Final Report
Stormwater Runoff from Log Storage Yards

Working Paper #37

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Results and Final Recommendations Report
for an investigative research project titled:
Development and Demonstration of Control Measures for the Reduction of Pollutants in Stormwater Runoff from Forest Log Sorting and Storage Facilities.

Submitted to

Water Pollution Control Division
Department of Environmental Quality
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ABSTRACT

Environment impacts of log storage facilities has become a concern in recent years. The ultimate goal of this investigation is to develop baseline data which government and industry can use to develop sound environmental protection strategies with regard to stormwater runoff from woodyards. The activities documented in this report include a survey of the size and other characteristics of log storage facilities in this state, characterization of the type and volume of pollutants in the runoff water, and evaluation of runoff control processes. The results of the project are intended to generate the basic data base for reference in developing regulations, and to recommend measures for pollution control from log storage facilities.

INTRODUCTION

Forests cover nearly half of the land area within Louisiana, making tree harvesting the number one "crop" in the state. Whereas a large percentage of the activities associated with forestry related activities fall within the traditional definition of nonpoint source pollution, log sorting and log storage facilities is an area of operation within the forest industry which has not been thoroughly investigated. LAC 33:1X.301.M.2.a. and b. defines point source silvicultural activities as follows:

a. Silvicultural Point Source - means any discernible, confined and discrete conveyance related to log sorting or log storage facilities which are operated in connection with silvicultural activities and from which pollutants are discharged into water of the state. The term does not include non-point source silvicultural activities such as nursery operations, site preparation, reforestation and subsequent cultural treatment, thinning, prescribed burning, pest and fire control, harvesting operations, surface drainage, or road construction and maintenance from which there is natural runoff. However, some of these activities (such as stream crossing for roads) may involve point source discharges of dredged or fill materials which may require a CWA Section 404 permit.

b. Log Sorting and Log Storage Facilities - means facilities whose discharges result from the holding of unprocessed wood, for example, logs or roundwood with bark, or after removal of bark, held in self-contained bodies of water (mill ponds of log ponds) or stored on land where water is applied intentionally on the logs (wet decking).

The Louisiana Department of Environmental Quality's Nonpoint Source Management Program currently works with the Louisiana Office of Forestry, the Louisiana Forestry Association, and the U.S. Forest Service on implementation of best management practices (BMP), statewide educational programs and a statewide BMP survey program which deals with the nonpoint source issues defined above. However, log sorting and log storage facilities have not yet been addressed.

Louisiana has an estimated 129 facilities wherein raw wood, or logs, are stored on a more-or-less permanent basis. Most of these sites are adjacent to primary processing facilities, such as sawmills, plywood mills or pulp/paper mills. These sites, whether adjacent to a mill or not, are referred to in the industry as woodyards.

Logs destined for use in pulp and paper mills are generally smaller in diameter and are more commonly referred to as pulpwood. Pulp/paper mills commonly have a large woodyard at the mill site and several satellite woodyards at distances of 20 to 100 miles from the mill. Individual dealers who have contracts to supply pulpwood to mills may also have their own woodyards. Such dealers are typically small business enterprises that have independent logging and pulpwood contractors deliver wood to their yards but do not process the wood. Satellite woodyards are rare throughout the rest of the forest products industry. In addition, most traditional satellite woodyards have been replaced by larger but fewer chip mills, wherein pulpwood is stored, debarked and chipped at a (usually independently-owned) chip mill and then trucked to a pulp/paper mill in the form of chips.

Logs are perishable. They are subject to attack from insects and fungi which cause holes, stains and rots. In the hot, humid climate along the Gulf Coast, raw logs can be stored a maximum of two weeks in the summer and two months in the winter. Use of a sprinkler system to keep the logs wet will prolong storage life to about six months for pine and two years for hardwood. Some companies have recently stored pine for two years with reasonable success. To reduce cost, woodyards equipped with sprinkler systems recycle the water. Use of sprinkler systems is common at large facilities, but less common at satellite woodyards and small sawmills. Use of ponds to submerge logs during storage was a common practice during the early part of this century, but is a non-existent to rare practice in the southern states today. To the best of our knowledge, no chemicals are used to preserve logs, due to cost considerations. Water alone does an adequate job.

The use of chemicals in silviculture (raising trees) is limited to herbicides for weed control and to kill undesirable tree species. Sometimes, young trees (1 to 3 years old) are given room to grow by killing competing vegetation, and older trees with no economic value may be killed by injecting herbicides under the bark to make room for more valuable trees. Trees killed by herbicides are never taken to a mill, as it makes no economic sense to spend money killing a tree prior to harvesting. Overall, harvesting (including thinnings) and prescribed burning are by far the most prevalent silvicultural tools. However, concerns about smoke management are causing an increased interest in herbicides.

Insecticides and fungicides are not used in Louisiana's forests because it costs more to use them than what the timber is worth. Even southern pine beetle outbreaks are controlled by cutting down infected trees and utilizing them, if possible.

Obviously, since no pesticides or herbicides of any type are ever applied to merchantable trees in the forest, there is no likelihood of these types of chemicals entering the stormwater runoff from woodyards and mill sites. Logs destined for export are, however, normally dipped in an anti-stain solution (fungicide and insecticide), but there are only a handful of facilities doing this.

Louisiana averages roughly sixty inches of precipitation annually, so there is naturally stormwater runoff from woodyard sites. Whether this runoff has a detrimental effect on the quality of water downstream from these sites is still unknown, but this investigation gives some insights into the nature and levels of pollutant parameters in the runoff. Surprising little research has been done on the chemical makeup of woodyard water runoff or its effect on the environment. At stake is government regulations and permit requirements.

OBJECTIVES

The overall objective of this project was to characterize the stormwater runoff from woodyards in Louisiana and recommend some (preferably low-cost) methods of improving the runoff water quality.

The general procedure used to conduct this investigation was:

1. Develop a general description of woodyards in Louisiana.
2. Select some typical woodyards and determine some typical levels of pollutant parameters in them.
3. Find or create some pollution control devices and measure their effectiveness in lowering certain pollutant parameter levels that might be of concern.
4. Make recommendations.

METHODOLOGY

The general descriptor of woodyards was developed by conducting a mail-out survey of woodyards in Louisiana. This activity resulted in a peer-reviewed paper which is included in this report. A detailed description of the methodology is given therein.

Through the use of the above-mentioned survey, and with the assistance of industry personnel, woodyards were selected for the measurements of stormwater pollutant parameters. Common stormwater parameters were measured, along with priority pollutants and heavy metals (plus cyanide and phenol). Some companies had already installed pollution control devices, so their effectiveness was then measured. Water samples were taken from both stormwater runoff and sprinkler system recirculation ponds.

The priority pollutants were analyzed by commercial laboratories after collecting informal bids. Initially, Thornton Laboratories, Inc., in Tampa, Florida, was the low bidder, and they were used at that time. A year later, Thornton Laboratories indicated that the bid was in error. A new collection of informal bids revealed that Analytical & Environmental Testing, Inc., (A&E) of Baton Rouge was the low bidder at about the same price as Thornton's initial bid. The advantages of using a local laboratory were obvious, so we used them during the rest of the project.

Heavy metals testing was initially performed by the LSU Biogeochemistry Laboratory, but problems with broken machinery caused undue delays. Later samples were taken to A&E for heavy metals analysis.

Biochemical oxygen demand over 5 days (BOD_5), chemical oxygen demand (COD), total suspended solids (TSS), total dissolved solids (TDS) and pH were measured in-house by graduate students under the supervision of the investigators at the water analysis laboratory in the Civil & Environmental Engineering Department using Standard Methods.

Where possible, automatic water sample collectors were used to collect stormwater runoff samples. Each machine had a rain guage and flowmeter attached. The flowmeter is a bit of a misnomer in that it actually measures water level (height). Combined with a flume or weir

(Figure 1), the flowmeter (Figure 2) is then capable of estimating the flow volume. The flowmeters were programed to signal the water samplers to start collecting the water whenever the water level reached a desired threshold. The samplers each held 24 one-liter bottles and were programed to collect a sample every 15 minutes once a storm event commençed. Three bottles constituted one sample. Thus, eight samples were collected during the first 1:45 hour of each storm event. Of course, some storm events were of shorter duration. Where automatic sample collectors were not feasible (or, sometimes, failed to collect), simple grab samples were taken by hand. All water samples taken from sprinkler recirculation ponds were also grab samples.

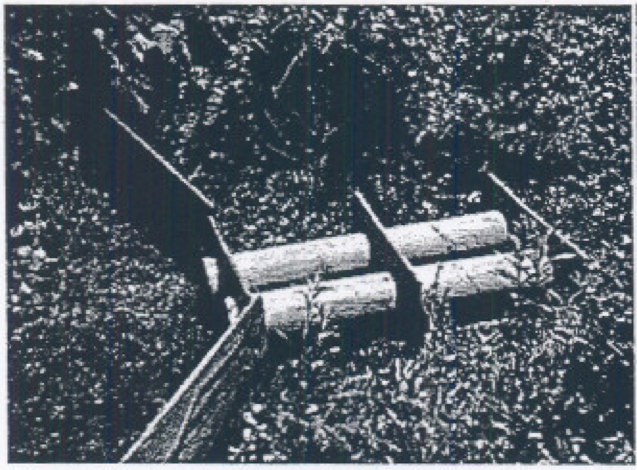

Figure 1. A double-pipe weir installed in a ditch for the determination of water flow.

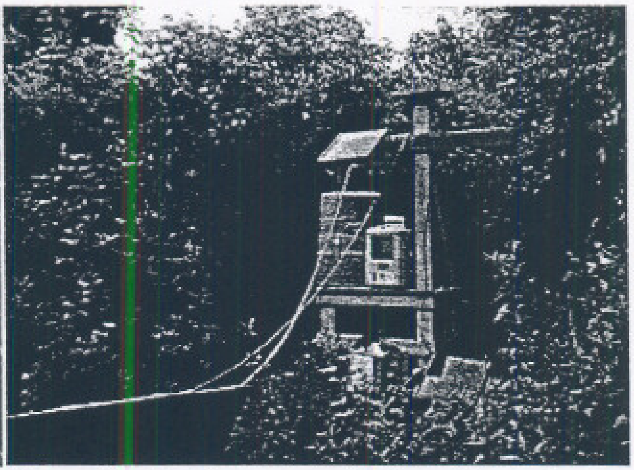

Figure 2. A solar-powered automatic water sample collector and flowmeter installed at a drainage ditch.

Since most of the woodyards are closely associated with a mill, it was difficult to find yards wherein the runoff was totally free of runoff from other activities. A major exception is logs under sprinkler systems. The yards also needed to be within reasonable driving distance of Baton Rouge or Ruston, LA. The locations selected for stormwater sampling were:
Hunt Plywood Co., Inc., Natalbany, LA (plywood mill).
Martin Forest Products, Winnfield, LA (chip mill).
Weyerhaeuser Corp. (formerly Cavenham Forest Products), Holden, LA (chip-N-saw mill).
An attempt was also made to use the Willamette Industries mill complex at Dodson (sawmill and plywood), but it turned out that the site selected had too much influence from mill site runoff, which was outside the context of the project. The Hunt Plywood yard's runoff was confined fairly purely to an active log yard. Most of its mill runoff drained in an opposite direction. The Martin site included runoff from a portion of the chip mill site itself, but that operation is small, uses no significant chemicals and did not appear to be a significant factor in the yard runoff. The Weyerhaeuser site included a significant portion of the sawmill, but it was used anyway because it provided a significant opportunity to test the effectiveness of an innovative stormwater treatment system already in place.

The following locations were selected for sampling from sprinkler system recirculation ponds:
Martin Forest Products, 3 miles south of Winnfield.
Weyerhaeuser Corp., Holden, LA (near the above site).
Willamette Industries, Dodson, LA.
In each case, the site was a self-contained watershed with no mill site influences, etc. We were told that the Weyerhaeuser site was completely self-contained and never overflows. The other sites probably overflow three or four times per year during extremely heavy rainfalls. All recirculation ponds require frequent to constant supplements of water (normally well water).

RESULTS OF OBJECTIVE 1

The results of Objective 1 are summarized in a peer-reviewed paper that follows. It is titled "An Overview of Logyards in Louisiana" and was published in the February 1998 edition of the Forest Products Journal. The terms "woodyard" and "logyard" may be used interchangeably.

AN OVERVIEW OF LOGYARDS IN LOUISIANA

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ABSTRACT

Federal and state regulatory agencies set water pollution standards for use in general stormwater permits. In order to help these agencies understand the nature and composition of log handling and storage facilities, a questionnaire was sent to logyards in the state of Louisiana requesting information on items that may relate to pollutants in stormwater runoff. Twenty-five percent of the yards were used for storage only. Soil type (sand, silt, clay) was fairly evenly distributed. Yard size averaged 7.1 ha with an average capacity of 42,000 metric tonnes. Seventeen percent of the surveyed yards handled chips. None handled shortwood. Two-thirds of the yards stored fuel, lubricants, or solvents on-site. Seventy-two percent of the yards had a stormwater pollution prevention plan in place, and an equal number of yards utilized sprinkler systems to extend log storage time. Fifty-eight percent of the yards have runoff water collect in a ditch before leaving the premises.

The nature of any pollutants developing in the surface water runoff from log concentration and storage yards may seem rather mild compared to the pollutants developed in some other industries, but there is concern among environmental regulators that pollutant levels may be high enough to warrant attention. In Louisiana, industrial wastewater discharge already requires permitting by the Water Pollution Control Division of the Louisiana Department of Environmental Quality. Regulators are currently developing standards for a "Log Yard General Stormwater Permit." To set standards for this industry sector, a better understanding of the types and levels of possible pollutants is needed. In addition, it would be helpful to both regulators and industry to have an overall description of logyards in the state, such as the number of yards, size, activity level, and other factors that could affect stormwater runoff quality or quantity.

The forest products industry is the second or third largest industry in Louisiana (10), depending upon the measurement criterion used, providing more than 25,700 manufacturing jobs and an estimated 8,000 additional jobs in the harvesting and transportation of timber (12). Forestry is by far the largest agricultural crop in the state, producing $3.8 billion in revenues (including value added) of the total $8.6 billion agricultural revenues (13). Despite this, it is a relatively low-profile industry with little statewide public awareness or understanding of its standard procedures. To improve public understanding of the industry, especially among regulators and policymakers, a description of logyards was created by asking industry officials to supply data on yard size and other relevant details.

LITERATURE REVIEW

Although many studies have been done on logyards, most of them are proprietary or not of scientific merit, so literature on logyards is scarce.

There is a textbook on logyard operations, but it contains no quantitative description of the industry and devotes only one paragraph to water quality (9).

Washington's Department of Natural Resources conducted annual surveys of the forest products mills in that state (4). The questions focused on mill productivity. There were questions about log consumption and inventory levels, but no questions pertaining directly to logyards. There are many published listings of forest products firms, and many of these listings contain references to mill size in terms of annual productivity or number of employees (2,8,11,15-17,19,21,23). One pulpmill directory lists the volume capacity of some logyards (16).

Although there has been considerable attention by industry and environmental regulators on the topic of stormwater runoff, much of it concerns urban runoff. Surprisingly little published data can be found on logyard stormwater runoff. A study in Oregon investigated the effects of logyards on water quality, but the yards were considerably different from yards found in the southern states (20).

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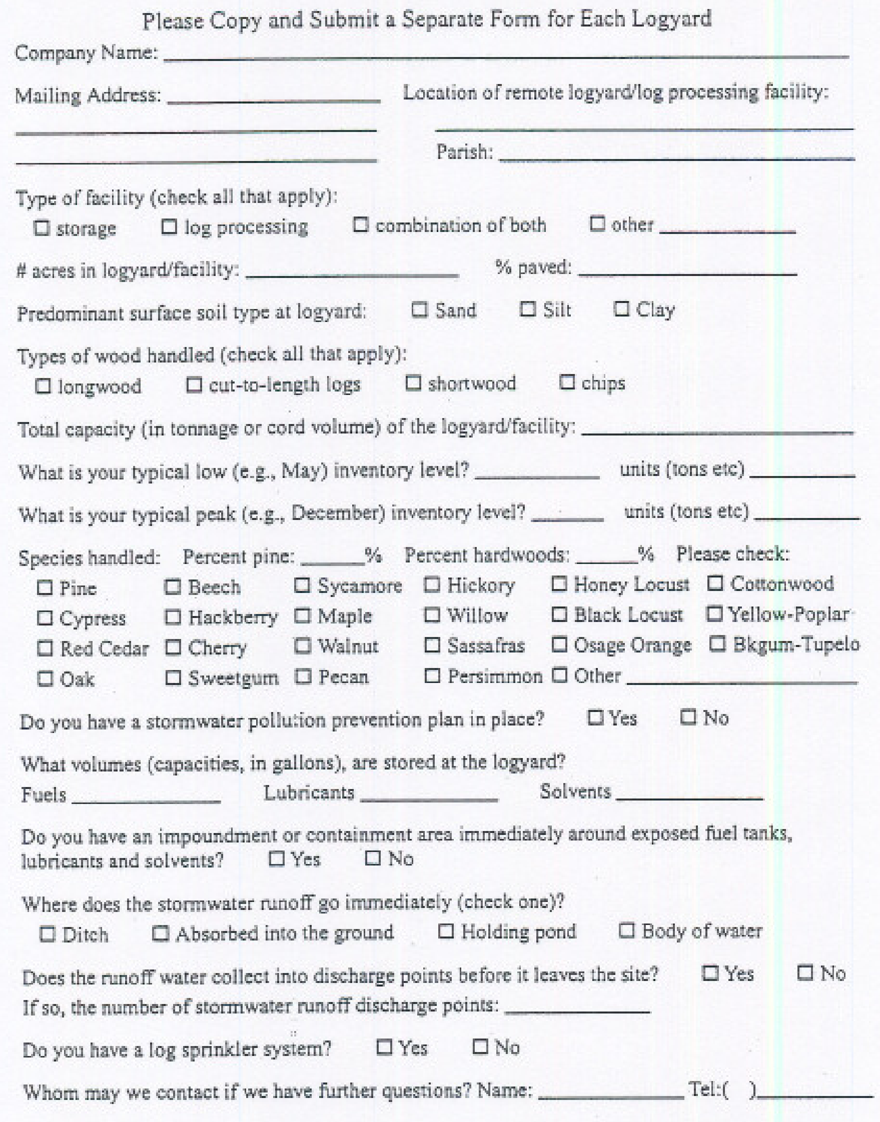

Please Copy and Submit a Separate Form for Each Logyard

Company Name: ______

Mailing Address: ______ Location of remote logyard/log processing facility:

______ ______

______ Parish: ______

Type of facility (check all that apply):
☐ storage ☐ log processing ☐ combination of both ☐ other ______

acres in logyard/facility: ______ % paved: ______

Predominant surface soil type at logyard: ☐ Sand ☐ Silt ☐ Clay

Types of wood handled (check all that apply):
☐ longwood ☐ cut-to-length logs ☐ shortwood ☐ chips

Total capacity (in tonnage or cord volume) of the logyard/facility: ______

What is your typical low (e.g., May) inventory level? ______ units (tons etc) ______

What is your typical peak (e.g., December) inventory level? ______ units (tons etc) ______

Species handled: Percent pine: ______% Percent hardwoods: ______% Please check:
☐ Pine ☐ Beech ☐ Sycamore ☐ Hickory ☐ Honey Locust ☐ Cottonwood
☐ Cypress ☐ Hackberry ☐ Maple ☐ Willow ☐ Black Locust ☐ Yellow-Poplar
☐ Red Cedar ☐ Cherry ☐ Walnut ☐ Sassafras ☐ Osage Orange ☐ Bkgum-Tupelo
☐ Oak ☐ Sweetgum ☐ Pecan ☐ Persimmon ☐ Other ______

Do you have a stormwater pollution prevention plan in place? ☐ Yes ☐ No

What volumes (capacities, in gallons), are stored at the logyard?
Fuels ______ Lubricants ______ Solvents ______

Do you have an impoundment or containment area immediately around exposed fuel tanks, lubricants and solvents? ☐ Yes ☐ No

Where does the stormwater runoff go immediately (check one)?
☐ Ditch ☐ Absorbed into the ground ☐ Holding pond ☐ Body of water

Does the runoff water collect into discharge points before it leaves the site? ☐ Yes ☐ No
If so, the number of stormwater runoff discharge points: ______

Do you have a log sprinkler system? ☐ Yes ☐ No

Whom may we contact if we have further questions? Name: ______ Tel:( )______

Figure 1. — Questionnaire sent to primary forest products industry.

Each of the yards utilized stream water that flowed through the yard. There was no effort to measure stormwater runoff. Only one yard studied utilized stream water for a flow-through sprinkler system (no water recirculation; mills in Oregon are now required to recirculate the water).

Luppold (14) provides a useful summary description of the evolution of stormwater regulations in the United States and the permitting process. States can opt to set their own guidelines under the auspices of federal guidelines. While the paper contains many descriptions that are useful to all states, it excludes Louisiana in the state descriptions.

OBJECTIVE

The objective of this study was to present a "picture" of the logyards in the forest products industry. Regulatory decisions concerning water quality and stormwater permits usually are made by individuals who are well-trained in environmental principles but have had little exposure to the forest products industry. It is hoped that the results of this study may benefit those who want to learn more about the industry. It is the intention of this paper to present some physical descriptors of logyards that could be factors in stormwater quality. Data on actual water quality is beyond the scope of this paper.

This study was also the "front-end" of a larger study concerning the nature and levels of water quality parameters in logyard stormwater runoff. Collecting information on yard size, species handled, soil types, and use of sprinkler systems would help develop an experimental design. The study of the water quality is still ongoing (7).

METHODOLOGY

A questionnaire was sent to each company known to have a logyard in the state of Louisiana; recipients were asked to fill out a questionnaire for each logyard owned or operated by that company.

Before mailing out the questionnaires, a comprehensive mailing list of the forest products industry was compiled. The Louisiana Forest Products Laboratory (LFPL) maintains a comprehensive mailing list of the forest products industry. The list was updated prior to sending out the questionnaires by cross-referencing with published data (15,16,19), telephone directories, and with a list maintained by the Louisiana Department of Agriculture and Forestry, Office of Marketing (5). In addition, the LFPL list had been updated in other studies (6,22). The entire mailing list contained 97 firms.

The responses to the questionnaire were entered into a database program. Latitude and longitude values were added for each location. Mapping of the sites allowed the authors to verify that all regions with a significant forest industry presence were represented.

SURVEY INSTRUMENT

The first questions concerned general descriptors: location, size of yard, soil type, and species handled. Since a company may have logyards located away from the mill or mailing address, the location of the logyard was requested. Although "woodyard" is the term commonly used for this type of facility, the questionnaire used the term "logyard" to minimize confusion. Sometimes the term "woodyard" includes the outdoor space where sawn lumber is stored. Questions about a yard's typical high and low inventory levels helped indicate whether yard capacity was a good indicator of its size. The soil type question was limited to simple answers (sand, silt, clay) because it was anticipated that few of the respondents would be very knowledgeable about soils. This question was included to see if certain soil types were preferred for logyards. It was anticipated that yards on sandy soil would have less surface water runoff and more infiltration, and this might affect pollutant parameter levels. Also, it was anticipated that yards with deep, sandy soils may not be appropriate for selection in future phases of the stormwater investigation because of perceived difficulty in collecting runoff water. Questions about species handled were included because it is unknown whether different species will affect stormwater quality in different ways. Also, specialists at the extension service occasionally get requests about where to obtain uncommon species, so by adding a detailed species list, the LFPL was able to assist them by collecting that information at virtually no additional cost (**Fig. 1**).

Other questions were placed in the questionnaire about topics that concerned stormwater runoff quality more directly, such as number of discharge points and whether the respondent had a stormwater pollution prevention plan in place. The respondents were not asked to distinguish between a formal, legally submitted document or some other type of plan. Volumes of fuels, lubricants, and solvents were requested to give regulators a better idea of the quantities of these chemicals that typically occur on the yards. Respondents were also asked if they had an impoundment or containment area around exposed tanks. Although these last two questions were open to interpretation (as is almost any question), it was anticipated that they would give some indication of what action the industry has already taken to assure that such chemicals are prevented from entering runoff water.

A question about where the runoff water goes immediately (ditch, absorbed in ground, holding pond, or body of water) was included to give the project investigators a starting point in formulating methods of improving runoff water quality. Likewise, respondents were asked if they have a log sprinkler system. The effect of sprinkler systems on water quality was unknown. Since sprinkler systems use recirculated water, it was anticipated that dissolved solids might be objectionably high. Also, since water being sprinkled through the air is obviously in contact with oxygen, it was anticipated that oxygen demand parameters might be substantially different from that in normal runoff water.

All of these questions were brief and could have been expanded to extract more information. However, the authors deliberately limited the questionnaire to one page in an effort to encourage participation. Experience in other LFPL projects by the authors indicated that multiple-page questionnaires get extremely low response rates.

Before mailing, the questionnaire was reviewed by several individuals familiar with logyards, including a forestry extension service specialist, an industry official, and an executive officer of the Louisiana Forestry Association. Interested individuals in the Louisiana Department of Environmental Quality also reviewed the form to verify that this was the type of information that they would like to know. No test questionnaires were sent out because the population was so small that it would have taken nearly the entire population to conduct an adequate test.

Each questionnaire was accompanied by a letter explaining the purpose of the project. The questionnaires were mailed on May 15, 1995.

RESPONSE

Of the 97 questionnaires mailed, 36 were completed and returned, and an additional 13 were returned as invalid (out of business, do not process logs, etc.). Several respondents duplicated the questionnaire and completed one for each logyard they operated. Of the 36 valid responses, about 20 were returned immediately. The remainder were obtained after prompting the respondents with telephone calls or personal visits.

The authors considered soliciting more firms to participate in the survey, but the respondents were reasonably representative of the industry. Any substantial improvement in the response rate appeared unlikely and would have required a much greater effort than was already expended. It also appeared likely that the sample would become biased toward large companies if more responses were actively solicited.

To validate whether the respondents were representative of the population, the respondents were compared to the nonrespondents by descriptors such as size of closely associated operations, types of operations and species handled. A more comprehensive search of essentially the same records from which the mailing list was compiled revealed 129 companies in Louisiana that most likely had logyards. Sawmills, chip mills, and pole peeler mills were under-represented by about 15 percent. Sawmills comprise about 56 percent of the population. Plywood and sawmill/panel mill complexes were over-represented by about 60 percent. Pulpmills were over-represented by about 30 percent.

The number of yards handling pine were over-represented while yards handling hardwood were slightly under-represented. The number of yards handling both species were closely representative. For 25 percent of the non-respondent yards, this information was unknown.

Respondents and non-respondents were compared on the basis of their associated mills' annual production, production capacity, and number of employees. This information was obtained from published literature and, in a few cases, personal knowledge. F-tests for sample variances were all favorable at the alpha = 0.05 level. Of these, the annual production numbers are probably the best indicators because that information is the most complete (84% complete for respondents and 48% complete for nonrespondents). For the mills with incomplete data, there still appears to be good representation of small-, medium-, and large-volume operations.

The major flaw with using F-tests is that the sample and population were not normally distributed. There existed many small and large mills, but relatively few medium mills. However, since the distribution was skewed only slightly toward the smaller mills, the F-test still had some validity.

The Kruskal-Wallis rank test is a better statistical test for variance comparison of non-normal distributions. This test was also favorable at the alpha = 0.05 level for annual production, shift production capacity, and number of employees.

RESULTS

USE OF YARDS

One yard was not in use. Fifty-six percent of the yards were used for both storage and handling of logs (**Fig. 2**). Twenty-five percent of the yards were used for storage only, while 19 percent were used only for processing (no appreciable storage of logs).

An alternative way to define whether a yard is designed for log storage is by looking for a sprinkler system. It is commonly known that, without any kind of

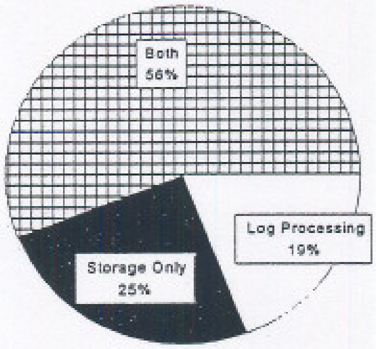

Figure 2. — Type of logyard facility.

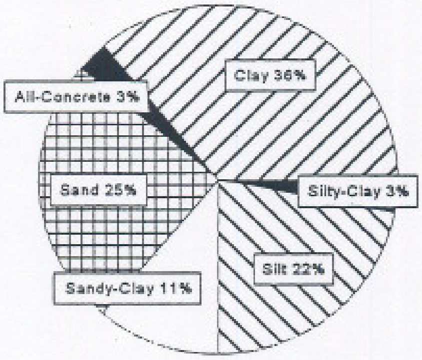

Figure 3. — Type of soil on which logyards are located.

treatment, pine logs in the Gulf Coast area stay in good condition for about 2 weeks after felling in the summer and up to 2 months in winter. Hardwood logs last about twice as long. Longer storage requires a water sprinkler system. Seventy-two percent of the yards had a sprinkler system, compared to the 81 percent who reported their yards to be used for storage or storage/handling.

GROUND-RELATED FEATURES

The logyards were most commonly located on clay soil (36%), followed by sandy soil (25%), silty soil (22%), and sandy clay (11%) (Fig. 3). One yard reported a silt-clay, and one very small yard (0.4 ha or 1 acre) was all concrete.

The average logyard size was 7.1 ha (17.6 acres) and ranged from 0.2 ha to 46.5 ha (1/2 to 115 acres; standard deviation = 8.7 ha) (Fig. 4). Forty-seven percent of the yards had a paved portion. Area paved averaged 0.45 ha (1.1 acres) and ranged from 0.04 to 3.2 ha (0.1 to 8 acres).

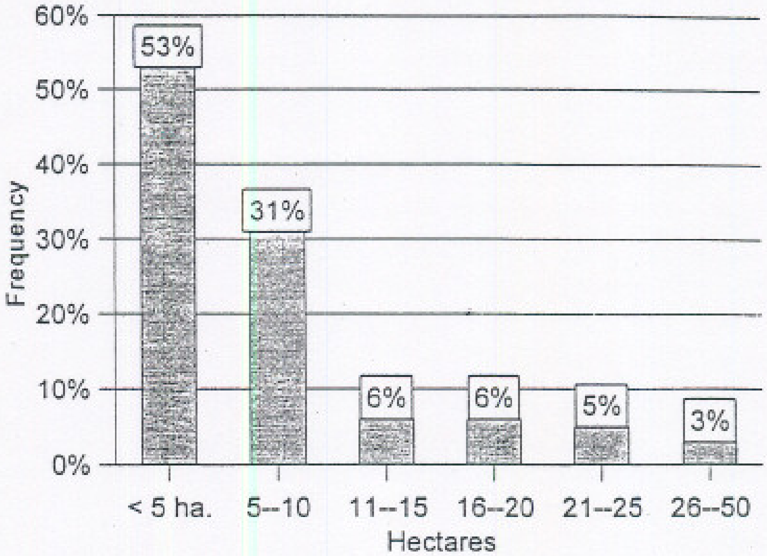

Figure 4. — Size of logyards in Louisiana.

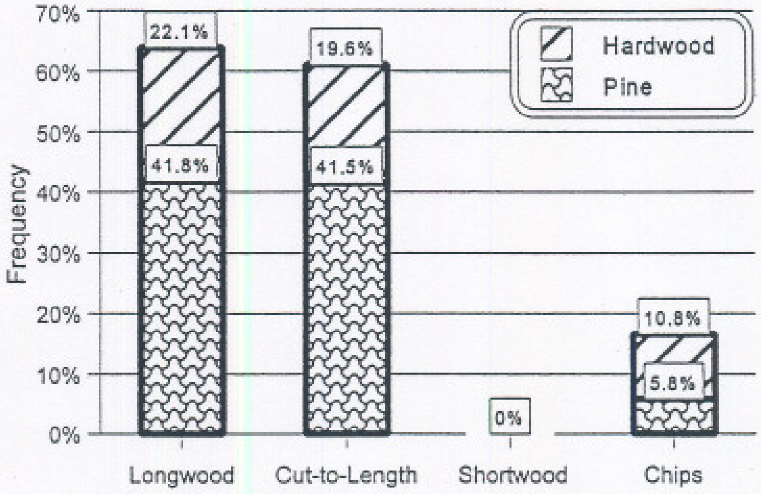

Figure 5. — Type of logs held on yards. For example, 41.8 percent of the yards carried pine longwood logs. Totals are more than 100 percent because many yards carry more than one type of log.

THE LOGS

Forty-seven percent of the yards handled only pine, while another 14 percent handled over 90 percent pine. Twenty-five percent of the yards handled only hardwood logs, one yard handled 90 percent hardwood, and 8 percent handled 55 to 70 percent hardwood.

Sixty-four percent of the yards handled longwood logs (generally 6 to 18 m, or 20 to 55 ft. long). Sixty-one percent of the yards handled cut-to-length logs (generally in multiples of 8 ft. plus trim), and 17 percent handled wood chips (Fig. 5). None of the surveyed yards handled shortwood (logs less than 8 ft. long).

Total capacity of the yards averaged 42,000 metric tonnes (46,600 U.S. tons, or about 1,600 truckloads) and ranged from 363 tonnes (14 truckloads) to 209,000 tonnes (8,000 truckloads). A typical low inventory was about a quarter of the yard's capacity. In the southern states, actual inventory levels are weather-dependent, with the lowest inventory levels usually occurring in late winter, after logging conditions have been difficult for some time. Any yard may dip to zero inventory level occasionally. Nevertheless, 25 percent of the yards reported a typical low inventory of zero, indicating that it was not uncommon for them to run out of logs.

TABLE 1. — Volumes of fuel, lubricants, and solvents stored at logyards.

Material	Average volume	Range Low	 High
	---------- (L (gal.)) ----------		
Fuel	6,637 (1,825)[a]	727 (200)	18,184 (5,000)
Lubricants	2,051 (564)	36 (10)	10,547 (2,900)
Solvent	85 (23)	18 (5)	200 (55)

[a] One yard reported 87,285 L (24,000 gal.); not included in this average.

Fifty-three percent of the yards reported typical maximum inventories to be at capacity. This usually happens in the late summer and fall of the year, when logging conditions normally are favorable. Eleven percent of the yards reported typical maximum inventories to be far less than capacity.

STORMWATER RUNOFF

Seventy-two percent of the yards reported having a stormwater pollution prevention plan in place.

Sixty-one percent of the yards reported storing fuels, lubricants, or solvents on the yard. Volumes are shown in **Table 1**. Seventy-two percent of the respondents had an impoundment or containment area immediately around exposed fuels, lubricants, and solvents. Several yards did not report volumes of fuel storage, etc., yet they reported having containment areas. Since these yards were associated with mill sites, it is possible that they were describing fueling locations away from the logyard itself. One yard reported underground fuel storage with test wells to monitor any possible seepage into the groundwater.

Respondents were asked where the stormwater runoff goes immediately and given four possible responses (**Fig. 1**). Although the respondents were asked to check only one answer, multiple answers were received because stormwater often leaves a yard in multiple directions. The response percentages are shown in **Table 2**.

TABLE 2. — Response percentages for the question, "Where does the stormwater runoff go immediately?"

Response	Percentage
	(%)
Ditch	58
Absorbed into ground	25
Holding pond	39
Body of water	3

On 64 percent of the yards, the stormwater gathered into discharge points before leaving the site. One yard reported sheet discharge in addition to two discharge points. The average was 2.4 discharge points per yard (range: 1 to 5).

SUMMARY

While most yards featured both storage and handling of logs, 25 percent of the yards were used exclusively for storage. Almost three-quarters of the yards utilized sprinkler systems for long-term storage. Logyards were found on virtually all soil types.

Yard size averaged 7 ha (18 acres). One-half of the yards had a 0.4-ha (1-acre) paved portion. Sixty-one percent of the yards handled almost exclusively pine species. The rest handled mixed hardwood species and some pine. Seventeen percent of the yards handled or stored wood chips. Virtually none of the yards handled shortwood.

Almost three-quarters of the yards had a stormwater pollution prevention plan in place. About two-thirds of the yards stored an average of 10,882 L of fuel (3,000 gal.), 2,051 L of lubricants (564 gal.), and/or 85 L of solvents (23 gal.).

Two-thirds of the yards had their stormwater runoff gather into 1 to 5 discharge points before leaving the site. Over one-half had the water enter into a ditch.

DISCUSSION

The authors know from conversations that at least three of the respondents who reported having a stormwater pollution prevention plan in place have yards that recirculate all of the runoff and have never been known to overflow. The yard personnel attributed this to high evaporation rates from sprinkler systems. Some yards add water to their sprinkler systems constantly. Since the stormwater never leaves the premises, it is unlikely that they need or have stormwater permits.

By extrapolation, we can see that two-thirds to three-quarters of the logyards in the state have given serious thought to stormwater pollution prevention. Still, the solution to the problem may not be simple in all cases because some yards do not have enough adjacent property to gather the stormwater and treat it before it leaves the premises. Keeping a yard clean of debris may or may not affect parameters such as oxygen demand, but may impact soil erosion.

Ditches with vegetation and holding ponds are reputed to be effective treatments for organic matter pollution problems (1,3,18,24,25). Since a substantial portion of the yards already utilize ditches or recirculating ponds, there should be some opportunities to test some of these facilities for their effectiveness in reducing stormwater pollution parameters. Some yards have installed screens to prevent bark from washing off with the stormwater, so their effectiveness would be relatively easy to assess.

For the substantial number of yards that store fuels and lubricants on the site, oil and grease can be a problem. Since solvent volumes are very small (and typically stored in a building or lockable shed), it does not appear that solvents on logyards cause a significant pollution problem.

It must be remembered that most logyards are located on the same grounds as the mill with which they are associated. Items such as fueling sites and stormwater runoff are commonly shared by both mill and yard. Therefore, it was difficult for some respondents to report items such as fuel volumes or discharge sites with respect to logyards only.

Most of the logyards in Louisiana have an active handling component. Thus, it would be logical to concentrate on these types of yards for initial stormwater studies. On these yards, the machinery constantly grinds the bark into smaller particles, which may be good for accelerating decomposition. However, the effect on pollutant parameter levels in the runoff water is unknown. These yards generally produce stormwater runoff every time it rains, so any effect they have on the water may be important.

Most of the log storage yards have sprinkler systems, which may give possible pollutants, such as dissolved solids, an opportunity to concentrate in the recirculation ponds. Stormwater runoff is seldom expected from yards under sprinklers, except in cases of extreme rainfall. The effect of overflowing ponds in those cases would be mitigated to some extent by the diluting effect of extreme rainfall. Also, the sprinkling effect of the water introduces oxygen into the system, possibly improving water quality that might otherwise have a low oxygen content. Analysis of water from these systems may be interesting from the standpoint of buildup of heavy metals and priority pollutants.

CONCLUSIONS

Most of the log-handling/storage facilities are located on sites with milling facilities. There are virtually no shortwood yards left in Louisiana. Logyard inventory levels are likely to range anywhere between zero and yard capacity over a year's time.

The managers of many yards have devised stormwater pollution prevention plans, indicating that they have either addressed the issue through stormwater permit applications, voluntarily taken measures to reduce runoff pollutants, or eliminated virtually any possibility of stormwater runoff from the sites.

Most of the stormwater runoff discharges into a ditch, which, if it contains vegetation and is long enough, is believed to be an excellent treatment for the type of pollutants expected in this type of water. More needs to be known about how the sizes and features of ditches affect logyard stormwater quality. Meanwhile, priority attention should be given to developing and testing methodologies for yards that have runoff flow directly into a body of water or do not have enough land for a long ditch.

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RESULTS OF OBJECTIVE 2

The results for Objective 2 involve sampling the water from selected woodyards so that it can be determine which pollutant parameters are of concern and which are not. The woodyard that provided the best opportunity for stormwater runoff sample collection was with Martin Forest Products in Winnfield. Their runoff collected into a ditch that was suitable for the placement of a weir and an automatic water sampler. This afforded opportunities to study the levels of pollutant parameters at various times during storm events. A V-notch weir constructed of plywood was installed at the edge of the woodyard. The results of the water sampling at Martin Forest Products are given in a peer-reviewed paper titled "Stormwater Runoff of a Louisiana Log Storage and Handling Facility" and published in the Journal of Environmental Science and Health - Part A Toxic / Hazardous Substances & Environmental Engineering [A33(2):165-177 (1998)]. The paper follows this page.

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STORMWATER RUNOFF QUALITY OF A LOUISIANA LOG STORAGE AND HANDLING FACILITY

Key Words: Stormwater, water quality, log yard, bark, pollutants.

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ABSTRACT

Very little attention has been paid to the stormwater runoff quality from log storage and handling facilities. This project determined the concentrations of conventional parameters such as BOD_5, COD and TSS, and 123 priority pollutants of stormwater runoff samples from a log storage and handling facility in Louisiana. No significant levels of priority pollutants were found and only about 1 to 13 % of COD was biodegradable. COD followed closely with TSS, suggesting that effective control of TSS will control COD as well. The pollutant strength resulting from summer to fall storms did not vary much.

INTRODUCTION

The forest industry is very important in Louisiana. Timber is first in annual harvest value with respect to all other agricultural crops (Jacob et al., 1990). Louisiana has a well-developed primary industry, which includes pulp/paper mills, sawmills, plywood mills and other panel mills. Log storage and handling facilities serve as places to house the logs until they are required for conversion at a mill. These yards are typically close to the mills to keep transportation costs low.

In the past, pulp/paper mills typically had satellite woodyards wherein shortwood (8 feet long or less) was gathered from local pulpwooders and loaded on rail cars to be transported to pulp/paper mills. Today, the shortwood yards have been replaced by chip mills, wherein pulpwood logs are delivered tree-length, de-barked and chipped into pieces roughly 8 cm. long and 1 cm. thick. The chips are then transported by truck, rail or barge to pulp/paper mills. Chip mills still keep enough logs on hand to assure constant operability. Mills in the southern U.S. typically like to have enough logs in inventory to supply operations for one week to one month, depending on the season.

Although there has been considerable attention by industry and environmental regulators on the topic of stormwater runoff, much of it concerns urban runoff. Surprising little published data can be found on log yard stormwater runoff. A study in Oregon investigated the effects of log yards on water quality (Schuytema and Shankland, 1976), but the yards were significantly different from yards found in the southern states. Each of the yards utilized stream water that flowed through or near the yard on a continual basis. There was no effort to measure stormwater runoff.

The U.S. Environmental Protection Agency (EPA) and the Louisiana Department of Environmental Quality (DEQ) are concerned about the stormwater runoff quality from log storage and handling facilities. The chemicals leached out from the bark of the stored logs may contribute to a higher chemical oxygen demand (COD) and a lower pH value, and some of them may even be harmful. The higher COD levels may result from the fact that a significant portion of the compounds present in bark are oxidized completely, one example being lignins (Sawyer et al., 1994). Lignins, however, are more of a common concern in a mill, rather than a log storage area, where concentrated acids are used to remove them before any processing occurs (Fengal and Wegener, 1984).

The pH of water is also of concern since bark has more acidic compounds than does the wood of the same tree (Fengal and Wegener, 1984). The pH is generally lower in the outer bark than in the inner bark. Southern pines were found to have the most acidic pHs with values ranging from 3.1 - 3.8, but it must be kept in mind that some of the pH tests were run with hot water treatment, which would give a lower pH than a cold water treatment (Fengal and Wegener, 1984).

This paper presents the quality of the stormwater runoff from the log yard of a typical chip mill. Permit discharge levels, established by DEQ, differ from one log storage facility to another. However, with the data collected in this project, the governmental agencies will be able to compile typical values for various chemical parameters, allowing them to establish a set of fair discharge levels for stormwater coming from log storage areas which can be applied uniformly. The forest products industries will also benefit from having this set of data, since they can immediately see how their operation measures up to other similar facilities. If these industries find that their levels are above the typical range, they can learn from the storage sites with low discharges and utilize similar control measures to bring their discharge levels within range.

METHODS AND MATERIALS

Stormwater runoff samples

All stormwater runoff data were collected from a chip mill log yard in north-central Louisiana. The study drainage area was about 4 hectares in size and contained a large portion of the active log handling area and short-term log storage yard. The debarker and infeed deck of the chip mill were also in within the drainage area, but it is not believed that this affected the results measurably. No chemicals were used in the entire process other than lubricants typical of any industrial mechanical process.

A portable automatic stormwater runoff sampler (Isco Model #3700) was placed in the yard's stormwater ditches. The sampler was hooked in series to a rain gauge and a flowmeter to allow respective readings of inches of rain and flow passing through a V-notch weir flow-measuring device. The sampler was programmed to collect a total of eight separate points in time. The first group of samples, or the first flush group, occured immediately after an adequate water level had been reached in the v-notch weir. A fifteen minute delay would then follow until the sampler began collection of the next set of 3 bottles. For every bottle set after the second one, there would again be a 15 minute delay between each collection until the eighth set. Since the sampler held twenty-four 1-L bottles, this gave a total of three liters for each point in time. Three liters were collected for each point to ensure that enough stormwater runoff was captured to perform all of the chemical analyses.

All samples were iced during shipment and preserved at a temperature of 4°C or lower. The samples were analyzed within 6 hours of collection. When this was not possible, they were analyzed within 24 hours, this being the absolute maximum storage time. When samples were sent to an EPA approved analytical laboratory for priority pollutants analysis, excluding heavy metals, the preservation techniques of that lab were specifically followed. For the heavy metals test, samples were brought down to a pH ≤ 2 with nitric acid. With this preservation technique, the samples could be stored up to a month before analysis.

Water Quality Analysis

Both conventional and priority pollutants were measured. The priority pollutant analyses, except heavy metals, were handled by Analytical Environmental Testing, Inc., a commercial analytical laboratory located in Baton Rouge, LA. The heavy metals analysis was conducted by the LSU Wetlands Biogeochemistry Laboratory, the LSU Agricultural Chemistry Lab, or the Baton Rouge commercial laboratory, depending on which was less busy. All these laboratories followed the approved EPA methods for the analysis of priority pollutants.

The conventional parameters (BOD_5, COD, TSS, and TDS) were analyzed at the LSU Department of Civil and Environmental Engineering Water Quality Laboratory. All tests were run in triplicate. In addition, pH and temperature (Orion Model 250A) of the samples were recorded on site. The conventional parameters were analyzed according to the procedures stated in Standard Methods (Eaton et al., 1995). Sections 5210B and 5220D (Closed Reflux, Colorimetric Method) of Standard Methods were used to measure BOD_5 and COD, respectively. TSS and TDS were determined according to Sections 2540D and 2540C of Standard Methods, respectively.

RESULTS AND DISCUSSION

Overall stormwater runoff quality characteristics

The overall BOD_5, COD, and TSS values during the period from June to November 1996 ranged from 0 - 48.4 mg/L, 0 - 14,723.8 mg/L, and 6.7 - 20,077.8 mg/L, respectively. The amount rainfalls during this period ranged from 0.1 to 1.53 inches. The pH of the runoff samples was rather stable and neutral, ranging from 6.7 to 8.1. Tables 1, 2, 3 and 4 show that all priority pollutants, i.e., volatiles, acids, bases, neutrals, and pesticides, were found to be below the standard detection limits, except for methylene chloride, chromium, thallium and zinc. The concentration of Methylene chloride, a common solvent chemical, was 15.4 μg/L, just slightly above the 5.0 μg/L detection limit. The concentrations of other metals were also low enough not to cause serious environmental concerns.

Seasonal and time variations of runoff quality

Time series data for BOD_5, COD and TSS are shown in Figures 1, 2 and 3, respectively. Sample collection took place from June 20, 1996 to November 1, 1996, thus giving a sufficient number of samples from both the summer and fall seasons. Initially, we expected to observe the strength of pollutants dissipate during rainfall. The BOD_5 levels were rather constant throughout the rainfalls ranging from 0.1" to

Table 1
Priority Pollutant Concentrations of the Stormwater Runoff Water Samples (EPA Method 625)

Compounds	Result (ug/L)	DL* (ug/L)	Compounds	Result (ug/L)	DL* (ug/L)
4-Chloro-3-Methylphenol	BD@	20.0	Chrysene	BD	10.0
2-Chlorophenol	BD	10.0	Dibenzo (A, H) Anthracene	BD	10.0
2, 4-Dichlorophenol	BD	10.0	Di-N-Butylphthalate	BD	10.0
2, 4-Dimethylphenol	BD	10.0	1, 2-Dichlorobenzene	BD	10.0
2, 4-Dinitrophenol	BD	50.0	1, 3-Dichlorobenzene	BD	10.0
2-Methyl-4, 6-Dinitrophenol	BD	50.0	1, 4-Dichlorobenzene	BD	10.0
2-Nitrophenol	BD	10.0	3, 3'-Dichlorobenzidine	BD	20.0
4-Nitrophenol	BD	50.0	Diethylphthalate	BD	10.0
Pentachlorophenol	BD	50.0	Dimethylphthalate	BD	10.0
Phenol	BD	10.0	2, 4-Dinitrotoluene	BD	10.0
2, 4, 6-Trichlorophenol	BD	10.0	2, 6-Dinitrotoluene	BD	10.0
Acenaphthene	BD	10.0	Di-N-Octylphthalate	BD	10.0
Acenapthylene	BD	10.0	Fluoranthene	BD	10.0
Anthracene	BD	10.0	Fluorene	BD	10.0
Benzidine	BD	10.0	Hexachlorobenzene	BD	10.0
Benzo (A) Anthracene	BD	10.0	Hexachlorocyclopentadiene	BD	10.0
Benzo (B) Fluoranthene	BD	10.0	Hexachloroethane	BD	10.0
Benzo (K) Fluoranthene	BD	10.0	Indeno (1, 2, 3-CD) Pyrene	BD	10.0
Benzo (A) Pyrene	BD	10.0	Isophorone	BD	10.0
Benzo (G, H, I) Perylene	BD	10.0	Napthalene	BD	10.0
Benzylbutylphthalate	BD	10.0	Nitrobenzene	BD	10.0
Bis (2-Chloroethyl) Ether	BD	10.0	N-Nitrosodimethylamine	BD	10.0
Bis (2-Chloroethoxy) Methane	BD	10.0	N-Nitrosodi-N-Propylamine	BD	10.0
Bis (2-Ethylhexyl) Phthalate	BD	10.0	N-Nitrosodiphenylamine	BD	10.0
Bis (2-Chloroisopropyl) Ether	BD	10.0	Phenanthrene	BD	10.0
4-Bromophenyl Phenyl Ether	BD	10.0	Phenol	BD	10.0
2-Chloronaphthalene	BD	10.0	Pyrene	BD	10.0
4-Chlorophenyl Phenyl Ether	BD	10.0	1, 2, 4-Trichlorobenzene	BD	10.0

@ Below detection limit * Detection limit

Table 2
Priority Pollutant Concentrations of the Stormwater Runoff Water Samples (EPA Methods 608/625 Pesticides)

Compounds	Result (ug/L)	DL* (ug/L)
Aldrin	BD@	1.0
Alpha-BHC	BD	1.0
Beta-BHC	BD	1.0
Delta-BHC	BD	1.0
Gamma-BHC	BD	1.0
Chlordane	BD	1.0
4, 4'-DDD	BD	1.0
4, 4'-DDE	BD	1.0
4, 4'-DDT	BD	1.0
Dieldrin	BD	1.0
Endosulfan I	BD	1.0
Endosulfan II	BD	1.0
Endosulfan Sulfate	BD	1.0
Endrin	BD	1.0
Endrin Aldehyde	BD	1.0
Heptachlor	BD	1.0
Heptachlor Epoxide	BD	1.0
PCB-1016	BD	1.0
PCB-1221	BD	1.0
PCB-1232	BD	1.0
PCB-1242	BD	1.0
PCB-1248	BD	1.0
PCB-1254	BD	1.0
PCB-1260	BD	1.0
Toxaphene	BD	1.0

@ Below detection limit

* Detection limit

Table 3
Priority Pollutant Concentrations of the Stormwater Runoff Water Samples (EPA Methods 624 Volatiles)

Compounds	Result (ug/L)	DL* (ug/L)
Benzene	BD@	5.0
Bromodichloromethane	BD	5.0
Bromoform	BD	5.0
Bromomethane	BD	10.0
Carbon Tetrachloride	BD	5.0
Chlorobenzene	BD	5.0
Chloroethane	BD	10.0
2-Chloroethylvinyl Ether	BD	50.0
Chloroform	BD	5.0
Chloromethane	BD	10.0
Dibromochloromethane	BD	5.0
Dichlorodifluoromethane	BD	5.0
1, 1-Dichloroethane	BD	5.0
1, 2-Dichloroethane	BD	5.0
1, 1-Dichlorethene	BD	5.0
trans-1, 2-Dichloroethene	BD	10.0
1, 2-Dichloropropene	BD	5.0
cis-1, 3-Dichloropropene	BD	5.0
trans-1, 3-Dichloropropene	BD	5.0
Ethylbenzene	BD	5.0
Methylene Chloride	15.4	5.0
1, 1, 2, 2-Tetrachloroethane	BD	5.0
Tetrachloroethene	BD	5.0
Toluene	BD	5.0
1, 1, 1-Trichloroethane	BD	5.0
1, 1, 2-Trichloroethane	BD	5.0
Trichloroethene	BD	5.0
Trichlorofluoromethane	BD	10.0
Vinyl Chloride	BD	10.0

@ Below detection limit

* Detection limit

Table 4
Priority Pollutant Concentrations of the Stormwater Runoff Water Samples (Metals, Cyanide and Phenol)

Compounds	Result (ug/L)	DL* (ug/L)	Compounds	Result (ug/L)	DL* (ug/L)
Antimony	BD®	9.0	Nickel	BD	9.0
Arsenic	BD	23.0	Selenium	BD	31.0
Beryllium	BD	3.0	Silver	BD	3.0
Cadmium	BD	3.0	Thallium	8	5.0
Chromium	3.5	2.0	Zinc	23	4.0
Copper	BD	2.0	Cyanide	BD	20.0
Lead	BD	12.0	Phenol	BD	50.0
Mercury	BD	0.2			

® Below detection limit * Detection limit

1.53" except the 11/1/96 samples as shown in Figure 1. For the 11/1/96 data, we suspect that the standing water in contact with bark for a long period of time was not adequately flushed out before taking the first sample due to very small rain and flow. It also may explain the unusually high COD concentration of 14,724 mg/L COD and 52,316 mg/L TSS for the first samples (these data are not shown in Figures 2 and 3).

In Figure 1, the BOD_5 levels for the summer storm (7/10/96) ranged from 4.5 - 39.1 mg/L, while the levels for the fall storm (9/27/96) were essentially the same with values spanning from 7.7 - 30.7 mg/L. The summer CODs (7/10/96) were anywhere from 156.0 - 3022.7 mg/L, while the fall CODs (9/27/96) were 85.6 - 1777.8 mg/L (Figure 2). Obviously, these CODs were somewhat lower, but the question must be asked whether this was due to some other variable, such as the differing rainfall totals of 0.64" and 1.53". According to Figure 3, the concentrations of TSS ranged from 352.2 - 2861.7 mg/L for the summer storm (7/10/96) and from 260.0 - 3301.7 for the fall storm (9/27/96). Figures 1, 2 and 3 show that there were not any easily identifiable relationships among BOD_5, COD, and TSS with respect to seasons.

<u>Relationship between rainfall totals and water quality</u>

One other interesting point was observed for the stormwater data. The

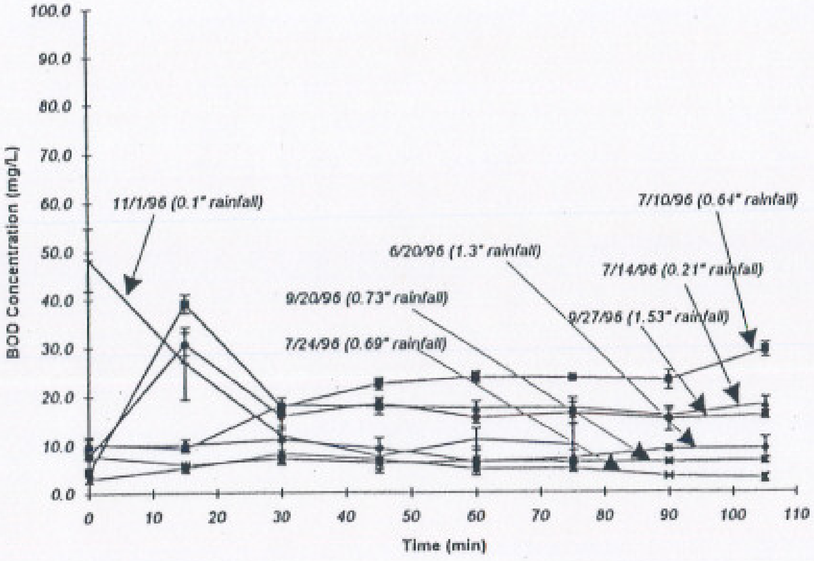

FIGURE 1

Stormwater Runoff BOD_5.

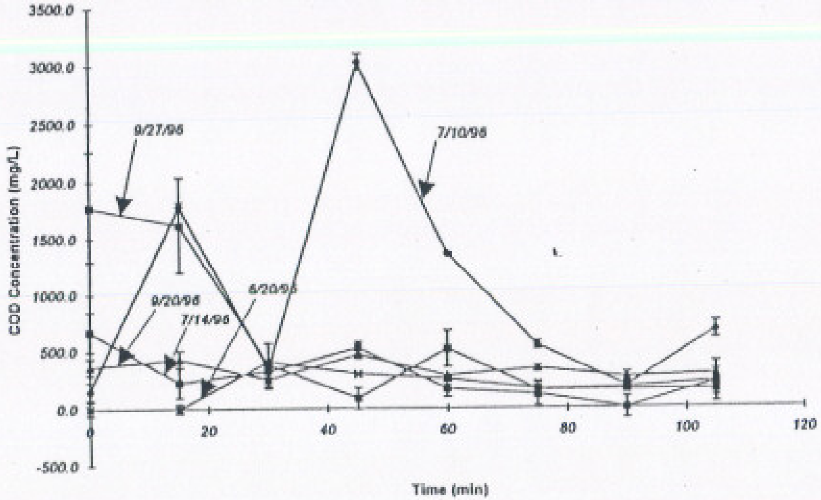

FIGURE 2

Stormwater Runoff COD.

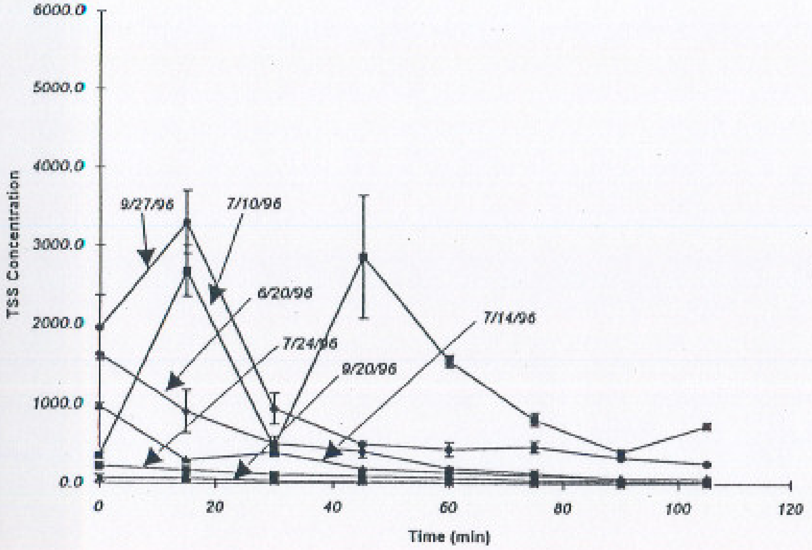

FIGURE 3

Stormwater Runoff TSS.

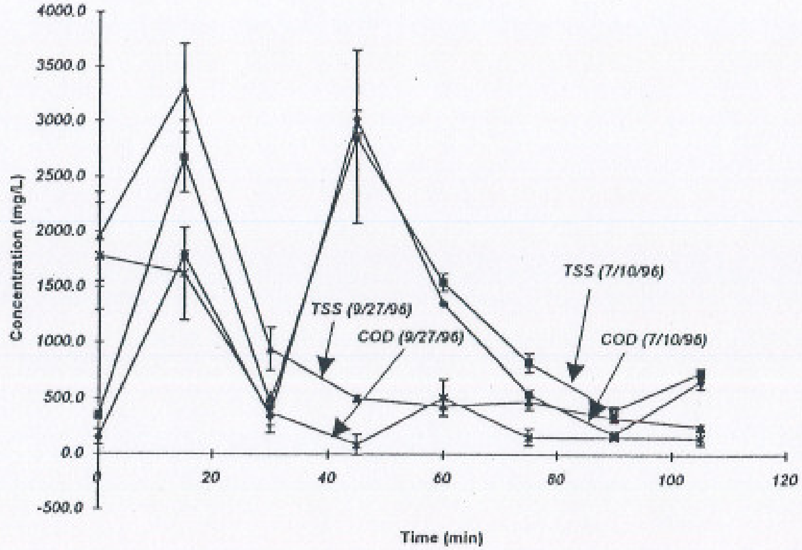

FIGURE 4

COD and TSS tend to have a close relationship.

conventional parameter levels were not directly related to the rainfall totals. It was initially suspected that higher rainfall totals would cause higher conventional parameter levels. However, as can be seen in Figures 1, 2, and 3, the rainfall totals actually did not have a bearing on the levels of the BOD_5, COD, and the TSS parameters. For instance, in Figure 2, the 1.3" rain (6/20/96) produced the lowest COD levels, while a 0.21" rain (7/14/96) caused the next highest levels of COD. It might be hypothesized that lower rainfall totals produce higher COD levels, but the 0.64" rainfall, which produced the highest levels, rules out this possibility. This indicates that there are certainly other variables affecting the conventional parameter levels. Some of the variables may include: the size of yard, the number of stored logs, the amount of bark and wood debris present within the yard, the amount of vehicle traffic, the type of stormwater management plan in use, the rainfall intensity, the length of time between rains, the soil type within the yard, the percentage of the yard which is paved, and the wood species stored or processed in the yard.

Relationship between BOD_5 and COD

An approximate range of 0.01 to 0.13 was observed for the BOD/COD ratios for all points in time or sampling locations. This, in turn, indicates that only 1 - 13% of the COD is biodegradable, and the COD fractions from log yards consist primarily of non-biodegradable organic matter. These BOD_5/COD ratios demonstrate that BOD_5 is not a major concern in a log yard. Thus, the dissolved oxygen levels of streams and rivers to which this runoff empties should not be affected. The high CODs found in a log storage area should not affect the environment in a negative fashion either, since the chemicals which contribute to these COD totals are not toxic as seen in Tables 1, 2, 3 and 4, but rather are found naturally in bark and wood. There may be some question, however, about the potential chemicals in stormwater runoff from a log processing yard where the runoff has had an opportunity to pick up a portion of the mill water effluent.

Relationship between COD and TSS

After viewing the time series data (Figures 1, 2 and 3), a curious relationship between COD and TSS was found to exist. The same general trend was observed in both parameter curves; that is, when the COD goes up, so does the TSS, and when the COD goes down, so does the TSS as showing in Figure 4. This trend indicates that most of the COD inherent in the water is a result of the TSS content. Thus, to effectively control the COD, the TSS must first be controlled. This could more than likely be accomplished with sedimentation or filtration, processes which are known to reduce suspended solids.

CONCLUSIONS

We investigated the stormwater runoff quality from a log storage and handling facility in Louisiana. The BOD_5 levels were not significant compared to COD and TSS. Most priority pollutants were not found, and a few were detected only in trace amounts that will not cause any serious environmental concerns. The stormwater runoff quality varied little from summer to fall. The rainfall totals did not correlate to the pollutants' strength. Only about 1% to 13 % of COD was biodegradable. It appears that much of the COD resulted from TSS, which suggests that COD can be removed if TSS is controlled.

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RESULTS OF OBJECTIVE 2 (continued)

Stormwater from the other yards tested immediately provided opportunities to test various types of remediation measures, so the results from their standard pollutant parameter tests are given later in this paper.

Priority pollutants

Both stormwater runoff and recirculation pond water were tested one time each for volatiles, semi-volatiles and pesticides (EPA 608, 624 and 625). All of these chemicals were below detectible limits except for methylene chloride, which was just above detectible limits in some cases. All water samples taken for these test were manual grab samples. The results are summarized in Table 1.

Table 1. Summary of EPA 608, 624 and 625 tests. The detectible limit for methylene chloride is considered 10 ug/L by Thornton Lab or 5 ug/L by A&E Testing.

Location	Type of water	Date	Result
Holden	Recirculation Pond	19 January 1996	All chemicals below detectible limits (BD).
Winnfield	Stormwater Runoff. Includes some mill stormwater runoff.	28 January 1997	Methylene Chloride 9.8 ug/L. All other chemicals BD.
Winnfield	Recirculation Pond	17 January 1997	Methylene Chloride 17.3 ug/L. All other chemicals BD.
Dodson	Recirculation Pond	17 January 1997	Methylene Chloride 7.1 ug/L. All other chemicals BD.

Heavy metals were collected in a similar manner to the above tests and are summarized in Table 2. The dates of collection were virtually the same as those for Table 1.

Table 2. Summary of concentrations of metals, cyanide and phenol in stormwater runoff (ug/L).

Compound	Result at Holden Recirculation Pond	DL	Result at Winnfield Stormwater Runoff	DL	Result at Winnfield Recirculation Pond	DL	Result at Dodson Recirculation Pond	DL
Aluminum	2,265	251						
Antimony			BD[@]	9	BD	9	BD	9
Arsenic	BD[@]	61	BD	23	BD	23	BD	23
Beryllium			BD	3	BD	5	BD	3
Cadmium	BD	21	BD	3	BD	3	BD	3
Calcium	24,433	76						
Chromium	11	11	3.5	2	BD	2	BD	2
Copper	BD	26	BD	2	BD	2	BD	2
Iron	1,672	26						
Lead	BD	36	BD	12	BD	12	BD	12
Magnesium	5,887	21						
Manganese	233	21						
Mercury			BD	0.2	BD	0.2	BD	0.2
Nickel	BD	36	BD	9	BD	9	BD	9
Phosphorus	BD	76						
Potassium	39,067	1,001						
Selenium			BD	31	BD	31	BD	31
Silver			BD	3	BD	3	BD	3
Sodium	24,097	101						
Thallium			8	5	BD	5	BD	5
Zinc	BD	21	23	4	7	4	39	4
Cyanide			BD	20	BD	20	BD	20
Phenol			BD	50	BD	50	BD	50

[@] Below Detection Level DL = Detection Level

Temperature and pH

Since there was no processing heat added to the tested waters, the water samples reflected ambient temperatures, and measuring temperature quickly became uninteresting. Since all of the mills processed pine species, it was expected that the pH levels would sometimes be very low. This was not the case. Typical pH levels were between 6 and 8, as shown in Table 3. In light of the low value of these parameters, measuring them became burdensome and was abandoned after a while. This was particularly true for samples coming from northern Louisiana, where a bus line schedule had to be met to get the samples to a Baton Rouge lab within 24 hours.

Table 3. Summary results of temperature and pH of woodyard water.

Site	Type	Date	Rainfall	Time	Avg pH	Temp. (°C)
Natalbany	Storm	27Sept96	1.60"	grab sample	6.21	24.6
Natalbany	Storm	25Oct96	6.60"	grab sample	6.02	18.7
Natalbany	Storm	7Nov96	0.31"	grab sample	6.90	21.7
Winnfield	Storm	9July96	0.69"	first flush	7.10	26.1
Winnfield	Storm	10July96	0.64"	first flush	6.71	27.4
				15 min	6.77	27.4
				30 min	6.71	27.0
				45 min	6.73	27.4
				1 hour	6.81	27.8
				1:15	6.88	27.4
				1:30	6.91	27.0
				1:45	6.89	26.9
Winnfield	Storm	14July96	0.21"	first flush	7.58	26.0
				15 min	7.81	25.7
				30 min	7.69	25.0
				45 min	7.74	25.0
				1 hour	7.71	25.0
				1:15	7.82	25.0

Table 3, continued.

Site	Type	Date	Rainfall	Time	Avg pH	Temp. (°C)
				1:30	7.30	25.0
				1:45	7.85	25.0
Winnfield	Storm	23July96	0.49"	first flush	6.66	25.8
				15 min	7.28	26.1
				30 min	7.49	26.1
Winnfield	Storm	24July96	0.69"	first flush	7.87	20.2
				15 min	7.80	20.1
				30 min	7.88	21.3
				45 min	7.92	21.0
				1 hour	7.96	20.9
				1:15	8.05	20.9
				1:30	8.05	22.1
				1:45	8.08	22.5
Winnfield	Storm	20Sept96	0.73"	first flush	7.66	27.2
	(2" mesh			15 min	7.67	27.2
	screen			30 min	7.69	27.2
	installed)			45 min	7.70	27.2
				1 hour	7.71	27.2
				1:15	7.71	27.2
				1:30	7.71	28.3
				1:45	7.73	28.1
Winnfield	Storm	27Sept96	1.53"	first flush	7.71	23.1
	(2" mesh			15 min	7.20	23.3
	screen			30 min	7.12	23.7
	installed)			45 min	7.07	23.5

Table 3, continued.

Site	Type	Date	Rainfall	Time	Avg pH	Temp. (°C)
				1 hour	7.12	23.9
				1:15	7.11	23.5
				1:30	7.09	23.7
				1:45	7.09	23.9
Winnfield	Recirculation Pond	17Jan97	N/A	grab sample	6.92	16.7
Winnfield	Storm	27Jan97		15 min	7.79	7.8
	(2" mesh			30 min	7.85	8.4
	screen			45 min	7.87	8.6
	installed)			1 hour	7.89	9.0
Dodson	Recirculation Pond	17Jan97	N/A	grab sample	7.16	16.9

RESULTS OF OBJECTIVE 3 (Testing control devices)

The following control devices were tested:

Metal screen.
Bark filter - a metal screen with bark backed up behind it, creating bark itself as a filter.
Bark removal / Oil skimming device.
Detention pond.
Oil-absorbing boom.
Vegetated ditch.

Metal screen

A metal screen to filter out the larger particles of bark was tested at two locations - Winnfield and Natalbany. At Winnfield, a pieced of plate metal full of 2 inch diameter holes was placed on the upstream side of the V-notch weir / sampler (placed against the entrance of the weir). The Natalbany screen consisted of a metal grate placed in a ditch with rectangular holes (approx. 1 x 3 inches) oriented horizontally.

One set of data was collected for this control measure at Natalbany and several data sets were caught at Winnfield with an installed screen. However, because the screen data obtained from Winnfield was not collected in the same manner as the data from Natalbany, the sets could not be effectively compared. The screen data from Winnfield was not gained through sampling points before and after the screen, but rather by sampling storms without the device installed and then with it installed. Since the rainfall total was not the only variable affecting the parameter levels, storms with similar rainfall totals could not simply be compared since there many other possible factors causing varied parameter totals. To alleviate this problem, the Winnfield data B was not included in the analysis of the screen.

For the one set of data collected for the individual screen at Natalbany, the BOD, COD, and TSS removal percentages can be found in Figure 3. As can be seen from this figure, the screen was ineffective in reducing any of the conventional parameters, other than the COD by 9.91% ± 2.94%. The COD could have been reduced due to the small amount of debris which accumulated before the screen over the course of the storm. The reason for the ineffectiveness of this device is the large openings (3.1" in length and 0.9" in width) of the screen, not allowing the solids to be effectively filtered out of the water.

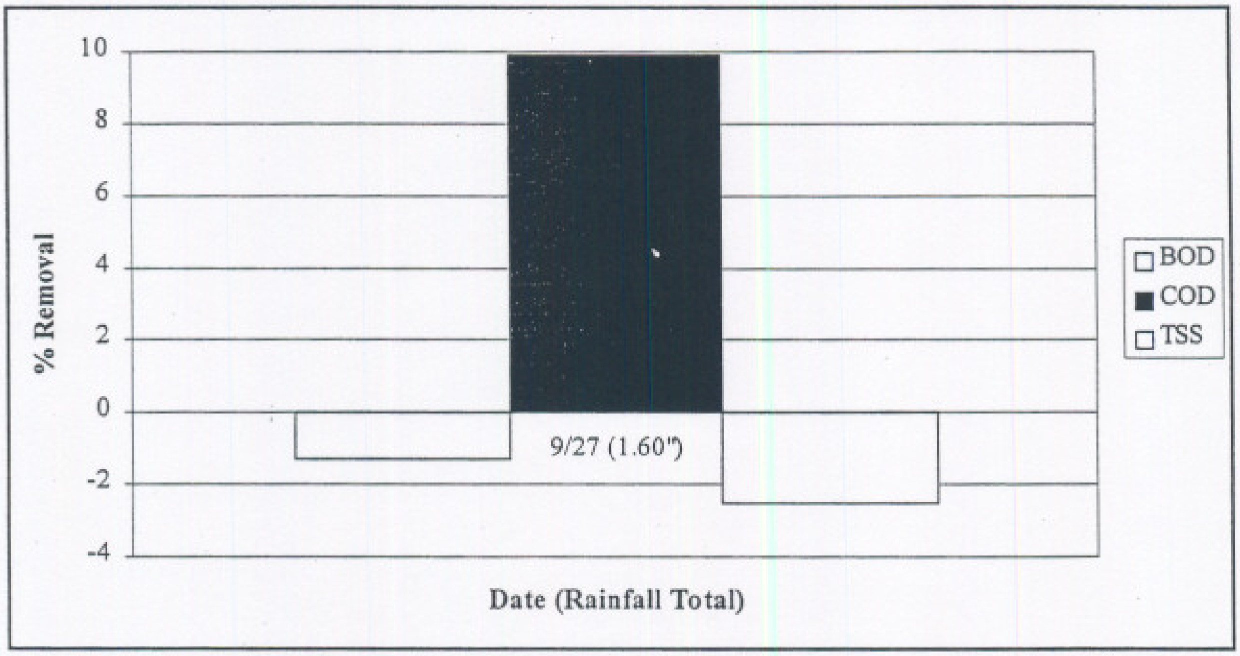

Figure 3. Removal percentages for individual screen.

The only manner in which the individual screen could be effective without a bark filter is if some type of micro-screen had been used. The removal percentages for the parameters would more than likely have gone up, but there would have been the problem of the screen tearing or ripping due to the weight of bark it was holding back from passing through the ditch.

Bark filter (screen with accumulated bark acting as a filter)

This control measure was studied at Natalbany. The grab sampling routine was changed to investigate this control measure when it was observed that the individual screen really served no other purpose than to block the bark and unintentionally create a bark filter which the stormwater had to pass through before it could even reach the screen. Thus, as bark accumulated within the front of the screen, it began to remove TSS in a more effective manner.

This control measure really had no effect on the BOD levels, but did decrease the TSS and COD. The actual removal percentages can be seen in Figure 4. Within the bar graph, it can immediately be seen that the BOD removal percentages for the two rainstorms where this device was tested were actually negative, meaning that this device actually increased BOD levels a little. The BOD levels increased by 12.6 and 2.18% for the respective 10/25 and 11/7 storms. This event was not necessarily expected, but it can be explained by the fact that the stormwater, after exiting from the bark filter, probably came into contact with some additional dirt and debris before it could be sampled.

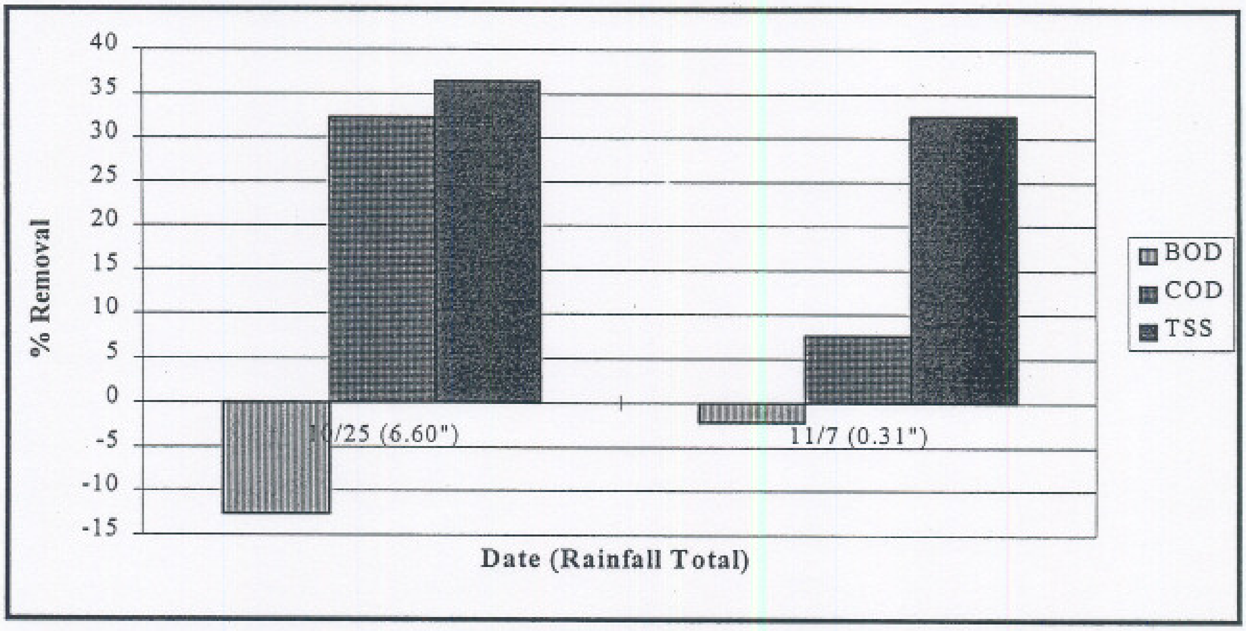

Figure 4. Removal percentages for screen with accumulated bark acting as a filter.

The TSS parameter experienced the highest reduction in this control measure. It dropped by 36.46 and 32.46% for the 10/25 (6.60") and 11/7 (0.31") storms. These figures were certainly expected, since the pile of bark in the front of the screen was in fact functioning as a filter, removing a considerable number of particles in suspension. It was hypothesized that a larger rainfall total would probably have a lower removal percentage, since it would force the water through the filter more quickly. This was not the case, but it should not be assumed that this always occurs, since only two rainstorms were caught and because the 36.46% had a corresponding standard deviation of ± 6.81%, higher than the ± 3.78% standard deviation for the 32.46% removal.

The effects of the bark filter on the COD levels were interesting. It is known that bark contributes to a higher COD, but the necessary contact time to cause the increase is not specifically known. For this reason, it was uncertain whether the bark would override the effects of removing the TSS. The data demonstrates that the TSS removal outweighed the bark effects with COD removal percentages of 32.31 and 7.56%, indicating that the particulate COD is most likely higher than the soluble COD fraction. It should be noted that the larger removal percentage of 32.31% took place for a 6.60" rainfall, indicating that this high of a removal efficiency may not be achievable if the water is not flowing quickly through the bark filter. The 7.56% COD removal took place for a rainfall total of 0.31", thus giving a much slower flow through the filter which quite possibly caused the lower removal efficiency. Further study of this device would have to be carried out to fully identify the major variables affecting the COD removal and to more accurately characterize the full range of effects that the filter has on all of these parameter levels.

Bark removal / Oil skimming device

A sawmill located at Holden had an interesting and rather unique device to control the quality of the stormwater runoff from the premises. The water itself consists of both log yard and mill yard runoff, so it was technically beyond the scope of this project. However, concept of this device appeared to have applications to log yards in general, and we were provided an opportunity to assess its effectiveness.

The bark removal/oil skimming device served to remove the majority of oil present in the mill water and stormwater before it moved on to the detention pond. This device was able to capture the oil and floating bark present in the water by simply blocking the flow with a concrete partition. This first chamber, where the bark and oil collected, was 3.92' in depth. The flow was then allowed to pass, without the presence of oil and floating bark, underneath an 8" thick concrete partition, since it did not go all the way to the bottom of the channel, to another chamber, which was 2.71' in depth and overflowed into the entrance channel for the detention pond. For a detailed sketch of the bark removal/oil skimming device, see Figure 5.

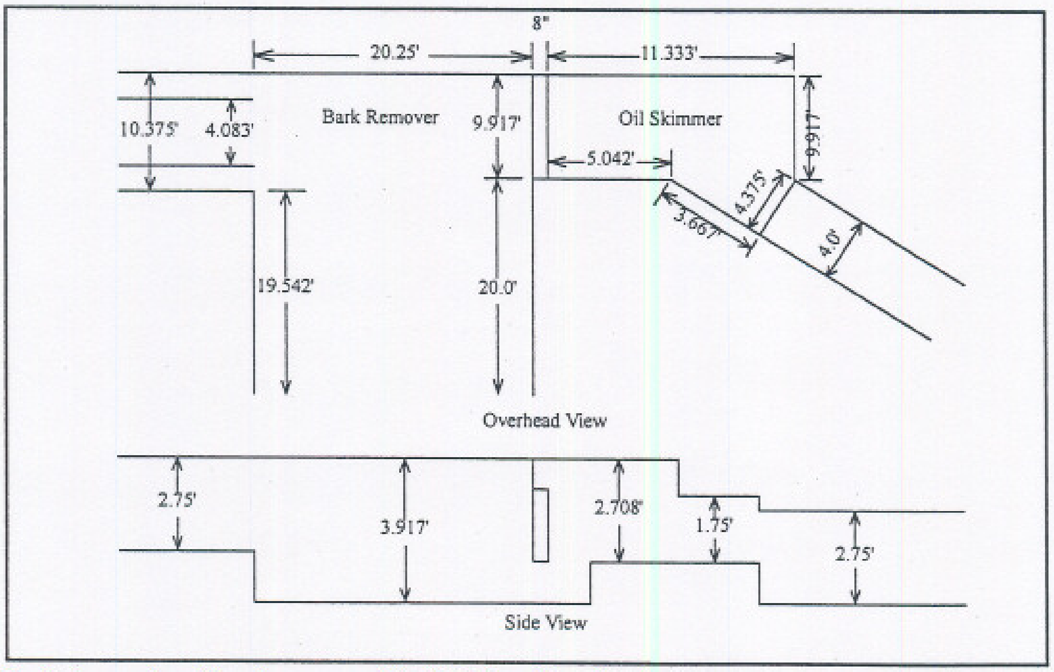

Figure 5. Schematic of bark removal / oil skimming device.

A long length of rubber tubing moved constantly through the second chamber up to a set of gears, and at the gear location, a wiper cleaned the oil off of the tubing. Due to the greater surface tension of the oil, the oil was able to stick to the tubing while most of the water on the tubing dripped off back into the oil skimmer.

Once the wiper cleaned the tubing free of oil, it was sent to a 55-gallon drum for collection. Because the water would sometimes not drip off totally from the tubing, it would be added to the drum with the oil. Thus, the drum had to be drained of water after all of the water had settled to the bottom of the barrel. A front end loader would lift the drum while it was unplugged at the bottom, and unwanted water would be drained from the drum. It would then be capped again when only oil began to drain out of it. After a drum was completely filled, it was disposed of, and another was setup in its place. It should also be noted that this bark removal/oil skimming device was usually cleaned out monthly by hand.

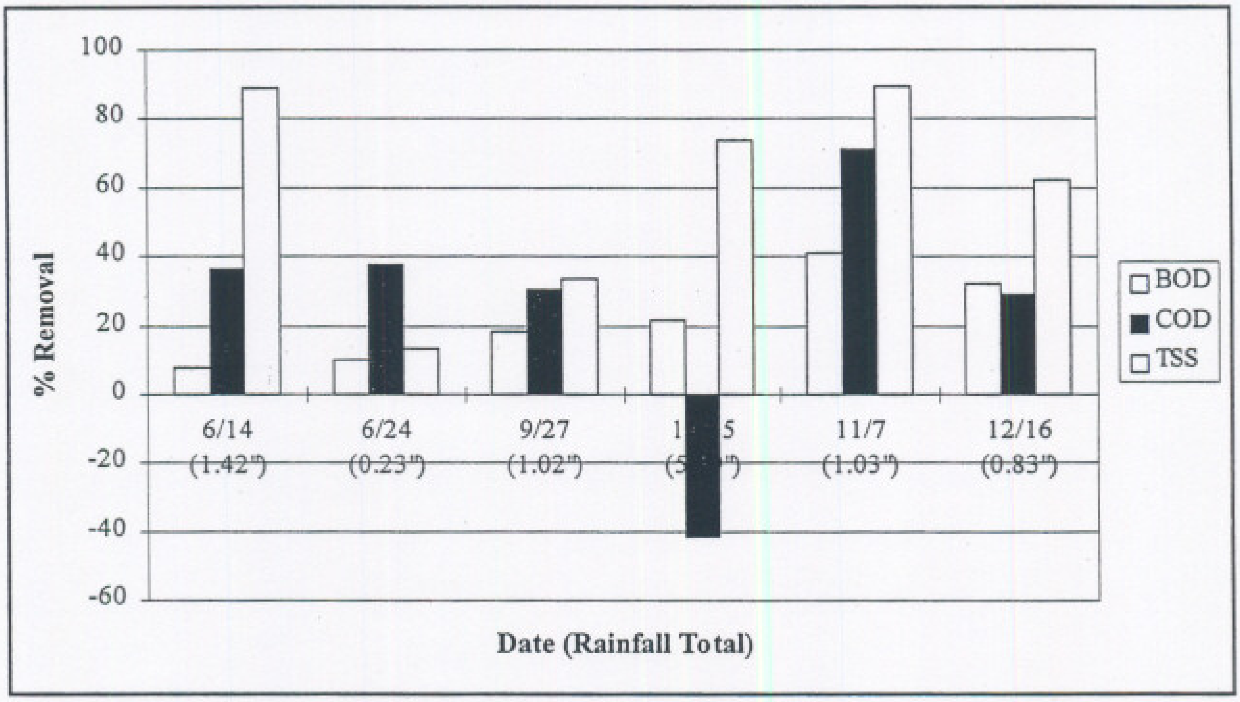

Figure 6. Removal percentages for bark removal / oil skimming device.

This control measure was found to be fairly effective at reducing BOD, COD, and TSS levels (Figure 6). It removed anywhere from 7.79 - 41.20% of the BOD within the stormwater/mill water, while COD percent removal ranged from -41.47 - 70.74% with a more likely range of 30.60 - 70.74%, since the negative removal percentage occurred for a 5.19" rainfall. During this large rainfall, the oil skimmer actually overflowed, dumping some of the wastes from previous storms into the exit channel of this device, leading to greater levels within the exit channel relative to the entrance channel. This entire occurrence could be properly prevented with some sort of overflow channel before the exit channel. The COD removal was expected since the synthetic chemicals from the processing portion of the yard were trapped within the oil skimmer portion of this control measure.

The TSS removal percentages were surprisingly high, ranging anywhere from 13.18 - 89.44%. These levels were unexpected due to the fact that the detention time is not as significant as some other control measures, such as the detention pond. Some sedimentation may occur within the device, since it actually blocks flow within the bark remover before the stormwater/mill water is allowed to enter the oil skimmer. Another possible explanation for the significant TSS reduction is that the particulate COD, thought to be the major portion of COD, was somehow being trapped within the oil, allowing it to remain within the device until it was cleaned out.

No relationship was found to exist between rainfall totals and removal efficiencies for this particular device. One additional variable which was not investigated in this project and could possibly affect the removal percentages of the conventional parameters was the frequency with which the bark removal/oil skimmer was cleaned out. More frequent cleaning could cause lower or higher reduction percentages.

Detention pond

Another remediation measure researched in this project was a detention pond, also located at Holden. The pond was approximately rectangular in shape and had an approximate surface area of 35,705 ft^2, with an individual length and width of 193' and 185'. The depth was estimated at 13' with original design plans, and all sides of the pond had a slope of 0.4333 on a foot-to-foot basis, or 43.33%. With the above dimensions, the maximum pond volume was found to be 340,145 ft^3, if the pond was filled totally to the top. Of course, the pond was never this full, but instead it fluctuated in volume due to precipitation and evaporation. With an average detention pond effluent of 0.2083 ft^3/sec (standard deviation of 0.1639) for all of the rainstorms caught at this yard, the retention time of the pond was found to be approximately 19 days (with use of the maximum volume for the detention pond).

The detention pond was very effective in removing all three major conventional parameters, namely BOD, COD, and TSS (Figure 7). The BOD removal percentages ranged from 73.26 - 92.07% for rainfalls totals between 0.23" and 5.19". The TSS was also effectively removed at percentages spanning from 57.47 - 97.19%, and as a result of the TSS being removed, it was suspected that the removal percentages for COD would also be high, since it was discovered that the COD and TSS time curves closely mimic each other. This was precisely the case, with COD removal percentages anywhere between 42.91 and 99.78%. It is also apparent that higher rainfall totals did not necessarily correspond to higher or lower removal efficiencies for this control measure.

It was suspected that all of the conventional parameters would be effectively reduced with the detention pond because of the many processes occurring within the pond. Because of the 19-day retention time associated with this pond, it was able to function as a sedimentation basin and remove a large majority of the TSS. With TSS removal, the COD totals fall as well. The BOD is also removed because of the microbial degradation and sedimentation taking place within the pond.

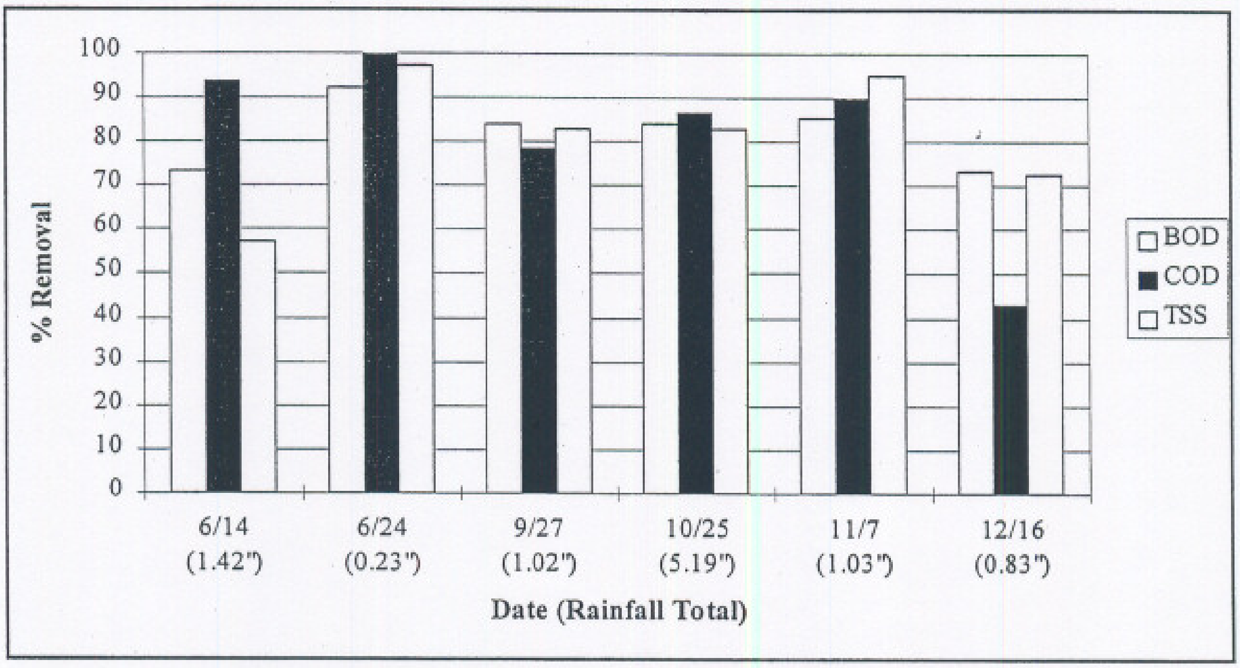

Figure 7. Removal percentages for detention pond.

Oil-absorbing boom

Initially, oil absorbing booms were dismissed by the investigative team as being effective for the removal of oil and grease but of no effect on other parameters. However, it later became apparent that the oil skimming device at Holden was also quite effective at reducing COD and TSS. With this knowledge, the question arose whether an oil-absorbing boom, then, was also effective in reducing COD and TSS.

An additional flume and water sampler were installed at the Winnfield yard location about 100 feet upstream from the existing weir, and an oil-absorbing boom was installed halfway in between the two devices. The boom was staked to the ground. The ditch was on a slope that is normally dry. At times, there were problems with the debris in the runoff covering much of the boom. At one time, the boom broke in half, but it was promptly replaced with a new one. Samples were collected during five storm events in October - December 1997 (fifteen sets of matching samples collected) during which the boom appeared to be functioning properly. During two of those events, the boom was observed to be working properly while the water samples were collected.

The results showed that the concentrations of BOD decreased 11%, COD decreased 5% but TSS concentrations increased an average of 181%. With TDS, the difference was less than 2%. The dramatic increase in TSS is hard to explain. It is likely that some additional material was picked up by the runoff water on its path from one sampler to the next. It is also likely that this additional material contained a higher proportion of dirt, which is much heavier than bark, and, consequently, causing a disproportionate rise in the weight of the suspended solids. Another likely explanation would be that the downstream sampler picked up additional sediment off of the bottom of the weir. Statistically, the results are inconclusive, indicating that the oil-absorbing boom has no measurable effect on these parameters. On the other hand, one could conclude that COD improved 17% despite the fact that there were over twice as many suspended solids.

Most of the negative results for all four parameters occurred during October, when the rains were flushing out dirt collected during a long dry spell. During December, the rains consisted of longer, steadier events. Also, for the two December rain storms collected, the boom was actually observed to be working properly. If only the two December storm events are considered (nine matched sets of samples), BOD decreased 4% (statistically, no discernible difference), COD decreased 27%, while TSS concentrations increased 47% (statistically, no discernible difference). Based on this data, one could conclude that an oil-absorbing boom causes a small improvement in COD concentrations.

Vegetated ditch

The Natalbany site provided an opportunity to measure the effect of a long, vegetated ditch on stormwater runoff. The ditch was about 200 feet long, with a sharp bend about midway. The bottom was fairly flat and about eight feet wide. The banks were at about a 45° angle and 60 to 100 cm high. Vegetation in the ditch included willow saplings, arrowroot and cattails. During dry times in summer and autumn, the ditch was dry. Both banks were densely covered in briar thickets. At the upper end of the ditch was a metal grate that held back most of the larger pieces of bark, although the area upstream from the grate was filled to overflowing with bark. An oil-absorbing boom was installed on top of the grate/bark. In effect, this created a bark filter at the upstream end of the ditch. There was also bark lining most of the bottom of the ditch, although most of the bark was evidently held back by the metal grate.

Coordinating the two samplers at opposite ends of the ditch to collect at approximately the same times proved to be a major obstacle. At the time of this writing, samples from only one storm event was successfully taken. Its results were inconclusive. Since all the logistics are now in place, it is the intention of the investigators to continue this endeavor for a few months with other funding and report the results to DEQ separately.

OTHER RESULTS

Relationship between BOD and COD

An interesting relationship between the BOD and COD parameters became apparent when viewing the results for all of the yards, even those with combined stormwater and mill water flows. An approximate range of 0.01 to 0.13 was observed for the BOD/COD ratios for all points in time or sampling locations, meaning that only 1 - 13% of the COD is made up of BOD. This, in turn, indicates that only 1 - 13% of the COD is biodegradable, and the COD fractions from log yards consist primarily of non-biodegradable organic matter.

The average BOD/COD values found at each yard can be seen in Table 4. These averages were based on all of the rainstorms sampled at each individual yard. Considering the values in Table 4, the range becomes even more defined with values from 0.0382 - 0.0721. It should be noted that outlier values were discarded before calculating the average BOD/COD ratios for each yard. Also, any values thought to be "out-of-character" with the other sets from the same yard were not included.

Table 4. Average BOD/COD ratios for yards. These ratios were calculated by finding the BOD/COD ratio for each grab sample point or point in time and taking an average of all values. Outlier values were excluded from the calculation of the average ratios.

Site	Water Type	Avg. BOD/COD Ratio	Standard Deviation (±)
Natalbany	Logyard	0.0614	0.011
Winnfield	Logyard	0.0382	0.032
Holden	Log & mill yard	0.0721	0.029
Dodson	Log & mill yard	0.0605	0.027

The "non-characteristic" values mostly included first flush samples which were caught in the "modified" v-notch weir at Winnfield. Because the weir actually blocked flow, it also blocked any debris that was carried by the stormwater runoff into the flow-measuring device. Thus, some erroneously high BODs, and consequently, higher than usual BOD/COD ratios, would occur because of the fact that the stormwater runoff picked up the loose sediment and debris around the facility.

Relationship between COD and TSS

Before discussion of the relationship between the COD and TSS parameters, the ranges found for each yard must be given. For Winnfield, COD and TSS levels were from 0 - 14,723.8 mg/L and 6.7 - 52,315.6 mg/L, respectively. For Natalbany, the respective COD and TSS ranges were 1086.7 - 2626.6 mg/L and 60.0 - 328.3 mg/L.

After viewing the time series data for the Winnfield facility, a curious relationship between COD and TSS was found to exist. The same general trend was observed in both parameter curves; that is, when the COD went up, so did the TSS, and when the COD went down, so did the TSS (See Figure 4 of the paper included under Results for Objective 2, "Stormwater Runoff Quality of a Louisiana Log Storage and Handling Facility).

This trend implies that most of the COD inherent in the water is a result of the TSS content. Thus, to effectively control the COD, the TSS must first be controlled. This could more than likely be accomplished with sedimentation or filtration, processes which are known to reduce suspended solids. Some of the existing control measures within the yard, such as the detention pond or the bark filter, could be effective at removing TSS. The bark filter could have problems, however, since bark is known to increase COD totals. Thus, if stormwater has been in contact with the bark for a sufficient period of time, then that runoff might have a very high soluble COD. More studies would have to be carried out on the bark filters to grasp what contact times are sufficient between the water and the bark to cause an increase in the water's COD.