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THE EFFECT OF PLANNING AND DEVELOPMENT ON THE POTABLE GROUNDWATER QUALITY IN BERMUDA

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THE EFFECT OF PLANNING AND DEVELOPMENT ON THE POTABLE GROUNDWATER QUALITY IN BERMUDA

BY

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RESEARCH PROJECT

OF

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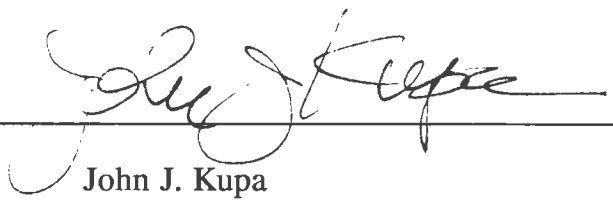
Major Professor 

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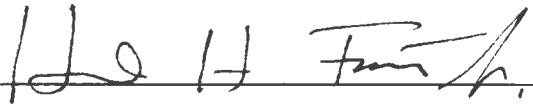
Director 

Howard H. Foster Jr.

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

Figures:

Tables:

A SYNOPSIS OF THE BERMUDA CASE

A concern for groundwater quality and its supply is universal in communities where it is either their sole or ancillary potable water supply. Bermuda is no exception, but, like many island communities, it must devise strategies to continue its status quo of self-sufficiency in regards to its water supply, although this has not always been the case.

Bermuda is one of the most attractive tourist resorts islands in the Atlantic Ocean, (although it is not classified among the Caribbean Islands) therefore extreme effort is made for it to remain competitive in the tourist market. While such attempt have proven to be economically advantageous the society, the trade-offs are manifested in the Island's natural resources, being, either deteriorated or gradually depleted. Certainly, the tourist industry cannot solely be blamed for Bermuda's environmental decline, since other factors must be considered, such as the total annual population, but to a greater degree, the impact of legislation on the physical landscape and (as is the crux of this thesis) on the groundwater. The old adage "An ounce of prevention..." has been herald by environmentalist ab initio, and this is indicative of the Bermuda case where,

in the past, authorities were less concerned with the consequences of land development on it groundwater supply. This does not hold true for today since groundwater quality has becomes an issue. The aim of this research project is to provide a comprehensive planning approach to the relationship of land development and groundwater quality.

OVERVIEW OF BERMUDA

GEOGRAPHY OF BERMUDA

The Islands of Bermuda is geographically located over 700 miles from the United States at 32.20 latitude and 65.45 longitude. The cluster of islands (many of which have been connected by bridge) are actually the peaks of the Bermuda Rise in the North American Basin of the Atlantic Ocean. Bermuda's geographical size today is approximately 21 miles squared, and this was made possible by connecting the larger islands with bridges or, as is the case with St. David's Island, (St. George's Parish Northeast) through land reclamation.

HYDROGEOLOGIC REGIMES

Bermuda's geologic age has been determined by studying its igneous and sedimentary rock formations. There is evidence to suggest that the rocks date back to the late Cretaceous period and show characteristics of subsequent evolutionary periods up to the present, indicating an approximate age of 1 million years. (Watson et. al. 1965) This is outlined in Table 1.1.

Table 1.1

BERMUDA IN THE GEOLOGIC TIME TABLE

Years	Era	Periods	Bermuda Rock Formations
20,0000	Recent	Holocene	a) Beach sediment b) Marsh deposits *
20,000 - 1.25 mya	Quaternary	Pleistocene	a) Southampton * b) Rocky Bay c) Belmont * d) Town Hill lower e) Town Hill lower f) Walsingham
1.25 - 70 mya	Tertiary	Pliocene Miocene Oligocene Eocene	
70 - 190 mya	Secondary	Cretaceous Jurassic	

Rock containing fresh water. (*)

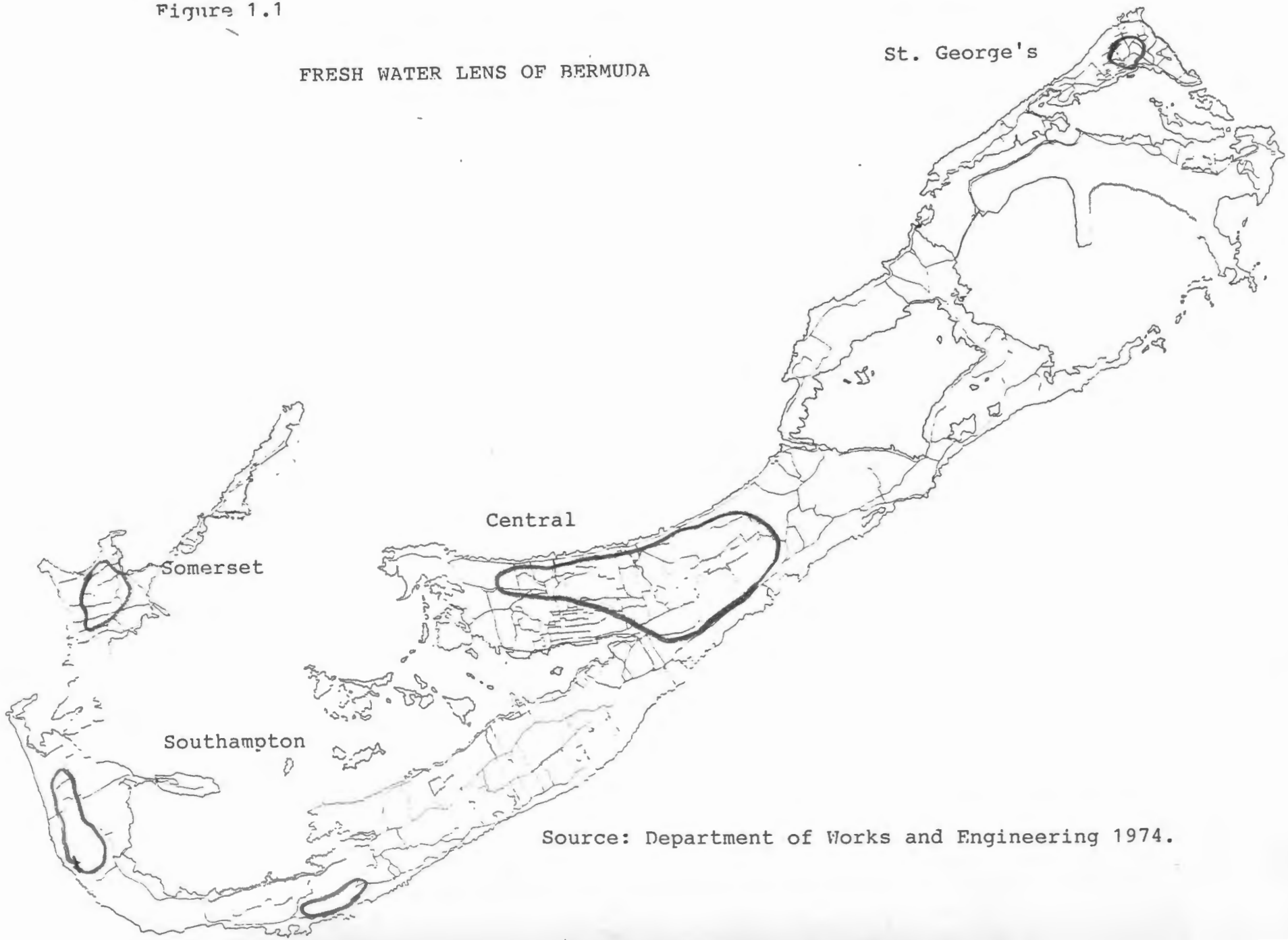
Source: Watson et. al., A Geography of Bermuda. 1965. Dept. of Works and Engineering, The Geologic Map of Bermuda. 1989.

The submerged portion of Bermuda has been formed from the volcanic lava flows of the mid-Atlantic Ridge (although the Bermuda platform is further East of the main Ridge). The surface of the Island is a limestone formation and is minuscule in depth by comparison, (Vacher 1974) at pproximately 100 fathoms (600 ft.) from the surface to

below sea level, contrasted to roughly 1,600 fathoms (9,600 ft.) of volcanic rock. Limestone is characteristically very porous and allows for a high degree of net recharge. However, although Bermuda's rock formations are a part of the two earliest geologic periods (Holocene and Pleistocene), and therefore, relatively young, the geology has resulted in brackish and saline aquifers being more prevalent than fresh water aquifers. Figure 1.1 shows the five known fresh water lenses in Bermuda - these generally occur in the Southampton and Rocky Bay rock formations. The Central lens covers the greatest area and is more significant environmentally, chiefly due to the presence of land use activities in the area that present a pollution risk, and secondly, because of the extent to which the groundwater is extracted for use. Of less environmental concern is the Southampton lens, which is the second most widely used fresh-water lens, but except for the potential of salt water intrusion due to over extraction, there are few land uses that pose a hazard to the groundwater quality. Aquifers in Warwick, St. George's and Somerset respectively, contain fresh water, and while the risk of contamination to the groundwater is consider to be low, increased land development may significantly alter the groundwater quality. This study will examine the conditions of four lenses (Somerset, Southampton, Central and St. George's), paying

Figure 1.1

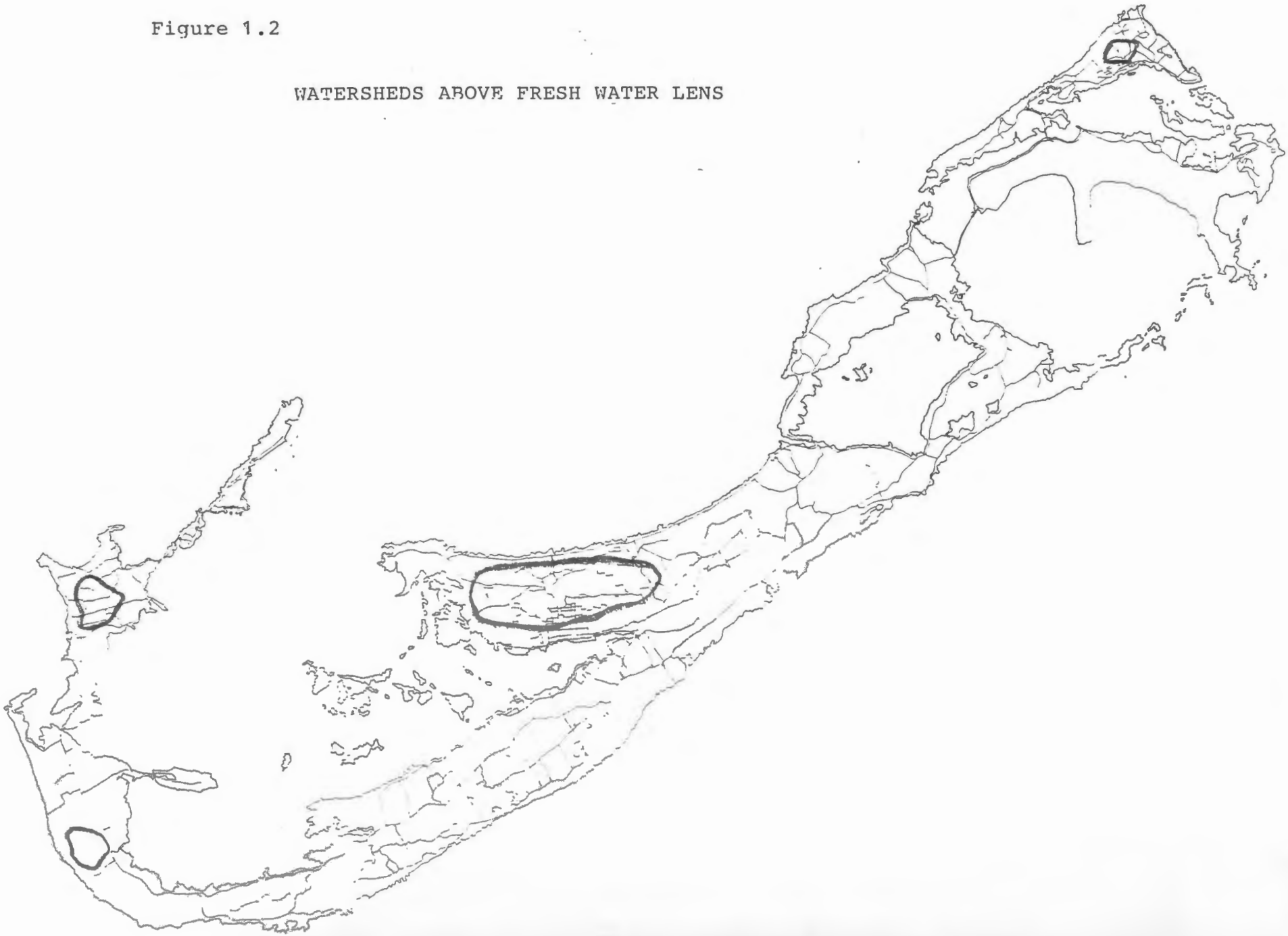
FRESH WATER LENS OF BERMUDA



Source: Department of Works and Engineering 1974.

Figure 1.2

WATERSHEDS ABOVE FRESH WATER LENS



closer attention to the Central lens due to the numerous issues surrounding its quality.

THE WATERSHEDS DEFINED

Watersheds were mapped above the major groundwater lenses (Figure 1.1) for the purposes of comparing the environmental systems of the study Parishes, and in doing so, determining the affect of land use activities on the Island's groundwater. The watershed areas range from about 33 acres in Southampton to 114 acres in Somerset. Pembroke's drainage basin covers the largest area (coinciding with having the greatest volume of potable groundwater and a diversity of land use activities), therefore it has been the main focus of groundwater research in Bermuda and the crux of this research project.

WATER RESOURCES IN BERMUDA

Isolated island communities such as Bermuda must take precautions to conserve its potable water supply in addition to ensuring that population demand for water resources is met by groundwater development. Water resources fall into three categories. The predominant type in Bermuda rainfall. This is trapped, with the aid of catchments, and stored in water tanks for later use. The average annual precipitation in Bermuda is about 58 inches, but water is often in short supply during the summer months when rainfall is low. It is during the dry period when residents must use alternate resources - these refer to groundwater extraction and development techniques. Although groundwater extraction is the focus of this section, the relationship of it to the catchment method, is an accessory to the complete "picture" of how land use activities in Bermuda have impacted on the groundwater.

RAINWATER SUPPLY AND CATCHMENT TECHNIQUES

Methods for trapping rainfall have evolved from less sophisticated practices, such as the use of rum barrel punchoens or cisterns, to more technical oriented water tanks, which the Department of Planning prescribes for all residential applications. This section of the study will

provide insight into the importance of catching rainwater and its contribution to the total potable water supply in Bermuda.

Roof Cistern System

Any discussion of the roof system's role in Bermuda's water supply deserves a concise description of its design. The Bermuda roof is constructed from limestone slates, (Waller 1982) which are of standard dimensions (30.5 cm x 45.7 cm x 7 cm (12 in. x 18 in. x 1/4 in.). The slate is overlapped on a wooden roof frame then sealed with either a limestone mortar or white paint. Storage tanks are formed either beneath a house or underground on the property, and are constructed with concrete block to prevent the water from escaping into the ground. Public health regulations for water tank capacities have increased significantly throughout the years changing from a maximum of 22,000 l/ occupant in 1951, to current capacities of approximately 68,000 l/occupant. Essentially, the Public Health Act states that (Saunders, Interregional Seminar on Development and Management of Island Groundwater Resources, ISDMG, 1985):

> - Any building shall not have less than four-fifths of its roof catch adequately guttered for catching rainwater or provided with a ground catchment of not less than four-fifths the area of the roof building.

- The storage tank or tanks have provided in respect of any building shall be not less than one hundred gallons for every ten square feet of prescribed area of catchment.

Pipes are extended from the roof to the tank to channel the rainwater downwards during a storm period, and when it is needed, the water is extracted with the aid of an electric pump.

While most structures have a Bermuda style roof, Planning legislation requires that all residential buildings be designed with a roof cistern system, since rainwater is primarily used for domestic purposes.

It is estimated that 75 percent of the precipitation that falls on roofs during a moderate storm frequency enters its storage tank. In Table 2.1, which provides a compilation of supply and demand of potable water in Bermuda (Waller 1982), the current supply for residential units averages 5,135 m/day. The supply of drinking water is exceeded by the demand, therefore, when precipitation levels decline, residents must resort to other means of obtaining potable water.

CATCHMENT TECHNIQUES

These are distinguished from roof catchments because they are relatively smooth sloping surfaces designed to catch stormwater and are mostly used by the major hotels (which may also use other means) because artificial catchments, due to their largeness, have the potential to trap considerable volumes of rainfall. Although artificial catchments are used by some of the major hotels on the Island, the British and U.S. Army and Navy have also used large catchments (Thomas, ISDMG 1985). The latter is currently in use to serve the U.S. Base personnel, while former provides an average of 3,000,000 gallons/year. However this amount is surpassed by the capacity of the Castle Harbour Hotel's catchment, which, although built during the 1930s, continues to supply 10,000,000 gallons/year for its guest.

Table 2.1

ESTIMATED SUPPLY AND DEMAND FOR POTABLE WATER

Supply:	Average	Peak
Groundwater	3,290	5,000
Desalination	1,705	2,670
Roof Cisterns:		
Residential	5,135	3,180
Hotel	365	365
Public	65	65
Other		680
Total Supply	10,560	11,960
Demand:		
Tourist	3,370	4,500
Cruise Ships	90	275
Residents	6,050	6,045
Losses	1,050	1,140
Total Demand	10,560	11,960

Source: Technical University of Nova Scotia, Centre for Water Resources Studies, June 1982.

Water Quality

This is contingent upon the maintenance of roofs and artificial catchments, (Waller 1982) and while there have been isolated cases of illness it has been due to poorly kept roof systems.

GROUNDWATER EXTRACTION TECHNIQUES

Groundwater has been extracted from Bermuda's fresh water lens for centuries by residents, and is considered to be

a viable alternative when rainwater is in short supply (although the consensus among residents is that rainwater is more pleasing to the palate). Saline and brackish water is also extracted for uses other than drinking. More recently though, successful attempts have been made to develop the groundwater by employing reverse osmosis techniques which makes the water fit for distribution to hotels and businesses in the City of Hamilton.

Groundwater Extraction Through Wells

While many residences have fresh water wells, the fresh water is best conserved when wells are drilled for brackish and saline water. The water can then be used for flushing. A major concern of the Department of Works and Engineering is the potential for over extraction of the fresh water lenses, which will result in salt water intrusion and a reduction of potable water. Thus fresh water extraction is closely monitored by government officials.

Development of Groundwater

The advent of groundwater development may be traced back to a private company, Watlington Waterworks, which initially, in 1931, extracted water from the Devonshire lens, to be distributed for flushing. During the decade of its establishment, tests revealed that the groundwater was of drinking water quality, but by 1940, further tests indicated

that the lens had been intruded by brackish water. Today, Watlington Waterworks continues to process brackish water, which it supplies to the City of Hamilton. Bermuda's major hotels are also supplied with water from the Devonshire lens, and with the aid of electro-dialysis units, they are able to receive potable water.

Another method of groundwater development employs the principles of "reverse osmosis". This technique is similar to electro-dialysis in that is converts brackish water into that of potable quality.

Concerns Regarding Groundwater Extraction and Quality

-Over use of the fresh water lenses (particularly the Central lens) will allow for intrusion of brackish and saline water. The concern is that this may result in irreversible damage to the lenses, other wise, it may be many years before the fresh lens will be replenished. Thus metering of groundwater extraction is carried out to prevent depletion of fresh water supply.

-The groundwater quality has deteriorated due to increasing levels of non-point source pollution, which is a repercussion of the following:

-burgeoning residential units and thus increases in leachate from cesspits.

-road runoff carrying toxic chemicals (oil, grease and trace metals) - deposited by combustible vehicles.

-road runoff pollutants resulting from human litter and animal dropping on impervious surfaces.

-Bermuda's landfill is perceived as a threat to the Central lens, although this is disproved by tests showing negative results.

These issues will be examined in detail, as they pertain to the three functional areas that impact on the groundwater quality in Bermuda. The study areas are housing and domestic sewage; transportation, ie. road development and vehicles; and the effect of legislation on issues relating to groundwater contamination.

EXAMINATION OF FUNCTIONAL AREAS

Residential communities similar to the Bermuda case, whose water supplies are limited are generally concerned with the effect that certain functional areas are having on their potable groundwater supply. The areas that will be studied in this section are those which directly, or otherwise affect the potable groundwater quality in the watershed Parishes, and are as follows: housing and land use, transportation and planning and legislation. These areas may be classified into two categories, the first of which refers to the built and natural environment, while the second is concerned with the impact of the planning process on the Island's physical growth. The information given will be confined to the following limitations. First, it should be assumed that the secondary statistical data showing Parish totals is also indicative of the general conditions of the watershed. Exceptions to this is the Southampton watershed where total impervious acreage is minimal when compared to that of the total area, and the Central watershed (often used interchangeably with the description Central area) in which approximately 10 percent of Devonshire is included at the design-point. Further, it should be noted that while some of the data is as recent as 1988, much of it dates back to 1981 and should not be considered to be an accurate "picture" of current conditions on the Island. Lastly, throughout the body of this paper,

more emphasis will be placed on the Central watershed (and thus, Central lenses), primarily, because it lies above Bermuda's largest and most frequently tapped groundwater reservoir and secondly, because the lens is contaminated as a result of the land use activities in the area.

DEVELOPMENT IMPACTING ON GROUNDWATER

HOUSING

The housing element in Bermuda has been studied extensively as a result of the burgeoning number of residential units over the past two decades and the negative effect of these developments on the natural environment. Our major concern in this text is how the housing element of Bermuda's functional areas effects the groundwater quality.

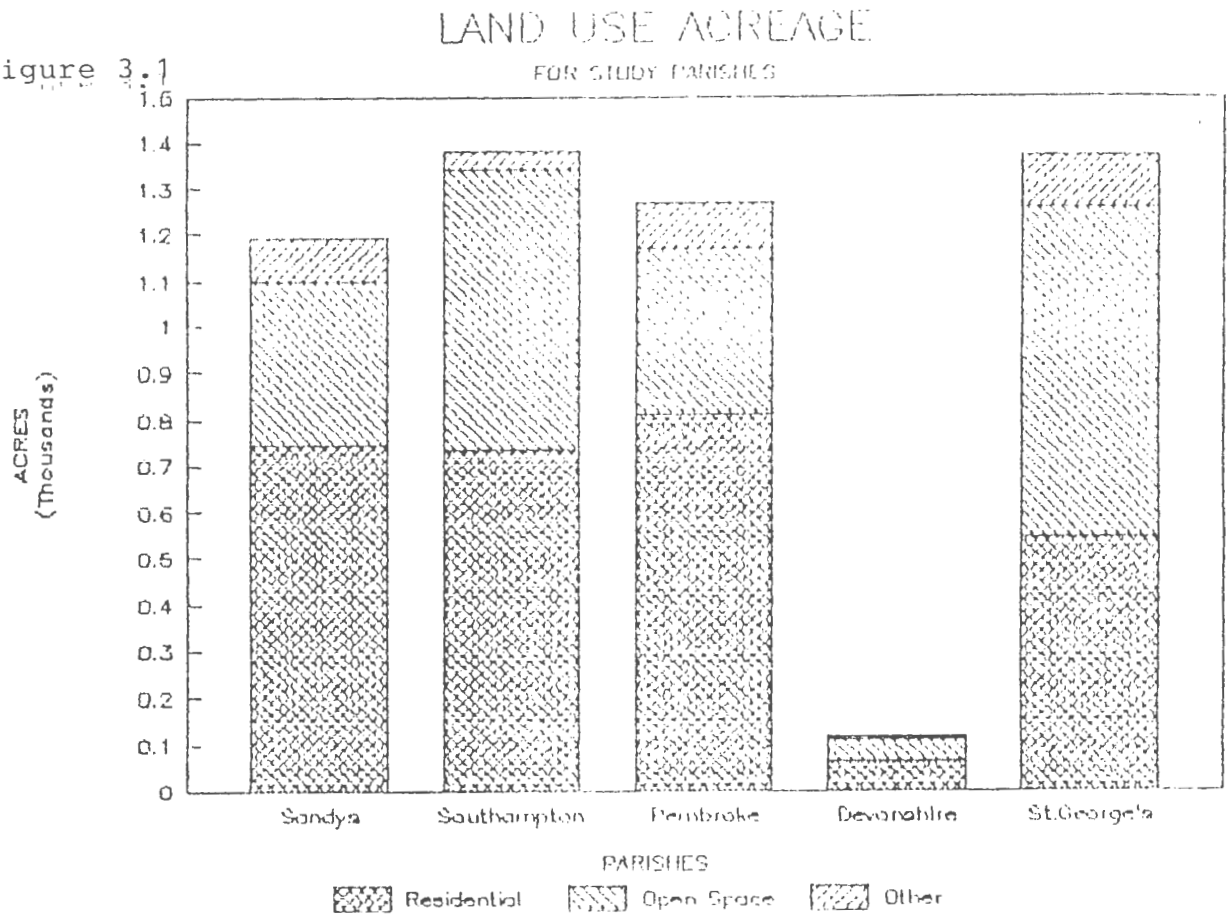
Zoning and Land Use

An examination of land use in Bermuda shows that residential activities are generally equally divided between the study and non-study Parishes although the former has 658 total land use acres less than the latter. In Figure 3.1 - 3.2 and Table 3.1 it is shown that housing in Bermuda accounts for over half of the total land use and is significantly higher than other developed land use activities. Open space consumes the second greatest amount of acreage and is substantially higher than other activities, (Bermuda

Development Plan, Discussion Paper Number 3, 1989) but there is concern that since the 1960s it is being replaced rapidly by development. It should be noted that the word open space also represents environmental protection areas and covers areas such as nature reserve, recreation, woodland reserve, arable land and open space. Open space actually comprises only 13.6 percent of the "open space" category. This is illustrated further in the
Appendix A.I.

In regards to the study Parishes, the land use conditions are similar - Figure 3.1 - 3.2 and Table 3.1 indicates that housing is approximately 55 percent while open space acreage is 39 percent. The category titled Other, consists of three functional areas - Hotel and Cottage Colony, Major Industrial and Special Government activities (Appendix A.II). These consume a limited amount of space in the study area but contribute to the total developed space. In reference to industrial zoning, the landfill in the Central watershed has been considered to be a threat to the major groundwater lens in the Central Parishes. These assumptions have been refuted consistently by scientists.

Figure 3.1



Source: Department of Planning 1989.

Figure 3.2

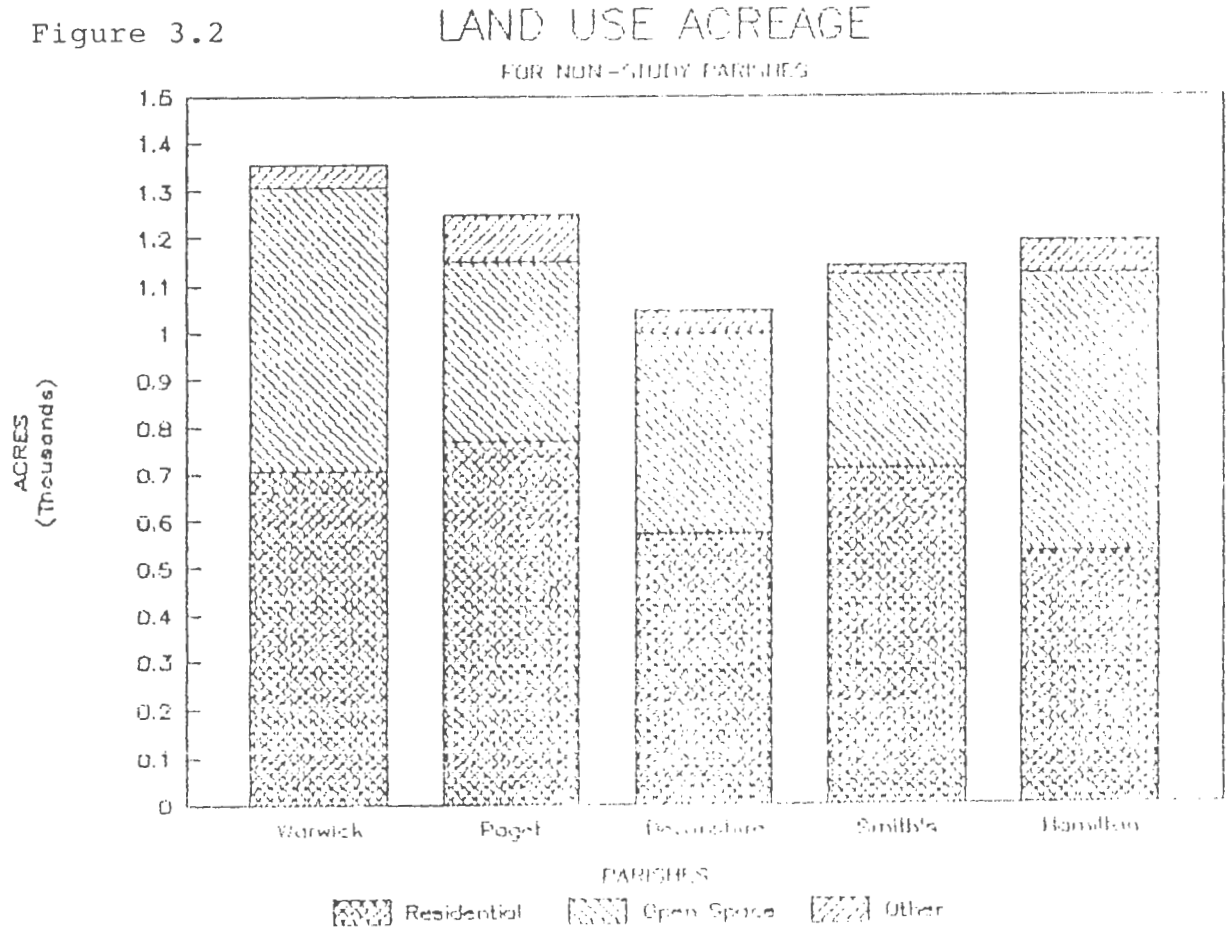


Table 3.1

LAND USE ACREAGE IN BERMUDA

LAND USE ACREAGE OF STUDY PARISH			
PARISH	RESIDENTIAL	OPEN SPACE	OTHER
Sandys	743 (62%)	358 (30%)	91 (8.%)
Southampton	743 (53%)	606 (44%)	41 (3.%)
Pembroke	809 (65%)	361 (29%)	95 (6.%)
Devonshire	63 (45%)	47 (41%)	06 (14%)
St. George's	543 (40%)	710 (52%)	114 (8.%)
TOTAL	2,892	2,082	347
LAND USE ACREAGE OF NON-STUDY PARISH			
Warwick	706 (52%)	599 (44%)	50 (4.%)
Paget	770 (62%)	380 (30%)	98 (8.%)
Devonshire	571 (55%)	426 (41%)	50 (4.%)
Smith's	708 (62%)	413 (36%)	19 (2.%)
Hamilton	503 (45%)	592 (50%)	67 (5.%)
TOTAL	3,285	2,410	284

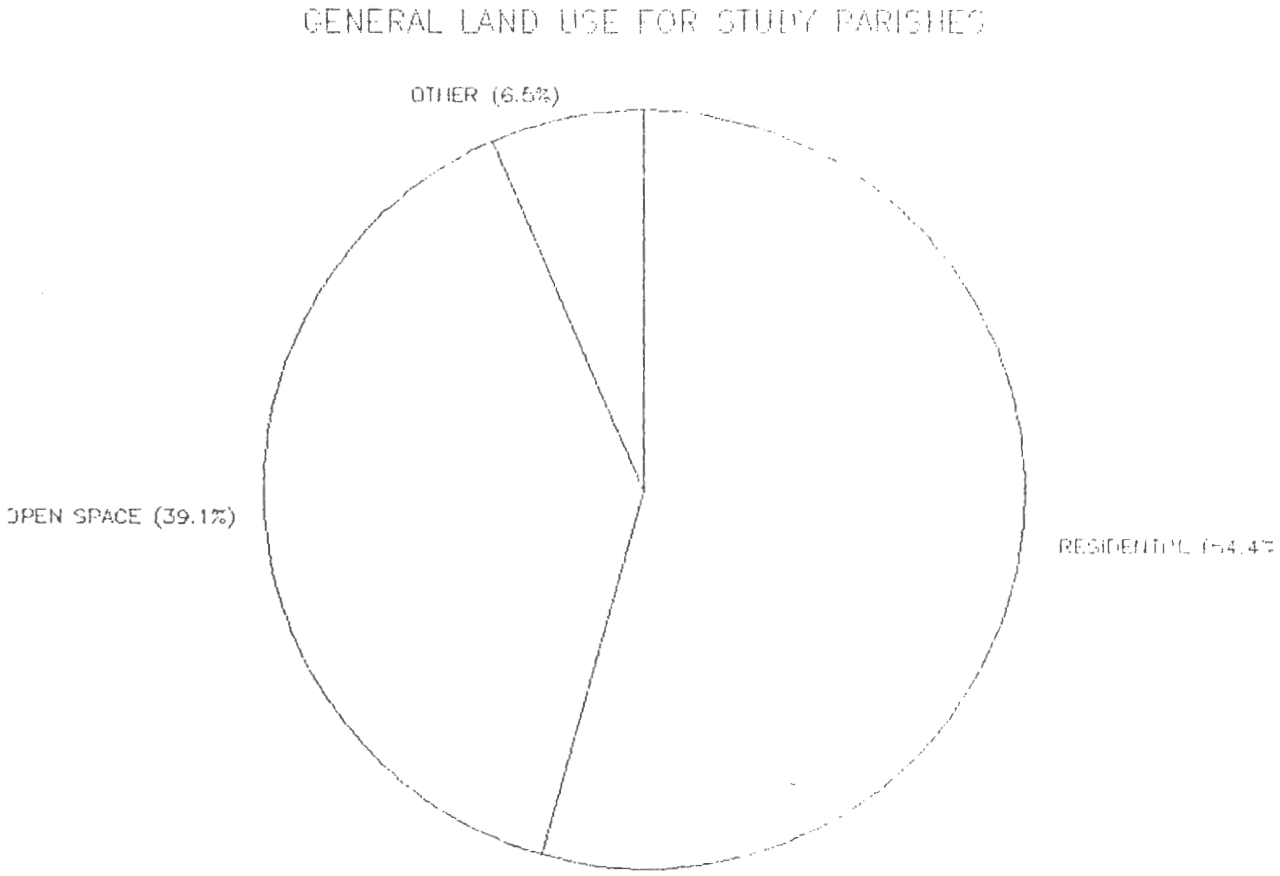
Source: Statistical Department, Ministry of Finance.
Bermuda Digest of Statistics 1989

The zoning and subdivision specifications for residential development in Bermuda are located in Appendix A.III of this paper. There are five residential zoning types in Bermuda, but these may be further classified into four general categories, as shown in Figure 3.4:

High Density

These areas allow a maximum of 8 houses per acre and a minimum lot size of 5,000 square feet for

Figure 3.3



Source: Statistical Department, Ministry of Finance 1989.

detached housing and 14 units per acre and a minimum lot size of 3,500 square feet for attached housing.

Medium Density

Minimum lot size is 9,000 square feet and 4 detached houses per acre and 4,000 square feet and a maximum of 8 units per acre.

Low Density and Clustered Low Density

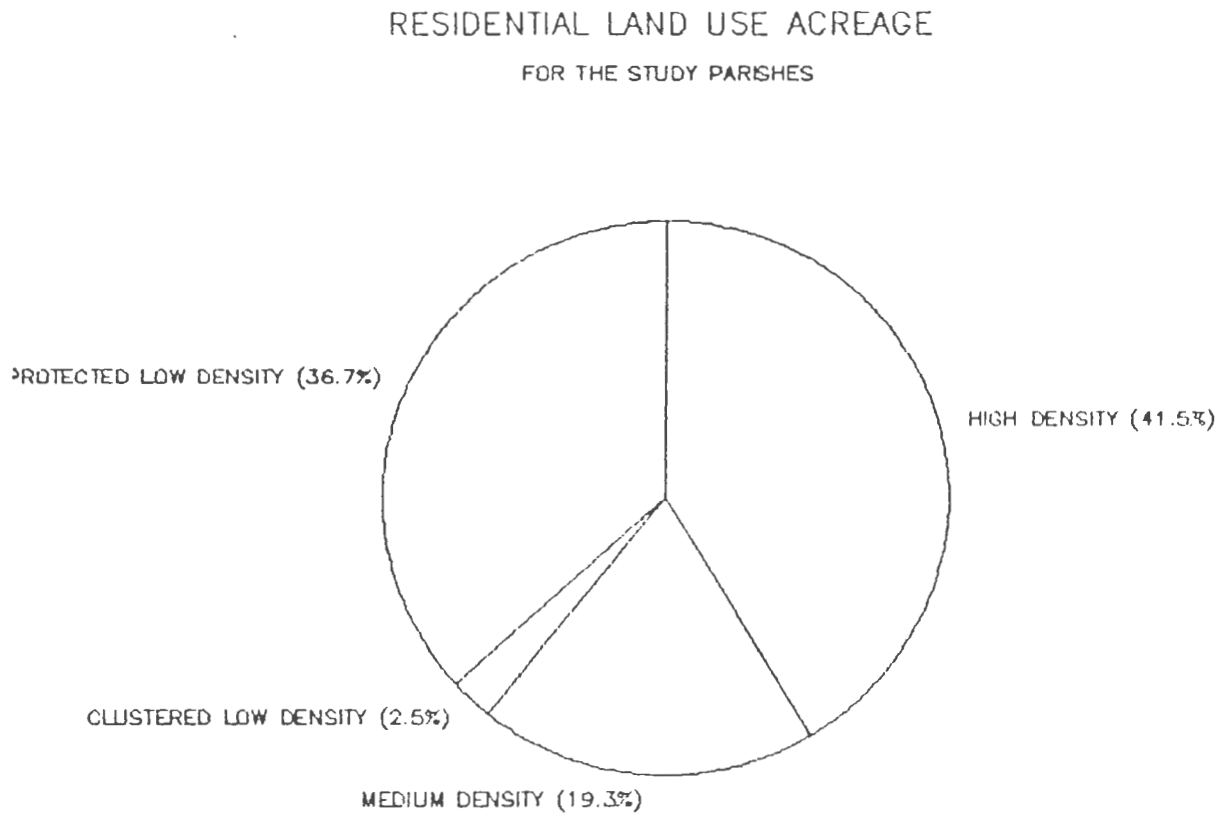
Two houses per acre and 17,000 square feet for detached houses, contrasted with 35,000 square feet and 8 units per acre.

Protected Low Density

i. Garden District - The purpose of this area is to preserve natural features, considered to be of good environmental quality, by zoning for large acre lots. Thus, one house is permitted on approximately 3/4 of an acre and three attached houses per acre. Minimum lot sizes are 25,000 and 14,000 square feet respectively, for detached and attached housing.

ii. Rural Area - While the maximum density for 1 and 2 houses is approximately 2 acres, the minimum lot size for 1 unit is 10,000 square feet and 5,0000 square for 2 units.

Figure 3.4



Statistical Department Ministry Of Finance Bermuda

Digest Of Statistics 1989.

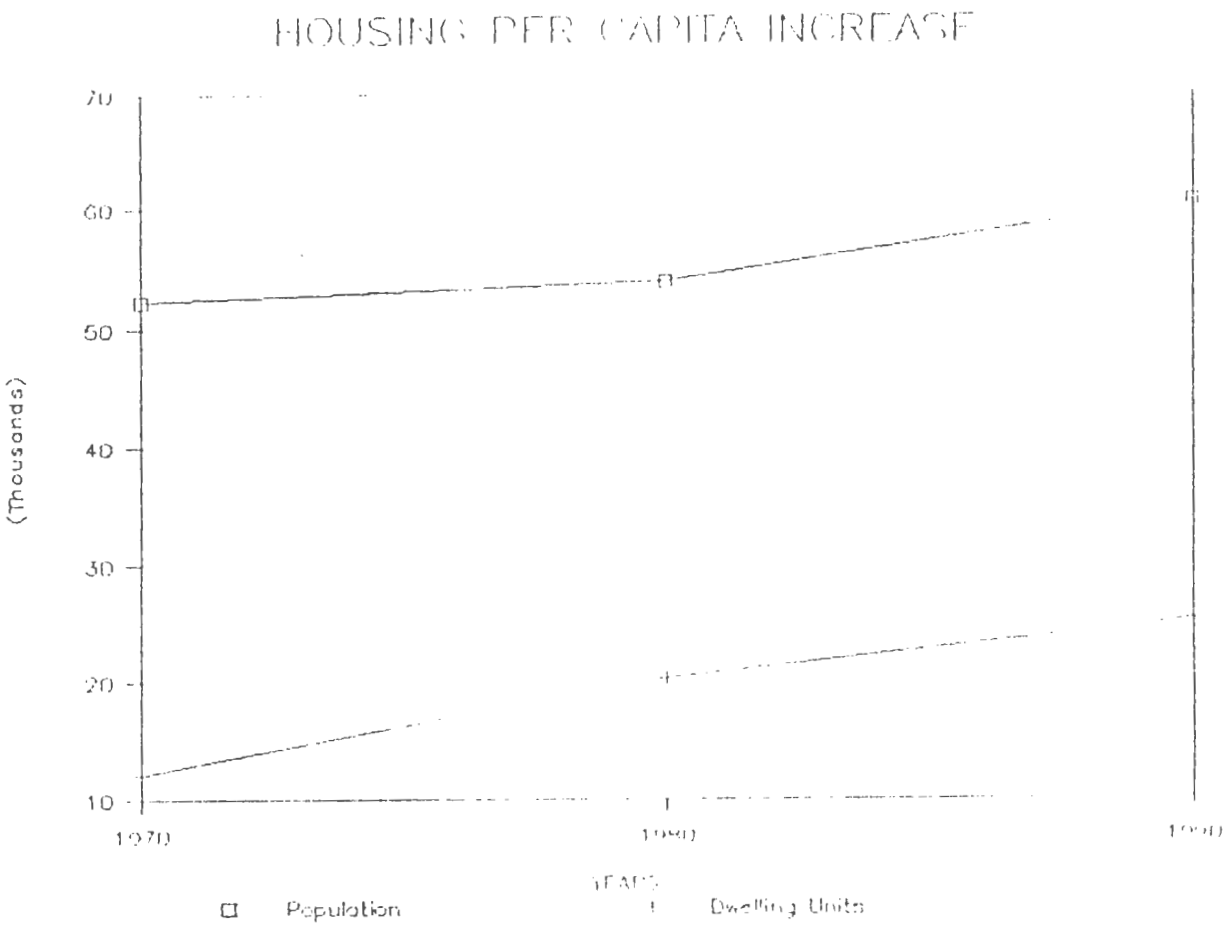
The land use distribution for Bermuda indicates that the predominant activity in the Central Parishes is high density residential zoning although it is questionable whether the limited amount of Medium and Clustered Low Density acreage falls within the Central watershed boundaries. Similarly, it has not been accurately determined what amount of land in the watershed is zoned for Garden District or Rural Area. Pembroke's high density acreage is 44 percent of the residential acreage in the study Parishes but when the design-point of the Central watershed is included (estimated at 10 percent of Devonshire's residential acreage) this figure is reduced to 30 percent. Zoning in the Central Parishes gives some indication to how extensively the land is used, and (as we shall discuss later) the amount of stress that this invariably places on the groundwater recharge system. However, it is assumed that the level of groundwater contamination is lower in the Somerset and St. George's because, while there is more high density acreage, medium, low and protected areas are generally evenly distributed. Finally, high density in Southampton is, an impressive 15 percent of the land area, although residential zoning in the watershed is low density and accounts for only 10 percent of the area.

Population and Development Types

Figure 3.5 shows that the number of Residential Valuation Units (RVU's) in Bermuda has steadily increased over the last twenty years, (Bermuda Development Plan, Discussion Paper Number 3, 1989) growing from 16,126 units in 1970 to 20,350 in 1980, (Bermuda Digest of Statistics, 1985 and 1989) then to 24,735 units by the end of 1989. It is estimated that release of statistical data for the end of 1990 will show an addition to the housing stock of 591 units. Most of the development between 1981 and 1988 has been in the form of one and two bedroom units (1,535 and 1,145 units respectively), followed by three bedroom units, at about 900 units, and studios dwellings at 725. Lastly, as is the norm in housing in Bermuda, there are fewer dwellings units with greater than three bedrooms. This category slightly exceeds 80 units.

The household occupancy rate has declined from 3.2 in 1970 to 2.7 in 1980 (Bermuda Development Plan, Discussion Paper Number 3, 1989). By the 1980 census there was a large gap between one and two person/s households and those with more than three persons. This has resulted in an imbalance of one and two persons households occupying over half of the residential units. The trend of a declining occupancy rate continued throughout the 1980s, falling from 2.7 in 1980 to 2.4 by the end of 1989; it is estimated that this will

Figure 3.5



Statistical Department Ministry Of Finance.

Bermuda Digest Of Statistics,1989.

Development Plan Background Reports:

Bermuda Development Plan. Discussion Paper Number 3.

continue due to various socio-economic factors (Bermuda Digest of Statistics, 1985 and 1989).

Perhaps the most striking point regarding the housing situation is the disproportionate population growth in contrast to the number of dwelling units from 1970 to 1980. While there was a population change of 3.3 percent, the change in the number of dwelling units had increased by 26.2 percent. By 1988 this trend had continued and although the total population had increased by 4 percent, residential development had fallen to 18.8 percent. Paradoxically, population growth in the Central Parish had stabilized by 1975 vis a vis increases in dwelling units.

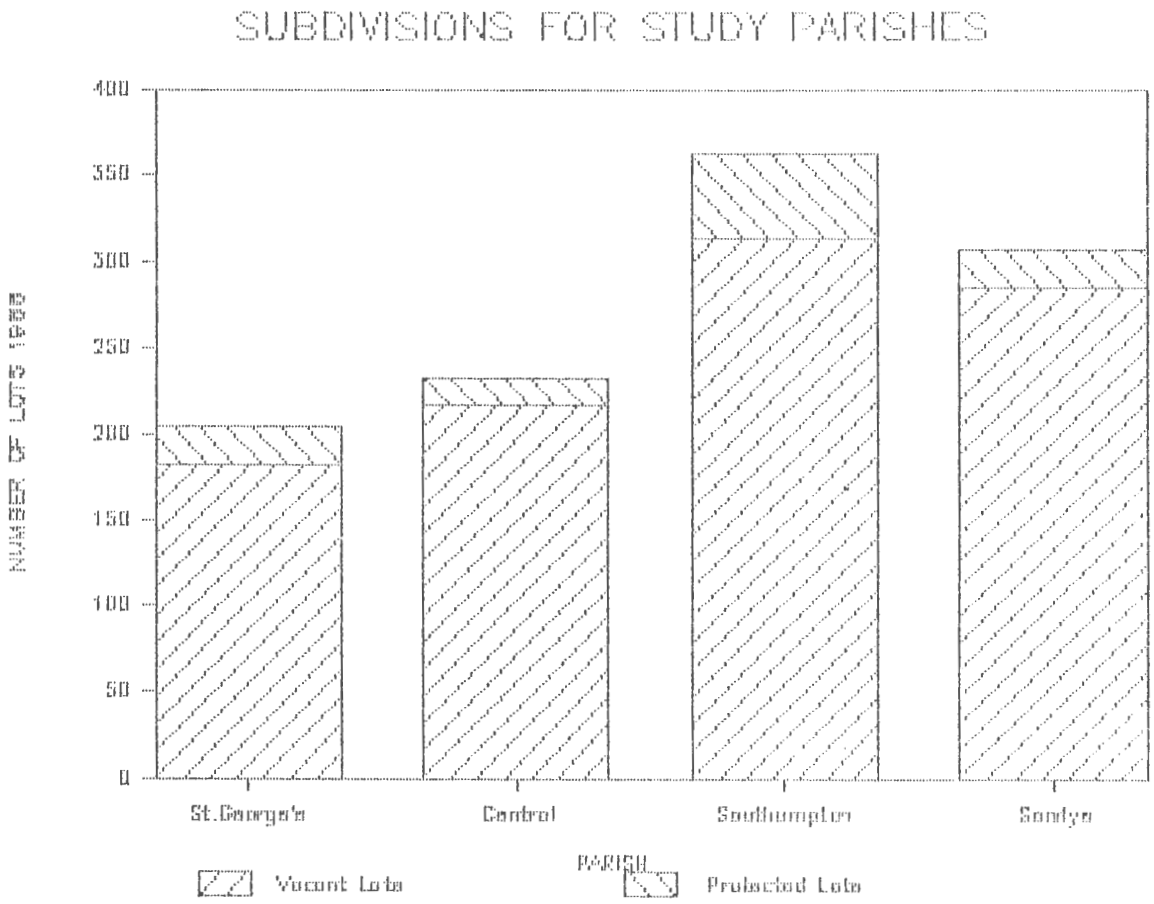
Future Housing

Bermuda's consistent increase in its housing stock may be explained in terms of both need and demand, both of which are the result of various socio-economic factors, and it follows that these elements will also determine future housing conditions. It has been determined that (Bermuda Development Plan, Discussion Paper Number 3, 1989) there is currently a demand for one-person and two-person housing, but there is also a need for accommodation of larger households.

Still another indicator of future conditions is the relatively high number of subdivisions, although it cannot be accurately determined when the lots will be developed. There are total of 9,515 lots in Bermuda, of which 2,144 (947.6 acres) are listed as Vacant lots. Of the vacant lots, 874 are registered and only 278 lots, referred to a Protected and Registered, are considered to be of environmental value. The Central Parish contains fewer lots than the other Study Parishes, followed by Sandys Parish and St. George's Parish. By comparison, Southampton represents the best situation, as it has over two times the number of Protected Lots than the other Parishes. The proportion of vacant to protected lots strongly indicates that if the development trend is to continue, then further exploitation of the natural environment can be expected.

It is in the interest of Bermuda to reduce housing development (particularly high density) due to the threat that it poses to Island's natural environment, but the constraints of obtaining this goal are clear. The first relates to a need and "pressing" demand for housing, therefore making it difficult for planning to impose restrictions on the new development, while the second refers to the planning department's inability to predict the number of subdivisions that will be developed in a given time.

Figure 3.6



Development Plan Background Reports:

Bermuda Development Plan. Discussion Paper Number 3.

TRANSPORTATION

Still another development type that contributes to groundwater contamination is the mileage of paved road surface in an area. These are perceived to be necessary upon development of a subdivision, particularly if there will be a large volume of traffic passing through the area. It is apparent that the Department of Planning and other authorities concerned with transportation, tend to focus on issues that are related to external factors such as aesthetics and vehicular congestion, but this section will assess how road runoff contributes to groundwater contamination in the mapped watershed areas, with particular emphasis on the Central watershed.

Modes of Transportation

The total number of registered vehicles has fluctuated from the mid-seventies to the late-eighties. However, Appendix B. I shows a consistent growth in domestic modes of transportation with the number of cars accounting for the greatest increase.

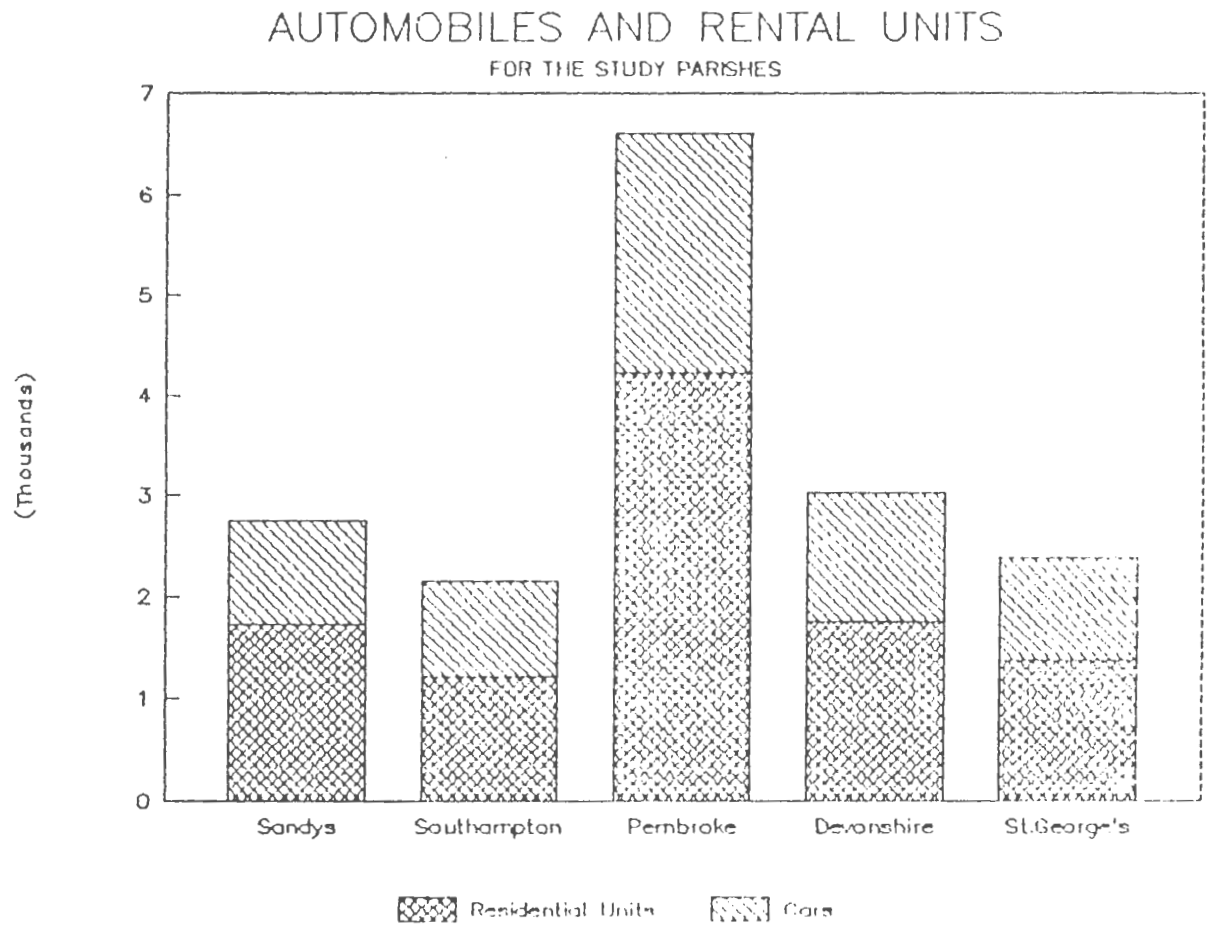
Current legislation restricts car ownership to one per RVU, as an attempt to reduce traffic congestion. However, this has not been achieved because the number of dwelling units have continued to increase annually, and while many homes do not have cars, the growth rate for vehicles continues

to exceed that of RVU's. Figure 3.7 shows the high proportion of cars to RVUs. As of 1988, there were 18,270 car for 24,179 residential valuation units, resulting in approximately three-quarters of RVU's on the Island having a car. Appendix B. I shows that private cars have increased throughout the years, except in 1986 when there was a decrease of 88 cars. A similar pattern has emerged for motor cycles and scooters, but auxiliary cycles appear to be less popular and to a large extent, this figure is misleading because many are used as commercial rentals by the seasonal population.

In a comparison between the growth rate for various indicators, it is evident that between 1970 and 1987/8 private cars had the highest growth rate per year (3.1 percent) while cycles increased by only 0.7 percent annually. Rental Valuation Units experienced the third highest rate of 2.3 which suggested that more households were purchasing cars.

Car ownership for the study Parishes ranges from 1 to 3 percent greater than the mean. This was particularly true in the case of Sandys, Southampton and St. George's; 67 percent of RVU's in the Central Parishes have cars, showing that although it is the most densely populated watershed area, that it has the least number of cars per RVU. This data is a poor reflection of the Southampton watershed, which contains an estimated 20 units, and the St. George's watershed where

Figure 3.7



Statistical Department Ministry Of Finance.
Bermuda Digest Of Statistics,1989.

approximately 1/4 of the area is zoned for residential units.

Road Classification

Bermuda's increased housing in addition to the proliferation of motor vehicles has brought about an increase in road mileage to accommodate the two. There is approximately a total of 1,437 miles of road and they are classified into five hierarchal categories. The first of which is the main artery referred to as Public Highways shown in Figure 3.8. There are 140 miles of this type. The second classification is referred to as Private Roads, although the mileage for this has not been determined. These are followed by roads that fall within the jurisdiction of Bermuda's Primary and Secondary business districts, such as The Corporation of St. George's and the Corporation of Hamilton. Still another classification pertains to roads referred to as Government Private roads which, as is suggested, exist on Government property.

An alternative to the current road hierarchy, has been recommended in a Government commissioned transportation study, but it appears that implementation of the "two-tier system" will bring about few changes in road use because the geography and land use in Bermuda prescribes the routes that motorist will use.

Road Usage

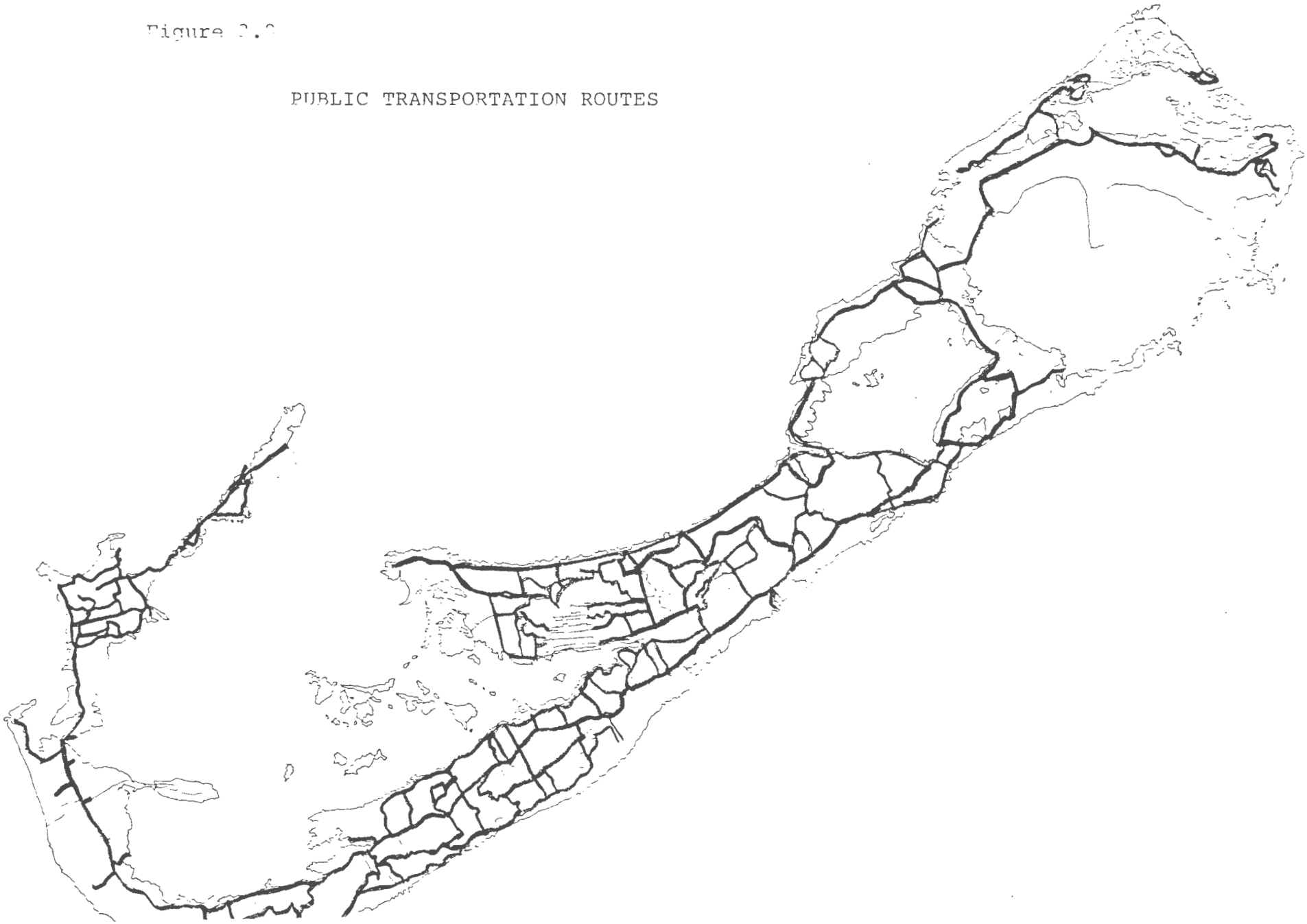
An examination of road mileage reveals that road development is relatively dense when compared to the size of the Island. In general, the watershed areas are no exception to this, particularly the Central watershed. However, the Southampton watershed has a limited number of roads and presents conditions that would be more favorable for the Central area.

The Southampton watershed has a limited number of road mileage and fewer Private roads than the other study areas, chiefly because the watershed is comprised of a golf course - these conditions are ideal for maximum infiltration of runoff into the groundwater. While the St. George's watershed has no major highways it is assumed that the Corporation roads are used extensively, primarily, because many residents must travel through them to other areas of Bermuda. The Town of St. George's (the secondary city) is the center of commercial activity for the Parish, and this is another reason for large volumes of traffic having to pass through the study area. The Sandys watershed has the second greatest road mileage to its Parish acreage but with fewer land use activities than Pembroke.

It is apparent that the Central watershed has more road development and classifications than the other study areas on

Figure 2.2

PUBLIC TRANSPORTATION ROUTES



the Island as a whole. There are several reasons for the occurrence of this. One is related to the geographical location of residential units in the Northeastern end of Pembroke Parish which have resulted in motorist having to travel through the study area to gain access to other sections of the island. Trips are generated through the area frequent because motorists must travel into the City of Hamilton daily to work. Further to this, there is a greater diversity of land use activities such as high density zoning, light industry, recreation and government property,
all of which are likely to generate large volumes of traffic into and from the watershed area. The recommended road hierarchy seems to suggest that traffic volumes may be abated in the Central Parishes, but this is unlikely unless amendments are made to the zoning legislation that would significantly alter land use patterns, particularly of the residential type.

Road Materials and Catchment Designs

It is assumed that today nearly all roads on the Island are paved - this includes private residential roads, which were mostly dirt roads at one time, but are increasingly being paved. In addition to this, many resident are paving their driveways and parking areas. There are many environmental implications to increased road development, but, adhering to the topic contamination, this paper will discuss the effect of

Figure 3.10

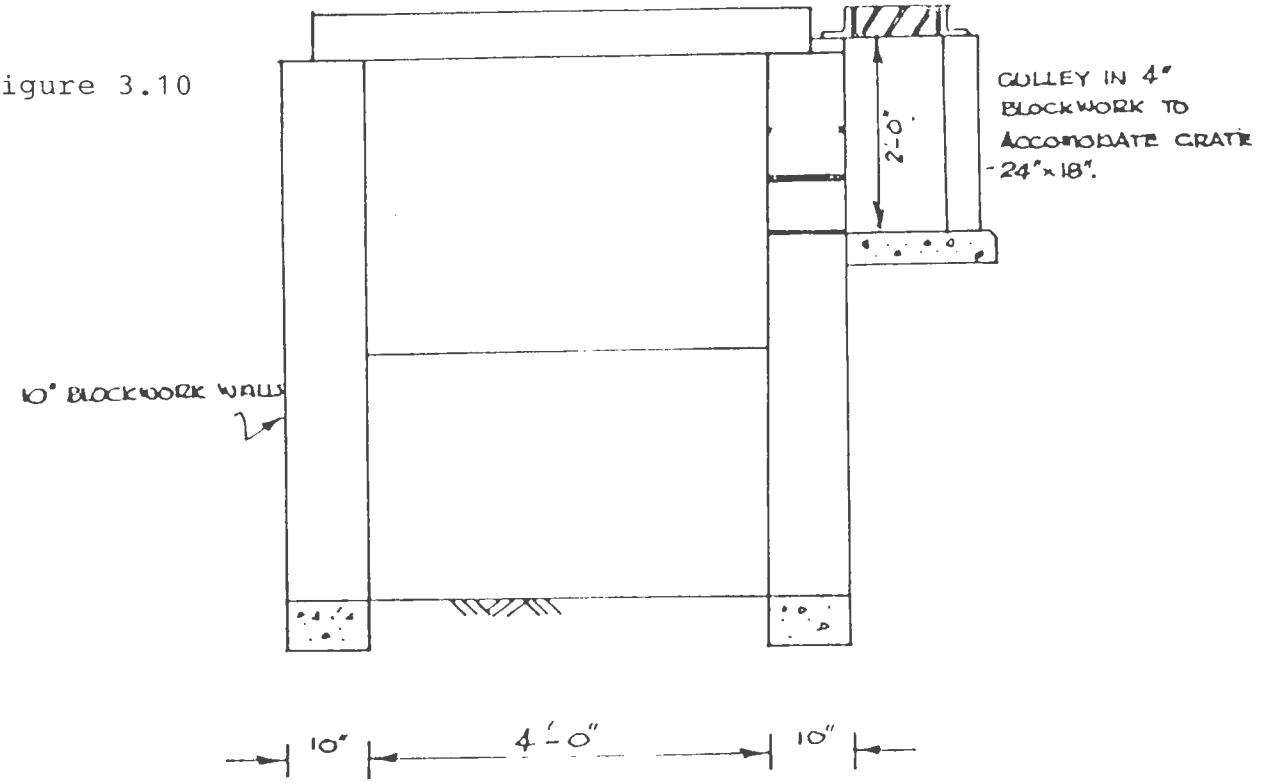
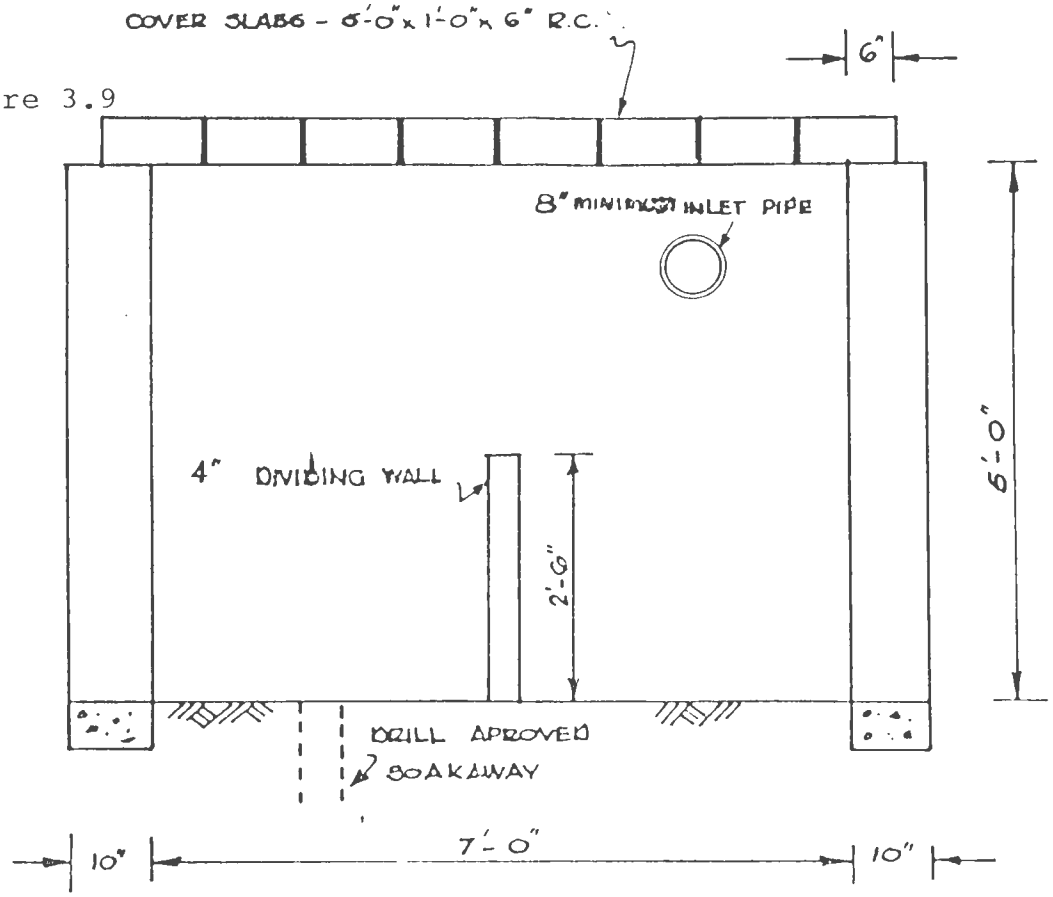


Figure 3.9



DRAINAGE PIT DETAILS.

PUBLIC WORKS DEPARTMENT · HAMILTON · BERMUDA.

road development types and their effectiveness in removing contaminants before they enter the groundwater recharge zone.

Treatment of road runoff does not appear to be of major concern to the Department of Works and Engineering due to the simplistic designs of the runoff catchments. However, it is apparent that they are primarily concerned with maintaining systems that can efficiently prevent flooding caused by a 3.5 inch storm frequency. Figure 3.9 illustrates the most effective storm water catchment design on the Island, referred to as the Storm Pit. This is a dual chamber basin from which runoff, either percolates through the soil or enters the groundwater directly via a well in the basin. The second type is the Soak Away (Figure 3.10) where boulders are used to reduce the velocity of runoff before it drains into an open pit. While these designs are typical of inland roads they are considered to be less suitable for shore line roads. There are two different designs used in these areas. In the first, runoff is directed into the ocean through holes in walls, otherwise storm water is simply allowed to drained off a grass verge into the sea. In either case the risk of pollution should not go unnoticed, because while phosphorus is the limiting nutrient in road runoff, eutrophication is likely to occur.

The absence of industrial activities that produce hazardous waste, and a frost-free climate are perhaps two

major reasons why road engineers in Bermuda are not concerned with the similar contamination issues associated with road runoff that engineers in many regions of the United States must face. Nevertheless, the toxins that are produced in road runoff should not go unnoticed for various reasons:

-Untreated storm runoff enters groundwater directly through roadside wetlands in addition to wells in Storm Pits. Runoff into the ocean may eventually enter the lower perched water body of the groundwater.

-Drainage basins used to hold storm water are not designed to treat toxins.

Proposal for Traffic Management

Listed in the Corporation of Hamilton's transportation policy, are recommendation that would alleviate "congestion, discomfort and pollution" caused by traffic (see Appendix B II). The ones that are applicable to this project are:

-Car ownership disqualification from driving is suggested if driver fails to respect the road.

-Car dimensions should be allowed to increase to accommodate more passengers although the engine size should remain the same.

-Traffic volumes should be measured continually.

-Public transportation clarification of rates are perceived to be the only issue - it was decided by public transportation authorities that fare tables should be

"simplified" so that they may be more comprehensible by tourist.

-Unleaded petrol and catalytic converters would have the effect of reducing toxins produced by vehicles.

-Hierarchy of roads Two-tier system of primary and secondary roads should be introduced.

Bermuda's competition in the tourist market is the major reason why a Government transportation study would be concerned with recommendations that are aimed at improving the physical environment, but, coincidentally, the above suggestions may also aid in reducing non-point source pollution in the watershed areas. From an environmental perspective, the more impressive points are those that will cause a reduction in fuel and metals being deposited on roads by moving vehicles. However, excluded from the list of recommendations is a suggestion for road designs that will remove storm water more efficiently.

ISSUES RELATING TO DEVELOPMENT AND NON-POINT SOURCE POLLUTION

Although Bermuda has become urbanized rapidly over the past 20 years, the dominant land use in the areas that lie directly above the fresh groundwater (watershed areas) is chiefly high density. This is particularly true in the case of the Central area, where there is also more diversity in land use activities.

Indicators of Groundwater Quality

Pollutants from man-made surfaces increase the amount of contaminants permeating the surface into the groundwater reservoir. These include leachate from cesspits, trace metals, oil and grease resulting from motor vehicles and impervious surfaces in general. The negative effects of this could be greater if runoff from roofs were not contained in water tanks (since roofs are designed to trap 75 percent of the rainfall on its surface), although during a high intensity storm much of the precipitation is infiltrated into the ground when roof glides and pipes entering water tanks are unable to catch most of the rainfall (Thomas ISDMG, 1985). Perhaps the same could be said for toxins that are produced by motor

vehicles, but regardless of the restrictions placed on the number of cars per RVU its contribution to non-point source pollution should not be ignored. The Central lens is targeted as an area of major concern because fresh water is extracted for household distribution while water from lower perched water bodies is treated and distributed to the City of Hamilton and major hotels. The groundwater in the Southampton watershed is also tapped for distribution, but it is considered to be less a matter of environmental concern than the Central area since there are fewer land use activities and less development in the watershed area. Although the Somerset and St. George's watersheds have relatively high runoff rates, contaminants in the runoff are deemed not to be an environmental threat. However, this paper contends that, while the Central watershed is undoubtedly an issue, the other drainage areas should not be ruled-out due to increasing residential development in Bermuda.

The Central lens should be used as a classic example of how urbanization can impact negatively on the potable groundwater water supply, hence this section will define the principal nutrients that determine groundwater quality (primarily nitrogen and phosphorus), in addition to presenting the findings of scientific studies that have been carried out on the groundwater in the Central lens.

Nitrates

Average nitrate concentration in the Devonshire lens exceeds the WHO and USEPA (1976) drinking water standards of 11.3 mg N/l and 22.6 mg N/l in exceptional cases (Thompson et.al. 1986). Tests show a correlation between nitrate concentrations and residential densities in the unsewered sections of the Central Parishes: 25-35 mg N/l in high densities which is said to have increased by 10 mg N/l since 1976; and 15-20 mg N/l in medium density areas, estimated to have increased by 5 mg N/l to date.

Since tests show a high incidence of nitrate concentrations in the upper perched zone, and notably lower levels in the saline and brackish lens, one may hypothesize that nitrate contamination originates more from the surface than from land outfalls, which is likely to permeate the lower perched zone. Unsewered sanitation has been determined to be the chief cause of nitrate contamination. Eight percent of households in Bermuda have sewered sanitation, all of which are North of the design-point of the Central watershed. It is prescribed that all households have at least one cesspit, usually of the dimensions 2.2m squared. Unlike most septic systems in the U.S., cesspits are designed to filter sewage naturally by allowing liquid to percolate through unlined pits before entering the zone of recharge. Currently, this is considered to be an effective filtering method, but tests

suggest that leachate from pits is the main cause of relatively high nitrate concentrations in the Central lens.

However, dissimilar patterns have emerged for nitrate concentrations surrounding the landfill. It is assumed that they are very low for various reasons - the main one being that the compressed peat at the bottom of the marsh removes pollutants from the leachate before it is recharged.

Phosphates

Ratios of nitrates to phosphates show comparatively lower levels of the latter to the nitrates in the Central area (Simmons et. al. 1985). While ratios of N/P are typically 9/1 in unsewered situation and 15/1 in pre-developed conditions, the Bermuda case shows a disparity of 400-1000/1 N/P at various sampling points in Central lens.

Ammonia

Tests form well sites reveal that ammonia concentrations are very low. This suggests an oxygen rich system, since ammonia is a nitrogen species that appears when oxygen is in limited supply.

Chloride

Chloride occurs naturally in rainfall 16 mg Cl/capita/a in Bermuda but concentrations appear minimal due to factors

such as urban runoff and infiltration of fertilizers in open spaces (Thomson et. al.1986). Urban runoff concentrations of approximately 50 mg Cl/l while the infiltration is roughly 64 mg Cl/l. Thus, both high density development and fertilization practices have a purifying effect on the groundwater recharge.

URBAN RUNOFF AND CONTAMINANT LOADING IN WATERSHED AREAS

Measurements of runoff and pollutant levels before they enter the groundwater recharge are also useful for planners and engineers in understanding the impact of development on the quality of surface runoff. Once this is determined, procedures may be taken to abate or, if possible, check runoff and pollutants that result from post-development conditions. This section will estimate the net results of development in the watershed Parishes, first, with the aid of a computer program referred to as Technical Release 55 (TR-55) which has been used to estimate storm runoff and peak discharge rates in small watersheds in the United States; and second, by using the Simple Method to compute estimated storm pollutant export for the watersheds.

DEVELOPMENT AND HYDROLOGY USING TECHNICAL RELEASE-55.

Since weather patterns in Bermuda are similar to those in many Southeastern States,(approximately 35 N, 87 W) the results of TR-55 may be assumed to be reliable. But for various reasons beyond our control, land use acreage within the watersheds should not be assumed to be accurate, given that the information was obtained from a condensed version of the land use map and personal recall (done with some

confidence, because of Bermuda's limited space). Details of the program may be found in the Appendix C I of the report. Listed below are the elements of used to compute the runoff curve numbers (RCNs) by TR-55 program.

Hydrologic Soil Group - The hydrologic soil group C was because, although the high level of development has reduced the stream network to mostly first order streams, moderate to steep slopes are still characteristic of the geology in Bermuda and range from 4 percent in Somerset to 15 percent in the Central watershed. As we have seen in the introduction, soil types do not differ greatly throughout the Island in terms of their chemical composition, thus it may be expected that they will show little differences in erosion rates during a storm period. Naturally, the erosion factor will vary according to the slope length and slope gradient of the land. In a hypothetical situation it would be expected that soils in the Pembroke watershed would experience higher rates of erosion during development if certain precautions were not taken to preserve the soil.

Runoff Curve Number (RCN) - This number may range from a low 25 RCN in woodlands and forests, to 98 RCN in areas with paved surfaces - the first indicates the best land use conditions while the latter is the least desirable. However RCNs between 70 and 75 are ideal for communities with

C group soils. In regards to the Bermuda case, RCNs suggest that values for the watershed areas are generally high. An exception to this is the Southampton watershed which has an acceptable weighted RCN of 76. The same may not be said for the conditions in the St George's watershed - the result is a RCN of 86. An unexpected outcome was that RCNs for the Somerset and Central watershed would have the same value, because:

- the land use activities are more development oriented in the Central watershed in addition to being more varied,
-and due to the presence of a large industrial area in the Central watershed, and the absence of any such activity in the Somerset area, although coverage for commercial and business is only 1 percent higher in the Somerset watershed.

Impervious Areas - These include paved parking, driveways and roof tops, but there is a high degree of skewness in the RCNs since much of the precipitation that reaches the roofs will not enter the groundwater recharge.

Although RCNs in the watersheds do not exhibit the "worst case scenario", one must be cognizant of the fact that Bermuda's geographical size and its location, ie. an

isolated island, affords little "room for error", therefore more efficient management practices must be sought for areas that lie above the freshwater lenses.

ESTIMATIONS FOR POLLUTANT LOADING

Pollutant estimations will be determined by using formulas that were designed for planners and engineers, desirous of minimizing contaminant export from the surface to the groundwater. All computations will be made, using a manual for estimating and reducing pollutant export.

The significance of this study is directed towards Bermuda's rapid urbanization, which has altered the natural environment drastically over the past 20 years. To reiterate concisely, changes to the ecosystem relating to our topic include the degeneration of streams to form mostly first order streams in the mapped watersheds. Higher stream orders have been eliminated during the development process, thus having the following net effect:

-increasing peak discharges of two to five times above pre-development levels and at least a 50 percent increase runoff volumes,

-and in many sections of the Island high runoff rates during intense storms have caused some flooding on the roads. This does not include the Central watershed because of its steep slopes.

Still another characteristic of the developed landscape in Bermuda refers to increased levels of pollutant export; this will eventually alter the groundwater quality. Of particular concern to this study are the nutrients (phosphates and nitrates), oil and grease resulting form vehicles and the occurrence of trace metals. Using the "simple method" we shall determine the extent to which these factors may be controlled for in the mapped watershed areas, first by estimating increased nutrients during a storm event; trace metals in runoff; and finally, Best Management Practices (BMPs) will be suggested. The limitations of the simple method hinge on the fact that values for the pollutant concentrations are derived from land uses in Washington, D.C., Baltimore and Virginia, all of which exhibit quantitatively different values from those in the Bermuda case, by virtue of the differences between Bermuda and the U.S. cities. Conversely, the similarities (such as climate an precipitation, particularly in Virginia which is about 4 degrees North of Bermuda) suggest that there may be a resemblance in soil composition of the areas. This implies comparable soil infiltration rates as well as filtering capacities, although differences in their geologic structure will effect pollutant concentration in the groundwater.

Estimating Pollutant Export

The simple method requires that the following parameters be used to compute the pollutant export for a watershed.

P - Annual rainfall, which is about 58.1 inches in Bermuda.

Pj - This corrects for the number of rainfall events that do not produce significant runoff. Hence the correction factor is set at 90 percent or 0.90.

Rv - The runoff coefficient is used to measure the sites reaction to runoff - this is based on vegetation cover, level of development, slope and soil type. Two equations are suggested, the first of which simply calculates Rv in terms of storm runoff and storm rainfall. The second equation yields more reliable results than the first, because it considers the relationship of the watersheds imperviousness (I) when solving for the runoff coefficient:

$$Rv = 0.05 + 0.009(I)$$

Note that the (I) was derived from the TR-55 data and includes all categories with some imperviousness - Impervious Areas, Streets and Roads, Urban Districts and Residential Districts.

A - refers to the size of the watershed, and it is recommended that the area not exceed 1 mile squared or 640 acres. The mapped watersheds fall within this limit, ranging from 33.4 acres in the smallest area, to 465.08

acres in the largest area (coincidentally the Central watershed).

C - Average pollutant concentrations were derived from more than 300 storm events in four different land uses in Washington D.C., Baltimore and Virginia. Pollutant totals were obtained from: New Suburban Sites in Washington, Older Urban Areas in Baltimore, Central Business Districts in Washington and Hardwood Forests in Northern Virginia.

Nutrient Loading for Different Phases Development

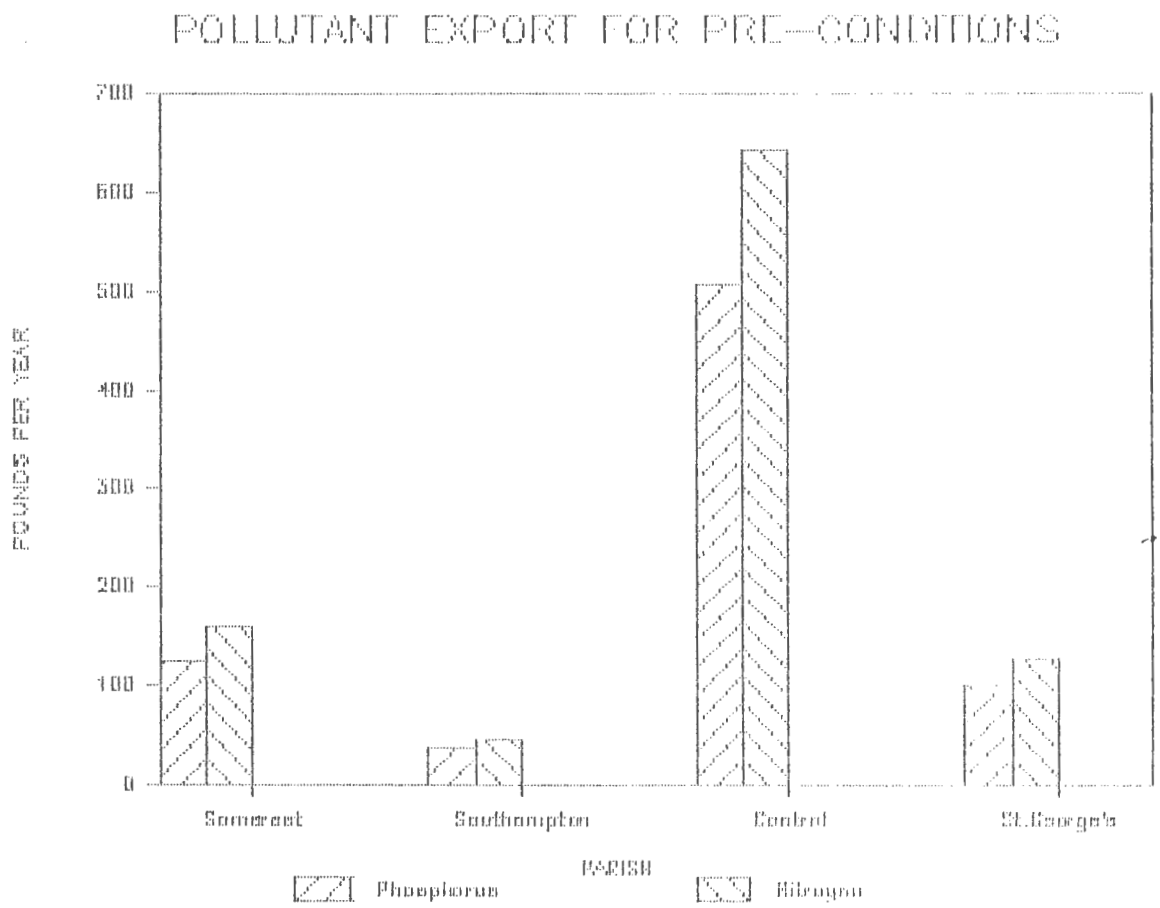
Appendix C.II compares current conditions to post-development conditions by computing the annual storm export in pounds for nitrogen and phosphorus using the following formula:

$$LTP = [(P)(Pj)(Rv)/12](C)(A)(2.72)$$

$$LTN = [(P)(Pj)(Rv)/12](C)(A)(2.72)$$

Nitrogen and phosphorus levels in runoff are markedly different in pre and post-conditions, with the concentrations for the latter being greater. Estimates for the Central watershed show increases of 308,970.72 pounds/year for nitrogen and 24,079.78 pounds/year for phosphorus.

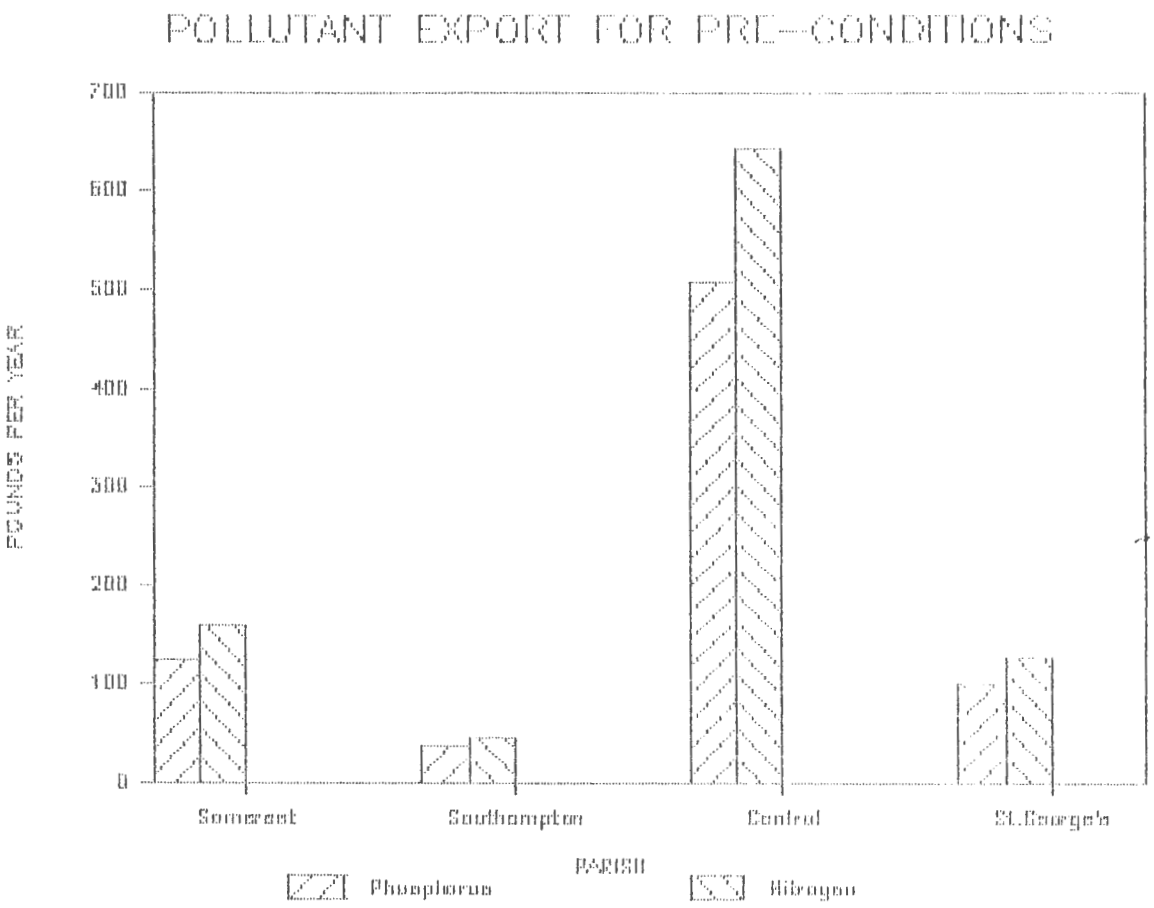
Figure 4.2



Department of Environmental Programs.
Metropolitan Washington Council Of Governments.
Controlling Urban Runoff.

Estimates Based on Pollutant Contamination Value for use with Simple Method.

Figure 4.2



Department of Environmental Programs.
Metropolitan Washington Council Of Governments.
Controlling Urban Runoff.

Estimates Based on Pollutant Contamination Value for use with Simple Method.

In the following section suggestions will be offered as to how best the Central watershed can be managed, in terms of reducing nutrient export in the runoff.

RECOMMENDATIONS

BEST MANAGEMENT PRACTICES FOR WATERSHED DEVELOPMENT

The purpose of using BMPs is to obtain, as far as possible, nutrient concentration levels in the groundwater that reassemble pre-development hydrological conditions. This can be achieved by reducing pollutants in runoff before it is recharged. However desirable a BMP may seem, planners and engineers should choose one that is best suited to the geography and geology of an area.

Reducing Pollutant Concentrations in the Groundwater

Options for two year storm are based on the dimensions of the watershed, soil permeability, topography and hydrogeology. While some BMPs are better suited to the features of the Central watershed, others are offered as alternatives because they are marginally appropriate for the area.

Extended Detention Pond - Particulate matter carrying pollutants will settle at the bottom of a detention pond. Although removal rates will vary according to the pollutants capacity to settle. In some cases, creating a shallow marsh will improve extraction of pollutants.

Wet Pond - Wet Ponds function in a similar way to extended detention ponds, except that in addition to settling, plant material is utilized to extract pollutants.

It is recommended that features of the wet pond and extended detention pond be combined to recreate the marsh, in a section of the landfill, and while it would be an artificial marsh, it would act as a wildlife habitat as well as improve the visual quality of the area.

LEGISLATION AS A MEANS OF CONTROLLING GROUNDWATER QUALITY

While the following suggestions should be practiced throughout the Island, they are specifically directed towards the Central watershed where excessive development accounts for the area having the highest pollutant export.

Suggestions for Controlling Contamination in Residential Areas

Short-term Goals

-Limitations on the amount of impervious area, having dirt driveways, lawns, porous pavement for parking spaces.

-Restrictions on additions to main structures and conversion of structures to form multi-unit apartments. This will have a dual effect of limiting the number of cars, (although not necessarily the total number of vehicles), and the volume of sewage leachate.

Long-term Goals

- Rezoning for larger lot sizes and clustered zoning. The first will have the effect of dispersing the population to areas of no fresh water value, while the second will increase the quality of runoff. Both residential types will have an aesthetic impact on the watershed, particularly the Central area, which is in need of improvement.
- Exploration of cesspit designs that will filter more effectively.
- Partial sewerage of areas in the mapped watersheds to reduce contaminants although it will also have the effect of reducing the recharge to the groundwater.

Controlling Runoff Due to Transportation

Short-term Goals

- The use of catalytic converters and unleaded gasoline.
- Continual maintenance of streets to remove sediment bound pollutants, although unkempt streets are uncommon in Bermuda.

Long-term Goals

- Reduction of road length in residential areas
- Introduction of road designs that will better filter runoff destined for recharge.

Proper implementation of BMPs and effective legislation is dependant upon communication between the Planning Department and the Department of Works and Engineering since the development functional areas (housing and transportation), are inseparable from the legislative process.

CONCLUSION

While it is difficult to place restrictions development during a period when the demand and need for housing in Bermuda is relatively high, strategies may be implemented to abate contamination of the potable groundwater that are based on effective management of the land use activities.

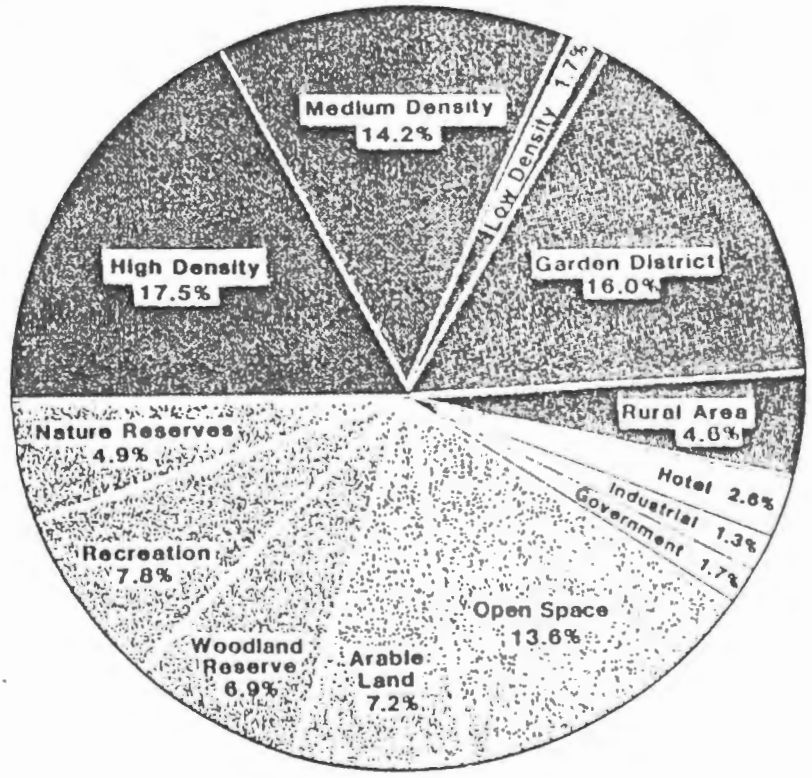
APPENDIX A. I

A SYSTEM OF OPEN SPACES

The reasons advanced in favour of retaining open space include, the need to conserve the natural environment; to maintain and enhance visual amenity; and to provide living space to offset an increasingly suburban way of life.

No hard and fast rules exist regarding the amount of open space which should b set aside, as the value attached to this resource and the reasons for retainin it will vary between individuals and between communities. A society, therefore, should determine its own level of open space provision and this wil depend on a range of economic, social, cultural and environmental factors.

Fig. 5 : Bermuda Development Plan 1983 - Zoning Distribution



Source : Department of Planning

The 1983 Development Plan zoned 40% of Bermuda as Environmental Protection Areas and in so doing established the principle that certain areas of land wer not available for building. However, this has not entirely prevented the development of these areas and the legacy of previous subdivision approvals an rights of development have combined to undermine the principle.

APPENDIX A. II

HIGH DENSITY AREA 101

Without prejudice to other provisions in this Plan, the following regulations shall apply in High Density Areas.

INTENTS

High Density Areas are designated for the development of high density housing and a range and distribution of appropriate services and facilities.

Development should aim to make the most efficient use of residential land with a scale and intensity of development compatible with the characteristics of the site. Redevelopment, rehabilitation and the re-cycling of land is to be encouraged.

All residential development should enhance the local environment through the provision of a high standard of accommodation and supplementary landscaping and planting.

The development of accessible service centres should be provided for as far as is compatible with the character of neighbouring residential areas.

In considering potential sites for non-residential development, the primary concern should be the impact of such development on established housing neighbourhoods.

The following matters are further regulated by certain Sections of this Statement :

RESIDENTIAL DEVELOPMENT STANDARDS	- Section VI
SUBDIVISION OF LAND	- Section VII
ROADS	- Section VIII
PARKING	- Section IX

RESIDENTIAL DEVELOPMENT

Development regulation		Detached house	Attached house	Apartment house / Guest house / Limited tourist accommodation	Apartment house (Special density on lots of 1 acre or more)
Maximum density	houses per acre	8	14	-	-
	units per acre	-	14	25	50
	bedrooms per acre	-	-	35	85
Minimum lot size		5,000 sq.ft	3,500 sq ft	5,000 sq.ft	1 acre
Maximum site coverage		40%	40%	40%	30%
Minimum setbacks	tourist route	50 ft	50 ft	50 ft	50 ft
	public road/RROW	25 ft	25 ft	25 ft	25 ft
	estate/private road	20 ft	20 ft	20 ft	25 ft
	lot line	10 ft	D	10 ft	20 ft
		Minimum setbacks are further regulated by paragraph 39.			
Maximum height		2 storeys	2 storeys	3 storeys	5 storeys
Special Provisions		-	1	2	3

OTHER FORMS OF DEVELOPMENT

Development regulation	Commercial	Industrial	Social	Recreational Open land
Minimum lot size	At the discretion of the Board			
Maximum site coverage	75%	75%	60%	D
Minimum setbacks	At the discretion of the Board			
Maximum height				
Special Provisions	4	5	6	7

D = At the discretion of the Board - = Not applicable RROW = Railway Right-of-Way

HIGH DENSITY AREA - SPECIAL PROVISIONS

The following matters are further regulated by certain Sections of this Statement :
RESIDENTIAL DEVELOPMENT STANDARDS - SECTION VI ; SUBDIVISION OF LAND - SECTION VII ; ROADS - SECTION VIII ; PARKING - SECTION IX

RESIDENTIAL

1.(1) An application which proposes the development of an attached house shall be accompanied by an application for approval of the related draft plan of subdivision.

(2) Approval of a final plan of subdivision, or any phase thereof, shall not be granted until the attached house development, or any phase thereof, has been completed and a certificate of completion for each dwelling unit has been issued.

(3) In the case of an application proposing three or more attached houses, the minimum lot size for a house with zero lot lines on both sides may be reduced to 2,500 sq.ft (ie, a mid-terrace house).

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2. In approving an application for an apartment house, guest house or limited tourist accommodation at a density of 25 dwelling units per acre or less, the Board shall be satisfied that -

(a) the development will not be detrimental to the residential environment and amenity of the neighbourhood; and
(b) the density and design of development are appropriate for the site taking into consideration such characteristics as location, lot configuration, topography and means of access; and
(c) the roads serving the site will accommodate safely and freely the traffic generated by the development.

---

3. On lots of 1 acre or more, apartment houses exceeding a density of 25 dwelling units per acre may be permitted at the discretion of the Board, subject to the following conditions -

(a) the density, design, scale and layout of development are appropriate for the site, taking into consideration such site characteristics as -
  (i) the location, size and configuration of the lot; and
  (ii) the relief and visual prominence of the land; and
  (iii) the environmental quality of the land and the incidence of natural features; and
  (iv) the suitability of roads and access to the site to accommodate safely and freely the traffic generated; and
(b) the development shall be designed in a manner that minimises the visual impact of any buildings in excess of two storeys, as viewed from public places and neighbouring properties; and
(c) the number of dwelling units containing three or more bedrooms shall not exceed 25% of the total number of units.

COMMERCIAL

4.(1) Commercial development may be permitted in locations adjacent to existing commercial development so as to contribute to the creation of identifiable service centres, provided -

(a) the development proposed will fill in between existing commercial developments ; or
(b) if lateral expansion of a service centre is proposed, the development will not be injurious to the character and environment of the neighbouring area.

(2) Outside of service centres, commercial development, including home occupations, may only be permitted at the discretion of the Board, provided -

(a) it merits, by virtue of its particular character and the nature of the enterprise, a location outside a service centre; and
(b) the application is for a specific commercial use that is compatible with the character and environment of the surrounding area; and
(c) the buildings and land will retain a residential appearance; and
(d) it does not result in a material increase in traffic through any neighbouring residential area.

(3) All commercial development shall satisfy the following conditions -

(a) the development shall not be detrimental to the environment of the surrounding area by reason of the scale of operation, excessive noise, intensity of traffic generated or appearance; and
(b) the development shall be located so that it is served directly by a commuter or other major road or a tourist route, or is easily accessible to such a road without resulting in a material increase in traffic on any private road to the detriment of the surrounding residential environment.

(4) The Board shall exercise its discretion with respect to height, setbacks and other details of planning to achieve -

(a) a scale and design of development appropriate for the area taking into consideration the nature, intensity and character of surrounding development; and
(b) safe access to the site and the provision of adequate off-street parking and servicing.

INDUSTRIAL

5.(1) Industrial development may only be permitted on sites which satisfy the following criteria -

(a) the characteristics of the site are such that reasonable quality residential development could not readily be accommodated;
(b) the site can accommodate industrial development without detriment to the environment or amenity of the surrounding area, particularly any residential area;
(c) the site is served directly by a commuter or other major road, or is easily accessible to such a road without resulting in a material increase in traffic through any neighbouring residential area.

(2) Notwithstanding sub-provision (1)(a), light industrial development may be permitted within an identifiable service centre provided the location satisfies sub-provisions (1)(b) and (c).

(3) The Board shall exercise its discretion with respect to height, setbacks and other details of planning to achieve -

(a) a scale and design of development appropriate for the area taking into consideration the nature, intensity and character of surrounding development; and
(b) safe access to the site and the provision of adequate off-street parking and loading; and
(c) a high quality of design of all building facades fronting public roads and non-industrial properties; and
(d) the provision of landscaping and screen planting to minimise the visual impact of all areas associated with servicing, loading, parking and outdoor storage as viewed from public roads and from neighbouring non-industrial properties.

SOCIAL

6.(1) Social development may be permitted to the extent that it contributes to an efficient provision and distribution of social services according to the needs of Bermuda's residents.

(2) Social development may only be permitted on sites which satisfy the following criteria -

(a) the site is conveniently located for the development's proposed catchment area (which may be all of Bermuda), taking into consideration the present distribution of such developments; and

(b) the size, configuration and topography of the site are suitable for the development proposed; and

(c) the site is served directly by a public road.

(3) Social development shall not be detrimental to the environment of the surrounding area by reason of the scale of operation, excessive noise or the intensity of traffic generated.

(4) The Board shall exercise its discretion with respect to height, setbacks and other details of planning to achieve -

(a) a scale and design of development that is compatible with the nature, intensity and character of existing development in the surrounding area; and

(b) safe access to the site and the provision of adequate off-street parking and servicing.

RECREATIONAL AND OPEN LAND

7.(1) Recreational or open land development shall be permitted to the extent that it contributes to an adequate provision and distribution of recreation and open space facilities to meet the needs of the residential neighbourhoods.

(2) Recreational development that would result in a material increase in traffic may only be located on sites with direct access to existing public roads and where additional traffic will not cause a nuisance to surrounding residential areas.

(3) With regard to buildings associated with recreational and open land development, the Board shall exercise its discretion with respect to height, setbacks and other details of planning to achieve -

(a) a scale and design of development that is compatible with the character of the surrounding area; and

(b) safe access to the site and the provision of adequate off-street parking and servicing.

TOWN OF ST. GEORGE

8.(1) Notwithstanding anything to the contrary in this Plan, in the urbanised portion of the Town of St.George the Board may permit a relaxation in any of the following provisions for any form of development -

(a) the minimum lot size;
(b) the maximum density;
(c) the maximum site coverage;
(d) the minimum setbacks;
(e) the residential development standards; and
(f) the on-site parking and loading requirements.

(2) The Board, in considering a relaxation under sub-provision (1) and in the exercise of its discretion with respect to the details of planning, shall ensure that -

(a) the development contributes to the maintenance and enhancement of the Town's distinctive architectural and historical character; and

(b) the scale, design and building materials of development are compatible with the traditional appearance; and

(c) a high quality pedestrian environment is provided.

MEDIUM DENSITY AREA 102

Without prejudice to other provisions in this Plan, the following regulations shall apply in Medium Density Areas.

INTENTS

Medium Density Areas are designated for the development of medium density housing and a limited range of services and facilities compatible with the predominantly residential environment.

Larger parcels of land should be subdivided and developed so that the most efficient residential use is made of that land with due regard being given to environmental quality and site characteristics.

All residential development should enhance the local environment through the provision of a high standard of accommodation and supplementary landscaping and planting.

In considering potential sites for non-residential development, the overriding consideration should be the maintainence of the character and amenity of the residential neighbourhoods.

The following matters are further regulated by certain Sections of this Statement :

RESIDENTIAL DEVELOPMENT STANDARDS	- Section VI
SUBDIVISION OF LAND	- Section VII
ROADS	- Section VIII
PARKING	- Section IX

RESIDENTIAL DEVELOPMENT

Development regulation		Detached house	Attached house	Apartment house / Guest house / Limited tourist accommodation	Apartment house (Special density on lots of 1 acre or more)
Maximum density	houses per acre	4	8	-	-
	units per acre	-	8	15	30
	bedrooms per acre	-	-	24	55
Minimum lot size		9,000 sq.ft.	4,000 sq.ft	9,000 sq.ft	1 acre
Maximum site coverage		25%	35%	25%	25%
Minimum setbacks	tourist route	50 ft	50 ft	50 ft	50 ft
	public road/RROW	30 ft	30 ft	30 ft	30 ft
	estate/private road	25 ft	25 ft	25 ft	25 ft
	lot line	10 ft	D	10 ft	20 ft
		Minimum setbacks are further regulated by paragraph 39			
Maximum height		2 storeys	2 storeys	3 storeys	5 storeys
Special Provisions		-	1	2	3

OTHER FORMS OF DEVELOPMENT

Development regulation	Commercial	Industrial	Social	Recreational Open land
Minimum lot size	At the discretion of the Board			
Maximum site coverage	75%	75%	60%	D
Minimum setbacks	At the discretion of the Board			
Maximum height	2 storeys	2 storeys	2 storeys	2 storeys
Special Provisions	4	5	6	7

D= At the discretion of the Board -=Not applicable RROW=Railway Right-of-Way

MEDIUM DENSITY AREA - SPECIAL PROVISIONS

2.112 ft. 25.34 H/mile
1:2500

The following matters are further regulated by certain Sections of this Statement :
RESIDENTIAL DEVELOPMENT STANDARDS - SECTION VI ; SUBDIVISION OF LAND - SECTION VII ; ROADS - SECTION VIII ; PARKING - SECTION IX

RESIDENTIAL

1.(1) An application which proposes the development of an attached house shall be accompanied by an application for approval of the related draft plan of subdivision.

(2) Approval of a final plan of subdivision, or any phase thereof, shall not be granted until the attached house development, or any phase thereof, has been completed and a certificate of completion for each dwelling unit has been issued.

(3) In the case of an application proposing six or more attached houses, the minimum lot size may be reduced to 3,500 sq.ft.

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2. In approving an application for an apartment house, guest house or limited tourist accommodation at a density of 15 dwelling units per acre or less, the Board shall be satisfied that -

(a) the development will not be detrimental to the residential environment and amenity of the neighbourhood; and
(b) the density and design of development are appropriate for the site taking into consideration such characteristics as location, lot configuration, topography and means of access; and
(c) the roads serving the site will accommodate safely and freely the traffic generated by the development.

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3. On lots of 1 acre or more, apartment houses exceeding a density of 15 dwelling units per acre may be permitted at the discretion of the Board, subject to the following conditions -

(a) the density, design, scale and layout of development are appropriate for the site, taking into consideration such site characteristics as -
  (i) the location, size and configuration of the lot; and
  (ii) the relief and visual prominence of the land; and
  (iii) the environmental quality of the land and the incidence of natural features; and
  (iv) the suitability of roads and access to the site to accommodate safely and freely the traffic generated; and
(b) the development shall be designed in a manner that minimises the visual impact of any buildings in excess of two storeys, as viewed from public places and neighbouring properties.

COMMERCIAL

4.(1) Commercial development may be permitted in locations adjacent to existing commercial development so as to contribute to the creation of identifiable service centres, provided -

(a) the development proposed will fill in between existing commercial developments ; or
(b) if lateral expansion of a service centre is proposed, the development will not be injurious to the character and environment of the neighbouring area.

(2) Outside of service centres, commercial development, including home occupations, may only be permitted at the discretion of the Board, provided -

(a) it merits, by virtue of its particular character and the nature of the enterprise, a location outside a service centre; and
(b) the application is for a specific commercial use that is compatible with the character and environment of the surrounding residential area; and
(c) the buildings and land will retain a residential appearance; and
(d) it does not result in a material increase in traffic through any neighbouring residential area.

(3) All commercial development shall satisfy the following conditions -

(a) the development shall not be detrimental to the environment of the surrounding area by reason of the scale of operation, excessive noise, intensity of traffic generated or appearance; and
(b) the development shall be located so that it is served directly by a commuter or other major road or a tourist route, or is easily accessible to such a road without resulting in a material increase in traffic on any private road to the detriment of the surrounding residential environment.

(4) The Board shall exercise its discretion with respect to height, setbacks and other details of planning to achieve -

(a) a scale and design of development appropriate for the area taking into consideration the nature, intensity and character of surrounding development; and
(b) safe access to the site and the provision of adequate off-street parking and servicing.

INDUSTRIAL

5.(1) Light industrial development shall be the only form of industrial development permitted.

(2) Light industrial development may only be permitted on sites which satisfy the following criteria -

(a) the characteristics of the site are such that reasonable quality residential development could not readily be accommodated;
(b) the site can accommodate industrial development without detriment to the environment or amenity of the surrounding area, particularly any residential area;
(c) the site is served directly by a commuter or other major road, or is easily accessible to such a road without resulting in a material increase in traffic through any neighbouring residential area.

(3) Notwithstanding sub-provision (2)(a), light industrial development may be permitted within an identifiable service centre provided the location satisfies sub-provisions (2)(b) and (c).

(4) The Board shall exercise its discretion with respect to height, setbacks and other details of planning to achieve -

(a) a scale and design of development appropriate for the area taking into consideration the nature, intensity and character of surrounding development; and
(b) safe access to the site and the provision of adequate off-street parking and loading; and
(c) a high quality of design of all building facades fronting public roads and non-industrial properties; and
(d) the provision of landscaping and screen planting to minimise the visual impact of all areas associated with servicing, loading, parking and outdoor storage as viewed from public roads and from neighbouring non-industrial properties.

SOCIAL

6.(1) Social development may be permitted to the extent that it contributes to an efficient provision and distribution of social services according to the needs of Bermuda's residents and provided the Board is satisfied the development could not be more appropriately located in a High Density Area.

(2) Social development may only be permitted on sites which satisfy the following criteria -

(a) the site is conveniently located for the development's proposed catchment area (which may be all of Bermuda), taking into consideration the present distribution of such developments; and

(b) the size, configuration and topography of the site are suitable for the development proposed; and

(c) the site is served directly by a public road.

(3) Social development shall not be detrimental to the environment of the surrounding area by reason of the scale of operation, excessive noise or the intensity of traffic generated.

(4) The Board shall exercise its discretion with respect to height, setbacks and other details of planning to achieve -

(a) a scale and design of development that is compatible with the nature, intensity and character of existing development in the surrounding area; and

(b) safe access to the site and the provision of adequate off-street parking and servicing.

RECREATIONAL AND OPEN LAND

7.(1) Recreational or open land development shall be permitted to the extent that it contributes to an adequate provision and distribution of recreation and open space facilities to meet the needs of the residential neighbourhoods.

(2) Recreational development that would result in a material increase in traffic may only be located on sites with direct access to existing public roads and where additional traffic will not cause a nuisance to surrounding residential areas.

(3) With regard to buildings associated with recreational and open land development, the Board shall exercise its discretion with respect to height, setbacks and other details of planning to achieve -

(a) a scale and design of development that is compatible with the character of the surrounding area; and

(b) safe access to the site and the provision of adequate off-street parking and servicing.

LOW DENSITY AREA 103

Without prejudice to other provisions in this Plan, the following regulations shall apply in Low Density Areas.

INTENTS

Low Density Areas are designated for the development of low density detached housing. A higher density of clustered housing may be achieved where the careful planning and siting of development permits important environmental features and significant open spaces to be preserved intact.

Clustered housing should be encouraged on appropriate sites in order to make the most efficient use of residential land and provide for the retention of open spaces, prominent natural features, mature trees and vegetation.

The following matters are further regulated by certain Sections of this Statement :

RESIDENTIAL DEVELOPMENT STANDARDS	- Section VI
SUBDIVISION OF LAND	- Section VII
ROADS	- Section VIII
PARKING	- Section IX

RESIDENTIAL DEVELOPMENT

Development regulation		Detached house	Attached house	Apartment house / Guest house / Limited tourist accommodation	Apartment house (Special density on lots of 1 acre or more)
Maximum density	houses per acre	2	8	–	–
	units per acre	–	8	8	20
	bedrooms per acre	–	–	18	40
Minimum lot size		17,000 sq. ft	3,500 sq. ft	17,000 sq. ft	1 acre
Maximum site coverage		20%	40%	20%	20%
Minimum setbacks	tourist route	50 ft	D	50 ft	50 ft
	public road/RROW	30 ft	D	30 ft	30 ft
	estate/private road	25 ft	D	25 ft	25 ft
	lot line	10 ft	D	10 ft	20 ft
		Minimum setbacks are further regulated by paragraph 39			
Maximum height		2 storeys	2 storeys	2 storeys	3 storeys
Special Provisions		–	1	2	3

OTHER FORMS OF DEVELOPMENT

Development regulation	Commercial	Industrial	Social	Recreational Open land
Minimum lot size	Commercial & Industrial development shall not be permitted		Only permitted as an accessory use to a housing development.	D
Maximum site coverage				15%
Minimum setbacks				D
Maximum height				2 storeys
Special Provisions			4	5

D = At the discretion of the Board -- = Not applicable RROW = Railway Right-of-Way

LOW DENSITY AREA - SPECIAL PROVISIONS

The following matters are further regulated by certain Sections of this Statement :
RESIDENTIAL DEVELOPMENT STANDARDS - SECTION VI ; SUBDIVISION OF LAND - SECTION VII ; ROADS - SECTION VIII ; PARKING - SECTION IX

RESIDENTIAL

1.(1) Lots for attached house development may only be created from a lot of 0.5 acre or more.

(2) An application which proposes the development of an attached house shall be accompanied by an application for approval of the related draft plan of subdivision.

(3) Approval of a final plan of subdivision, or any phase thereof, shall not be granted until the attached house development, or any phase thereof, has been completed and a certificate of completion for each dwelling unit has been issued.

(4) The maximum lot size for any attached house shall be 4,500 sq.ft.

(5) In the case of an application proposing three or more attached houses, the minimum lot size for a house with zero lot lines on both sides may be reduced to 2,500 sq.ft (ie. a mid-terrace house).

(6) Where a lot is to be subdivided to create attached house lots, an area comprising 30% of that lot, excluding any roadways, shall be set aside as an undeveloped open space.

(7) Lots for attached house development shall be located and clustered so as to -

(a) preserve intact the significant areas of open space and environmental quality; and
(b) retain as many of the existing trees and large shrubs as possible.

(8) The Board shall apply its discretion with respect to setbacks in accordance with paragraph 39 and in a manner that secures the most appropriate siting of development in relation to prominent natural features, trees and vegetation.

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2. In approving an application for an apartment house, guest house or limited tourist accommodation at a density of 8 dwelling units per acre or less, the Board shall be satisfied that -

(a) the development will not be detrimental to the environmental quality of the area; and
(b) the design of development is appropriate for the site taking into consideration such characteristics as location, topography and means of access; and
(c) the roads serving the site will accommodate safely and freely the traffic generated by the development.

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3. On lots of 1 acre or more, apartment houses exceeding a density of 8 dwelling units per acre may be permitted at the discretion of the Board, subject to the following conditions -

(a) the development shall not be detrimental to the environmental quality of the land; and
(b) development shall be sited to retain important natural feature and mature trees and vegetation considered worthy of preservation; and
(c) the density, design and scale of development are appropriate for the site taking into consideration such characteristics as location, lot configuration, topography and means of access; and

(d) the roads serving the site will accommodate safely and freely the traffic generated by the development; and

(e) the development shall be designed in a manner that minimises the visual impact of any buildings in excess of two storeys, as viewed from public places and neighbouring properties.

SOCIAL

4. Social development may only be permitted as an accessory use to a housing development and in such cases the Board shall exercise its discretion with respect to the details of planning to achieve a scale and design of development that are compatible with the housing it serves.

RECREATIONAL AND OPEN LAND

5.(1) Only those forms of recreational and open land development shall be permitted which do not result in any significant alteration to the existing topography nor any reduction in significant stands of vegetation.

(2) The Board shall exercise its discretion with respect to the details of planning to achieve a siting, scale and design of development that are compatible with the environmental quality of the land and the character of the surrounding area.

GARDEN DISTRICT AREA 104

Without prejudice to other provisions in this Plan, the following regulations shall apply in Garden District Areas.

INTENTS

Garden District Areas are residential areas with an established pattern of subdivision and a high quality character of development.

Further development should maintain this quality with complimentary and generous lot sizes; the careful siting and design of buildings; the protection of existing vegetation and natural features; and the provision of additional landscaping where appropriate.

The following matters are further regulated by certain Sections of this Statement :

RESIDENTIAL DEVELOPMENT STANDARDS	- Section VI
SUBDIVISION OF LAND	- Section VII
ROADS	- Section VIII
PARKING	- Section IX

RESIDENTIAL DEVELOPMENT

Development regulation		Detached house	Attached house	Apartment house Guest house Limited tourist accommodation	Apartment house (Special density on lots of 1 acre or more)
Maximum density	houses per acre	1 per 30,000 sq.ft.	3	-	Not applicable
	units per acre	-	3	4	
	bedrooms per acre	-	-	10	
Minimum lot size		25,000 sq.ft	14,000 sq.ft	27,500 sq.ft	
Maximum site coverage		15%	15%	15%	
Minimum setbacks	tourist route	50 ft	50 ft	50 ft	
	public road/RROW	30 ft	30 ft	30 ft	
	estate/private road	25 ft	25 ft	25 ft	
	lot line	20 ft	D	20 ft	
		Minimum setbacks are further regulated by paragraph 39			
Maximum height		2 storeys	2 storeys	2 storeys	
Special Provisions		2	3	4	

OTHER FORMS OF DEVELOPMENT

Development regulation	Commercial	Industrial	Social	Recreational Open land
Minimum lot size	Commercial, Industrial and Social development shall not be permitted.			D
Maximum site coverage				10%
Minimum setbacks				D
Maximum height				2 storeys
Special Provisions				5

D= At the discretion of the Board --=Not applicable RROW=Railway Right-of-Way

GARDEN DISTRICT AREA - SPECIAL PROVISIONS

The following matters are further regulated by certain Sections of this Statement :
RESIDENTIAL DEVELOPMENT STANDARDS - SECTION VI ; SUBDIVISION OF LAND - SECTION VII ; ROADS - SECTION VIII ; PARKING - SECTION IX

AMENITY CONSERVATION AREA

1. All areas zoned as Garden District Areas shall be subject to the provisions of a Class 1 Amenity Conservation Area 301 and the Board shall exercise its discretion with respect to such matters as the subdivision of land and the siting of buildings in accordance with those provisions.

RESIDENTIAL

2. For detached house development on an undersize lot of less than 25,000 sq.ft that existed prior to commencement day, the minimum setback from a lot line may be reduced to 10 feet.

3.(1) An application which proposes the development of an attached house shall be accompanied by an application for approval of the related draft plan of subdivision.

(2) Approval of a final plan of subdivision, or any phase thereof, shall not be granted until the attached house development, or any phase thereof, has been completed and a certificate of completion for each dwelling unit has been issued.

4. In approving an application for an apartment house, guest house or limited tourist accommodation, the Board shall be satisfied that -

(a) the development will not be detrimental to the residential environment and amenity of the neighbourhood; and

(b) the density and design of development are characteristic of that in the neighbourhood.

RECREATIONAL AND OPEN LAND

5.(1) Only those forms of recreational and open land development shall be permitted which do not result in any significant alteration to the existing topography nor any reduction in significant stands of vegetation and are intended for the use of residents in the immediate neighbourhood.

(2) The Board shall exercise its discretion with respect to the details of planning to achieve a siting, scale and design of development that are compatible with the character of the surrounding residential area.

RURAL AREA 105

Without prejudice to other provisions in this Plan, the following regulations shall apply in Rural Areas.

INTENTS

Rural Areas are large tracts of open countryside and Bermuda's remaining lands with a rural character.

All subdivision and development should be strictly controlled to ensure that the preservation of this rural character takes precedence over all other planning considerations.

Where appropriate, subdivision should be in the form of smaller lots, concentrated and located so that the rural nature of the land is maintained.

The following matters are further regulated by certain Sections of this Statement :

RESIDENTIAL DEVELOPMENT STANDARDS	- Section VI
SUBDIVISION OF LAND	- Section VII
ROADS	- Section VIII
PARKING	- Section IX

RESIDENTIAL DEVELOPMENT

Development regulation		Detached house	Attached house	Apartment house / Guest house / Limited tourist accommodation	Apartment house (Special density on lots of 1 acre or more)
Maximum density	houses per acre	1 per 90,000 sq.ft.	2 per 90,000 sq.ft.	-	Not applicable
	units per acre	-	2 per 90,000 sq.ft.	2	
	bedrooms per acre	-	-	10	
Minimum lot size		10,000 sq.ft.	5,000 sq.ft.	60,000 sq.ft.	
Maximum site coverage		Special Provision 2(2)		10%	
Minimum setbacks	tourist route	50 ft.	50 ft.	50 ft.	
	public road/RROW	30 ft.	30 ft.	30 ft.	
	estate/private road	25 ft.	25 ft.	25 ft.	
	lot line	20 ft.	D	20 ft.	
		Minimum setbacks are further regulated by para. 39			
Maximum height		2 storeys	2 storeys	2 storeys	
Special Provisions		2	3	4	

OTHER FORMS OF DEVELOPMENT

Development regulation	Commercial	Industrial	Social	Recreational Open land
Minimum lot size	Commercial, Industrial and Social development shall not be permitted.			D
Maximum site coverage				5%
Minimum setbacks				D
Maximum height				2 storeys
Special Provisions				5

D = At the discretion of the Board -- = Not applicable RROW = Railway Right-of-Way

RURAL AREA - SPECIAL PROVISIONS

The following matters are further regulated by certain Sections of this Statement :
RESIDENTIAL DEVELOPMENT STANDARDS - SECTION VI ; SUBDIVISION OF LAND - SECTION VII ; ROADS - SECTION VIII ; PARKING - SECTION IX

AMENITY CONSERVATION AREA

1. All areas zoned as Rural Areas shall be subject to the provisions of a Class 1 Amenity Conservation Area 301 and the Board shall exercise its discretion with respect to such matters as the subdivision of land and the siting of buildings in accordance with those provisions.

RESIDENTIAL

2.(1) Paragraph 51 shall apply to the subdivision of land.

(2) The maximum site coverage permitted for detached house development shall depend on the size of the lot in accordance with the following provisions -

Lot size	Maximum site coverage
(a) less than 10,000 sq.ft	35%
(b) 10,000 sq.ft to 14,999 sq.ft	25%
(c) 15,000 sq.ft to 19,999 sq.ft	20%
(d) 20,000 sq.ft to 39,999 sq.ft	15%
(e) 40,000 sq.ft and over	10%

(3) For detached house development on a lot of less than 25,000 sq.ft, the minimum setback from a lot line may be reduced to 10 feet.

3.(1) An application which proposes the development of an attached house shall be accompanied by an application for approval of the related draft plan of subdivision.

(2) Approval of a final plan of subdivision, or any phase thereof, shall not be granted until the attached house development, or any phase thereof, has been completed and a certificate of occupancy for each dwelling unit has been issued.

(3) The maximum site coverage permitted for attached house development shall be in accordance with Special Provision 2(2).

4. In approving an application for an apartment house, guest house or limited tourist accommodation, the Board shall be satisfied that -

(a) the preservation of the rural environment takes precedence; and
(b) the density and layout of development are compatible with the rural environment; and
(c) the design and scale of buildings are characteristic of that in the neighbourhood; and
(d) adequate vehicular access can be provided from a public or private road without the need to construct additional paved driveways that would be detrimental to the rural character of the land.

RECREATIONAL AND OPEN LAND

5.(1) Only those forms of recreational and open land development shall be permitted which do not result in any significant alteration to the existing topography nor any reduction in significant stands of vegetation.

(2) The Board shall exercise its discretion with respect to the details of planning to achieve a siting, scale and design of development that are compatible with the rural character of the area.

MAJOR HOTEL / COTTAGE COLONY AREA 106 - SPECIAL PROVISIONS

The following matters are further regulated by certain Sections of this Statement :
RESIDENTIAL DEVELOPMENT STANDARDS - SECTION VI ; SUBDIVISION OF LAND - SECTION VII ; ROADS - SECTION VIII ; PARKING - SECTION IX

INTENT

Major Hotel/Cottage Colony Areas are designated to facilitate the continuing operation and expansion of Bermuda's tourist industry.

These areas are intended primarily for the development of tourist accommodation. Nevertheless, accessory services and facilities may be permitted, provided the scale of such ancillary development is relative to the size of the tourist facility in terms of the number of persons to be accommodated.

The layout, scale and design of development should be compatible with the topography of the site and sensitive to the natural environment.

All hotel and cottage colony developments should provide adequate open space and recreation space for the enjoyment of and to meet the needs of persons accommodated in the development.

AMENITY CONSERVATION AREA

1. All areas zoned as Major Hotel/Cottage Colony Areas shall be subject to the provisions of a Class 1 Amenity Conservation Area 301 and the Board shall exercise its discretion with respect to the details of planning in accordance with those provisions.

IMPORTANCE OF MAJOR HOTEL AREAS

2. In considering any planning application, the Board may determine that a specific parcel of land is of such importance to the future requirements of the tourist industry that no development other than tourist accommodation shall be permitted on the site, notwithstanding that development of the land in such a manner does not fall within the then existing Hotel Phasing Programme.

PERMITTED FORMS OF DEVELOPMENT

3.(1) Major hotel, cottage colony and guest house development shall be permitted forms of development.

(2) Residential and limited tourist accommodation forms of development may be permitted at the discretion of the Board.

(3) No other form of development shall be permitted as a principal use.

(4) Other forms of development may be permitted as accessory uses to the principal hotel, cottage colony or guest house use, provided that -

(a) such development comprises services or facilities normally accessory to, or appropriate in conjunction with, the principal use; and
(b) such development is integrated into the layout and design of the principal development; and
(c) the scale of such development is relative to the scale, in terms of the number of persons that can be accommodated, of the principal tourist development.

MAJOR HOTEL / COTTAGE COLONY

4.(1) In considering an application for hotel, cottage colony or guest house development, the following matters shall be at the discretion of the Board -

(a) the siting and layout of development;
(b) the scale, density and design of development;
(c) the amount, location and layout of on-site parking and servicing facilities;
(d) the arrangements for vehicular and pedestrian access;
(e) the amount, type and location of landscaping required; and
(f) the accessory uses to be permitted.

(2) The Board shall exercise its discretion under sub-provision (1) and with respect to other details of planning to achieve -

(a) a siting, layout and scale of development that is compatible with the topography of the land; and
(b) the preservation of significant natural features and important stands of trees and large shrubs; and
(c) a design and scale of development that minimises the visual impact on any Coastal Conservation Area; and
(d) the appropriate landscaping of all development; and
(e) the provision of sufficient open space and recreation space to meet the needs of persons to be accommodated in the development.

RESIDENTIAL

5. Residential and limited tourist accommodation development, where permitted, shall comply with the provisions of the surrounding or adjoining Broad Development Area and where adjoining more than one Broad Development Area, the Board shall determine which provisions shall apply, having regard to the nature, topography and environmental quality of the site and its surroundings.

ACCESSORY DEVELOPMENT

3.(1) Commercial development, restricted in this case to office and retail use, may be permitted at the discretion of the Board as accessory uses, provided that -

(a) the commercial use is integral to the principal industrial use and functions as part of the industrial operation; and

(b) the gross floor area of the commercial development does not exceed 25% of the gross floor area of the aggregate of the principal industrial use and the accessory use.

(2) Residential development may be permitted only if -

(a) it is for the purpose of accommodating a caretaker or security guard in connection with the industrial development; and

(b) it consists of no more than one dwelling unit.

SPECIAL GOVERNMENT AREA - SPECIAL PROVISIONS

The following matters are further regulated by certain Sections of this Statement :
RESIDENTIAL DEVELOPMENT STANDARDS - SECTION VI ; SUBDIVISION OF LAND - SECTION VII ; ROADS - SECTION VIII ; PARKING - SECTION IX

INTENT

Special Government Areas are designated for the development of a range of uses and building types to meet the special needs of Government.

While the Board has wide discretionary powers in considering any proposal, particular attention should be given to the impact of development on the topography and environment of the site and to the effect development may have on the amenity enjoyed by surrounding neighbourhoods.

SPECIAL GOVERNMENT AREAS

1. Special Government Areas include, but are not limited to -

(a) H.M.Prison, Casemates, Ireland Island, Sandys;
(b) Freeport, Ireland Island, Sandys;
(c) Bermuda Government Military Establishment, Warwick Camp, Warwick;
(d) Warwick Post Office, Warwick;
(e) Department of Hotel Technology, Stonington, Paget;
(f) Bermuda College, Devonshire;
(g) National Stadium, Devonshire;
(h) Bermuda Police Headquarters and Fort Prospect, Devonshire;
(i) Fort Langton, Devonshire;
(j) Public Works Quarry and Depot, Hamilton;
(k) Civil Air Terminal, St.George's; and
(l) Women's Prison and Senior Training School, Ferry Reach, St.George's.

FORMS OF DEVELOPMENT

2.(1) The forms of development permitted shall be at the discretion of the Board.

(2) Unless the Board is satisfied as to the existence of special circumstances to the contrary, development shall normally be part of or accessory to the principal use for which the area was established.

DETAILS OF PLANNING

3.(1) The Board shall exercise its discretion with respect to all details of planning to ensure that -

(a) development is compatible with the topography of the land; and
(b) development is sited such that significant natural features, stands of trees and mature vegetation are preserved; and
(c) public buildings feature a high standard of architectural design and treatment; and
(d) development of an industrial nature is designed and landscaped in a manner that minimises the visual impact as viewed from public roads, other public places, neighbouring lands and the water; and
(e) development will not have a detrimental impact on the environment and amenity presently enjoyed by the surrounding area, particularly any area in open space, residential or hotel use; and
(f) safe access and adequate on-site parking and servicing space are provided.

ACCESSORY DEVELOPMENT

3.(1) Commercial development, restricted in this case to office and retail use, may be permitted at the discretion of the Board as accessory uses, provided that -

(a) the commercial use is integral to the principal industrial use and functions as part of the industrial operation; and

(b) the gross floor area of the commercial development does not exceed 25% of the gross floor area of the aggregate of the principal industrial use and the accessory use.

(2) Residential development may be permitted only if -

(a) it is for the purpose of accommodating a caretaker or security guard in connection with the industrial development; and

(b) it consists of no more than one dwelling unit.

SPECIAL GOVERNMENT AREA - SPECIAL PROVISIONS

The following matters are further regulated by certain Sections of this Statement :
RESIDENTIAL DEVELOPMENT STANDARDS - SECTION VI ; SUBDIVISION OF LAND - SECTION VII ; ROADS - SECTION VIII ; PARKING - SECTION IX

INTENT

Special Government Areas are designated for the development of a range of uses and building types to meet the special needs of Government.

While the Board has wide discretionary powers in considering any proposal, particular attention should be given to the impact of development on the topography and environment of the site and to the effect development may have on the amenity enjoyed by surrounding neighbourhoods.

SPECIAL GOVERNMENT AREAS

1. Special Government Areas include, but are not limited to -

(a) H.M.Prison, Casemates, Ireland Island, Sandys;
(b) Freeport, Ireland Island, Sandys;
(c) Bermuda Government Military Establishment, Warwick Camp, Warwick;
(d) Warwick Post Office, Warwick;
(e) Department of Hotel Technology, Stonington, Paget;
(f) Bermuda College, Devonshire;
(g) National Stadium, Devonshire;
(h) Bermuda Police Headquarters and Fort Prospect, Devonshire;
(i) Fort Langton, Devonshire;
(j) Public Works Quarry and Depot, Hamilton;
(k) Civil Air Terminal, St.George's; and
(l) Women's Prison and Senior Training School, Ferry Reach, St.George's.

FORMS OF DEVELOPMENT

2.(1) The forms of development permitted shall be at the discretion of the Board.

(2) Unless the Board is satisfied as to the existence of special circumstances to the contrary, development shall normally be part of or accessory to the principal use for which the area was established.

DETAILS OF PLANNING

3.(1) The Board shall exercise its discretion with respect to all details of planning to ensure that -

(a) development is compatible with the topography of the land; and
(b) development is sited such that significant natural features, stands of trees and mature vegetation are preserved; and
(c) public buildings feature a high standard of architectural design and treatment; and
(d) development of an industrial nature is designed and landscaped in a manner that minimises the visual impact as viewed from public roads, other public places, neighbouring lands and the water; and
(e) development will not have a detrimental impact on the environment and amenity presently enjoyed by the surrounding area, particularly any area in open space, residential or hotel use; and
(f) safe access and adequate on-site parking and servicing space are provided.

APPENDIX A. III

Table 13.1 **Value of Domestic Agricultural Output** **$thousand**

Year	Vegetables	Fruit	Milk	Eggs	Meat	Honey	Sales from Government Marketing Centre
1978	2,010	600	740	700	200	50	378
1979	2,350	641	949	792	282	58	316
1980	2,132	747	971	796	220	66	397
1981	3,810	916	974	934	230	157	551
1982	4,066	1,053	885	932	400	160	510
1983	4,300	808	901	720	420	140	440
1984	3,000	550	1,009	495	300	140	430
1985	3,770	900	1,053	800	400	175	376
1986	3,700	450	1,121	360	166	100	599
1987	3,900	500	1,209	399	100	54	637
1988	3,380	400	1,173	390	65	40	630

Source: Department of Agriculture and Fisheries

Table 13.2 **Land Use Structure by Parish (1981)** **Acres**

Parish	Total	High Density[1]	Medium Density[2]	Clustered Low Density[3]	Garden District[4]	Rural[5]	Major Hotel/ Cottage Colony[6]	Major Industrial[7]	Special Gov't[8]	Open Space[9]
Total	11,300	2,029	1,584	184	1,872	508	289	149	193	4,492
Sandys	1,192	242	112	34	152	203	34	7	50	358
Southampton	1,381	114	385	9	200	26	25	12	4	606
Warwick	1,355	340	176	27	119	44	40	3	7	599
Paget	1,248	47	267	20	369	67	90	–	8	380
Pembroke	1,265	501	3	25	280	–	17	78	–	361
Devonshire	1,163	333	124	2	123	52	9	4	43	473
Smith's	1,140	52	354	15	217	70	19	–	–	413
Hamilton	1,189	154	118	36	189	33	25	11	31	592
St. George's	1,367	246	45	16	223	13	30	34	50	710

Source: Bermuda Development Plan '83 (Department of Planning)

The following notes provide a brief guide to the meaning of the various density classifications and zonings; users are directed to the Bermuda Development Plan 1983 for complete descriptions.

[1] High Density: Intensive residential development with a broad range of commercial services.

[2] Medium Density: Low to medium residential. Limited range of commercial services

[3] Clustered Low Density: Clustered housing to preserve open space.

[4] Garden District: Low density residential. Emphasis on vegetation.

[5] Rural: Intended to preserve large parcels of open land and country side.

[6] Major Hotel/Cottage Colony: To accommodate major tourist accommodation and provide for any expansion of tourism.

[7] Major Industrial: Designated employment centres specifically for industrial and warehouse development.

[8] Special Government: To provide for a range of uses and building types to meet the special needs of government.

[9] Open Space Area: For the preservation of Bermuda's limited supply of open land. To retain a balance between developed and undeveloped land.

APPENDIX B. I

Table 10.1 Registered Road Vehicles in Bermuda

Year	Total	Private Cars	Buses, Taxis & Limousines	Trucks & Tank Wagons	Tractors & Engines: General Haulage	Tractors & Engines: Agricultural	Ambulances & Fire Engines	Construction Vehicles
1978	34,781	12,741	687	1,649	12	32	43	44
1979	36,271	13,186	687	1,932	14	40	49	57
1980	37,816	13,619	690	1,996	16	46	53	58
1981	40,402	14,422	691	2,132	16	47	51	70
1982	40,224	15,118	687	2,268	14	43	55	69
1983	41,666	15,843	700	2,463	18	37	60	64
1984	41,568	16,697	700	2,592	19	42	59	76
1985	43,359	17,240	706	2,718	18	39	58	67
1986	44,013	17,152	700	2,768	19	45	58	62
1987	44,064	17,644	685	2,822	20	41	54	63
1988	44,518	18,399	728	2,926	20	34	36	69

Year	Forces Vehicles	Trailers	Auxiliary Cycles[1]	Motor Cycles & Scooters	Other
1978	192	189	12,500	6,651	41
1979	206	211	12,544	7,287	58
1980	223	196	12,882	7,989	48
1981	249	208	13,147	9,312	57
1982	268	196	11,697	9,751	58
1983	287	196	11,184	10,753	61
1984	281	215	9,911	10,915	61
1985	356	200	10,482	11,413	62
1986	292	206	10,366	12,284	61
1987	331	215	11,103	11,024	62
1988	338	195	10,558	11,157	58

Source: Transport Control Department

[1] Includes livery cycles

APPENDIX B. II

- The East Broadway corridor has been operating at capacity during the morning peak hour since the late 1970s. Additional peak period demand since 1972 on this corridor appears to have been accommodated by a spreading of the peak. In 1972, some 62 per cent of the available 6000 vehicle capacity was used; in 1989, 87 per cent was used.

- Surveys indicate that the major public off-street car parks are dominated by long-term employee parking.

- Because off-street car parks are full, opportunities for short-term parking in the City centre are almost entirely restricted to on-street locations, and even here opportunities are limited.

- It appears there is significant "violation" of the parking restrictions in the City centre either by moving cars every hour (legal) or simply by parking longer than an hour (illegal).

- One quarter of cars parked on City centre streets consume 60 per cent of available capacity, to the disadvantage of City centre visitors requiring short-term parking.

Recommendations

TRANSPORTATION POLICY

Road safety

- The consultants support the Ministry of Transport and Police actions in furthering road safety and driving education and the strict enforcement of the traffic laws.

Use of low lead petrol and catalytic converters

- This should be pursued via legislation, with pricing differentials to encourage owners with the option of using normal or low lead fuels to choose the latter.

Hierarchy of Roads

- The concept introduced in the 1972 report should be reinforced by introducing a two-tier system of primary and secondary distributors.

Car ownership

- The consultants support car ownership disqualification if the owner shows disrespect for traffic laws by being convicted of more than one serious motoring offence within a given period, say 5 years.

- Overall the consultants consider that the benefits of fixing the maximum number of cars permitted within Bermuda will outweigh the disbenefits of accepting a continued increase in car ownership. Other than for replacement of existing vehicles, there needs to be a suspension of the current procedure for vehicles to be added to the existing car fleet. This suspension should be for five years to enable the detailed consequences to be assessed and evaluated prior to complete overhaul of the 1951 Act.

- During the suspension:

  - secondhand cars could be sold subject to safety checks;

  - there should be a free market in car licences subject to the one car per household principle.

Car dimensions
- Permitted car dimensions should be increased to 67 inches in width and 169 inches in length; the existing engine size limit of 2000cc should be maintained.

Measurements of traffic
- Traffic growth should be monitored:

  - by recording vehicle mileage and multiplying by the number of vehicles;

  - by undertaking a continuous traffic count using automatic traffic counters.

Public transport
- The consultants recommend that the presentation of fare structure should be simplified so that it is more easily understood, especially by tourists.

Bus station
- The Hamilton bus station should be upgraded either by renovation or replacement.

Bermuda Aviation Services Ltd. (BAS)
- It is recommended that consideration is given to relaxing the specifications and operating restrictions applicable to BAS in order to maintain a broad choice of public transport services for tourists.

Taxis
- Consideration should be given to extending the role of taxis by permitting shared taxi operations.

Traffic control in general
- Road markings should be renewed more frequently or the paint specification improved.

- Signing on main tourist routes should be reviewed.

- Non-standard road signs should be reviewed.

Highway design standards
- Traffic speed should be taken into account where possible so that adequate visibility is achieved when providing or improving accesses onto major roads.

East Broadway
- The consultants support the principles behind the proposed improvement scheme.

APPENDIX C. I

TR 55 CURVE NUMBER COMPUTATION VERSION 1.11

Project : IMPACT OF DEVELOPMENT User: MRT Date:
County : BERMUDA State: Checked: ____ Date: _____
Subtitle: ON THE GROUNDWATER - PRESENT CONDITION
Subarea : SOIL

COVER DESCRIPTION			Hydrologic Soil Group A	B	C	D
				Percent (CN)		
FULLY DEVELOPED URBAN AREAS (Veg Estab.)						
Open space (lawns,parks etc.)						
Good condition; grass cover > 75%			-	-	17(74)	-
Impervious Areas						
Paved parking lots, roofs, driveways			-	-	8(98)	-
Streets and roads						
Paved; curbs and storm sewers			-	-	4(98)	-
Dirt (w/ right-of-way)			-	-	1(83)	-
Urban Districts	Avg % imperv					
Commercial & business	85		-	-	11(94)	-
Residential Districts	Avg % imperv					
(by average lot size)						
1/8 acre (town houses)	65		-	-	50(90)	-
CULTIVATED AGRICULTURAL LANDS						
Row crops	Straight row (SR)	good	-	-	8(85)	-
OTHER AGRICULTURAL LANDS						
Woods - grass combination		fair	-	-	1(79)	-
Total Area (by Hydrologic Soil Group)			-	100	-	-

SUBAREA: SOIL TOTAL DRAINAGE AREA: 100 Percent WEIGHTED CURVE NUMBER:88

TR-55 CURVE NUMBER COMPUTATION VERSION 1.11

Project : IMPACT OF DEVELOPMENT Hour: NRT Date:
County : BERMUDA State: Checked: ____ Date: _____
Subtitle: ON THE GROUNDWATER - PRESENT CONDITION
Subarea : PEM/DV

COVER DESCRIPTION	Hydrologic Soil Group A	B	C	D
		Percent	(CN)	
FULLY DEVELOPED URBAN AREAS (Veg Estab.)				
Open space (lawns,parks etc.)				
Poor condition; grass cover < 50%	-	-	10(86)	-
Fair condition; grass cover 50% to 75%	-	-	15(79)	-
Good condition; grass cover > 75%	-	-	3(74)	-
Impervious Areas				
Paved parking lots, roofs, driveways	-	-	7(98)	-
Streets and roads				
Paved; curbs and storm sewers	-	-	5(98)	-
Urban Districts Avg % impery				
Commercial & business 85	-	-	3(89)	-
Industrial 72	-	-	10(81)	-
Residential districts Avg % impery				
(by average lot size)				
1/8 acre (town houses) 65	-	-	8(77)	-
1/4 acre 38	-	-	1(61)	-
OTHER AGRICULTURAL LANDS				
Woods - grass combination Fair	-	-	37(73)	-
Total Area (by Hydrologic Soil Group)			100	

SUBAREA: PEM/DV TOTAL DRAINAGE AREA: 100 Percent WEIGHTED CURVE NUMBER:88

TR-55 CURVE NUMBER COMPUTATION VERSION 1.11

Project : IMPACT OF DEVELOPMENT User: MRT Date:
County : BERMUDA State: Checked: ____ Date: _____
Subtitle: ON THE GROUNDWATER - PRESENT CONDITION
Subarea : SPTON

COVER DESCRIPTION	Hydrologic Soil Group A	B	C	D
		Percent		
FULLY DEVELOPED URBAN AREAS (Veg Estab.)				
Open space (lawns,parks etc.)				
Good condition; grass cover > 75%	-	-	[illegible]	-
Impervious Areas				
Paved parking lots, roofs, driveways	-	-	[illegible]	-
Streets and roads				
Paved; open ditches (w/right-of-way)	-	-	[illegible]	-
Dirt (w/ right-of-way)	-	-	[illegible]	-
Urban Districts Avg % imperv				
Commercial & business 85	-	-	[illegible]	-
Residential Districts Avg % imperv				
(by average lot size)				
.1/3 acre 30	-	-	[illegible]	-
OTHER AGRICULTURAL LANDS				
Woods - grass combination good	-	-	[illegible]	-
Total Area (by Hydrologic Soil Group)			[illegible]	

SUBAREA: SPTON TOTAL DRAINAGE AREA: 100 Percent [illegible] NUMBER=36

TR-55 CURVE NUMBER COMPUTATION VERSION 1.11

Project : IMPACT OF DEVELOPMENT User: MRT Date:
County : BERMUDA State: Checked: ____ Date: ________
Subtitle: ON THE GROUNDWATER -- PRESENT CONDITION
Subarea : ST.GEO

COVER DESCRIPTION	Hydrologic Soil Group A	B	C	D
		Percent (%)		
FULLY DEVELOPED URBAN AREAS (Veg Estab.)				
Open space (lawns,parks etc.)				
Good condition; grass cover > 75%				-
Impervious Areas				
Paved parking lots, roofs, driveways				-
Streets and roads				
Paved; curbs and storm sewers				-
Dirt (w/ right-of-way)				-
Urban Districts Avg % Imperv				
Commercial & business 85				-
Residential districts Avg % Imperv				
(by average lot size)				
1/8 acre (town houses) 65				-
CULTIVATED AGRICULTURAL LANDS				
Close seeded Straight row good				-
legumes or				
rotation				
meadow				
OTHER AGRICULTURAL LANDS				
Woods - grass combination fair				
Total Area (by Hydrologic Soil Group)				

SUBAREA: ST.GEO TOTAL DRAINAGE AREA: 100 Percent WEIGHTED CURVE NUMBER=86

APPENDIX C. II

ESTIMATING STORM POLLUTANT EXPORT IN WATERSHED AREAS

CURRENT CONDITIONS

Parameter	Somerest	Southampton	Central	St.George's
P	58.1	58.1	58.1	58.1
Pj	0.9	0.9	0.9	0.9
Rv	4.01	0.94	4.13	3.77
C(P)	0.26	0.26	1.08	0.26
C(N)	2	2	13.6	2
A	114.36	33.4	465.08	91.25
LTP	1413.18	96.75	24587.13	1060.11
LTN	10870.63	744.24	309615.66	8154.75

PRE-CONDITIONS

Parameter	Somerest	Southampton	Central	St.George's
P	58.1	58.1	58.1	58.1
Rv	0.9	0.9	0.9	0.9
Rv	0.118	0.118	0.118	0.118
C(P)	0.15	0.15	0.15	0.15
C(N)	0.78	0.78	0.78	0.78
A	114.36	33.4	465.08	91.25
LTP	124.75	36.48	507.35	99.54
LTN	158.59	46.37	644.94	126.54

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