERATURE REVIEW OF LAND USE IMPACTS

2.1. Impact Assessment And Natural Resource Management and Development

Impact assessment has been one of the significant tools of resource management and development since the last two decades (Smith, 1993). There has been mixed outcomes of such programs and there has been numerous failures of the past impact assessment practices. The basis of these failures was the state of the art in impact assessment methods and methodology. It was argued that appropriate method exists to conduct impact assessment but that the science of impact assessment has not been strong (Smith, 1993). Moreover, the dominant paradigm for impact assessment has emphasized the production of an impact statement as the means to provide information to decision makers regarding the appraisal of project implementation. This is a narrow focus and it has inhibited the ability of impact assessment to address such issues as risk, uncertainty and cumulative effects. Presently, impact assessment has good technique but poor process (Clark & Herington, 1988).

The need is for impact assessment to become integral to environmental planning and resource decision-making rather than just serve as a check upon them (Bisset, 1983a). This is a new role for impact assessment. It requires the redefinition of impact assessment and the reconsideration of its function within a broader resource management context. To this end, impact assessment should be redefined as a process of environmental planning that provides a basis for resource management to achieve the goal of sustainability. This definition requires that impact assessment become a bridge to integrate the science of environmental analysis with the politics of resource management. Central to this design are the institutional arrangements for decision-making that define the provisions for impact assessment in resource management. These provisions must then be understood and implemented within the framework of components, namely: the policy process, interest representation and impact assessment as a process of environmental planning (Smith, 1993).

2.2. Agriculture And Water Quality

It is well known that agriculture is the single largest user of freshwater resources, using a global average of 70% of all surface water supplies (ESCAP, 1994). Except for water lost through evapo-transpiration, agricultural water is recycled back to surface water and/or groundwater. However, agriculture is both cause and victim of water pollution. It is a cause through its discharge of pollutants and sediment to surface and/or groundwater, through net loss of soil by poor agricultural practices, and through salinization and water-logging of irrigated land. It is a victim through...
use of wastewater and polluted surface and groundwater which contaminate crops and transmit disease to consumers and farm workers. Agriculture exists within a symbiosis of land and water and, as FAO (1990) makes quite clear, "... appropriate steps must be taken to ensure that agricultural activities do not adversely affect water quality so that subsequent uses of water for different purposes are not impaired."

Sagardoy (FAO, 1993) summarized the action items for agriculture in the field of water quality as:

- establishment and operation of cost-effective water quality monitoring systems for agricultural water uses.
- prevention of adverse effects of agricultural activities on water quality for other social and economic activities and on wetlands, *inter alia* through optimal use of on-farm inputs and the minimization of the use of external inputs in agricultural activities.
- establishment of biological, physical and chemical water quality criteria for agricultural water users and for marine and riverine ecosystems.
- prevention of soil runoff and sedimentation.
- proper disposal of sewage from human settlements and of manure produced by intensive livestock breeding.
- minimization of adverse effects from agricultural chemicals by use of integrated pest management.
- education of communities about the pollution impacts of the use of fertilizers and chemicals on water quality and food safety.

### 2.3. IMPACTS OF FOREST HARVESTING

#### 2.3.1 Leaching of Nutrients from Disturbed Forest Watersheds

Various studies have demonstrated that soluble nutrients can leach from forested watersheds after disturbance by cutting or wildfire (Tamm *et al.*; 1974; Cobette *et al.*; 1978; Hornbeck & Ursic, 1979; Hornbeck *et al.*; 1987a). This process causes a reduction of site nutrient capital that is incremental to the nutrients that are removed with harvested biomass. Leaching is especially important for nutrients that are relatively mobile in soil, such as nitrate and potassium.
A frequently cited example of this effect of forest disturbance is a study done at Hubbard Brook (Bormann et al., 1974; Liken et al., 1978), New Hampshire. Over a 10-year post-disturbance period, the deforested watershed had a stream-water loss of 499 kg/ha of NO$_3$-N, 450 kg/ha of Ca, and 166 kg/ha of K. These were much larger than the losses from an undisturbed reference watershed of 43 kg/ha of NO$_3$-N, 131 kg/ha of Ca, and 22 kg/ha of K (Bormann et al.; 1974; Likens et al.; 1978). The effect on nutrient flux in stream water was partly due to an average 3-year increase of 31% in the yield of water from the cut watershed, which was caused by the disruption of transpiration. More important, however, was an increase in nutrient concentration in the stream water, by factors of 40 for NO$_3$, 11 for K, 5.2 for Ca, 5.2 for Al, 3.9 for Mg, and 2.5 for H$^+$ (Bormann & Likens, 1979).

There are several reasons why nitrate and other ions are leached from watersheds after disturbance.

a. After disturbance there is an increase in the rate of decomposition of organic matter, causing the release of soluble forms of nutrients. The rate of decomposition can be increased to disturbance, including a warmer surface soil, an influx of organic matter to the forest floor, and an increased availability of inorganic nutrients and moisture, due in part to a decreased uptake by higher plants in the first years after disturbance (Cole & Gessel, 1965; Cole et al.; 19750; Likens et al.; 1970; Bormann et al.; 1974; Bormann & Likens, 1979; Piene, 1974; Harvey et al.; 1976, 1980; Jurgensen et al., 1979).

b. Ammonification converts organic N to ammonium, which can be oxidized to nitrate by the bacterial process of nitrification. This process enhances the potential leachability of the fixed nitrogen capital of the site, since nitrate is very mobile in soil. In some situations, the rate of nitrification is greatly increased after disturbance; in other cases it is not, especially if the soil is acidic (Likens et al.; 1970, Reinhart, 1973; Bormann & Likens, 1979; Wallace & Freedman, 1986).

2.3.2 Soil Erosion Resulting from Disturbance

Severe erosion has occurred on many deforested watersheds, particularly those containing steep slopes. Frequently, erosion is triggered by poor forestry practices, including the faulty planning and construction of logging roads, the clear-cutting of forest immediately adjacent to water bodies, running skid trails down slopes instead of along them, and removing forest from steep slopes that are hypersensitive to soil loss (Packer, 1976a). Sever erosion of soil has many ecological impacts, including (1) the loss of mineral soil substrate, which in severe cases can expose bedrock; (2) the loss of soil nutrient capital; and (3) secondary effects on recipient aquatic systems, including siltation, flooding hazard, and the destruction of fish habitat. Because of the damage that can be caused by erosion after forest harvesting on some sites, the phenomenon has been the focus of much research, and several reviews have been published (Rice et al.; 1972; Fredriksen et al.; 1975; Anderson et al.; 1976; Corbett et al.; 1978; Hornbeck and Ursic, 1979; McColl and Grigall, 1979).
The most important factors that characterize erosion from harvested lands are (Rice et al.; 1972) (1) most logging activities increase the rate of erosion from forested lands; (2) erosion is spatially variable on harvested sites (3) initially there is a large rate of sedimentation in streams after disturbance, followed by a rapid reduction to the pre-disturbance condition, usually within 2-5 years; (4) landslides and creep are the quantitatively most important erosional processes in mountainous areas; (5) steep slopes are especially vulnerable; and (6) road building is a very important factor in the initiation of erosion, especially the inadequate number or size, or the improper installation, of culverts.

Studies of erosion from harvested watersheds have shown a wide range of effects, with soil loss measured as suspended sediment ranging from much less than 1 to 5 MT ha⁻¹year⁻¹ (McColl and Grigall, 1979). Megahan and Kidd (1972) studied a harvested Pinus ponderosa watershed in Idaho with an average slope of 70%, and found a 6-year average erosion loss of 4000 kg ha⁻¹year⁻¹, compared with 90 kg ha⁻¹year⁻¹ from an uncut reference watershed. Haupt and Kidd (1965) reported a much smaller effect in another P.ponderosa watershed in Idaho with a 35-55% slope, where the 5-year postharvest sediment loss averaged 120 kg ha⁻¹year⁻¹, compared with essentially zero for an uncut watershed.

Many studies have shown that a large erosional loss from watersheds managed for timber production can be prevented by following certain operational guidelines (Packer, 1976a; Kochenderfer, 1970; Rothewell, 1971; Simmons, 1979; Miller and Sirois, 1986). These include (1) the careful planning of forest roads; (2) the installation of a sufficient number of adequately sized culverts; (3) the avoidance of direct disturbance to stream beds by heavy equipment; (4) leaving a buffer strip of uncut forest along water courses; (5) the use of skidding techniques that minimize the physical disturbance of the forest floor, for example, cable or skyline yarding; (6) allowing or encouraging a vigorous regrowth of vegetation so as to speed the reestablishment of biological control over erosion; and ultimately (7) a decision to leave hypersensitive site uncut.

Many researchers have identified logging roads that were poorly planned, constructed, or maintained as the primary factor causing erosion from many harvested watersheds (Haupt & Kidd. 1975; Corbett et al.; 1978; McColl and Grigall, 1979). Dyness (1967) found that following a severe rainstorm in a 6000-ha watershed in mountainous terrain in Oregon, 72% of 47 massive erosion events were associated with roads, even though roads accounted for only 2% of the terrain. The highly compacted, mineral substrates of roads and skid trails are susceptible to erosion because they encourage the overland flow of water. Compacted soil of this sort was found to be present on 20% of a harvested area in Nova Scotia present on 20% of a harvested area in Nova Scotia (Henderson, 1978), and 10% of another area in Newfoundland (Case & Donnelly, 1979).

A buffer strip of uncut forest adjacent to streams, rivers, and lakes can reduce erosion after harvesting of the forest. A buffer strip can also reduce or eliminate temperature increases in water, preserve riparian habitat for wildlife, and reduce the esthetic impacts of harvesting (Van Groenwoud, 1977; McColl & Grigall, 1979). While it is generally accepted that buffer strips have these mitigative effects, there
is no consensus as to the width of uncut strip that should be used. This is an economically important consideration, since a large area of merchantable timber can be withdrawn from the potential harvest when uncut buffer strips are designated. Trimble & Sartz (1957) recommended a strip width of only 8 m between logging roads and streams on level sites in the U.S., and an increase in width of 0.6 m for each 1% increase in slope of the land. However, they recommended that the strip width be twice as large on municipal watersheds, since the requirement for good water quality is greater in the case of drinking water.

2.4. Hydrologic Effects of the Disturbance of Watersheds

Forest vegetation exerts a powerful influence on watershed hydrology, and this can be important in terms of preventing erosion and downstream flooding, and in reservoir management. This hydrologic effect is caused because transpiration by vegetation evaporates a large quantity of water into the atmosphere (Freedman et al., 1985). In the absence of this process an equivalent quantity of water would exit the watershed as stream flow or seepage to deep groundwater (actually, this overstates the effect somewhat, because in the absence of a forest canopy the rate of non-biological evaporation is enhanced). Freedman et al.; (1985) studied four gauged forest watersheds with shallow soil and impervious bedrock in Nova Scotia. On an annual basis, evapotranspiration ranged from 15% to 29% of the total precipitation input. Runoff via steams or rivers accounted for the remaining 71-85% of the atmospheric input of water.

The influence of the forest on watershed hydrology is affected by disturbance caused by cutting or wildfire. Effects include changes in the timing and amount of stream flow, with secondary downstream effects such as flooding and erosion. In addition, on an imperfectly drained site there can be change in the height of the water table (Hibbert, 1967; Douglass & Swank, 1972; Hornbeck & Ursic, 1979).

The increase stream flow from a watershed is roughly proportional to the severity of the harvest, that is, in terms of the relative amount of foliar transpiration surface that is removed (Troendle, 1987). The increase in flow can be as large as 40% in the first year after the clear-cutting of an entire watershed. Rothacher (1970) found a stream-water yield increase of 32% in a totally clear-cut Douglas-fir (Pseudotsuga menziessii) watershed in Oregon, compared with a 12% increase in another watershed that was clear-cut over 30% of its area. Reinhart et al.; (1963) compared four cutting methods that differed in the intensity of tree removal from mixed-hardwood watersheds in West Virginia. The most intensive technique was clear-cutting, which caused an increase in water yield of 19% in the first postcutting year. In comparison, a less intensive diameter-limit cut caused a 10% increase, and a selection cut caused only a 2% increase.

Usually, the largest increase in stream flow takes place in the first post-cutting year, with a rapid recovery to the precutting condition after 3-5 years because of revegetation and the consequent re-attainment of transpirational surface area of foliage (Douglass & Swank, 1975). In many temperate regions, the largest increases in stream flow occur during late spring, summer, and early autumn, when
transpiration normally exerts its strongest influence on watershed hydrology. Douglass and Swank (1975) monitored stream for 6 years. In the first post-cutting year there was an increase in yield of 11.4 cm; this decreased to 7.3, 5.0, 3.3, 2.0, and 0.9 cm in subsequent years. Hydrologic effects were measured for the previously described 16-ha hardwood watershed at Hubbard Brook that was clear-felled and then herbicided for 3 years. In the first 3 post-disturbance years there were increases in stream water yield of 40%, 28%, and 26%, respectively. However, in the second full season after cessation of the herbicide treatment of the experimental watershed, the hydrologic effect largely disappeared because of the vigorous regeneration of vegetation (Likens, 1985). A similar effect was observed in a clear-felled and herbicided 60-ha watershed in West Virginia, where 5 years after the cessation of herbiciding the stream water enhancement was reduced to about 20% of the initial impact, again because of a rapid re-vegetation of the site (Kochenderfer & Wendel, 1983).

Forest management can also affect the size and timing of the peak steam-watershed. These effects can occur both for storm flow and for spring meltwater flow (Hewlett & Helvey, 1970; Leaf & Brink, 1972; Very, 1972; Hornbeck, 1973; Swanson et al.; 1986; Hornbeck et al.; 1987a). The storm-flow effect takes place because deforested terrain has a relatively small ability to moderate the speed of the lateral flow of water, and thereby enhance its rate of percolation into the ground and ultimately to stream water. This occurs because the compacted soils that are often present in harvested watersheds encourage overland water flow.

A change in the nature of the forest community can also affect hydrology. After the conversion of a mixed hardwood forest to a white pine (Pinus strobes) forest in the southern Appalachians of the eastern United States, there was a decrease in annual stream flow of about 20% (Douglass & Swank, 1975). The reason for this effect was that the pines had a more extended transpiration season than did the seasonally deciduous angiosperms that they replaced. In the same region, the conversion of a mixed-hardwood forest to a grassland resulted in a long-term increase in water yield (Douglass & Swank, 1975).

Perhaps the opportunities did not arise due to the stringent requirements of such impact studies that can only be carried out over a considerable period of time. There is therefore a dearth of information in Malaysia on the progressive changes in the characteristics of water quality, quantity and regimes before deforestation, during the various stages of deforestation and subsequently replaced by other forms of vegetation. In fact most researches to date with the exception of the Sungei Tekam and Jengka studies, have been carried out on an ad hoc basis whenever opportunities arose and resources were available.
2.5. Forest Stand Influences

Forest cover maintains very low erosion rates and consequently low suspended sediment concentration in streams. Forest litter protects the soil from rain drip impact and helps maintain high infiltration. Thus surface erosion is seldom a problem in undisturbed forest. Tree roots also help reduce mass soil movement even on steep slopes (Lee, 1980). The degree of soil erosion is dependent on slope, vegetative cover, soil type and precipitation (Daniel & Kulasingam, 1974).

Timber harvesting is an ecosystem disturbance with potentially drastic impacts on the quality of stream flow. Increase in erosion and sedimentation following deforestation has been reported frequently. However, Brown (1979) pointed that felling trees is usually insufficient to produce increases in turbidity and suspended sediment. Rather, it is the extracting of logs, which often causes soil disturbance and consequently erosion. Kocherderfer and Aubertin (1975) found that when exceptional care was used in the location, construction and maintenance of skidtrails, roads and landings, stream turbidity increases were relatively small compared with the effects produced by commercial harvesting methods with minimum or no controls.

The compacted surfaces of logging roads and skidtrails, increases surface runoff during storms thus become significant sources of sediment in streams. The problem is compounded if road drainage systems are poorly planned of maintained, but may interdict normal subsurface flow patterns as well (Brown, 1979). Movement of sediment downslope from a road depends on the amount and velocity of runoff, availability of erodible soil and obstructions to sediment transport (Haupt, 1959).

Successful erosion prevention and control depend on the care and skill in skidding and hauling logs and in the construction and maintenance of trails and roads used for these purposes (Anderson et al. 1976). A clear-cutting operation on the Fernow Experimental Forest (Hornbeck, 1967), where skidroads were carefully laid out, drained and maintained, yielded a maximum streamflow turbidity of 83 ppm, with 95 per cent of the samples having turbidities between 0 and 10 ppm.

Notwithstanding the above quoted studies the magnitude of anthropogenic impacts of land use change and practices remain little known, speculative or controversial. The focus and emphasis made on environmental issues in the tropical regions especially those related to forest harvesting and agriculture as ' the tropical habitats are more sensitive, less resilient, and in greater danger of complete destruction than are the temperate or boreal habitats' (Sonle and Wilcox, 1980). This serves as the interlude of most assessments of environmental impacts of ecosystem change at large and land use in particular, namely timber harvesting and agriculture.

2.6. Local Studies on Impacts of Landuse on Watershed and Water Quality

It is only in the last three decades that a diverse range of research studies concerned specifically with the effects of land use in relation to different aspects of the hydrological and geomorphological processes, has begun to appear. Most of these research studies have investigated the impacts of forest harvesting and agriculture on surface runoff, streamflow turbidity, and suspended sediment concentrations in streams.
researches are epitomized by expressions of great concern with environmental disruptions accompanying development (Soepadmo and Singh (eds.), 1973), injudicious methods of forest clearance and logging resulting in excessive soil erosion and gullying (Burgess, 1971; Liew, 1974) and deterioration of river water quality (Prowse, 1968; Ho, 1973; Douglas, 1967). Others are concerned with the removal of forest cover in catchment areas which resulted in increases in runoff (Douglas, 1967, 1968, 1970; Leigh & Low, 1973), erosion (Leigh, 1973) and siltation (Peh, 1978), while pure hydrological studies of rainfall-runoff relationships in forested (Low, 1971) and partially altered catchments (Goh, 1972), have rapidly been extended in later years to studies concerned with the effects of forest clearance and the subsequent change to other forms of land-use such as for oil palm or cocoa in the Sungai Tekam Experimental Watersheds (Peh & Low, 1979) with the impetus and co-operation given by the Government Agencies. The dynamics of forests in relation to slope processes, forms and landscape morphometry which have direct impacts on soil detachment and soil erosion (Eyles, 1968; Swan, 1970; Morgan, 1971; Peh, 1976) are enhanced by the detailed denudation studies at Pasoh forest are by Leigh (1978) & Peh (1980) under the International Biological Programme.

All these studies are indicative of a growing awareness since the sixties of an overall view that areas under forest vegetation are diminishing at an alarming and unprecedented rate, and which if left unchecked, would not only result in a permanent loss of one of the country’s most valuable natural resource base (Salleh, 1972), but also push the remaining forest to the steep hill areas creating a whole range of more serious disruptive problems such as erosion, siltation of rivers and coasts, floods and pollution which may be hard to control.

2.7 General Impacts Of Land Use Changes

Anthropogenic impacts though are usually interrelated, iterative and cumulative, it has been classified into three arbitrary categories (Aiken & Collin H.L., 1992) viz environmental, biological and human.

The potential environmental impacts include changes in climate, hydrological conditions, soils, and nutrients. Although there is no firm evidence that regional rainfall significantly increased by afforestation or decreased by deforestation (Gouldie, 1986), it was observed that forest clearance may result in altered rainfall patterns and intensities (Brunig, 1977). Potential impacts on regional and global climatic change are still unclear as model predictions indicate contradictory results (Dickinson, 1981; Salati & Vose, 1984). However the burning of forest biomass has been variously implicated in the rising carbon dioxide content of the atmosphere (Wong, 1978; Woodwell, 1978; Goreau & Mello, 1988).

Impact studies by Brunig (1977), Gentry and Lopez-Parodi (1980), Salati and Vose (1983), and Myers (1986a) suggested that removal of the rainforests for varied development and land uses including timber harvesting and agriculture resulted in higher albedo, lower evapotranspiration, reduced rainfall interception, lower infiltration rates, increased runoff, accelerated soil erosion, river sedimentation,