CHAPTER 3

CAUSES OF IMPAIRMENT AND SOURCES OF WATER POLLUTION

3.1 INTRODUCTION

A number of substances cause pollution and water quality impairment. *Sources* of these substances are divided into two categories called *point* sources and *nonpoint* sources. Point sources are typically piped discharges from wastewater treatment plants and large urban and industrial stormwater systems. Nonpoint sources can include stormwater runoff from smaller urban areas, forestry, mining, agricultural lands, rural residential development, and others. Section 3.2 identifies and describes the major causes of impairment in the basin. Sections 3.3 and 3.4 describe point and nonpoint source pollution in the basin.

3.2 CAUSES OF IMPAIRMENT

Causes of impairment refer to the substances which enter surface waters from point and nonpoint sources and result in water quality degradation and impairment. The general causes of water quality impairment are shown in Table 3.1. Each of these causes of impairment is discussed in the following sections.

Table 3.1 Causes of Impairment and Sources of Water Pollution

Cause of Impairment	Source Index PS	Source Index NPS	Description
Sediment		++	Mostly nonpoint source activities including: construction and mining sites, disturbed land areas, streambank erosion, cultivated farmland, removal of vegetative buffers along streams
Color	++		Generally associated with industrial wastewater or municipal plants that receive certain industrial wastes, especially textile manufacturers that dye fabrics and pulp and paper mills.
Toxic and Synthetic Substances	+	+	Pesticide applications, disinfectants (chlorine), automobile fluids, accidental spills, illegal dumping, urban stormwater runoff, leaky automobiles
Oxygen-Consuming Wastes	++	+	Wastewater effluent, organic matter, leaking sewers and septic tanks, animal waste which result in low d.o.
Fecal Coliform Bacteria	+	++	Failing septic tanks and leaking sewers, animal waste, runoff from livestock operations, wildlife, improperly disinfected wastewater effluent
Nutrients	++	++	Fertilizer (on agricultural, residential, commercial and recreational lawns), animal wastes, leaky sewers and septic tanks, atmospheric deposition, municipal wastewater which can cause algal blooms

++ = significant or primary source; blank = little or no contribution PS = Point Source (see Section 3.3)
+ = limited source that may be locally significant NPS = Nonpoint Source (see Section 3.4)

3.2.1 Sedimentation and Erosion

Sedimentation is a major source of water quality impairment in the Broad River basin. The processes of erosion and sedimentation are described below. This section concludes with sedimentation trends in the Broad River basin.

Introduction

Erosion is a natural process by which soil and rock material is worn away by rain, wind, and ice. Natural erosion occurs on a geologic time scale, but the process can be greatly accelerated when human activities alter the landscape. The sediment produced by erosion generally winds up in the surface waters.

Some of the activities that increase sediment loads to waterbodies include: construction activities, unpaved private access roads, state road construction, golf courses, uncontrolled urban runoff, mining, timber harvesting, agriculture, and livestock operations.

Some of the adverse impacts of sediment include:

- Streambank erosion: Streams with high sediment load have a much greater potential to scour the streambank. Also, as the streambed fills in with sediment, the stream will widen to carry the flow. Streambank erosion causes the loss of valuable property.
- Damaged aquatic communities: Sediment damages aquatic life by destroying stream habitat, clogging gills, and reducing water clarity.
- Polluted water: Sediment often carries other pollutants with it, including nutrients, bacteria, and toxic/synthetic chemicals. This pollution can also threaten public health if drinking water sources and fish tissue become contaminated.
- Increased costs for treating drinking water: Sediment-filled waters require costly filtration to make them suitable for drinking. Water supply reservoirs lose storage capacity when they become filled with sediment, necessitating expensive dredging efforts.

Recommendations aimed at addressing sedimentation are listed in Chapter 6. Programs and best management practices aimed at addressing sedimentation are briefly described in Chapter 5 and Appendix V and VI.

North Carolina does not have a numeric water quality standard for suspended sediment. However all point source dischargers must at a minimum meet federal effluent guidelines (e.g. 30 mg/l for domestic dischargers) for total suspended solids (TSS). The biological oxygen demand (BOD) limits required for most point sources usually necessitate a degree of treatment that assures the removal of solids to a level below federal requirements. A TSS limit of 10 mg/l is required for discharges to those High Quality Waters (HQW) which are trout waters or primary nursery areas, and a limit of 20 mg/l is required for discharges to other HQWs.

North Carolina has adopted a numerical instream turbidity standard as follows:

- 50 Nephelometric Turbidity Units (NTU) in streams not designated as trout waters;
- 25 NTU in lakes and reservoirs not designated as trout waters;
- 10 NTU in trout waters.

Land disturbing activities are considered to be in compliance with the standard if approved best management practices have been implemented.

Effects of Sedimentation on Water Quality and Aquatic Habitats

Sedimentation is often divided into two categories: *suspended load* and *bed load*. Suspended load is composed of small particles that remain in suspension in the water. Bed load is composed of larger particles that slide or roll along the stream bottom. Suspension of load types depends on water velocity and stream characteristics. Biologists are primarily concerned with the *concentration* of the suspended sediments and the *degree of sedimentation* on the streambed (Waters 1995).

The concentration of suspended sediments affects the availability of light for photosynthesis, as well as the ability of aquatic animals to see their prey. Several researchers have reported reduced feeding and growth rates by fish in waters with high suspended solids. In some cases it was noted that young fish left those stream segments with turbid conditions. Suspended sediments can clog the gills of fish and reduce their respiratory abilities. These forms of stress may reduce the tolerance level of fish to disease, toxicants and chronic turbid conditions. Suspended solids are reported as Total Suspended Solids or as Turbidity. They are measured in parts per million or milligrams per liter (Waters 1995).

The degree of sedimentation affects both the habitat of aquatic macroinvertebrates and the quality and amount of fish spawning and rearing habitat. Degree of sedimentation can be estimated by observing the amount of streambed covered, the depth of sedimentation, and the percent saturation of interstitial space or embeddedness. Eggs and fry in interstitial spaces may be suffocated by the sediments thereby reducing reproductive success (Waters 1995). Effects of sedimentation on macroinvertebrates can be seen in alterations in population density, diversity, and community structure (Lenat et al. 1979).

The findings of academic research have noted the potential impact of sedimentation on fisheries, in particular on wild trout populations. Inorganic sediments can affect trout productivity in three ways: direct effects - impairment of respiration, feeding habits, and migration patterns; reduced egg hatching and emergence due to decreased water velocity and dissolved oxygen; and, trophic effects - reduction in prey (macroinvertebrates). As fine suspended solids increase in the waters, the dissolved oxygen, permeability, and apparent velocity decrease.

The impact of sedimentation on fish populations depends on both concentration and degree of sedimentation, but impact severity can also be affected by the duration (or dose) of sedimentation. Suspended sediments may occur at high concentrations for short periods of time, or at low concentrations for extended periods of time. The greatest impacts to fish populations will be seen at high concentrations for extended time periods. The use of a dose-response matrix in combination with field investigations can help predict the impact of suspended sediments on various life stages of fish populations (Newcombe 1996).

Sedimentation impacts streams in several other ways. Eroded sediments may gradually fill lakes and navigable waters and may increase drinking water treatment costs. Sediment also serves as a carrier for other pollutants including nutrients (especially phosphorus), toxic metals, pesticides, and road salts.

Sedimentation Processes

Sedimentation involves two stages: the movement of eroded material from its original site to a stream channel and movement through the channel network. During both of these stages, sediment movement is discontinuous, driven by the episodic nature of storm events. While some sediment may move directly from field or construction site to a stream and then to the watershed outlet during the course of a single storm, most sediment does not move in this manner. Rather, a particle of eroded material is generally remobilized and redeposited by a number of storms as it works its way through the watershed. Depending upon storm characteristics and antecedent soil conditions, one storm in a given basin may result in the delivery of only a small percentage of eroded material to a stream, while another event may remobilize large quantities of previously eroded material.

The proportion of eroded material reaching a given point on a river or stream is often referred to as the sediment delivery ratio (SDR) (Novotny and Chester, 1989; Walling, 1983). SDRs calculated for the Carolinas and Georgia (Roehl, 1962) indicate that only about 10% of the material eroded from moderate sized drainages (100 square km) leaves those watersheds on an annual basis. For extremely small basins (1 square km) the SDR is about 50%. While specific estimates vary, researchers have repeatedly found that the delivery ratio declines as basin size increases. Sediment storage occurs in all watersheds, but especially in larger ones. This stored material can, if not stabilized, serve as a source of sediment for a long time after the original erosion occurs. However, over a period of years or even decades a large percentage of eroded material may never reach the lower portions of a watershed.

The sediment load carried by a stream thus reflects both past and present land use activities. Load measurements alone, however, tell us little about the source of the sediment or the amount of ongoing erosion. Under many conditions, the amount of sediment carried by a stream will increase as erosion in the watershed increases and decrease as watershed erosion declines (referred to as a "supply limited" stream). However a stream has only a finite capacity for transporting sediment. Once the supply of sediment exceeds the capacity of a stream to carry it, any additional sediment reaching the stream will be deposited in channels and on floodplains rather than carried out of the watershed (referred to as "transport limited"). These stored deposits can be remobilized into the stream years or decades later if the rate of upland erosion declines to levels below the transport capacity.

Measuring Sediment Loads

Suspended sediment is a very useful indicator of active erosion in a particular basin. Suspended sediment concentrations are very sensitive to landscape disturbance, and its conceptual simplicity as a measurement tool gives it broad appeal. The primary problem with using suspended sediment as a monitoring tool is its inherent variability. Representative samples are difficult to obtain, and suspended sediment samples vary tremendously over time. Suspended sediment concentrations in a river vary dramatically with streamflow. Sampling during high flows is critical for the accurate estimation of suspended sediment loads. Significant differences in suspended sediment concentrations can also occur with depth. In particular, concentrations are often lower near the surface since fine material is generally distributed throughout the water column, while coarser particles remain closer to the stream bed.

Most sampling schemes take individual or composite samples at regular time intervals (e.g. daily). Since high flows are relatively rare, a sampling system based on equal time intervals will result in a large number of samples at relatively low flows, when suspended sediment concentrations are low, and very few samples at high flows, which is when most of the suspended sediment transport takes place. This is both inefficient and results in a high level of uncertainty with regard to the total sediment load. For a clear picture of sediment dynamics in a particular watershed, sediment sampling programs should be carefully designed using staged, point integrated, or depth integrated samplers to include measurements at relatively high flows. The accurate characterization of suspended sediment concentrations thus requires the use of depth-integrating samplers and other methods that maximize the likelihood that the sample taken represents average conditions in the water column (Edwards and Glysson, 1988).

Because of these sampling requirements, few studies have attempted to estimate suspended sediment loads in North Carolina. Total suspended solids (TSS) is measured at the Division of Water Quality's ambient monitoring stations. The TSS parameter is similar to suspended sediment, but is based on a grab sample rather than depth-integrated sampling. Moreover, since ambient data are collected on a regularly scheduled basis (usually monthly), high flows are undersampled at most sites. TSS data can be useful for confirming the cause of high turbidity levels and to support the targeting of nonpoint source programs, but they are likely to yield substantial underestimates if used to calculate sediment loads.

Sediment and Streamflow

Peak flows have important effects on stream channel morphology and bed load particle size. Higher flows move larger particles. Peak flows are also important in determining the stability of large woody debris in the stream and the rate of bank erosion. Increased bank erosion and channel migration affects the riparian vegetation and can increase the amount of active sediment in the stream channel.

The vast majority of the sediment transport occurs during peak flows, as sediment transport capacity increases exponentially with discharge. The ability of a stream to transport the incoming sediment will help determine whether there is deposition or erosion within the stream channel. The relationship between sediment load and sediment transport capacity affects habitat types, channel morphology and bed load particle size. Increased size of peak flows due to urbanization have been shown to cause rapid channel erosion and severe decline in fish habitat quality.

In developing areas, the erosive forces brought by increased flood flows must be addressed at the source—increased runoff—for instream restoration efforts to be successful. Recent studies underscore the importance of overall watershed imperviousness in determining water and habitat quality. Increased impervious cover in a watershed has many direct impacts on streams in the watershed. Streams broaden or deepen to accommodate larger flushes of water, specialized habitats such as pool and riffle structures and overhanging vegetation are lost, instream water quality declines, stream temperatures rise and stream biodiversity of aquatic insect and fish populations. Each of these impacts has been shown to increase with higher levels of watershed imperviousness.

A change in the size of peak flows can also have important consequences for human life and property. Structures such as bridges, dams, and levees are designed according to a presumed distribution of peak flows. If the size of the peak flows is increased, this could reduce the factor of safety and lead to more frequent and severe damage.

Sediment and Streambank Erosion

Streambank erosion can contribute sediment loads to a stream. Streambank erosion can result from clearing instream obstacles or streamside vegetation, livestock trampling stream banks, or higher than normal floods resulting from increased impervious surfaces. The bank material, vegetation type, and vegetation density affect the stability and form of the streambanks. Change in any one of these factors is likely to be reflected in the size and shape of the stream channel, including the banks.

Streambank stability refers to the inclination of the stream bank to change in form or location over time. Streambank stability can be an important indicator of watershed condition and can directly affect several designated uses of streams. A higher incidence of bank instability can be initiated by natural events that disrupt the quasi-equilibrium of the stream, or by human disturbance. Unstable banks contribute sediment to the stream channel by slumps and surface erosion. Because all the material from an eroding streambank is delivered directly to the stream channel, the adverse impact of bank instability can be much greater than the adverse effects of a comparable area of eroding hillslope.

Even in undisturbed streams some streambank instability usually occurs. In valleys with a defined floodplain there is often lateral migration through bank erosion and point bar accretion. In V-shaped valleys there is less opportunity for lateral migration and bank instability may stem from the input and eventual removal of obstructions resulting from fallen trees, landslides, or debris flows.

Although in some cases the erosion of one bank will be matched by deposition on the opposite bank, streambank erosion caused by human activities generally increases stream width. The corresponding increase in stream surface area allows more direct solar radiation to reach the stream surface and this will raise maximum summer water temperatures. In most cases an eroding streambank will provide little or no cover for fish.

Actively eroding streambanks also support little or no riparian vegetation, and the loss of this vegetation adversely affects a wide range of wildlife species and increases the long-term input of organic matter into the aquatic ecosystem. Both the increase in summer water temperatures and the loss of fish cover along an eroding stream bank will be exacerbated by the reduction in riparian cover.

Historic practices of disturbing the stream channel and removing large woody debris have been shown to increase the amount of fine sediment in the steam channel. Removal of, or a reduction in, the riparian vegetation is another mechanism by which management activities can increase the amount of fine sediments. Grazing often exacerbates the effect of reducing the vegetative cover by simultaneously trampling the vegetation, compacting the soil, and trampling the streambanks. The use of structural techniques such as: bank sloping, use of tree roots for stabilization, buffer strips, and fencing cattle out of streams can greatly reduce streambank erosion. Average annual soil loss has been shown to be decreased by 40% after cattle were fenced away from streams. This decrease resulted in nearly a 60% reduction in average sediment concentration during stormflow events (Owens, et al 1996). Stormwater management measures for urban development areas can also lessen the potential for streambank erosion.

Stream Modification

Natural streams around the world have certain physical characteristics in common, regardless of location and geologic conditions. One of the most important of these characteristics is known as bankfull stage. The bankfull stage corresponds to the flow at which channel maintenance is most effective, that is, the discharge that results in the average size and shape of channels.

Almost all natural streams have a bankfull discharge with a recurrence interval of 1-1.5 years. In other words, natural stream channels do not form with the capacity to carry a 50 year, 25 year, or even 2 year storm without overflow. Natural channels on average can carry the flow from an annual storm without overflow. In streams that have not been channelized or manipulated by human activities, streamflows larger than a typical annual event are generally carried in both the channel and a floodplain.

Humans have modified many natural streams by increasing the capacity of the stream channel to carry high flows, sometimes to carry even the flow from a 50 or 100 year storm. Such modifications are conceived in the name of flood control and are often used to justify development of floodplains for human occupancy and other activities which constrict or encroach upon the floodplain.

Most engineering channel designs give a great deal of attention to conveyance of floodwaters. Very few channel designs include close attention to sediment conveyance. Given that the equilibrium channel size tends toward a bankfull discharge with a 1-1.5 year recurrence interval, larger stream channels will naturally initiate disequilibrium erosional processes. For example, a channel that has been straightened and enlarged to carry a 50 year storm, will begin building a smaller channel, point bars, floodplains, meanders, etc. as a result of the natural physical behavior of sediment and the frequency distribution of streamflows. As a result, we have created streams which are unstable; they lose their equilibrium shape and slope and erode, degrade, and aggrade rapidly. Such unstable channel conditions can ultimately lead to degraded water quality as result of excessive sediment loads.

Sedimentation Trends in the Southern Piedmont

Most of the Broad River basin is located in a region of the state designated by the U.S. Department of Agriculture as the southern piedmont. The extreme western portion of the basin in located in the Blue Ridge Mountains Region.

In the 19th and early 20th centuries, erosion increased dramatically in the southern piedmont due to the agricultural practices of the time and the large proportion of the land planted in row crops (Trimble, 1994). Erosion then began a sharp decline beginning around 1920 as some farmland was taken out of production and the implementation of various conservation practices was initiated. By 1967 levels of erosive land use in the southeastern piedmont were only 1/5 to 1/3 of their peak levels (Trimble, 1974). USDA data show that row cropped acreage accounted for about 45% of the North Carolina piedmont in 1937, but declined to about 18% by 1990 (Richter et al, 1995).

Urban impacts on numerous streams increased during this century, due both to the input of sediment eroded from upland areas and to streambank erosion caused by the increase in impervious surfaces and the resulting increase in storm runoff. Nonetheless, most large piedmont basins are experiencing less erosion today than earlier in this century.

By 1970 the suspended sediment discharges of large rivers in the southeast had declined to one third to one half their 1910 levels (Meade and Parker, 1985; Meade and Trimble, 1974). Yet given the decline in agricultural erosion and the amount of material trapped by impoundments, suspended sediment loads are not nearly as low as one might expect. Many scientists have concluded that sediment stored in river channels and floodplains is contributing to the present load (Meade et al, 1990; Meade, 1982; Meade and Trimble, 1974; Jacobson and Coleman, 1986; Phillips, 1991). This material was deposited on floodplains and in channels during periods of high erosion when sediment supply to the channel network exceeded transport capacity. Evidence from the Maryland piedmont (Jacobson and Coleman, 1986), for example, indicates that high yields can persist after active erosion has declined as streams rework floodplain material deposited during previous decades and build a new floodplain at a lower elevation.

It is likely that many large rivers in the southern piedmont are presently moving some amount of stored sediments, deposited earlier during times of intensively erosive agricultural land use, through their channel networks. When erosion declines, stored sediment is first removed from tributary streams and later from larger rivers (Meade et al, 1990; Trimble, 1983). It is thus reasonable to expect that a further reduction in upland erosion in many small rural basins will result in lower sediment yields for those watersheds. How quickly control efforts in small watersheds will result in lower sediment yields in the larger rivers to which they drain is a more difficult question.

Statistics compiled by the US Department of Agriculture, Natural Resource Conservation Service (formerly known as the Soil Conservation Service) indicate a statewide decline in erosion from 1982 to 1992 (USDA, NRCS, 1992) as shown in Table 3.2.

Table 3.2 Overall Erosion Trends in North Carolina

	1982	1987	1992
Area (1,000 acres)	33,708.2	33,708.2	33,708.2
Gross Erosion (1,000 tons/yr)	46,039.5	43,264.6	36,512.9
Erosion Rate (Tons/Yr/Ac)	1.1	1.4	1.3

The most widely used tool to evaluate erosion at the landscape level is the Universal Soil Loss Equation (USLE). The NRCS statistics also indicate a statewide reduction per acre on cropland erosion using the Universal Soil Loss Equation (Table 3.3). Although tons/acre/year is a standard unit of measurement for erosion, it does not reflect the high spatial and temporal variability of erosion. Sediment impacts do not generally originate from a county wide "average" area; the majority of sediment comes from localized high impact areas. It is very easy to average out a sediment impact over a whole watershed or county or state area and thereby give the impression that the problem is less significant than it actually is in the immediate area. It makes much more sense from a management perspective to reduce sediment from 40 tons/acre to 2 tons/acres in a high impact area than to reduce erosion from cropland from 6.5 to 6.3 tons/acre. This points to the need for targeted management efforts coupled with a monitoring strategy which effectively measures sediment transport under both average and extreme conditions.

Table 3.3 USLE Erosion on Cultivated Cropland in North Carolina

	1982	1987	1992
Cropland Area (1,000 acres)	6,318.7	5956.8	5538.0
Gross Erosion (1,000 tons/yr)	40,921.4	37475.3	30,908.3
Erosion Rate (Tons/Yr/Ac)	6.5	6.3	5.6

While there is an overall 10-year downward trend statewide in the erosion rate on agricultural lands, the erosion rate per acre and the 10-year trends vary by region as shown in Table 3.4. The greatest improvement in erosion control is seen in the Southern Piedmont and Sand Hills with a small uptrend in the tidewater area and a significant increase in the mountains. In the mountain region, it is noted that while the 10-year trend is up, the five-year trend from 1987 to 1992 was down. The reasons for the dramatic changes in the mountain basin erosion rates are not fully known.

Table 3.4 North Carolina Erosion on Major Land Resource Areas (MLRA)

	1982	1987	1992
Blue Ridge Mountains	12.7	20.8	18.3
Southern Piedmont	12.3	12.0	10.5
Carolina and Georgia Sand Hills	6.0	5.6	5.1
Southern Coastal Plain	3.9	3.9	4.0
Atlantic Coast Flatwoods	3.2	3.1	3.2
Tidewater Area	1.4	1.5	1.6

Sedimentation Trends in the Broad River Basin

Sedimentation is a significant cause of water quality impairment in the Broad River Basin. Walnut Creek, Catheys Creek and Lick Branch are all streams that are considered impaired partly due to sedimentation based on recent data. In addition, although it is not considered impaired, Lake Lure was significantly impacted by sedimentation before and during the flood that occurred in September of 1996. The Town of Lake Lure spent $1,232,000 to dredge 235,000 cubic yards of sediment out of the lake. The dredging operation had already been planned prior to the flood due to a build-up of sediment. The following discussion presents some sediment information that is specific to the Broad River basin in North Carolina. Suggested management strategies for reducing sedimentation are presented in Chapter 6.

The only comprehensive study of suspended sediment loading in North Carolina, conducted by the USGS (Simmons, 1993), involved the assessment of sedimentation at 152 sites statewide during the 1970-79 period. Selected data are shown in Table 3.5. The comparison is limited to unimpounded rivers (the Haw and Neuse were not yet impounded at the time this study was conducted.)

Table 3.5 Major North Carolina Rivers: Mean Annual Suspended Sediment Yield at Selected Stations, 1970-79.

Station	Drainage Area (square miles)	County	Tons per Square Mile
Haw River at Haw River	606	Alamance	260
Neuse River near Falls	772	Wake	180
Yadkin River at Elkin	869	Yadkin	350
Broad River near Boiling Springs	**875**	**Cleveland**	**390**
Dan River near Wentworth	1,053	Rockingham	440
Neuse River near Clayton	1,150	Johnston	190
Haw River near Bynum	1,277	Chatham	140
Rocky River near Norwood	1,372	Stanley	200

Source: Simmons CE, 1993

The Broad River mainstem near Boiling Springs (which is a lower site for the river in North Carolina and includes all major drainages except the First Broad River) carried a relatively high sediment load compared to other piedmont rivers. Simmons notes that rivers flowing from one physiographic province to another (such as the Broad which flows from the mountains to the piedmont) tend to retain the sediment transport characteristics of the province of origin. Table 3.6 summarizes data for all Broad sites included in the USGS study.

Table 3.6 Broad River Basin: Mean Annual Suspended Sediment Yield, 1970-79

STATION	Drainage Area (Sq Mi)	County	Tons/ Sq Mile
Cove Creek near Lake Lure	79	Rutherford	380
Second Broad River at Cliffside	220	Rutherford	230
Broad River near Boiling Springs	875	Cleveland	390
First Broad River near Casar	60.5	Cleveland	250
Sugar Branch near Boiling Springs	1.4	Cleveland	550

Source: Simmons CE, 1993

All stations transported relatively large amounts of sediment in 1970-79. Sugar Branch, the smallest watershed represented, carried the most amount of sediment. This result could be the reflection of even a small, poorly managed land-disturbing activity.

One of the defining characteristics of suspended sediment transport is that most of the load is transported during a relatively small number of storm events (Meade et. al., 1990). Transport characteristics for the Broad River at Cliffside reflect this (Simmons, 1993). Data between 1970 and 1979 indicate that at this site, half of the sediment load for the entire year was carried during approximately one and a half days.

3.2.2 Oxygen-Consuming Wastes

Oxygen-consuming wastes, or Biochemical Oxygen Demand (BOD), include decomposing organic matter or chemicals that reduce dissolved oxygen in the water column through chemical reactions or biological activity. Maintaining a sufficient level of dissolved oxygen in the water is critical to most forms of aquatic life, especially trout.

A number of factors affect dissolved oxygen concentrations. Higher dissolved oxygen is produced by *turbulent actions*, such as waves, rapids and waterfalls, which mix air and water. *Lower water temperature* also generally allows for retention of higher dissolved oxygen concentrations. Therefore, the cool swift-flowing streams of the mountains are generally high in dissolved oxygen. Lower dissolved oxygen levels tend to occur more naturally in warm, slow-moving waters. In some cases, dissolved oxygen levels may naturally decrease in the warmer months below the state standard. In addition, high inputs of effluent from wastewater treatment plants during low flow conditions may significantly decrease dissolved oxygen from natural conditions. In general, the lowest dissolved oxygen concentrations occur during the warmest summer months and particularly during low flow periods. *Water depth* is also a factor. In deep slow-moving waters, such as reservoirs or estuaries, dissolved oxygen concentrations may be very high near the surface due to wind action and plant (algae) photosynthesis but may be entirely depleted (anoxic) at the bottom.

Sources of dissolved oxygen depletion may include wastewater treatment plant effluent, the decomposition of organic matter (such as leaves, dead plants and animals) and organic waste matter that is deposited, washed or discharged into the water. Sewage from human and household wastes is high in organic waste matter, as is waste from trout farms. Bacterial decomposition can rapidly deplete dissolved oxygen levels unless these wastes are adequately treated at a wastewater treatment plant. In addition, some chemicals may react with and bind up dissolved oxygen. Industrial discharges with oxygen consuming wasteflow may be resilient instream and continue to use oxygen for a long distance downstream.

Oxygen-Consuming Wastes in the Broad River Basin

Dissolved oxygen levels in waters of the Broad River basin are generally good. There are some streams, however, that are affected by discharges from wastewater treatment plants. The Second Broad River, in particular, receives effluent from a number of discharges. Recommendations for specific areas are presented in Chapter 6.

Point Source Wasteflow and BOD changes from 1987 to 1996

Wasteflow and BOD data from the discharge monitoring reports (DMR) for 1987 and 1996 were evaluated for point source inputs to the basin. Average daily loads for BOD were multiplied by 365 and added together for all discharges to determine the total annual point source load for BOD. Although the wasteflow increased, there was a 23% decrease in estimated BOD loading to streams from 719,659 pounds per year to 551,109 pounds per year (Figure 3.1). The permitted wasteflow increased by 129 % from 10,000 million gallons per year in 1987 to 22,994 million gallons per year in 1996. The increases in wasteflow to the system are due to the addition of new dischargers and existing facilities expanding their wasteflow. The largest increase in the ten-year period occurred in subbasin 030802 (includes Forest City, Spindale, and Burlington - J.C. Cowan plant) where the total wasteflow more than tripled and six new dischargers were added.

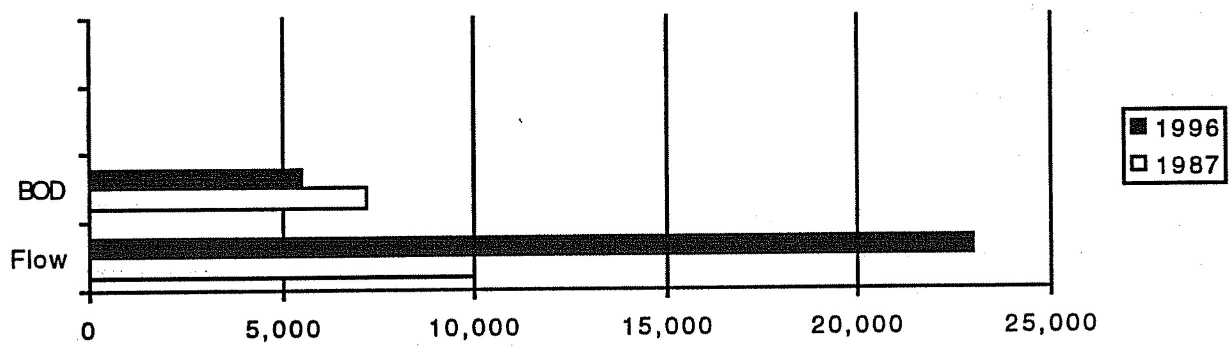

Figure 3.1 Comparison of Annual BOD Loading (in hundreds of pounds) and Annual Wasteflow (in million of gallons per year) from Point Sources in 1987 and 1996

3.2.3 Color

Color in wastewater is generally associated with industrial wastewater or with municipal plants that receive certain industrial wastes, especially from textile manufacturers that dye fabrics and pulp and paper mills. For colored wastes, 15A NCAC 2B .02113(f) states that the point sources shall discharge only such amounts that will not render the waters injurious to public health, secondary recreation, aquatic life and wildlife, or adversely affect the palatability of fish, aesthetic quality or impair the waters for any designated uses. NPDES permit requirements regarding color are included on a case-by-case basis since no numeric standard exists for color, and because a discharger may have high-color values but no visual impact instream due to dilution or the particular color of the effluent. Chapter 6 discusses ongoing efforts to study color and to develop a realistic approach to addressing this problem.

Color in the Broad River Basin

In the Broad basin, discharges with a high degree of color come primarily from certain industrial facilities and from municipal dischargers receiving highly colored industrial effluent. Participants in the basinwide planning workshops conducted in the Broad basin in June of 1997 indicated that color was an important concern for them. Some of the specific concerns that participants associated with color were general aesthetic impacts and water supply treatment. While colored effluent can be discharged by a number of industries, textile firms constitute the most significant source of color in the Broad basin.

3.2.4 Toxic Substances

Regulation 15A NCAC 2B. 0202(36) defines a toxicant as "any substance or combination of substances ... which after discharge and upon exposure, ingestion, inhalation, or assimilation into any organism, either directly from the environment or indirectly by ingestion through food chains, has the potential to cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions or suppression in reproduction or growth) or physical deformities in such organisms or their offspring or other adverse health effects". Toxic substances frequently encountered in water quality management include chlorine, ammonia, organics (hydrocarbons and pesticides) heavy metals and pH. These materials are toxic to different organisms in varying amounts. The effects may be evident immediately, or may only be manifested after long-term exposure or accumulation in living tissue.

North Carolina has adopted standards and *action levels* for several toxic substances. These are contained in 15A NCAC 2B .0200. Usually limits are not assigned for parameters which have action levels unless 1) monitoring indicates that the parameter may be causing toxicity or, 2) federal guidelines exist for a given discharger for an action level substance. This process of determining action levels exists because these toxic substances are generally not bioaccumulative and have variable toxicity to aquatic life because of chemical form, solubility, stream characteristics and/or associated waste characteristics. Water quality based limits may also be assigned to a given NPDES permit if data indicate that a substance is present for which there is a federal criterion but no water quality standard.

Whole effluent toxicity (WET) testing is required on a quarterly basis for major NPDES dischargers and any discharge containing complex (industrial) wastewater. This test shows whether the effluent from a treatment plant is toxic, but it does not identify the specific cause of toxicity. If the effluent is found to be toxic, further testing is done to determine the specific cause. This follow-up testing is called a toxicity reduction evaluation (TRE). WET testing is discussed in Chapter 4 and Appendix II. Other testing, or monitoring, done to detect aquatic toxicity problems include fish tissue analyses, chemical water quality sampling and assessment of fish community and bottom-dwelling organisms such as aquatic insect larvae. These monitoring programs are discussed in Chapter 4.

Each of the parameters below can be toxic if sufficient in quantity or concentration.

pH

Changes in pH to surface waters are primarily through point source discharges. However, changes can also occur with the introduction of substances in the form of spills to a waterbody. As the pH of a water decreases, metals are more bioavailable within the water column and are therefore more toxic to the aquatic organisms. As the pH increases, metals are precipitated out of the water column and less toxic to aquatic organisms. If a surface water has had chronic introductions of metals and the pH gradually or dramatically decreases, the metals in the substrate will become more soluble and be readily available in the water column. While lower pH values may not be toxic to the aquatic organisms, the lower values can have chronic effects on the community structure of macroinvertebrates, fish, and phytoplankton. Macroinvertebrates will show a shift from intolerant species to tolerant species and have less community diversity.

The NC standard for pH in surface fresh waters is 6.0 to 9.0. Trout reproduction is adversely affected in waters with pH values below 5.5.

Metals

Municipal and industrial dischargers and urban runoff are the main sources of metals contamination in surface water. North Carolina has stream standards for many heavy metals; the most common metals in municipal NPDES permits are cadmium, chromium, copper, nickel, lead, mercury, silver and zinc. Standards are listed in Appendix I. Each of these, with the exception of silver, is also monitored through the ambient network along with aluminum and arsenic. Point source discharges of metals are controlled through the NPDES permit process. Municipalities with significant industrial users discharging wastes to their treatment facilities limit the heavy metals from these industries through a *pretreatment program*. Source reduction and wastewater recycling at WWTPs also reduces the amount of metals being discharged to a stream. Nonpoint sources of pollution from urban runoff are controlled through best management practices, stormwater control programs, and sedimentation and erosion control plans.

Chlorine

Chlorine is commonly used as a disinfectant at NPDES discharge facilities which have a domestic (i.e., human) component. These discharges are a major source of chlorine in the State's surface waters. Chlorine dissipates fairly rapidly once it enters the water, but it can have significant toxic effects on sensitive aquatic life such as trout and mussels. North Carolina has adopted a freshwater standard for trout waters of 17 ug/l (micrograms per liter). For all other waters an action level of 17 ug/l is applied to protect against chronic toxicity. It is recommended that new and expanding discharges provide dechlorination or alternate disinfection of wastewater. A total residual chlorine limit is assigned based on the freshwater action level of 17 ug/l or a maximum concentration of 28 ug/l for protection against acute effects in the mixing zone. Federal guidelines for residual chlorine of 8 ug/l for chronic effects and 13 ug/l for acute effects are used in saltwaters. In 1993, letters were sent to existing facilities with chlorine monitoring requirements. These letters encouraged permittees to examine their effluent chlorine levels and noted that limits may be implemented in the future. At this time, the State requires chlorine limits for all trout waters and any new or expanding facilities using chlorine for disinfection.

Ammonia (NH_3)

Point source dischargers are one of the major sources of ammonia. In addition, decaying organisms which may come from nonpoint source runoff and bacterial decomposition of animal waste products also contribute to the level of ammonia in a waterbody. At this time, there is no numeric standard for ammonia in North Carolina. However, DWQ has agreed to address ammonia toxicity through an interim set of instream criteria of 1.0 mg/l in the summer (April - October) and 1.8 mg/l in the winter (November - March). Currently, limits will be given no less than 2 mg/l in summer and 4 mg/l in winter, unless dissolved oxygen problems or modeling analysis dictate stricter limits. These interim criteria are under review, and the State may adopt a standard in the future.

Toxic substances in the Broad River Basin

Twenty-two facilities in the Broad River basin are required to monitor the toxicity of their effluent. These include industries and municipal wastewater treatment facilities. Two facilities are currently out of compliance (as of the approval date of this basin plan) with their toxicity limit and are operating under Special Order by Consent (SOC). These are the Spindale wastewater treatment plant and PPG-Shelby.

3.2.5 Fecal Coliform Bacteria

Fecal coliform bacteria are typically associated with the intestinal tract of warm-blooded animals. Common sources of fecal coliform bacteria include leaking or failing septic systems, leaking sewer lines or pump station overflows, runoff from livestock operations, wildlife and pets, as well as improperly disinfected wastewater effluent.

Fecal coliform bacteria are widely used as indicators of the potential presence of waterborne pathogenic organisms (which cause such diseases as typhoid fever, dysentery, and cholera). Fecal coliform bacteria in treatment plant effluent are controlled through disinfection methods including chlorinating, ozonation or ultraviolet light radiation.

Due to the low number of animal operations and limited development in the basin, the chances of bacterial contamination in streams is relatively low. However, failing septic systems, straight piping of waste waters to streams and animal operations without appropriate best management practices can cause elevated bacterial levels in any stream.

Fecal Coliform Bacteria in the Broad River Basin

Ambient monitoring indicates that the lower reaches of the First Broad River, Sugar Branch and Buffalo Creek have elevated levels of fecal coliform. Thus, these waters have been given use support ratings of fully supporting but threatened. It is believed that nonpoint sources of pollution are the main contributor to the elevated coliform concentrations. Additional discussion of these issues can be found in Chapter 4 and Chapter 6.

3.2.6 Nutrients

The term *nutrients* in this document refers to the two major plant nutrients, phosphorus and nitrogen. These are common components of fertilizers, animal and human wastes, vegetation, trout farms and some industrial processes.

Nutrients in surface waters come from both point and nonpoint sources. Nutrients are beneficial to aquatic life in small amounts. However, when conditions are favorable, excessive nutrients can stimulate the occurrence of algal blooms and excessive plant growth in slow-moving waters such as ponds, lakes, reservoirs and estuaries.

Algal blooms, through respiration and decomposition, can deplete the water column of dissolved oxygen and can contribute to serious water quality problems. In addition to problems with low dissolved oxygen, blooms can be aesthetically undesirable, result in an unbalanced food web, impair recreational use, impede fishing and pose difficulties for water treatment in water supply reservoirs. Excessive growth of larger plants, or macrophytes, such as milfoil, alligator weed and *Hydrilla*, can also be problematic by limiting recreation.

Dissolved oxygen depletion from nutrient overenrichment and algal growth fluctuates seasonally and even over the course of a day. In the presence of sunlight, oxygen is produced by algae and other plants through the process of photosynthesis. At night, however, photosynthesis and dissolved oxygen production slow down and oxygen is consumed by algae through respiration. During the summer months, this daily cycle of daytime oxygen production and night time depletion often results in the supersaturation of surface waters by oxygen during sunny days and low dissolved oxygen concentrations during late night and early morning hours. Supersaturation refers to dissolved oxygen levels greater than the saturation value for a given temperature and atmospheric pressure. Excessive dissolved gas levels can be lethal to fish populations, causing gas bubbles in the circulatory system and inhibiting the flow of blood. Additionally, algae may settle to the bottom of a waterbody and contribute to sediment oxygen demand as they decompose through bacterial action. This decomposition lowers dissolved oxygen concentrations in the bottom waters of lakes and other bodies of water.

Lake Eutrophication

Bodies of water which are nutrient rich and which support high levels of algal or macrophyte growth are often referred to as eutrophic. Eutrophication is a natural process which occurs as lakes and reservoirs gradually accumulate nutrients and sediments. As lakes age, they generally become more nutrient rich and biologically productive. Nutrients, soil or organic matter added by human activities can greatly accelerate this process. This is sometimes referred to as cultural eutrophication. As a group, reservoirs tend to have higher inflows and nutrient and sediment loads than natural lakes and are thus more likely to be eutrophic. In North Carolina this is especially true of piedmont reservoirs.

The classical lake succession sequence (Figure 3.2) is usually depicted as a unidirectional progression corresponding to a gradual increase in lake productivity from oligotrophy to hypereutrophy. The trophic states are:

- **Oligotrophic** - Nutrient-poor and low biological productivity. More typical of cold-water lakes.
- **Mesotrophic** - Intermediate nutrient availability and biological productivity.
- **Eutrophic** - Nutrient-rich and highly productive.
- **Hypereutrophic** - Extreme productivity characterized by algal blooms or dense macrophyte populations (or both) frequently having a high level of sedimentation.

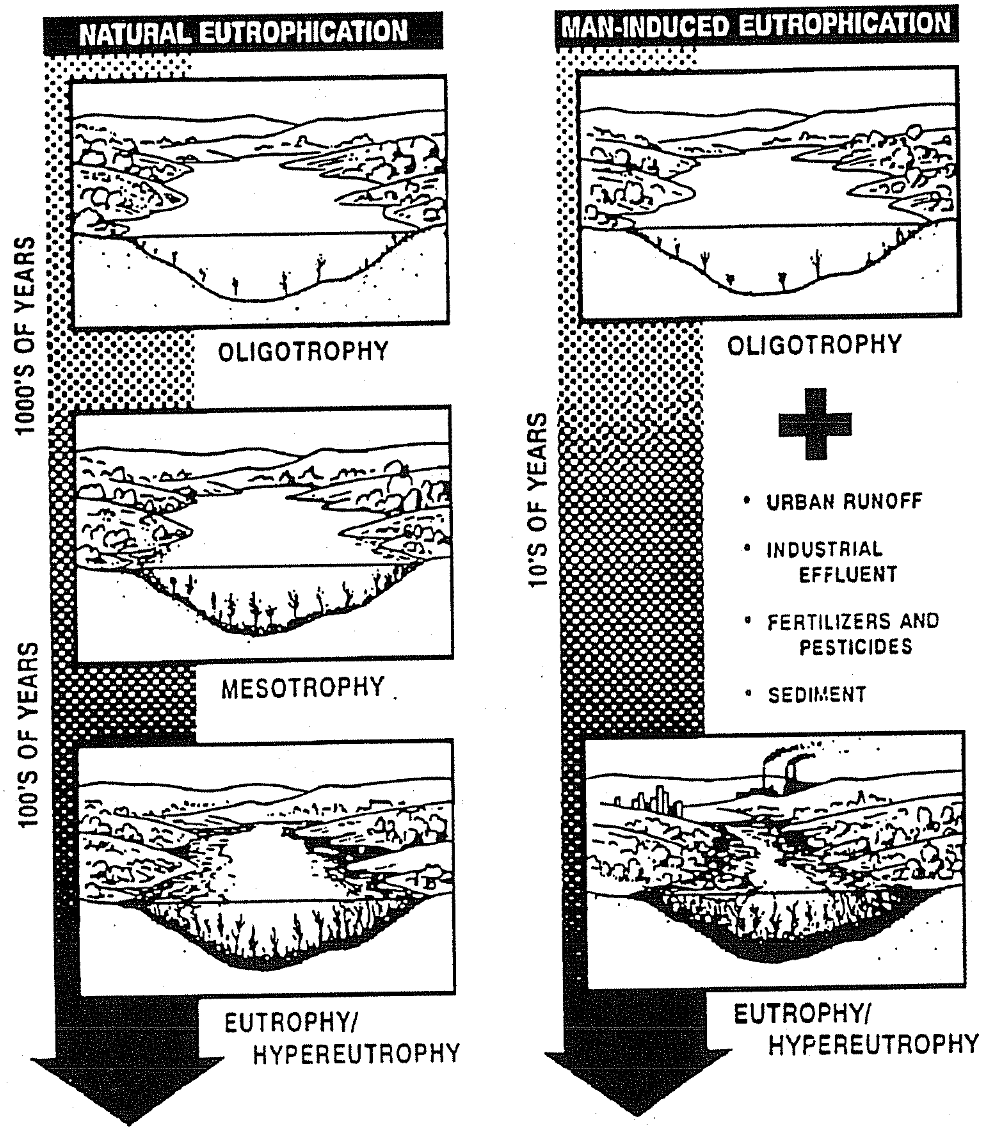

Figure 3.2 Natural versus Man-Induced Eutrophication

However, there is evidence that changes in lake trophic status is not necessarily gradual or unidirectional. If watersheds remain relatively undisturbed, lakes can retain the same trophic status for many thousands of years. Rapid changes in lake nutrient status and productivity are often a result of human-induced disturbances to the watershed rather than gradual enrichment and filling of the lake basin through natural means.

Eutrophic conditions--that is, high levels of nutrients and algal productivity--can but do not necessarily interfere with the uses of a waterbody. Some lakes and reservoirs can support substantial algal growth without significant interference with recreational activity or risk to aquatic organisms. Free-flowing streams with relatively undisturbed watersheds tend to have low nutrient levels. Increased nutrient inputs can affect aquatic life in streams, for example by supporting increased growth of benthic algae which in turn support a fish community that differs somewhat from what would otherwise be expected. Nutrient loading can cause some degradation of water quality in free-flowing piedmont streams, but does not generally result in water quality impairment.

North Carolina has a chlorophyll *a* standard of 40 ug/l (micrograms per liter) for lakes, reservoirs and slow moving waters not designated as trout waters, and 15 ug/l for trout waters. Chlorophyll *a* is a constituent of most algae and is a widely used indicator of algal biomass. Total dissolved gas levels in excess of 110% of saturation are also a violation of standards.

Agricultural and urban runoff, wastewater treatment plants, as well as atmospheric deposition are the main sources of nutrients reaching North Carolinas water bodies. Nutrients in nonpoint source runoff come mostly from fertilizer and animal wastes. Nutrients in point source discharges are from human wastes, food residues, some cleaning agents and industrial processes.

Nutrient Loading

Effective January 1, 1988 the General Assembly limited the quantity of phosphates in household laundry detergents to 0.5%. A statewide study of 23 municipal wastewater plants found that this phosphate detergent "ban" significantly reduced the amount of phosphorus entering wastewater treatment plants and resulted in an average reduction of 33% in the mass phosphorus load discharged from these facilities (NCDEM, 1991). An analysis of several sites in the state found reductions in ambient phosphorus levels downstream of major WWTPs (NCDEM, 1991).

It is important to distinguish between the nutrient loading to streams in a watershed (the 'end of pipe' or 'edge of field' loads) and the nutrients reaching a particular lake or estuary (the delivered load). Nutrients entering surface waters may be delayed for some time before reaching a downstream lake and may exist in a different chemical form by the time they arrive. For example, dissolved orthophosphorus from fertilizer or discharged wastewater may adsorb to suspended sediments once it enters a stream. Since sediment transport is episodic, occurring primarily during storms, the sediment-attached phosphorus may take weeks or months to reach a lake or estuary where it may potentially contribute to algal growth. In some cases--such as the loss of nitrogen to the atmosphere via denitrification--nutrients can leave the aquatic system entirely. It is the delivered load that influences algal growth, but these nutrient 'fate and transport' issues can sometimes be significant.

Phosphorus is usually the limiting nutrient in most freshwaters. Nutrient limitation can vary seasonally, however, and nitrogen can be limiting in situations where significant amounts of phosphorus have been added by human activity. Since algae use nitrogen and phosphorus in more or less fixed amounts, the ratio of nitrogen to phosphorus in a lake (the N:P ratio) is commonly used to evaluate which major nutrient is likely to be limiting. Algal growth potential tests are another method used to assess nutrient limitation. Algal growth potential tests (AGPT) are conducted by adding sufficient quantities of N or P to a water sample and observing the response of a test alga under controlled conditions.

Nutrients in the Broad River Basin

Although nutrient enrichment is not currently contributing to the impairment of any waters in the Broad River basin, symptoms of enrichment have been noted in the North Pacolet River, Second Broad River, Catheys Creek and Beaverdam Creek during biological sampling (especially in fish community structure sampling). Kings Mountain Reservoir, in particular, is considered borderline between oligotrophic and mesotrophic and could potentially develop symptoms of nutrient enrichment in the future. It is important to be aware of the potential for problems to develop in order to prevent them.

3.3 POINT SOURCES OF POLLUTION

3.3.1 Defining Point Sources

Point source refers to a discharge that enter surface waters through a pipe, ditch or other well-defined point of discharge. The term applies to wastewater and stormwater discharges from a variety of sources. Wastewater point source discharges include municipal (city and county) and industrial wastewater treatment plants and small domestic wastewater treatment systems that may serve schools, commercial offices, residential subdivisions and individual homes. Stormwater point source discharges include stormwater collection systems for municipalities which serve populations greater than 100,000 and stormwater discharges associated with certain industrial activities as defined in the Code of Federal Regulations [40 CFR 122.26(a)(14)]. The primary pollutants associated with point source discharges are oxygen-demanding wastes, nutrients, sediment, color, and toxic substances including chlorine, ammonia and metals.

Point source dischargers in North Carolina must apply for and obtain a National Pollutant Discharge Elimination System (NPDES) permit from the state. Discharge permits are issued under the NPDES program which is delegated to North Carolina by the EPA. See Chapter 5, Water Quality Programs and Program Initiatives in the Basin, for a description of the NPDES program and permitting strategies. Definitions and examples of the various categories can be found in Table 3.7.

3.3.2 Wastewater Point Source Discharges in the Broad River Basin

There are 85 permitted NPDES wastewater dischargers in the Broad River basin. There are 61 dischargers covered under individual permits and 24 dischargers covered under general permits. The locations of the permitted facilities are shown in Figure 3.3. Table 3.8 lists the major dischargers (≥1.0 MGD) as shown on the map with number designations. Table 3.9 provides a summary of total and average discharge for each category of permitted facility.

3.3.3 Stormwater Point Source Discharges in the Broad River Basin

Excluding construction general permits, there are 89 general permits and 2 individual stormwater permits issued within the river basin. Activities covered under the general stormwater permits include: construction; mining/borrow pits; metal waste recycling and manufacture of metal products and equipment; manufacture of timber products; apparel, printing, paper, leather, and rubber products manufacturing; food, tobacco, cleaning preparations, perfumes, cosmetics, and drug manufacturing and public warehouse storage; manufacture of stone, clay, glass, and concrete products; vehicle maintenance, transportation, and postal service activities, public warehousing and petroleum bulk stations and terminals; used automobile parts and scrap yards; non-metal waste scrap and recycling; ready mixed concrete production; manufacture of asphalt paving mixtures and blocks; production of textile mill products; and furniture and fixture manufacturing. The two facilities covered under individual permits are a polyester filament yarn manufacturing facility and a facility which produces lithium chemicals and castings of lithium material.

The primary source of concern from industrial facilities is the contamination of stormwater from contact with exposed materials. In addition, poor housekeeping can lead to significant contributions of sediment and other pollutants which have a detrimental effect on the water quality in receiving streams.

There are currently no municipalities in the Broad River basin that are subject to NPDES stormwater permitting.

Table 3.7 Definitions of Categories of NPDES Permits

CATEGORY	DEFINITION	EXAMPLES
Major vs. Minor discharges (NC00 Facilities)	For publicly owned treatment works, any facility discharging ≥1 MGD is defined as a Major discharge. For industrial facilities, the EPA provides evaluation criteria including daily discharge, toxic pollutant potential, public health impact and water quality factors. Any facilities which do not meet the criteria for Major status are defined as Minor discharges.	NC0020664 - Town of Spindale (6 mgd) NC0004685 - PPG Industries (1.3 mgd)
General Permits (NCG Permit Facilities)	Permits for dischargers in categories which all have similar discharges, operations and monitoring, and limits. Generally minor effluent on receiving stream individually.	Most stormwater permits. Non-contact cooling water, many groundwater remediation treatment systems, sand dredging operations, seafood packing, fish farms and single family residences
100% Domestic	A system which treats wastewater containing household-type wastes (bathrooms, sinks, washers, etc.).	Housing subdivision WWTPs, schools, mobile home parks.
Municipal	A system which serves a municipality of any size.	NC0025984 - Town of Forest City (4.95 mgd)
Process Industrial	Water used in an industrial process which must be treated prior to discharge.	NC0006025 - Burlington Industries (2.5 mgd)
Nonprocess Industrial	Wastewater which requires no treatment prior to discharging[1].	
Stormwater Facilities	Discharges of runoff from rainfall or snow melt. NPDES permits are required for "stormwater discharges associated with industrial activity" and from municipal stormwater systems for towns over 100,000 in population.	"Stormwater discharges associated with industrial activity" include most types of manufacturing plants. Landfills, mines, junkyards, steam electric plants, transportation terminals and any construction activity which disturbs 5 acres or more during construction.

1. Non-contact cooling water may contain biocides; however, the biocides must be approved by the DWQ Aquatic Toxicology Unit. The approval process predicts that the chemicals involved have no detrimental effect on the stream when discharged with the non-contact cooling water.

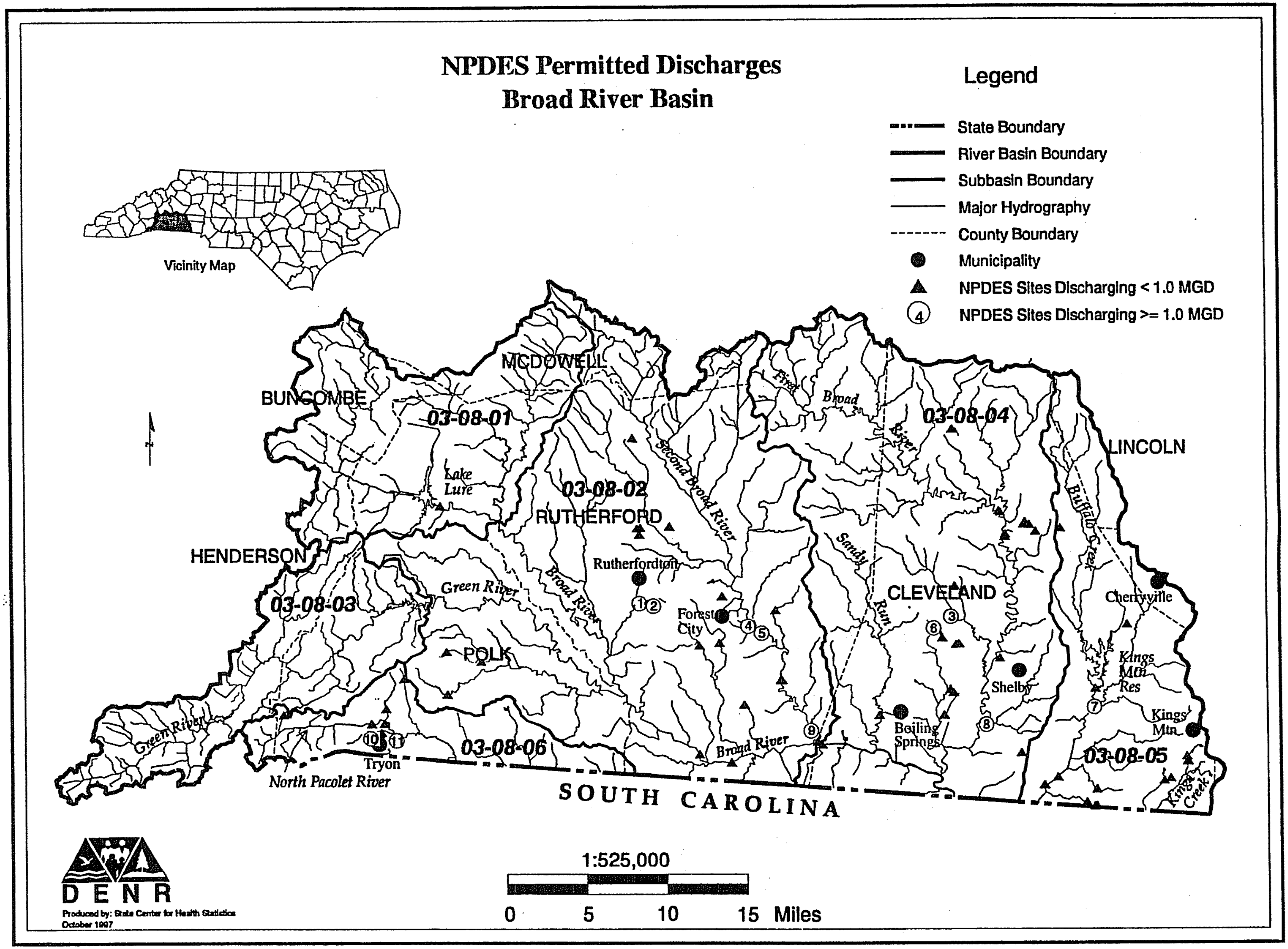

Figure 3.3 Map of NPDES Wastewater Permittees in the Broad River Basin

Table 3.8 Major dischargers in the Broad River Basin (numbers correspond to numbers in Figure 3.3)

Map No.	Facility	County	Permit No.	Design Flow (MGD)	Receiving Stream
1	Spindale WWTP	Rutherford	NC0020664	6.0	Hollands Creek
2	Rutherfordton WWTP	Rutherford	NC0025909	1.0	Cleghorn Creek
3	PPG Industries (pipe 1)	Cleveland	NC0004685	1.3	Overflow Branch
4	Forest City WWTP	Rutherford	NC0025984	4.95	Second Broad River
5	Burlington Industries	Rutherford	NC0006025	2.5	Second Broad River
6	PPG Industries (pipe 2)	Cleveland	NC0004685	1.3	Overflow Branch
7	Kings Mountain WWTP	Cleveland	NC0020737	6.0	Buffalo Creek
8	Shelby WWTP	Cleveland	NC0024538	6.0	First Broad River
9	Cone Mills Corporation	Rutherford	NC0004405	1.75	Second Broad River
10	Tryon WWTP (pipe 2)	Polk	NC0021601	1.5	Unnamed Trib. to Pacolet River
11	Tryon WWTP (pipe 1)	Polk	NC0021601	1.5	Vaughn Creek

Table 3.9 Summary of NPDES Dischargers and Permitted and Actual Flows for the Broad River Basin

FACILITY CATEGORIES	SUBBASIN 01	02	03	04	05	06	TOTAL
Total Facilities	3	31	5	24	14	8	85
NC00 Facilities	1	23	2	17	11	7	61
NCG Facilities	2	8	3	7	3	1	24
Total Permitted Flow (MGD)	1.00	18.45	0.03	8.50	7.79	2.08	37.84
***Major Discharges**	0	8	0	3	4	2	17
Total Permitted Flow (MGD)	0.00	17.29	0.00	8.08	7.63	1.95	34.95
***Minor Discharges**	1	15	2	14	7	5	44
Total Permitted Flow (MGD)	1.00	1.16	0.03	0.42	0.16	0.13	2.90
100% Domestic Wastewater	1	9	2	8	5	4	29
Total Permitted Flow (MGD)	1.00	0.11	0.03	0.39	6.14	0.13	7.80
Municipal Facilities	1	5	0	2	2	2	12
Total Permitted Flow (MGD)	1.00	12.95	0.00	6.30	6.10	1.60	27.95
Major Process Industrial	0	5	0	2	3	1	11
Total Permitted Flow (MGD)	0.00	5.34	0.00	2.08	1.63	0.45	9.50
Minor Process Industrial	0	4	1	2	1	1	9
Total Permitted Flow (MGD)	0.00	0.82	0.02	0.02	0.00	0.00	0.86
Nonprocess Industrial	0	9	1	11	5	3	29
Total Permitted Flow (MGD)	0.00	0.00	0.01	0.10	0.06	0.03	0.20
*** NC00 / Individual permit facilities**							

3.4 NONPOINT SOURCES OF POLLUTION

Nonpoint source (NPS) pollution refers to runoff that enters surface waters through stormwater, snowmelt or atmospheric deposition (e.g., acid rain). There are many types of land use activities that are a source of nonpoint source pollution including land development, construction, mining operations, crop production, animal feeding lots, failing septic systems, landfills, roads and parking lots. As noted earlier, stormwater from large urban areas (>100,000 people) and from certain industrial sites is considered a point source since NPDES permits are required for piped discharges of stormwater from these areas. However, a discussion of urban runoff will be included in this section.

Sediment and nutrients are major pollution-causing substances associated with nonpoint source pollution. Others include fecal coliform bacteria, heavy metals, oil and grease, and any other substance that may be washed off the ground or removed from the atmosphere and carried into surface waters. Unlike point source pollution, nonpoint pollution sources are diffuse in nature and occur at random time intervals depending on rainfall events. The majority of water quality problems, including stream impairment, in the basin are from nonpoint source pollution. Below is a brief description of major categories of nonpoint sources of pollution in the Broad River basin.

3.4.1 Agriculture

There are a number of activities associated with agriculture that can serve as sources of water pollution. Land clearing and plowing make soils susceptible to erosion, which can then cause stream sedimentation. Pesticides and fertilizers (including chemical fertilizers and animal wastes) can be washed from fields, orchards, or improperly designed storage or disposal sites. Construction of drainage ditches on poorly drained soils enhances the movement of stormwater into surface waters. Concentrated animal feed lot operations or dairy farms without adequate waste management systems or fencing to keep animals away from streams can be a significant source of oxygen consuming wastes, fecal coliform bacteria, sediment and nutrients. Untreated discharge from a large animal operation has a nutrient load comparable to the discharge from a secondary waste treatment plant serving a small town.

Sediment production and transport has historically been greatest from row crops and cultivated fields (Waters, 1995; Lenat et al. 1979). However, with the gradual reduction of cultivated cropland acreage, implementation of the 1985 and 1990 Farm Bills and wider spread use by farmers of BMPs such as no-till farming, contour plowing, terracing, conservation tillage and grassed waterways, trends in sediment loss from cropland have been downward. Other recommended BMPs aimed at continuing to reduce sedimentation from agricultural land include maintaining a vegetated buffer between fields and streams, and fencing cattle and dairy cows from streams to protect streambanks from trampling and protect streamside vegetation. The use of these and other best management practices (BMPs) to reduce erosion can mitigate the impacts of sedimentation (Lenat, 1984). This is evidenced in the USDA, NRCS data in Table 3.3 which show a decline in cropland erosion rates on a per acre basis.

In reference to nutrient loading from animal operations, researchers from NC State University (Barker and Zublena, 1995) did a comparison between the amount of nutrients generated through manure and the amount of nutrients (nitrogen, phosphate, zinc and copper) needed for crop and forage production for each county in the state. These nutrient data were reported in "Livestock Manure Nutrient Assessment in North Carolina". The report was initiated to: 1) geographically depict where livestock are located and identify high livestock production density area around support facilities such as feed mills, hatcheries, processing plants, etc.; 2) assess current generation of manure by county; 3) determine the amount of nutrients from manure which can be recovered and made available to agronomic crops; 4) determine the quantity of nutrients required for non-legume agronomic crops and forages in each county; and 5) calculate the percent of agronomic crop and forage nutrients which can be supplied by animal manure. A percentage greater than 100 means that there are more nutrients generated in manure than can be used by the crops and forage grown in that county. Plant recoverable manure nutrients are those that remain from the time the animal voids the manure until the time it is transported to the field for spreading (in other words, the nutrients that can be recovered or taken up and used by the plants). During this period, much of the nutrients can be lost through drying or dilution, surface runoff, volatilization or microbial digestion. Since different manure management systems either conserve or sacrifice varying amounts of nutrients, an estimate was made of the percentage of farms using specific systems. These percentages were applied to the manure characteristics appropriate for the specific method which gave the remaining nutrients after storage and treatment losses.

For the three counties that have most of their area in the Broad River Basin (Cleveland, Polk and Rutherford), most of the data result in low percentages (between 4% and 30%) for all nutrients. However, in Cleveland County, figures for zinc and copper were 274% and 574%, respectively. This means that for those parameters in that county, there are many more nutrients generated in manure than can be used by the crops and forage grown. It should be noted that this figure does not take into account commercial fertilizer applications in the counties. Alternatives to cropland application need to be considered in this area, such as application on forest land or transportation/distribution of the collectable manure to counties that have capacity and could use this nutrient source in lieu of commercial fertilizers.

Chapter 5 discusses agricultural nonpoint source control programs and general management strategies for controlling agriculture related sedimentation. A list of BMPs for addressing agricultural runoff is presented in Appendix V.

3.4.2 Urban/Residential Stormwater

It is commonly known that urban streams are often polluted streams (Mulholland and Lenat, 1992). As a rule, runoff from urbanized areas is more localized, but can often be more severe, than agricultural runoff. Any type of land-disturbing activity such as land clearing or excavation can result in soil loss and cause sedimentation of the waters in the watershed. The rate and volume of runoff in urban areas is much greater than in undeveloped areas due both to the high concentration of impervious surface areas and to storm drainage systems that rapidly transport stormwater to nearby surface waters. This increase in volume and rate of runoff can result in streambank erosion and sedimentation in surface waters. Some potential impacts of stormwater runoff include:

- <u>Polluted water</u>: Numerous pollutants may be present in urban stormwater, including sediment, nutrients, bacteria, oxygen demanding substances, oil and grease, trace metals, road salt, and toxic/synthetic chemicals. These pollutants can impair aquatic life, reduce recreational value and threaten public health if drinking water sources and fish tissue become contaminated.
- <u>Flooding:</u> Flooding damages public and private property, including infrastructure. It can also threaten public safety.
- <u>Eroded streambanks</u>: Sediment clogs waterways and fills lakes and reservoirs. It can also smother the plants and animals in waterbodies and destroy the habitat necessary for reproduction of fish and aquatic animals. The erosion of streambanks causes loss of valuable property as stream width grows.
- <u>Increased Flow Variability</u>: High flows caused by runoff from impervious surfaces can increase erosion and alter the aquatic habitat and fauna.
- <u>Economic impacts</u>: The economy can be impacted from a loss of recreation-related business and an increase in drinking water treatment costs.

There is abundant information on the effects of urban runoff on macroinvertebrates (Lenat and Eagleson, 1981; Crawford and Lenat, 1989). Stream organisms are affected not only by water quality, but also by the character of the physical habitat. One component of stream habitat is flow regime. Most fish and macroinvertebrates in streams require flowing water and may be adversely affected by either extreme high or low flow. Development within a catchment may affect streamflow by increasing flow variability and/or altering base streamflow.

Natural streams with forested watersheds and vegetated riparian zones experience relatively little overland runoff. Much of the rainfall percolates through the soil and enters the groundwater. Therefore, natural streamflow is primarily the result of groundwater inputs. Both urban development and agricultural land use may include structures intended to prevent flooding by routing water directly to streams. This is especially true for urban landscapes where large amounts of impervious surfaces promote overland flow at the expense of groundwater recharge. The immediate result is high streamflow following rainfall, which can scour the stream bottom. Scouring is the physical movement of bedload, which disrupts the stream biology and habitat. The long-term result of increased overland flow is to accentuate summer low flows, due to the reduction of groundwater storage. Many streams in developed areas may stop flowing during summer months. This type of stress may severely limit the diversity of the aquatic fauna.

In addition, many streams are used as a source of irrigation water and this practice can reduce streamflow. The use of nearby well water might also reduce streamflow. In streams which normally experience low summer flows (especially in the Slate Belt region), water withdrawals for irrigation (or other uses) might be sufficient to convert a permanent stream into an intermittent stream. The lack of flowing water in the summer months can severely reduce the diversity of the aquatic fauna. This problem has not been investigated in North Carolina and further research is needed.

Storm drainage systems, including curb and guttered roadways, also allow pollutants to reach surface waters quickly and with little or no filtering. Pollutants include lawn care products such as pesticides and fertilizers; automobile-related pollutants such as fuel, lubricants, abraded tires and brake linings; lawn and household wastes (often dumped in storm sewers); road salts, and fecal coliform bacteria (from animals and failing septic systems). The diversity of these pollutants makes it very challenging to attribute water quality degradation to any one pollutant.

Replacement of natural vegetation with pavement, removal of streamside buffers and managed lawns reduce the ability of the watershed to filter pollutants before they enter the stream. The chronic introduction of these pollutants and increased flow and velocity into a stream results in degraded waters. Many urban streams are rated as biologically poor.

Urban Stormwater Impacts in the Broad River Basin

The population density map presented in Chapter 2 is an indicator of where urban development and potential urban stream impacts are likely to occur. Between 1982 and 1992, the most significant land use change in the basin was seen in the urban/built-up category with a 71% increase. Although population growth in the basin has been and is projected to be moderate, it will be important to properly manage the growth that will likely occur in the larger municipal areas. Hickory Creek, which runs through the City of Shelby, has been identified as having impaired water quality in part due to runoff from urban areas. Management strategies for addressing urban runoff are presented in Chapter 6. A list of BMPs for addressing urban runoff is presented in Appendix V.

Management strategies for addressing urban runoff are presented in Chapter 6, Section 6.6. A list of BMPs for addressing urban runoff is presented in Appendix V.

3.4.3 Construction

Construction activities that entail excavation, grading or filling (such as road construction or land clearing for development) can produce significant sedimentation if not properly controlled.

Sedimentation from developing urban areas can be a major source of pollution due to the cumulative number of acres disturbed in a basin.

As a pollution source, construction activities are typically temporary, but the impacts can be severe and long lasting (see discussion in Section 3.2.1). Construction activities tend to be concentrated in the more rapidly developing areas of the basin. However, construction is throughout the basin.

Construction-related sedimentation is addressed through the Sedimentation Pollution Control Act (see Chapter 5 and Appendix VI). Construction activities are thought to be associated with the impairment of Hickory Creek (subbasin 030804) and Buffalo Creek (subbasin 030805). In addition, construction can contribute to sedimentation which is the most prevalent problem in the basin. Recommended management strategies for construction activities can be found in Chapter 6, Section 6.6. A list of BMPs for controlling erosion and sedimentation is presented in Appendix V.

3.4.4 Timber Harvesting

Forested areas are an ideal land cover for water quality protection. They stabilize the soil, filter rainfall runoff and produce minimal loadings of organic matter to waterways. In addition, forested stream buffers can filter impurities from runoff from adjoining nonforested areas.

Improper forest management practices can adversely impact water quality in a number of ways. Without proper BMPs, harvesting operations can change the hydrology of an area and significantly increase the rate and flow of stormwater runoff. This results in both downstream flooding and stream bank erosion. Clearcutting, when compared to selective cutting, can cause a much higher rate of erosion (Waters 1995). Some experts have concluded that sedimentation from timber harvesting is more related to roads and skid trails than it is to the method of harvest (Stone, et. al., 1978).

Careless harvesting and road and stream crossing construction can transport sediment to downstream waters. Streams with sedimentation may require many years to restore. Removing riparian vegetation along stream banks can cause water temperature to rise, destabilize the shoreline and minimize or eliminate the runoff protection benefits of the buffer. Sedimentation due to forestry practices is most often associated with the construction and use of logging roads, particularly when roads are built near streams (Waters 1995). Density and length of logging roads can be major factors in the amount of sedimentation produced.

Timber harvesting is an important industry in the Broad River basin and is sometimes done at the onset of clearing for site development and agricultural activities. However, it is critical that all efforts be made to minimize sediment loss and runoff so as to protect other natural resources in this basin. These resources include fish spawning areas and habitat, recreational uses and aesthetics. This is especially important in light of a trend toward increased logging in North Carolina and in the southeast United States, in general.

Timber Harvest in the Broad River Basin

A recent concern related to timber harvesting that is receiving attention in the Broad River basin, as well as statewide, is chip mills. These are facilities that produce wood chips for use in the production of paper products. One of the big concerns about these facilities is their potential to increase the amount of timber harvesting, especially clearcutting, in their vicinity. In response to North Carolina citizens' increasing concerns regarding this industry, Governor Hunt directed the NC Department of Environment and Natural Resources (NC DENR) to conduct an environmental and economic study of wood chip production in the state. For several months, NC DENR staff have been gathering information needed to identify issues that should be examined in the study.

In October of 1997, three public meetings were held across North Carolina to receive general public input into this process. DENR received a large number of comments from state and federal agencies, individuals, businesses and groups. More than 100 persons presented oral comments at the pubic meetings and more than 200 written were also received by DENR. Comments received overwhelmingly supported the Governor's decision to conduct an environmental and economic study of this sector, with few, if any, commentors recommending that the study not be pursued. There also appeared to be general agreement that the study should be conducted in an informed, objective and unbiased manner, with frequent opportunities for public review and comment during the study process itself. Attendance was good and many ideas regarding the scope and nature of the forthcoming study were received.

An ongoing effort to manage timber harvesting in the Broad River basin such that it does not have a negative impact on water quality is being undertaken by the NC Division of Forest Resources (DFR). DFR is implementing various measures for protecting water quality statewide. These measures began with the creation of voluntary *Forest Practices Guidelies Related to Water Quality* (FPGs). These measures were voluntarily applied best management practices, which had no enforcement power by any agency. In 1989, the Sedimentation Pollution Control Act (SPCA) was amended to require compliance with nine performance standards in order to remain exempt from the SPCA's permitting requirements. These nine standards are the FPGs whose compliance is accomplished through the use of BMPs. The *Forestry Best Management Practices Manual* was published in September, 1989 to guide forestry operations in protecting water quality. The manual and the FPGs are available from any DFR office at no charge.

FPG/BMP inspections are carried out continuously by DFR field personnel in the course of their normal duties. Examinations of 3,779 sites in fiscal year 1996-97 revealed an initial compliance rate of 94.7%. Two systematic surveys by a DFR staff hydrologist in 1995 and 1996 examined 196 and 223 sites respectively. Compliance with FPGs and BMPs was found to be 92% and 95% for the two years, respectively. A summary of activities and past accomplishments in the Broad River basin is reported in Chapter 5.

Chapter 5 describes several programs that are aimed at either encouraging or requiring utilization of forest best management practices at the state and federal level. A list of FPGs is presented in Appendix V.

3.4.5 Onsite Wastewater Disposal

Septic systems receive wastewater from a household or business. The septic tank removes some wastes, but the soil drainfield provides further absorption and treatment. Septic tanks can be a safe and effective method for treating wastewater if they are sized, sited, and maintained properly. However, if the tank or drainfield malfunction or are improperly placed, constructed or maintained, nearby wells and surface waters may become contaminated.

Some of the potential problems from malfunctioning septic system include:

- <u>Polluted groundwater</u>: Pollutants in sewage include bacteria, nutrients, toxic substances, and oxygen-consuming wastes. Nearby wells can become contaminated by septic tanks.
- <u>Polluted surface water</u>: Often, groundwater carries the pollutants mentioned above into surface waters, where they can cause serious harm to aquatic ecosystems. Septic tanks can also leak into surface waters both through or over the soil.
- <u>Risks to human health</u>: Septic system malfunctions can endanger human health when they contaminate nearby wells, drinking water supplies, and fishing and swimming areas.

Pollutants associated with onsite wastewater disposal may also be discharged directly to surface waters through *straight pipes* (i.e., direct pipe connections between the septic system and surface waters). These types of discharges, if unable to be eliminated, must be permitted under the NPDES program and be capable of meeting effluent limitations specified to protect the receiving stream water quality, including disinfection.

Onsite wastewater disposal is most prevalent in rural portions of the basin and at the fringes of urban areas. Data from the 1990 census indicates that in Polk, Rutherford and Cleveland counties combined, approximately 65% of the total number of housing units are on septic systems. Fecal coliform bacteria contamination from failing septic systems is of particular concern in waters used for swimming, tubing, water supply and other related activities. Regulatory programs and BMPs pertaining to onsite wastewater disposal are presented in Appendix V.

3.4.6 Solid Waste Disposal

Solid wastes may include household wastes, commercial or industrial wastes, refuse or demolition waste, infectious wastes or hazardous wastes. Improper disposal of these types of wastes can serve as a source of a wide array of pollutants. The major water quality concern associated with modern solid waste facilities is controlling the leachate and stabilizing the soils used for covering many disposal facilities. Properly designed, constructed and operated facilities should not significantly effect water quality.

Groundwater and surface water monitoring is required at all permitted Municipal Solid Waste Sites (MSW) and all Construction and Demolition landfills. Monitoring efforts have been required since July 1989. All MSW landfills must have a liner system in place by January 1, 1998. All existing unlined landfills must close at this same time.

Solid Waste Disposal in the Broad River Basin

During the public workshops conducted in the Broad River basin, concerns about the water quality impacts of a landfill near Kings Mountain Reservoir (Moss Lake) were expressed. Monitoring groundwaters and surface waters has been conducted around this site. No water quality violations have been detected through the surface water monitoring program, but monitoring will continue. In compliance with the requirements described above, the unlined portion of this site is being closed and a new area that has been lined will begin to be used.

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