Final Report

International Paper XL-2 Effluent Improvements Project

Report Submitted to

U.S. Environmental Protection Agency
Maine Department of Environmental Protection
Jay, Maine Planning Office

Report Submitted by

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MANAGEMENT SUMMARY

An XL-Project, designated International Paper XL-2 Effluent Improvements Project, was conducted at the International Paper (IP) Androscoggin Paper Mill (Mill) in Jay, Maine between the project start date of July 29, 2000 and its formal conclusion on December 29, 2004. Between 1997 and 2002, Project XL was a national an Environmental Protection Agency (EPA) initiative to evaluate the extent to which regulatory flexibility and other innovative environmental approaches could can be used to achieve superior environmental performance at reduced economic and administrative burdens. In this case, a "collaborative team approach" was used to reduce effluent pollutants (Chemical Oxygen Demand and color) through process improvements. Under the terms of a site-specific federal rule (40 CFR 430.03, subpart k) which accompanied the Final Project Agreement, International Paper would be was exempted from Best Management Practices (BMP) provisions of the Pulp and Paper Cluster Rule at the Androscoggin Mill and management agreed to spend the $780,000 (saved by not implementing BMPs) on effluent improvement projects designed to reduce the Chemical Oxygen Demand (COD) and color in the final Mill effluent and improve the Mill operation.

The funds expended on the XL-2 Project were approximately $1,054,000; with $990,000 for direct project cost and $64,000 for testing and ancillary studies. IP spent an additional $786,000 on projects that improved effluent water quality going to the Mill's wastewater treatment plant (WWTP) by changing the cooking process in the softwood "A" Kraft mill. These projects, although outside the scope of the XL-2 Project ("the Project") program, reduced COD in process effluent going to the WWTP. Additionally, IP spent untold engineering hours developing these projects and others in the initial stages of design and installation, as did project partners from the EPA, the Maine Department of Environmental Protection (MEDEP) and the Town of Jay (Town), ME.

Methodology

Mill-wide COD balances were performed in August 2000 and again in August 2001 to assess the quantity of COD and color being discharged from the various Mill unit processes and to identify/confirm major sources of COD and color. Based on the balances, COD abatement projects were developed and implemented in 2002 and 2003. Lastly various process steams and the Mill effluent were monitored for COD in calendar year 2004.

The results of the balances showed that more than half the total COD and flow came from the paper machines, about a third came from the black liquor cycle and the remainder from other sources. By contrast, 78% of the dissolved (soluble) COD originated from the black liquor cycle compared to only 13% from the paper mill. Based on these results, COD abatement projects related to the black liquor cycle were developed and implemented in an effort to reduce the toxicity of the final Mill effluent.

Effluent Reduction Projects Implemented Under XL-2

Six projects were implemented under the Project program with three additional projects, outside the scope of the Project program, implemented by IP that reduced the COD in effluent going to the WWTP. Projects implemented under XL-2 involved: reducing point sources of COD going to the sewer in the black liquor cycle side, mainly by reducing effluents associated with screening the Kraft pulp; reducing COD effluent going to the sewer in the bleach plant by making process improvements to the oxygen delignification system; and installing equipment to monitor the sewer. All of the implemented process improvement projects were successful to some degree in reducing the total COD going to the WWTP.

Changes to the Mill During XL-2 Project

Several changes to the Mill were made during the course of the Project that increased paper production at the Mill and increased effluent discharges. These changes included an expansion of the groundwood pulping and bleaching process, an expansion of the papermaking production facility, and dredging and modifications to the aeration lagoon at the WWTP. The groundwood pulp mill is a COD source though not included in the BMP regulations it has an impact on the COD and color in the final effluent. Paper production, almost all coated paper, increased from 545,000 tons to 640,000 tons annually, which increased the discharge of COD in the final effluent. COD sources associated with the discharge of coating solids were discovered, during the Project, to be persistent through the wastewater treatment process and would impact the final COD and color target measurements. This was contrary to the original thoughts at the inception of the Project, wherein it was believed that spent cooking (black) liquor would be the major constituent of the total COD that persisted through the wastewater treatment plant.

Effluent Monitoring Results

Data for the effluent COD and color samples collected over the 2004 testing period were compared to the base period of July 1 through December 31, 1998. The average COD of the effluent samples for the 2004 testing period was 35.6 kg per metric ton of air dried unbleached pulp and compared favorably for the base period, where the average discharge was 38.0 kg per metric ton of air dried pulp. This represented a reduction of 6.5% relative to the base period and is modest on the face of the number. The reasons for this modest reduction in the final effluent COD are discussed in detail in this report.

Similarly, the data for color compared favorably with the base period values. The average color discharge, for the test period during 2004 was 83.8 pounds per air dried ton of unbleached pulp, whereas, the base period average discharge was 105.5 pounds per air dried ton of unbleached pulp, a reduction of 20% in the color amount.

Whereas, the COD and color targets established at the beginning of the Project assumed a relatively steady state in Mill operations, the Mill during the four years of the Project actual experienced significant growth and changes in Mill processes and product necessitated by a changing marketplace.

The varied reductions in the average discharge of COD and the color are attributed to the numerous changes that have taken place in the Mill. The screen rooms in both Kraft mills have been closed and the oxygen delignification system has been improved. These changes which normally reduce the discharge of both COD and color from the black liquor cycle going to the WWTP, were offset by an increase in paper mill coated paper production and major changes in the groundwood mill which increased the discharge of COD going to the WWTP. Consequently, there was a quantifiable reduction in color but a much smaller reduction in COD. Also, during intervals of this Project, there were extensive performance issues taking place at the WWTP along with the dredging of the lagoon that temporally raised the level of COD. All of these changes to the Mill influenced the final results.

Conclusions Regarding the XL-2 Project

Project Accomplishments. Since the Mill already had dikes and a spill prevention program, and black liquor spills from storage tanks were rare, monies were spent on Mill process modification projects to accomplish Mill process improvements while reducing COD and color going to the WWTP and in the Mill effluent. The Project conducted at the Mill was a win for IP and the objectives of the Project.

Goals of the Project. The XL-2 Project goals, set forth in the Agreement, were 26 kg COD per metric tonne of air dried unbleached pulp and 50 pounds color per air dried US ton of unbleached pulp. These were stretch goals and perhaps not attainable given the limited scope agreed upon for the Project. The original goals of the Project were predicated upon the Mill as configured in 1999 and did not anticipate the numerous changes that took place during the Project which influenced the effluent discharge results.

Recommended New COD Discharge Limits for Mill Effluent. Using a method suggested by the Maine Department of Environmental Protection to determine new effluent limits, the two sigma (95%) upper limit for the monthly average COD data for the 2004 monitoring period was estimated to be 47.6 kg/tonne. This represents the new recommended monthly average COD discharge limit which is a 6% reduction in the proposed monthly average discharge limit value of 50.7 kg/tonne specified in the XL-2 Agreement. The three sigma (99% percentile) value for the daily maximum effluent limit was estimated to be 68.6 kg COD per metric tonne of air dried unbleached pulp using the 2004 monitoring data and is the new recommended maximum value. This new recommended daily maximum represents an 8.5% reduction from the 75 kg per metric tonne of air dried unbleached pulp value specified in the XL-2 Agreement. Using similar criteria for color, the recommended maximum monthly average discharge limit on color would be 113.2 lbs/US Ton AD Pulp and corresponds to the two sigma limit from the 2004 monitoring data. This new recommended color discharge limit (113.2 lbs/US Ton) may be compared to a value of 120 lbs per US Ton specified in the original XL-2 agreement. The new recommended discharge limit represents a 5.7% reduction relative to that specified in the original XL-2 agreement for the monthly average. Similarly, the recommended maximum daily effluent limit for color would be 127.2 lbs per AD US Ton and would correspond to the maximum color value obtained in the effluent during the 2004 monitoring data.

Limits for COD and color will be included in the Mill's upcoming MEPDES effluent discharge permit recently proposed by MEDEP.

Effluent Metric. The current COD and color metrics are based upon the total production rate of unbleached Kraft pulp and do not recognize contributions from the numerous unit processes that exist at the Mill site. Alternative COD metrics for the Mill discharge limits are plausible. The simplest change would be to base the discharge limits on: the combined Kraft and groundwood pulp production; the dry tons of paper produced; or a combination of dry tons of paper produced and market Kraft pulp sold. A more realistic metric would account for the contributions of COD and color coming from the Otis Mill and discount what is in the incoming water from the Androscoggin River.

Transferability. The methodology employed during the XL-2 Project is transferable to other paper mill sites. The results show that improved environmental performance over straight BMP compliance was realized along with additional Mill process operational benefits. A collaborative approach was used, once COD balances and process analyses were performed, prior to the identification and selection of the process improvement projects. Subsequent engineering analysis, although time consuming, had positive benefits for the Project. Also, since the XL approach takes time to come to fruition, allowances must be made for changes at the Mill necessitated by the business climate.

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INTRODUCTION

International Paper XL Project

An XL Project was conducted at the International Paper (IP) Androscoggin paper Mill in Jay, Maine. A detailed description of this Project is given in the Final Project Agreement.[1] Project XL is an EPA initiative to evaluate the extent to which regulatory flexibility and other innovative environmental approaches can be used to achieve superior environmental performance at reduced economic and administrative burdens. To exempt IP from the Cluster Rules, new federal rules were promulgated by the Federal Environmental Protection Agency (EPA) and subsequently were adopted by the Maine Department of Environmental Protection (MEDEP). These new rules applicable to the IP Androscoggin Mill (Mill) took approximately one year to achieve and permitted IP's participation in the XL-2 Project.[1]

Under the terms of this Project, the Mill was exempt from Best Management Practice (BMP) in the water pollution portion of the Cluster Rules[2] in order to reinvest resources to implement effluent improvement projects designed specifically to reduce final effluent discharge of Chemical Oxygen Demand (COD) and color from the Mill into the Androscoggin River. In exchange for this exemption, IP agreed to take a number of steps designed to improve the quality of the Mill effluent for COD and color greater than the levels likely to be attained through implementation of the BMP requirements. The Final Project Agreement committed IP to spend the money saved on not implementing BMPs ($780,000) on the effluent improvement projects. The identification and implementation of projects was done by using a collaborative process with IP, EPA, the MEDEP, the Town of Jay, ME and other active stakeholders.

The collaborative process was implemented by taking the Collaborative Process Team as a whole dividing the Team members into the Technical Assessment Subgroup. Appendix A lists the original members of the Collaborative Process Team. Those persons that were designated as members of the Technical Assessment Subgroup are also

[1]"International Paper XL Project: Effluent Improvements", Final Project Agreement, Androscoggin Mill, Jay, Maine. (June 29, 2000)

[2] Cluster Rules, 40 CFR Pt 430.03 Promulgated in 1998.

indicated. Ten (10) progress reports have been written summarizing progress on this project[3,4].

Technical Assessment Subgroup. The Technical Assessment Subgroup was comprised of personnel from the EPA, the MEDEP, the University of Maine and IP engineers. This technical group was charged with identifying a list of potential effluent improvement projects at the Mill primarily in the pulping operation, which when implemented would assist in the reduction of color and COD discharges to meet the goals of the XL-2 Project (Project).

Collaborative Team Concept. The Collaborative Process Team involved members from the EPA, IP, MEDEP, the Town of Jay, Maine and other active stakeholders. The function of the Collaborative Process Team was to evaluate and recommend effluent improvement projects from the list generated by the Technical Assessment Subgroup and assess their potential for COD reduction as well as their overall cost. The projects implemented were chosen by the Collaborative Process Team to best meet the performance goals established in the Final Project Agreement. IP implement the effluent improvement projects determined through the collaborative process. Approval of the projects was by full agreement of the Collaborative Process Team.

Mill Layout at the Initiation of the XL-2 Project

The IP Mill is a fully integrated mill that produces predominately coated and uncoated groundwood and Kraft printing papers (Figure 1). In an integrated mill, raw

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[3] Genco, J. M., and van Heiningen, A., "Topical Report on XL-2 Project at IP, Jay, Maine Results of Laboratory O_2 Delignification Experiments", August 12, 2002; "Second (2nd) Mill-Wide COD Balance to Identify Important COD Point Sources", December 21st, 2001 (7th report), "Status Report on XL-2 Projects at IP Androscoggin Mill, Jay, Maine; Progress as of September 30, 2001", October 25th, 2001 (Sixth 6th Report); "Effluent Reduction by Process Closure Short Course", Aug. 12, 2001: "Status Report on XL-2 Projects at IP Androscoggin Mill as of June 30, 2001", July 23, 2001 (5th report), "Status Report on XL-2 Projects at IP Androscoggin Mill", April 25, 2001 (4th report), "Comparative Analysis of XL-2 Projects", December, 28, 2000 (3rd report), "Mill-Wide COD Balance to Identify Important COD Point Sources", October 18, 2000 (2nd report), "First Summary Report for IP XL-2 Project, Initial Evaluation of COD Balance", August 9, 2000 (1st report).

[4] Cronin, John, IP "Collaborative Team, XL-2 BMP Project 2003 Semi Annual Update and Meeting Minutes", (April 30, 2003), IP Collaborative Team 2003 Second Half, 2003 Semi Annual Update (October 31, 2003).

wood and other raw materials are converted into finished products. In the case of the Androscoggin Mill the finished products are printing papers, specialty papers and market pulp. The production rate of finished paper is approximately 1860 tons per day and necessitates operation of numerous important unit processes at the Mill. Important unit processes include Kraft and Groundwood pulping facilities, paper manufacturing, energy production facilities and utilities including a wastewater treatment plant.

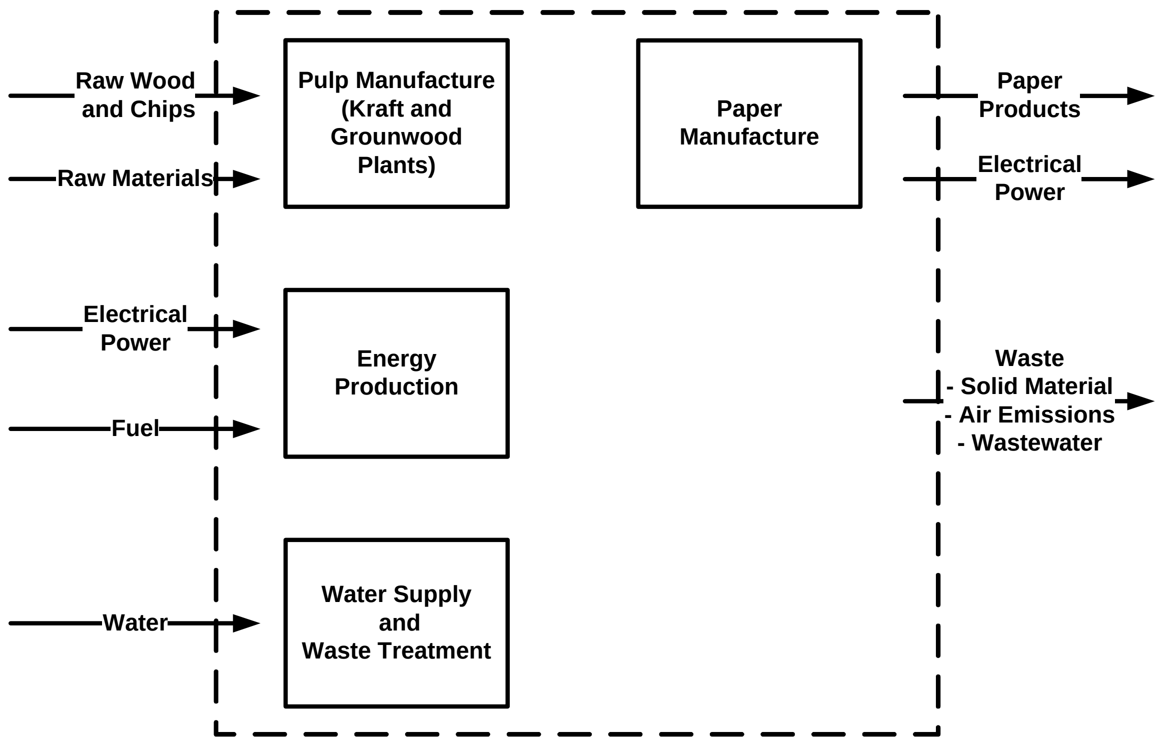

Figure 1. Mill Complex (Adopted from Gullichsen and Paulapuro 2000[5])

Intent of the XL Project

The intent of the XL Project was to provide excellence, leadership in environmental stewardship, and foremost -- to protect the quality of the Androscoggin River. A very important secondary intent of the XL Project was the development of a methodology and technology that would be transferable to other sites and projects.

[5] Gullichsen, J. and Paulapuro, H., Papermaking Science and Technology, Book 8, Papermaking Part 1, Stock Preparation and Wet End", page 14, Finnish Paper Engineers' and TAPPI, Fapet Oy, Helsinki Finland (2002).

Objective and Scope of Project

Scope of XL-2 Project. As part of the cluster rules, Best Management Practice (BMP) was implemented to contain spills of spent Kraft cooking (black) liquor which is persistent and inadequately destroyed in the wastewater treatment plant. The basic assumption at the inception of the XL-2 Project was that residual lignin compounds in the black liquor resulted in discharge of toxic substances and that controlling black liquor spills would reduce COD, color and discharge of toxic substances from the Mill. IP was required under the cluster rules to install dikes to control spills of black liquor from black liquor storage tanks at the Mill. Such a project would require an expenditure of about $780,000.

Since the Jay, Maine facility had very few spills this appeared to be a poor use of capital resources. Therefore, under the flexibility of the XL-2 Project Agreement, the plan was to use $780,000 for process improvements that would lead to reductions of COD and color that were greater than what would have been achieved by investing in the dikes. The initial list of potential effluent improvement projects included the installation of:

- Knot liquor recovery system;
- Pulp screening liquor recovery system;
- Pulp digester heater drains recovery;
- Power house sump drains collection system;
- Computerized mill sewer conductivity display; and
- Recycle of "A" pulp mill wash water.

Objective of XL-2 Project. The XL-2 projects would control the discharge of COD and color on a continuous basis rather than control just intermittent spills. Since the paper business is very competitive it was deemed a worthwhile idea to invest funds into Mill process improvements rather than remedial measures where water quality improvement results would be marginal. The objective of the XL-2 Project was to change the emphasis from end of pipe treatment to Mill process improvement. The objective of this report is to summarize the results of the XL-2 Project that was conducted at the IP Androscoggin Mill in Jay, Maine over the period from June 29, 2000 to December 31, 2004.

Judgment of Project Success

The IP XL-2 Project was conducted over a three and one-half year period. The Collaborative Process Team evaluated the entire Project and made recommendations contained in this report regarding the Project as a whole. It was anticipated that the overall Project would be judged a success provided the environmental results were superior to what might have been attained as the result of compliance with the Best Management Practice provisions of the Cluster Rules. The limits that were agreed upon for the Mill effluent in the original agreement are shown in Table 1[6].

Table 1. Baseline Performance, New Permit Limits and Performance Goals for the IP XL-2 Project

	A	B	C	D
Pollutant	Baseline Performance July-Dec. 98 (six month average)	New Discharge Permit Limits Under XL	Performance Goals[2] (3 yrs after FPA signing)	Potential Future Discharge Limits[5] (4 years after FPA signing)
COD	46.7 kg/kkg[1]	75 kg/kkg[3] and 50.7 kg/kkg[4]	26 kg/kkg	26 kg/kkg
Color	106 lbs/ton paper	120 lbs/ton[2,6]	50 lbs/ton[7]	50 lbs/ton

(1) kkg denotes air-dried metric tons of unbleached pulp production.
(2) Long-term average (LTA)
(3) Daily maximum
(4) Maximum monthly averages
(5) Actual limits will be based on performance (determined through 12 months of sampling) once effluent improvement projects have been completed.
(6) 60 kg/k kg
(7) 25 kg/k kg
(8) FPA denotes, Final Project Agreement

The COD goal enunciated in the Agreement following the three year project was 26 kg COD per unbleached ADMT (air-dried) metric ton based upon a monthly average. The long-term color goal was 50 pounds per U.S. ton (air dried) of Kraft pulp produced as a quarterly average limitation.

[6] "International Paper XL Project: Effluent Improvements", Final Project Agreement, Androscoggin Mill, Jay, Maine. (June 29, 2000)

Limits on Mill Effluent

Upon implementation of the projects, COD measurements were made during a twelve month monitoring period. This was done between January and December 2004 during which time assorted process streams and the final Mill effluent were monitored for soluble and total COD. The process monitoring data were used by the Collaborative Process Team to recommend permit limits to the permitting authority that were consistent with Sections D through G in the Agreement.

Financial Obligations

IP agreed to spend $780,000 in capital and engineering costs to implement process modification projects to meet the goals of the Project. This amount is the equivalent financial obligation that would have been spent to comply with the Best Management Practice provisions of the Cluster Rules.

Transfer of Methodology

An important component of the XL-2 Project is transferability of the methodology and techniques used in this Project to other mill sites.

UNIT PROCESSES AT THE ANDROSCOGGIN MILL

Unit Processes at the Inception of the XL-2 Project

A detailed description of the pulp and papermaking facilities at the Androscoggin Mill is presented in Appendix B. Important unit processes are shown in Figure 2 as they related to discharge of effluent.

Wood Preparation and Pulping Facility. Both round wood and chips are delivered to the pulp mill for conversion into Kraft and groundwood pulps. The wood preparation facilities at the Androscoggin Mill consist of a wood yard, wood room, and two ring barkers that are used in preparing round wood and chips. Bleached stone groundwood pulp (SGW) is produced from four foot logs in a groundwood facility. Chemical pulp is produced in two Kraft pulp mills using both softwood and hardwood chips. These pulp mills are designated Mill “A” and Mill “B” and are used for preparing Kraft Brownstock chemical pulp. Mill "A" produces softwood Kraft Brownstock pulp while Mill "B" produces hardwood Kraft Brownstock pulp which goes to a bleach plant for eventual use in the production of fine papers. In the softwood ("A") Mill, the pulp is further delignified using the oxygen process.

Bleach Plant. The hardwood and softwood Kraft Brownstock pulps are bleached to high brightness in a bleach plant that consists of two separate lines. The softwood pulp is bleached to high brightness (88 ISO) using a $D_OE_{OP}D$ bleaching process. In the bleach plant D_0 represents a chlorine dioxide (ClO_2) stage, E_{OP} represents an extraction stage reinforced with oxygen and hydrogen peroxide, and D represents a final chlorine dioxide stage. In the hardwood ("B") Mill, the hardwood is bleached also using the $D_oE_{OP}D$ bleaching sequence except that there is no oxygen delignification process. The chlorine dioxide (ClO_2) used in the bleaching process is generated by reacting sodium chlorate, sulfuric acid and hydrogen peroxide to form ClO_2 where it is absorbed in water and stored for usage in the bleach plant. The ClO_2 is used in the initial and final stages of bleaching in both the Mill "A" and Mill "B" fiber lines. The hydrogen peroxide and oxygen used in the bleach plant are purchased and made down at the Mill site.

Chemical Recovery and Steam and Power Operations. Chemicals and energy used in the Kraft Process are generated in the Kraft recovery process operated at the Mill site. Electrical power and steam that are used at the Mill site are generated in two recovery boilers operating in conjunction with turbo-generators. In the recovery boiler, sodium carbonate (Na_2CO_3) and sodium sulfide (Na_2S) are recovered from spent Kraft cooking liquor as smelt.

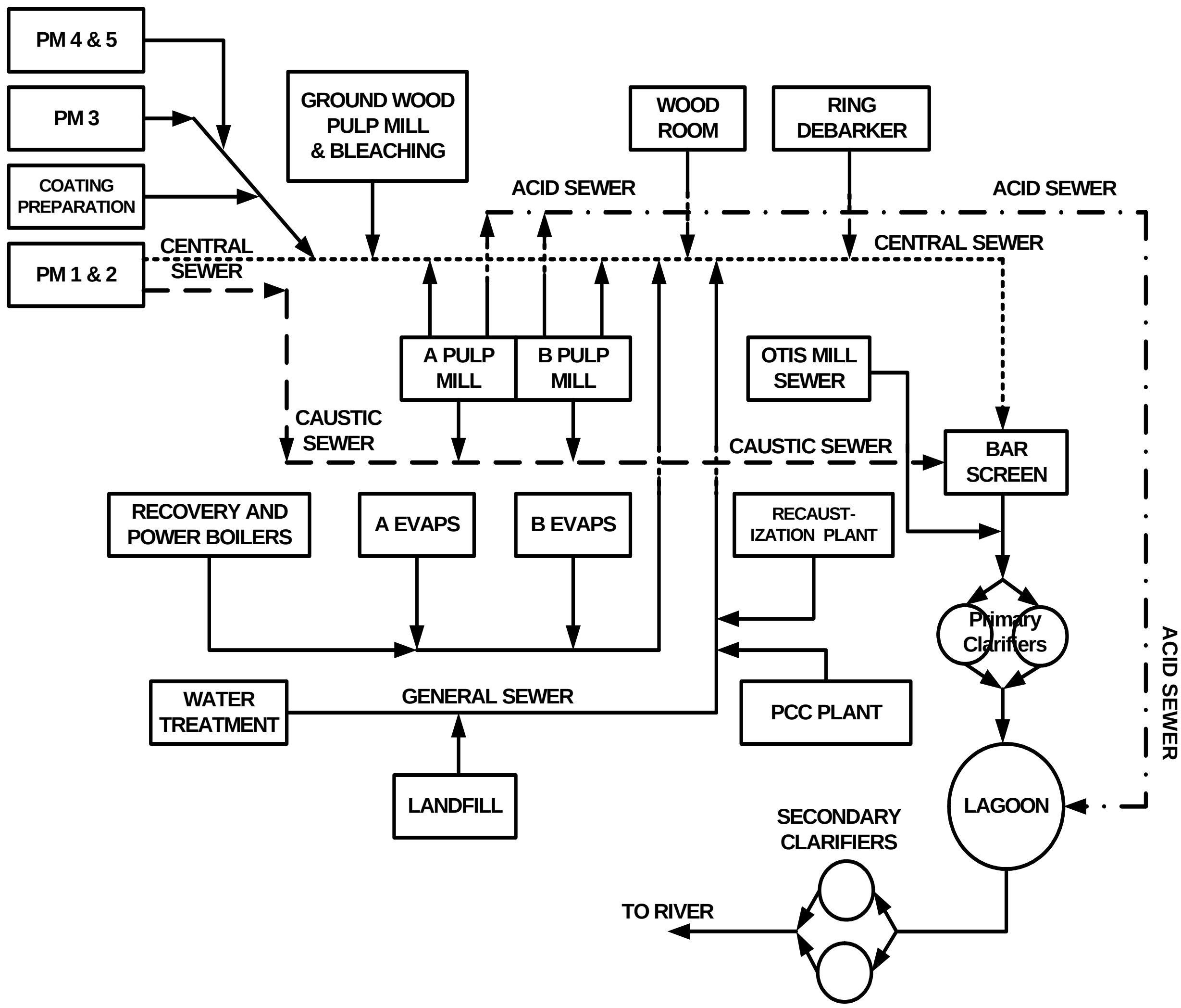

Figure 2. Schematic Diagram of the IP Jay Paper Mill Showing Points of Discharge to Sewer System

In addition to the two recovery boilers, the Mill also operates a bark boiler for burning bark and sludge. A natural gas fired co-generation facility provides the Mill with purchased steam and electrical power. There are two idle power boilers at the site that use bunker-C oil as fuel.

To concentrate the black liquor prior to firing in the recovery boilers, the Mill operates two trains of evaporators and a recaustization plant for generating the NaOH and Na_2S for use in the Kraft digester. The sodium hydroxide (NaOH) is obtained by causticizing sodium carbonate (Na_2CO_3) that is generated in the recovery boilers with slaked lime $(CaOH)_2$).

Paper Mill. The paper mill consisted of five paper machines. At the initiation of the XL-2 Project, three of the paper machines produced coated paper while two of the machines produced uncoated paper. To facilitate preparation of the coating or "paint" used on the three coated machines, the paper mill operates a coating preparation plant. In addition there is a roll finishing department for converting the paper produced on the machines to the proper size and shape sold to customers. At the site, there is a precipitated calcium carbonate plant used to prepare $CaCO_3$ that is used as filler in the base stock prepared on the paper machines and as a pigment in the coatings applied to the paper.

Utility Operation. Utilities operations found at the Mill site include a river pump house, a river water treatment plant, fuel oil storage, waste reclaim operation, a landfill and a wastewater treatment facility. The Mill also treats wastewater produced at a neighboring mill located in Otis, Maine.

Wastewater Treatment Plant. The average daily wastewater flow generated by the unit processes located at the Mill is approximately 34 to 35 million gallons per day (MGD). The wastewater treatment facility treats process wastewater generated by the Mill and, in addition, contact and non-contact cooling water, water treatment plant backwash, landfill leachate, site storm water, as well as process wastewater from the Wausau-Mosinee Paper Corporations Otis Mill Corporation. The Otis Mill produces about 200 tons per day of specialty papers and generates approximately 1.6 to 4.5 million gallons of process wastewater and non-contact cooling water per day. Wastewater from a precipitated calcium carbonate plant operated by Specialty Minerals Incorporated (SMI) and a gas-fired co-generation facility operated by Androscoggin Energy are also treated in the Mill's wastewater treatment plant. Lastly, wastewater from various housekeeping, maintenance and shutdown activates that are dumped to the Mill's sewer are also treated at the WWTP.

Changes to the Mill during XL-2 Project

Several changes took place at the Androscoggin Mill since the inception of the IP XL-2 Project. A detailed description of these changes is given in Appendix C. Changes include modifications to the softwood digester, increases in production of bleached groundwood, changes to groundwood bleaching process and an increase in the production rate on No. 3 coated groundwood paper machine. These changes took place during 2003. The Cluster Rules hard piping option was installed in 2002 for the treatment of methanol in the wastewater treatment plant's aerated lagoon. Ashcrete trials were initiated in 2001 and later discontinued. Also, the lagoon was dredged in 2004, in an effort to increase the lagoon volume, which changed the efficiency of the wastewater treatment plant to remove BOD. These changes were not part of the XL-2 Project but had significant impact on the quantity and nature of the COD being sent to the WWTP.

SUMMARY OF MILL-WIDE COD BALANCES

Mill-wide COD sewer surveys were performed in August 2000 and in August 2001. The primary objective of the two sewer surveys was to assess the sources and quantity of COD and color being discharged from the various Mill unit processes. Other objectives were to delineate XL-2 Projects for process modification to reduce color and COD and determine the suitability of using COD as a process-monitoring tool. The results of these surveys have been previously reported by Genco and van Heiningen[7,8] and some highlights are summarized in Appendix D. The following conclusions were drawn from the sewer surveys.

Focus on the Black Liquor Cycle. Over 50% of the flow and COD going to the wastewater treatment plant originated in the paper mill. The results from toxicity testing lead to the conclusion to select projects related to the black liquor cycle. This was done in an effort by the Collaborative Process Team to reduce the toxicity of the final effluent. Also, predicated on the sewer surveys, the Collaborative Process Team decided to select projects in the following areas.

Reduce Continuous Point Sources from Kraft Mill During Pulp Screening. It was recommended that the Collaborative Technical Team focus on reducing the continuous point sources of black liquor going to the sewer. This strategy was termed

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[7] Genco, J. M., and van Heiningen, A.,"Second (2nd) Mill-Wide COD Balance to Identify Important COD Point Sources", December 21st, 2001 (7th report). "

[8] Genco, J. M., and van Heiningen, A. "Mill-Wide COD Balance to Identify Important COD Point Sources", October 18, 2000 (2nd report).

“closing the screen rooms” and was pursued in both the hardwood ("B") and softwood ("A") pulp mills.

Reduce Black Liquor Carryover. Efforts would be made to reduce black liquor carryover from the "A" Pulp Mill flash tanks going to the sewers.

Re-Use Clear PM White Water in Pulp Mill. Projects would be selected that substituted clear paper machine whitewater in selected locations in the pulp mills. White water originating from the saveall filters on the paper machines contains lower concentrations of organic material, measured as COD, than convention sources of dilution water being used in the pulp mills. This strategy represented an extension of an existing technology, since machine white water was already being used in limited applications in the pulp mills, for example, to mine high-density pulp storage.

Reduce Impact of the Bleach Plant Effluent. Efforts of the Collaborative Technical Team were directed at reducing the kappa number going to the "A" bleach plant, since the combined bleach plant effluent was the largest contributor to COD and color released in the black liquor cycle. Optimization of the oxygen delignification system on the softwood side and improved pulp washing would reduce the effluent from the bleach plant on the softwood side.

Sewer Monitoring Program. A visit was made to the Blue Ridge Paper Company Mill in Canton, North Carolina by two of the Collaborative Technical Team members[9]. The Canton mill had both hardwood and softwood Kraft mills and had instituted an extensive sewer monitoring program. Conductivity probes and samplers had been installed in sewer streams and spill collection tanks installed. Composite samples were analyzed daily for COD and reports generated and distributed to operating and supervisory personnel. It was decided to investigate employing a similar strategy at the Androscoggin Mill. Existing flow meters would be calibrated and new flow meters installed on important sewer streams, which lacked such a device. Conductivity probes would be installed on important sewer streams.

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[9] Genco, J. M. and Leber, B., “Effluent Reduction by Process closure Short Course”. University of Maine Report dated August 12, 2001.

EFFLUENT REDUCTION PROJECTS IMPLEMENTED UNDER XL-2

Table 2 presents the list of effluent reduction projects that were undertaken to reduce COD that were funded under the XL-2 Project. Projects implemented under XL-2 involved: reducing point sources of COD going to the sewer on the black liquor cycle side, mainly by closing up the screen room and improved handling of assorted black liquor streams; reducing COD effluent going to the sewer in the bleach plant by making process improvements to the oxygen delignification system; and installing sewer monitoring equipment. The focus of these projects was to reduce COD related to black liquor. Due to budget constraints and the results of the sewer surveys and toxicity testing, COD reduction projects associated with the paper machines were not considered.

Slotted Screen Baskets Project in Hardwood ("B") Pulp Mill

Slotted profile screen baskets were added to the primary and secondary screens in the hardwood ("B") Kraft Pulp Mill. 6-mil slotted screens were installed in both the primary and secondary screens replacing 55-mil conventional round holes. The new screen baskets greatly improved the efficiency of the screens and enabled IP to shutdown of the cleaning system and pump thus eliminating the continuous flow of tertiary rejects from the cleaning system. It was estimated that shutting down the cleaner system reduced the COD, per year, going to the wastewater treatment plant by approximately 3.3×10^6 pounds. This change also eliminated the electrical draw from the 4,200 hp hardwood cleaner pump. The changes to the screening and cleaning system in the hardwood pulp mill are illustrated in Figure 3. The cost of the slotted screen baskets and their installation was $98,000.

Table 2. Effluent Reduction Projects Funded Under XL-2

Source of Project	Description	Actual Cost (Dollars)	Comments
Slotted Screen Baskets on Hardwood ("B") Pulp Mill	Upgrade "B" Screens Eliminate Cleaners & Pump	$98,000	Project Completed in March 2000.
Sluice Filtrate on Quaternary Screens in Softwood ("A") Pulp Mill	Replace Decker filtrate with paper machine white water on the softwood ("A") side quaternary flat screens.	$13,000	Project was started in December 2001.
Time Dump Cleaners in Hardwood ("B") Pulp Mill	A time dump cleaner system (sand separators) was installed in the screening system in the Hardwood ("B") Pulp Mill.	$91,000	Project completed in September 2001. Actual measured improvement was thought to be about 5,500,00 pounds/yr COD and 1,600,000 pounds color /yr
O_2 Delignification System - Nuclear Level Transmitter[(a)]	Installation of a nuclear level transmitter in the standpipe in the O_2 delignification system	$26,000	Project completed in March 19, 2002. Improved the operation of the medium consistency pump on the O_2 delignification system
O_2 Delignification System – Vent Pipe in Feed system[(a)]	Installation of a vent pipe in the oxygen delignification system to improve level control.	$19,000	Project was completed in March, 2002. The vent pipe improved feeding pulp in the O_2 delignification system.
O_2 Delignification System – O_2 Mixer[(a)]	Installation of a Kvaerner O_2 mixer. DuoFlow™	$256,000	Project was completed in April, 2003. The mixer improved oxygen distribution in the O_2 delignification system.
O_2 Delignification System – Steam Mixer[(a)]	Installation of a Kvaerner steam jet mixer	$270,000	Project completed in October, 2003. Steam mixer permits an increase in temperature in the O_2 delignification system.

Table 2 Effluent Reduction Projects Funded Under XL-2 (Continued)

Source of Project	Description	Actual Cost (Dollars)	Comments
Sewer Conductivity Probes and Monitoring Program	Installation of conductivity probes in key sewers throughout the pulp mills and power plant areas with computerized display available for operating personnel.	$120,000	Project was completed in August, 2002.
Tie-Ins for Flash steam condenser on Softwood ("A") Pulp Mill	Installation of entrainment separator and demister to reduce the carryover of black liquor from flash tanks.	$19,000	Installation of the tie in for this project was completed in April, 2002. Project was abandoned for lack of space and high capital cost.
Evaporator Sump Control System **Total Project Costs**	Installation of sump pumps and diversion system for the softwood ("A") and hardwood ("B") evaporator areas.	$78,000 **($990,000)**	Project completed in May, 2003. "A" and "B" sumps on bypass control operating on conductivity diverts.
Cost for testing, reports and studies **Total Costs**	COD and toxicity testing, cost of oxygen delignification study and preparation of reports.	$64,000 **$1,054,000**	Testing, sewer surveys and reporting cost.

(a) Installation of the nuclear level transmitter, improvements in venting the standpipe, and installation of the Kvaerna oxygen and steam mixers must be considered as a package. All are improvements to the oxygen delignification system that permit higher delignification and less load on the bleach plant.

(b) COD estimate based on raising the percent delignification from 25% to 30% after installation of the O_2 improvement projects.

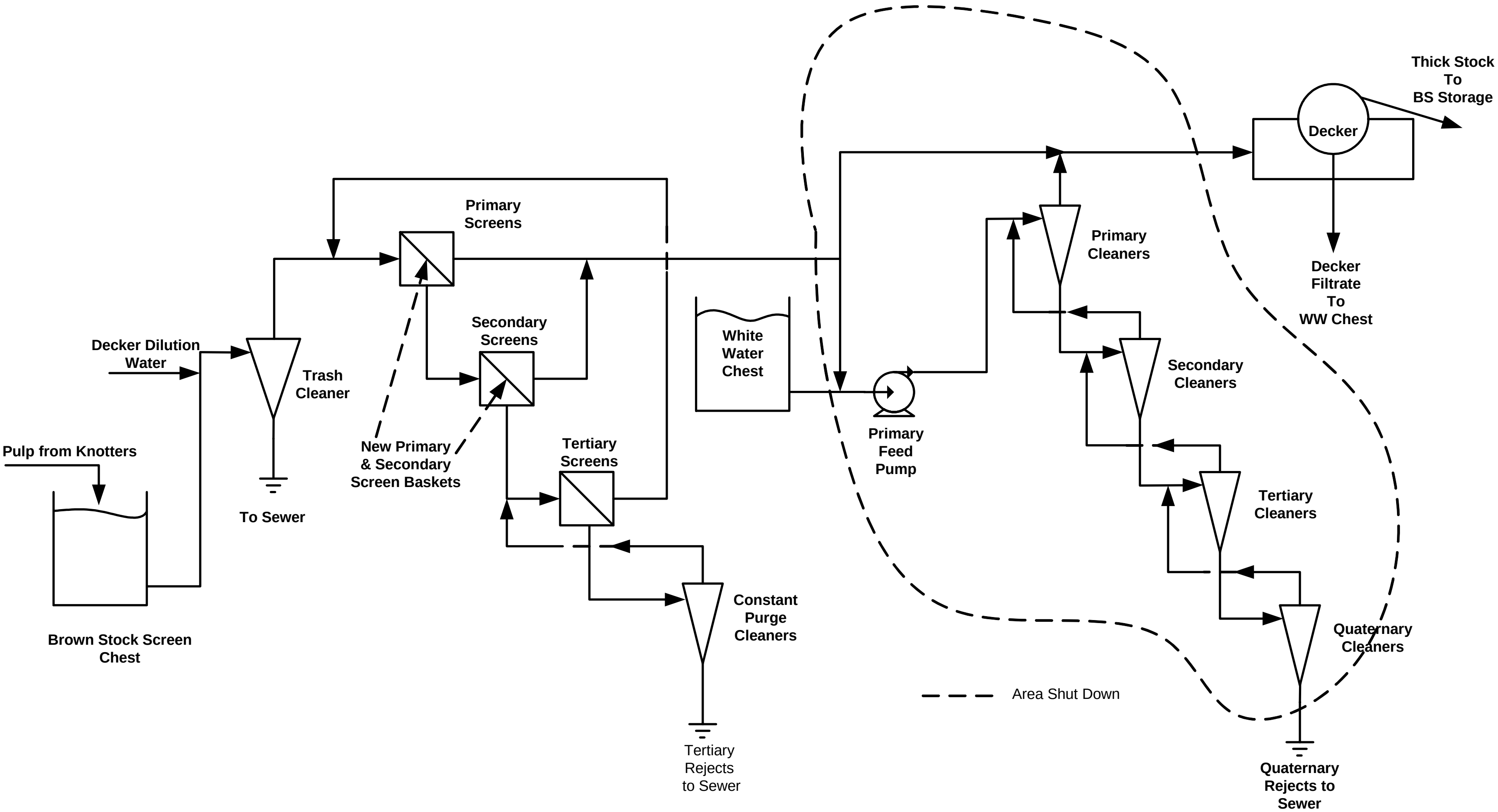

Figure 3. Schematic Diagram Illustrating Slotted Screen Basket Project in Hardwood ("B") Pulp Mill

Sluice Filtrate Project on Quaternary Screens in Softwood ("A") Pulp Mill

The objective of the quaternary screens sluice filtrate project was to close up the screen room in the softwood ("A") Pulp Mill. This was done by substituting paper machine clear white water for Decker filtrate for conveying screen rejects to the sewer in the quaternary screens (Figure 4). This project substituted a stream with low COD concentration, clear paper machine white water, for a stream with high COD, the Decker filtrate. The original estimate for this project was a reduction in COD going to the wastewater treatment plant of approximately 2.06×10^6 pounds per year. This project was completed at a cost of $13,000 which was spent on piping modifications to facilitate switching to paper machine clear whitewater. The quaternary screen sluice filtrate project was started up in December 2001.

Hardwood ("B") Pulp Mill Time Dump Cleaner Rejects Project

A time dump cleaner was installed in the hardwood ("B") Kraft pulp mill. The screening system on the hardwood ("B") pulp mill resembles the screening system in the softwood ("A") side shown in Figure 4. The time dump cleaners are sand separators and were installed after the tertiary screens as part of the XL-2 Project. The use of time dump cleaners circumvent the need for a continuous purge from the cleaners and send rejects to the sewer on a time cycle (Figure 5). The objective of this process modification was to further close up the screen room by reducing the rejects going to the sewer on a continuous basis. Installation of the time dump cleaners replace a continuous purge to the sewer with a discontinuous dump depending upon the level of rejects collected in the base of the cleaner (Figure 5). The time-dump cleaners were installed and started up during the first quarter of 2001. The cost of the time dump cleaner project was $91,000. It was estimated originally that the time dump cleaner project would result in a reduction of COD going to the wastewater treatment plant of 1.1×10^6 pounds per year. The actual improvement was thought to be closer to 5,500,000 pounds per yr COD and 1,600,000 pounds per year of color based on measurements obtained before and after the installation of the time dump cleaners.

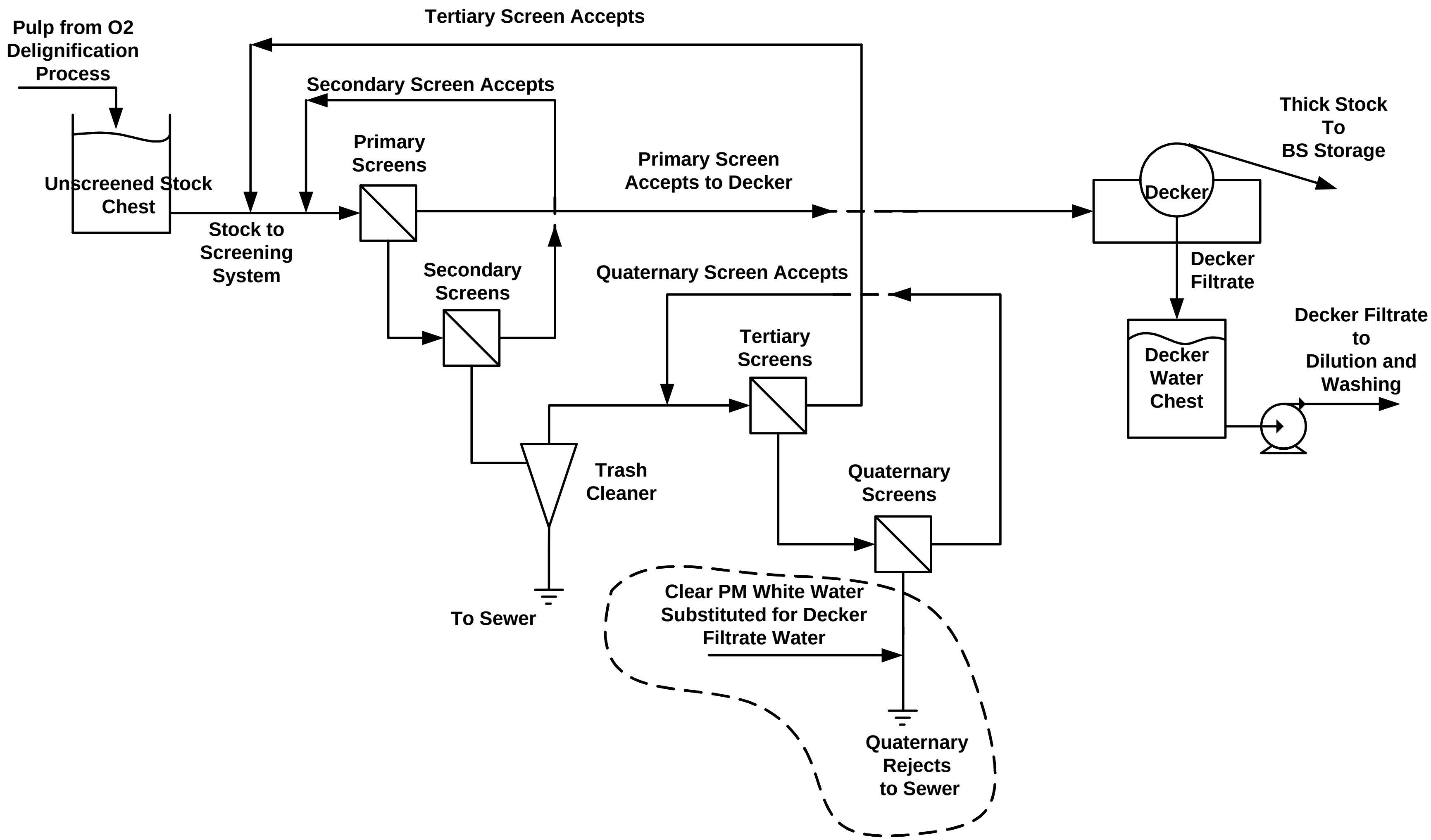

Figure 4. Quaternary Screens Sluice Filtrate Project in Softwood ("A") Pulp Mill

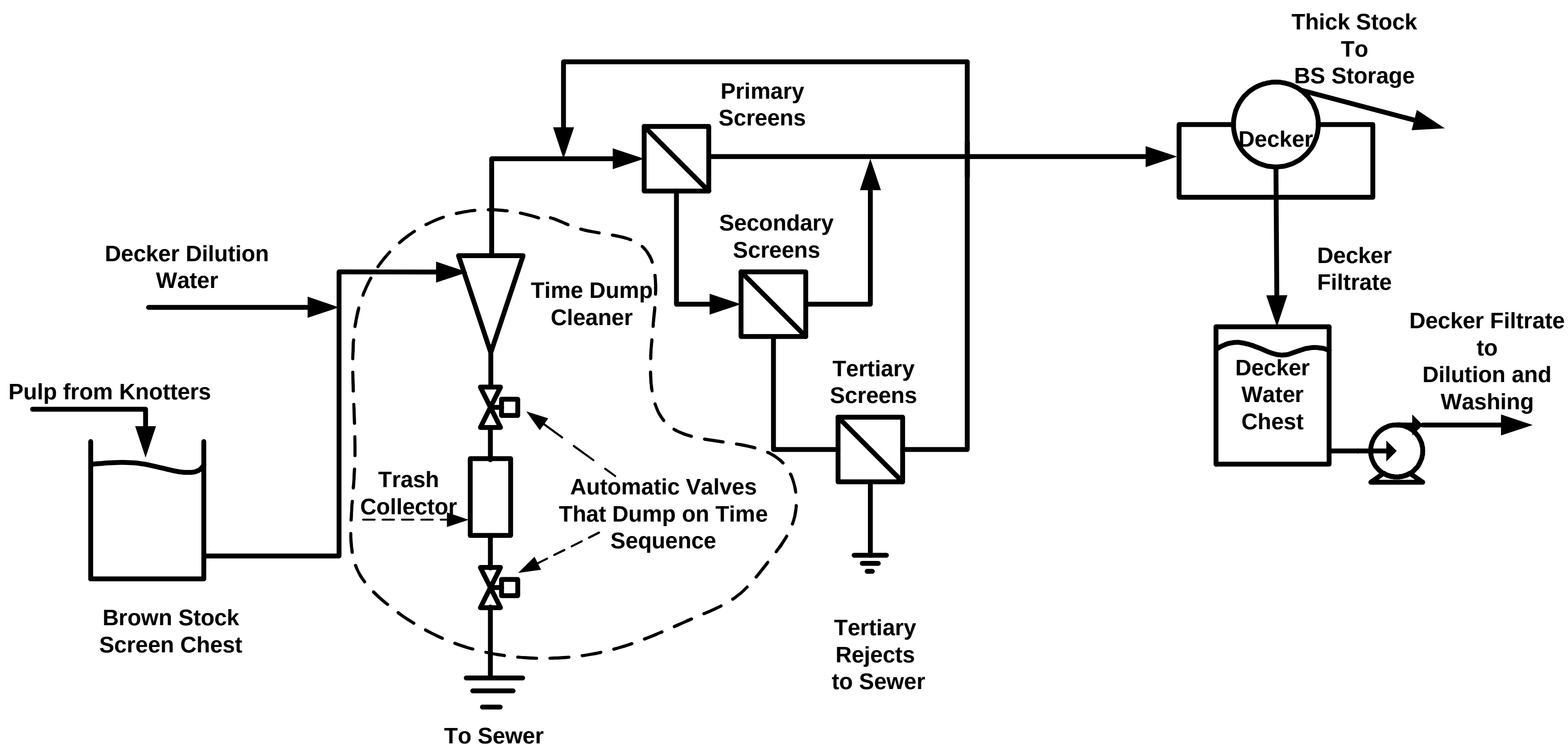

Figure 5. Schematic Diagram of Time Dump Cleaner Project. Sand Separators with Discontinuous Purge to Sewer Installed in the Hardwood ("B") Pulp Mill Screening System

Improvements to Oxygen Delignification System in Softwood ("A") Kraft Pulp Mill

A major strategy to reduce COD and potentially toxic substances going to the wastewater treatment plant is to reduce the effluent from the bleach plant. Important process variables controlling the level of delignification in the oxygen system, in their order of importance, are the reaction temperature, alkali concentration, and oxygen pressure. Of the variables investigated experimentally, raising the temperature in the reactor is the most important variable driving the reaction. Genco and van Heiningen[10] estimated that raising the temperature in the primary oxygen reactor to 200 °F would raise the oxygen delignification on the softwood side to 35% to 40%. The increase in temperature in the reactor would cause a reduction in COD and color going to the River of about 1.9 Kg per metric ton of pulp and about 5 kg per metric ton of pulp, respectively. The exact reduction to be gained for COD and color would depend upon the starting kappa number, the level of delignification, the pulp washing efficiency, the reduction factor, and the removal efficiencies in the wastewater treatment plant of COD and color. This represented the largest decrease in color and COD of any project on the list of projects considered.

Using this strategy as a guide, four projects were undertaken in the oxygen delignification system in the softwood ("A") pulp mill (Figure 6). The intent of these projects was to improve the reliability and operational efficiency of the oxygen delignification system. These projects must be taken together when estimating the impact of these improvements.

Nuclear Level Transmitter. A nuclear level transmitter, beta-gauge, was installed in the oxygen standpipe to detect the level of pulp on the medium consistency pump (Figure 6). The benefit of this project was that the level in the standpipe was stabilized and this eliminated situations whereby the oxygen delignification reactor was bypassed because of an overflow in the feed system. The nuclear level transmitter also insures that there is a constant head on the medium consistency pump and the net positive suction head requirements of the pump are fulfilled. The cost of the nuclear level transmitter was $26,000.

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[10] Genco, J. M., and van Heiningen, A., "Topical Report on XL-2 Project at IP, Jay, Maine Results of Laboratory O_2 Delignification Experiments", August 12, 2002.

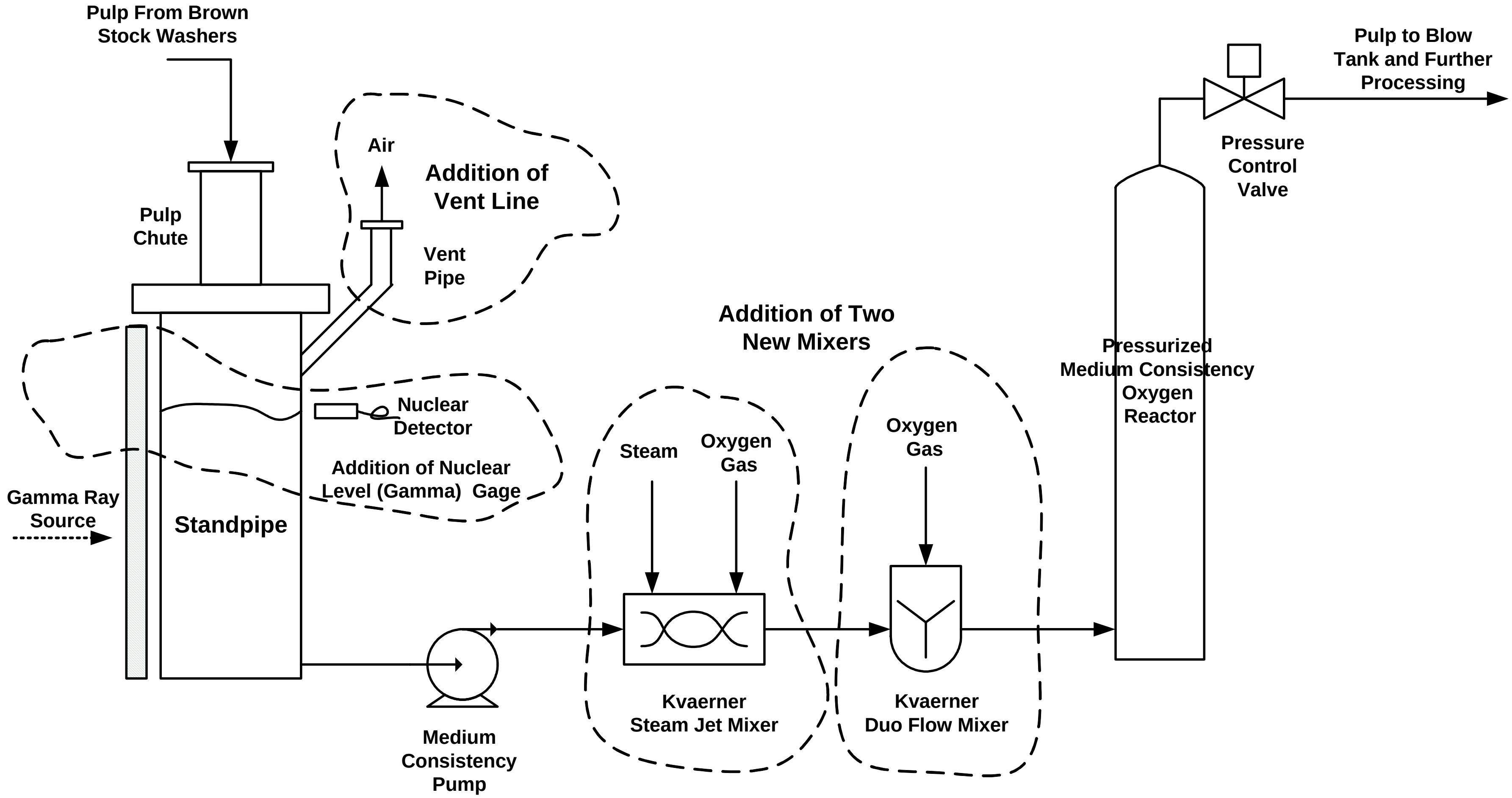

Figure 6. Schematic Representations of Process Modifications to Oxygen Delignification System

Vent Pipe. Improvements were also made to the feed system on the oxygen delignification system. A vent pipe was installed in a chute located between the second stage of the Brownstock washers and the standpipe in the oxygen delignification system (Figure 6). The function of the vent pipe was to remove entrained air that accumulated in the standpipe and impeded the flow of pulp to the medium consistency pump. The vent pipe improved feeding pulp from the brown stock washers to the oxygen delignification system and has improved the operation of the medium consistency pump. The cost of the plumbing for the vent pipe was $19,000.

Steam and Oxygen Mixers. Two new mixers were installed in the oxygen delignification system to improve the operating efficiency of the system (Figure 6). A new Kvaerner-Duo Flow oxygen mixer was added to the system to improve the contact of oxygen with the pulp and process liquid. The installed cost of the Kvaerner-Duo Flow mixer was $256,000. A steam Jet Mixer was installed to permit higher operating temperatures to be obtained in the oxygen delignification system and to permit oxygen to be fed and mixed at a second addition point (split oxygen feed). The installed cost of the Kvaerner steam Jet mixer was $270,000.

Results of Improvements to Oxygen Delignification System. Prior to installation of the nuclear level transmitter and the vent pipe, flow of pulp to the oxygen delignification system was erratic and the chute would become plugged. On these occasions the oxygen delignification system would be bypassed altogether. Additional delignification would be done in the bleach plant with the result that increased bleach plant effluent and COD were sent to the sewer. Since installation of the nuclear level transmitter and the vent pipe, the oxygen delignification system is rarely bypassed and pulp flow to the system has been stabilized.

Installing the oxygen and steam mixers resulted in mixed results. Raising the reactor temperature appreciably increased the pulp temperature. This caused a decrease in the washing efficiency of the vacuum Brownstock washers, which strongly depends upon temperature. During the process monitoring system, the temperature in the reactor was not increased because of these operational problems. Recently however, process water has been added to the pulp leaving the atmospheric tower (Figure 6) going to the post oxygen washers. This has permitted raising the temperature in the oxygen system.

Under the new operating strategy, the COD and color going to the wastewater treatment plant would decrease because more lignin would be removed from the pulp in the oxygen delignification system and additional dissolved solids would be sent to the recovery boiler. Thus, less lignin would be removed in the bleach plant and fewer solids would be discharged from the bleach plant to the wastewater treatment plant.

An estimate was made for the reduction in color and COD going to the wastewater treatment plant by the upgrade of the oxygen delignification system in the softwood ("A") Kraft pulp mill. Genco and van Heiningen[11] published data for the COD and color in the effluent emanating from for oxygen delignification at 12% consistency of Kraft Brownstock pulp obtained from the Androscoggin Mill as part of the XL-2 Project. Data for COD and color in the effluent following oxygen delignification were correlated as a function of the change in kappa number *(ΔK)*:

COD (Kg/Dry Tonne Pulp): $$Effluent_{COD} = 0.1058 * \Delta K^2 + 2.547 * \Delta K \quad (1)$$

$R^2 = 0.973$

Color (Kg/Dry Tonne Pulp): $$Effluent_{Color} = 0.2005 * \Delta K^2 + 6.449 * \Delta K \quad (2)$$

$R^2 = 0.976$

In addition to the change in kappa number *(ΔK)*, the reduction in COD and color going to the wastewater treatment plant will depend upon the production rate of softwood pulp *(P_{Dry})*, the washing efficiency *($\eta_{washing}$)*.

COD (Pounds per Year) $$COD = Effluent_{COD} * P_{dry} * \eta_{washing} \quad (3)$$

Color (Pounds per year) $$Color = Effluent_{COD} * P_{dry} * \eta_{washing} \quad (4)$$

Figures 7 and 8 summarize the calculations for the reduction in effluent for COD and color going to the wastewater treatment plant as a function of the percent delignification assuming an initial kappa number of 26 going to the oxygen delignification system. In these calculations it was assumed that the production rate is 650 dry tons per day and the washing efficiency is 100%. Analysis of Mill process data suggests that the current oxygen delignification system achieves approximately a 30% to 35% reduction in kappa number; up from 25% delignification prior to making the

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[11] Genco, J. M., and van Heiningen, A., "Topical Report on XL-2 Project at IP, Jay, Maine, Results of Laboratory O2 Delignification Experiments (August 14, 2002)

changes to the oxygen delignification system. Hence the estimated reductions in COD and color reduction going to the wastewater treatment plant are approximately 1.7 x 10^6 pounds per year for COD and 4.1 x 10^6 pounds per year for color.

Additional COD reductions can be obtained by further raising the temperature in the oxygen delignification system. This can be done by replacing the post oxygen vacuum washers with pressure washers that would permit the temperature in the oxygen reactor to be increased further. Replacing the existing vacuum washers with pressure washers was clearly outside of the scope of the XL-2 Project since it would involve a major expenditure of capital funds.

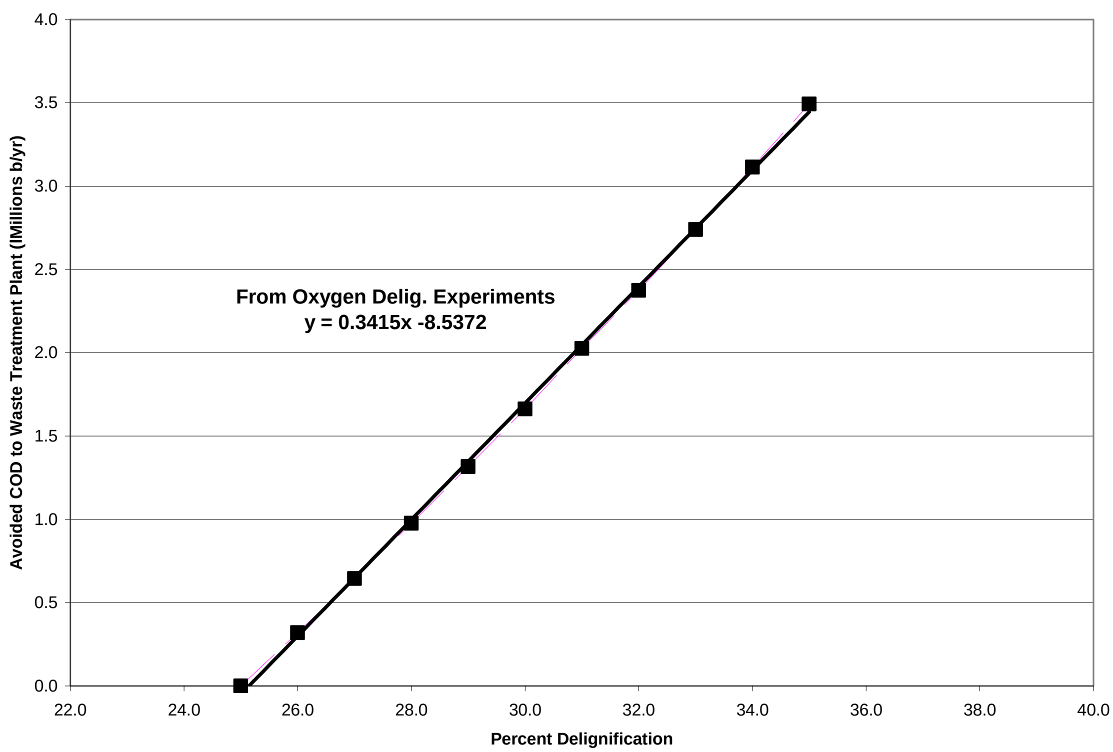

Figure 7. Estimated Avoided COD to Wastewater Treatment Plant Assuming 90% Washing Efficiency and Production Rate of 600 Dry Tons/Day

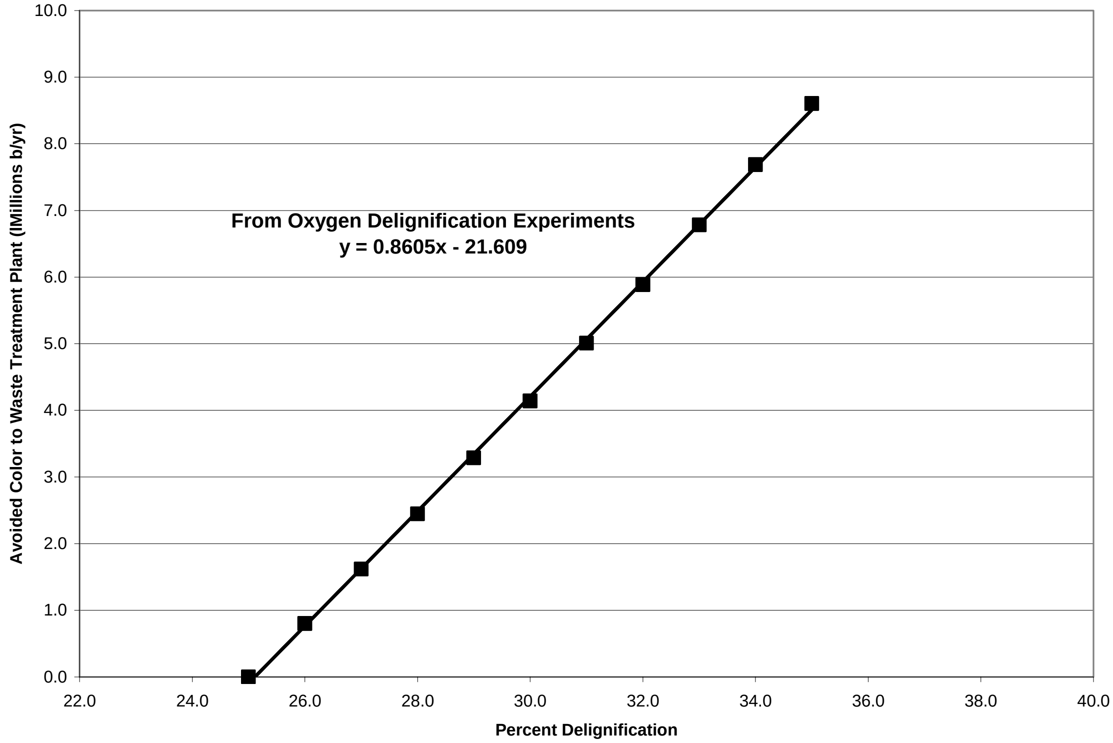

Figure 8. Estimated Avoided Color to Wastewater Treatment Plant Assuming 90% Washing Efficiency and Production Rate of 600 Dry Tons/Day

Conductivity Probes and Continuous Sewer Monitoring Program

Over the years, the Mill had traditionally monitored solids in selected sewer streams, primarily as a way to monitor fiber losses from the paper machines. Under the XL-2 Project, a continuous sewer monitoring program was initiated. Funds allocated directly under the XL-2 Project were used to purchase ten conductivity probes and a computerized display system. In the pulp mill, conductivity probes were located in the: blow tank sewer; diffusion washer/digester sewer on the hardwood side; hardwood ("B") general sewer; softwood ("A") general sewer; and acid sewer. In the recovery plant conductivity probes were located in the: softwood ("A") evaporator sewer; hardwood ("B") evaporator sewer; softwood ("A") concentrator sewer; and No. 2 recovery boiler sewer. The sewer system at the Mill is shown schematically on Figure 2 in the Introduction.

The conductivity probes, installed in key sewers throughout the pulp mill and power plant areas of the Mill, are being used continuously to measure conductivity and pH. The signal from the probes are displayed and recorded in the Mill PI system. High conductivity values cause an alarm in the appropriate control room, and require that the operators investigate the cause and take corrective action(s). New flow meters were added to several sewer streams and the Mill sewer monitoring program was expanded to the paper mill using funds outside those allocated for the XL-2 Project.

Sewer Monitoring Program. The Mill has expanded upon this process greatly by including other process sewers. Flow meters in related sewers have been upgraded and visual inspection rounds of these sewers are conducted at least once every four hours. This includes visual observations of the sewer, associated pumps and tanks as well as recording or measurement of pH, conductivity, flow, and consistency. All of this information is recorded in the Proficy data base system. Any "upsets" are responded to and communicated to wastewater treatment plant personnel. Sewer monitoring reports are prepared daily under the continuous sewer monitoring program. The reports are circulated to management and operating personnel that show the number of incidents and the total minutes that the values of the sewer conductivity exceeded the safe limits. The outcome of these rounds is a reduction of material going to the sewer and the wastewater treatment plant.

Installed Cost. The installed cost of the conductivity probes was $120,000 and lead to the Mill sewer monitoring system. The sewer monitoring program has directly resulted in the reduction of COD and color going to the wastewater treatment plant. However, quantitative estimates for the avoidance of COD and color are not possible.

Entrainment Separator Project in Softwood ("A") Pulp Mill

The objective of the entrainment separator project was to install entrainment separator/demisters in the softwood ("A") Kraft mill to eliminate black liquor carryover with the flashed steam emanating from the flash tanks (Figure 9). The tie-ins necessary for the installation were installed at a cost of $19,000. However, the actual installation of the separator/demister was abandoned because of lack of space for proper installation and the high capital cost of the project. Process improvements to the softwood ("A") digester in the 2nd quarter of 2002, further reduced the need for the Separator/Demister project.

Evaporator Sump Control Project

The evaporator sump control project was undertaken as part of the XL-2 Project and is illustrated in Figure 10. In this sump project, piping systems were installed to divert evaporator condensates from the "A" and "B" Evaporator areas to a large holding tank, called the Black Liquor Multi-Purpose (BLIMP) tank. This control action is taken when the conductivity in the evaporator condensates is high and exceeds the high-level conductivity set-point. Condensate with high conductivity is then gradually recycled (metered) back to the evaporators for eventual disposal in the recovery boiler. Thus, rather than sending condensate with high COD to the wastewater treatment plant, it is stored in the BLIMP tank and bled back to the evaporator system and re-concentrated for entry into the recovery boiler. Also, the sum control system allows “water” of very-low conductivity to flow to the wastewater treatment plant and not to the evaporator cycle. The evaporator sump control project cost $78,000. Similar to the sewer monitoring project, the evaporator sump control project resulted directly in reductions of COD and color going to the wastewater treatment plant. However, quantitative estimates for the avoidance of COD and color are not possible.

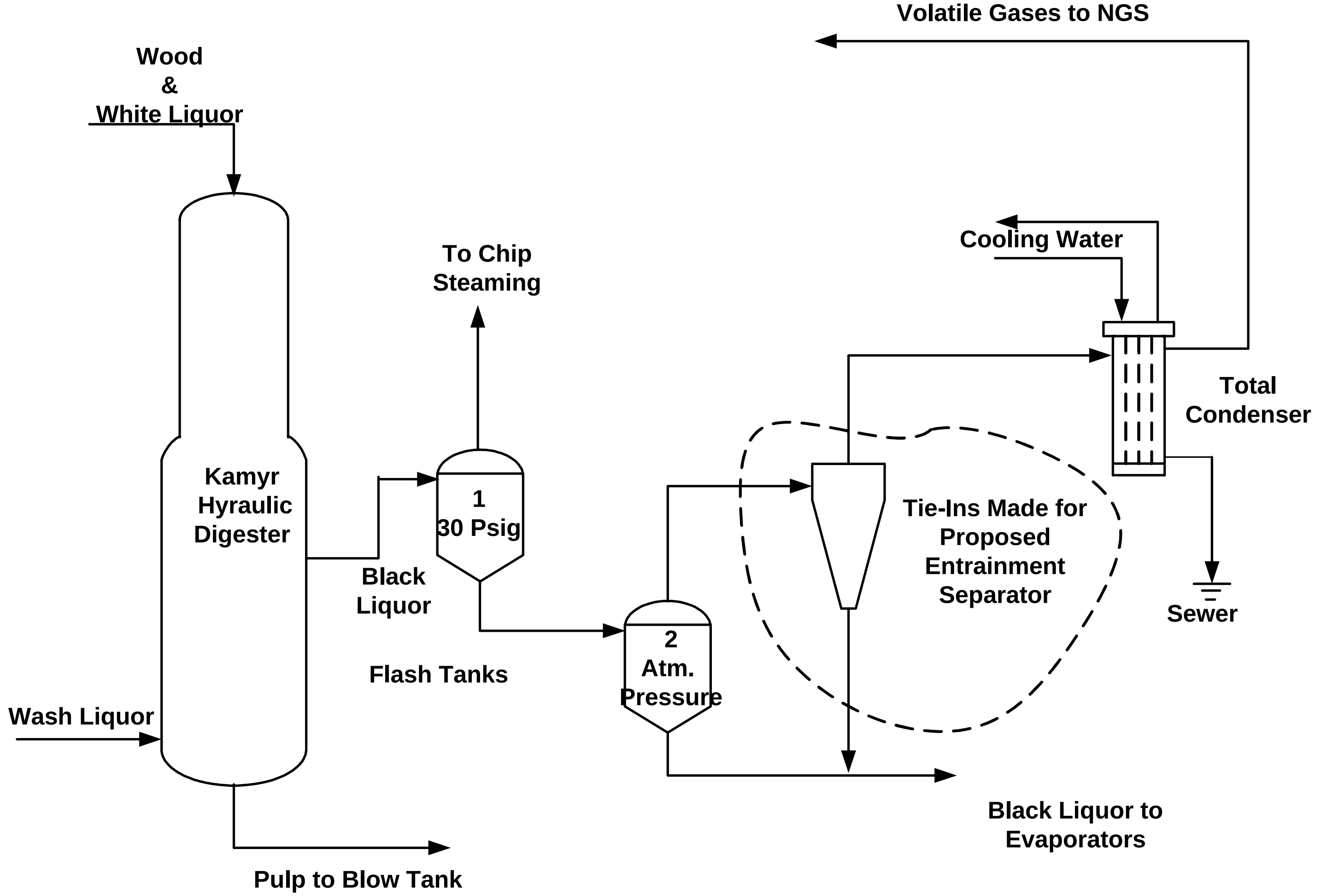

Figure 9. Tie In Project on Proposed Entrainment Separator Project for Softwood "A" Side Flash Tanks

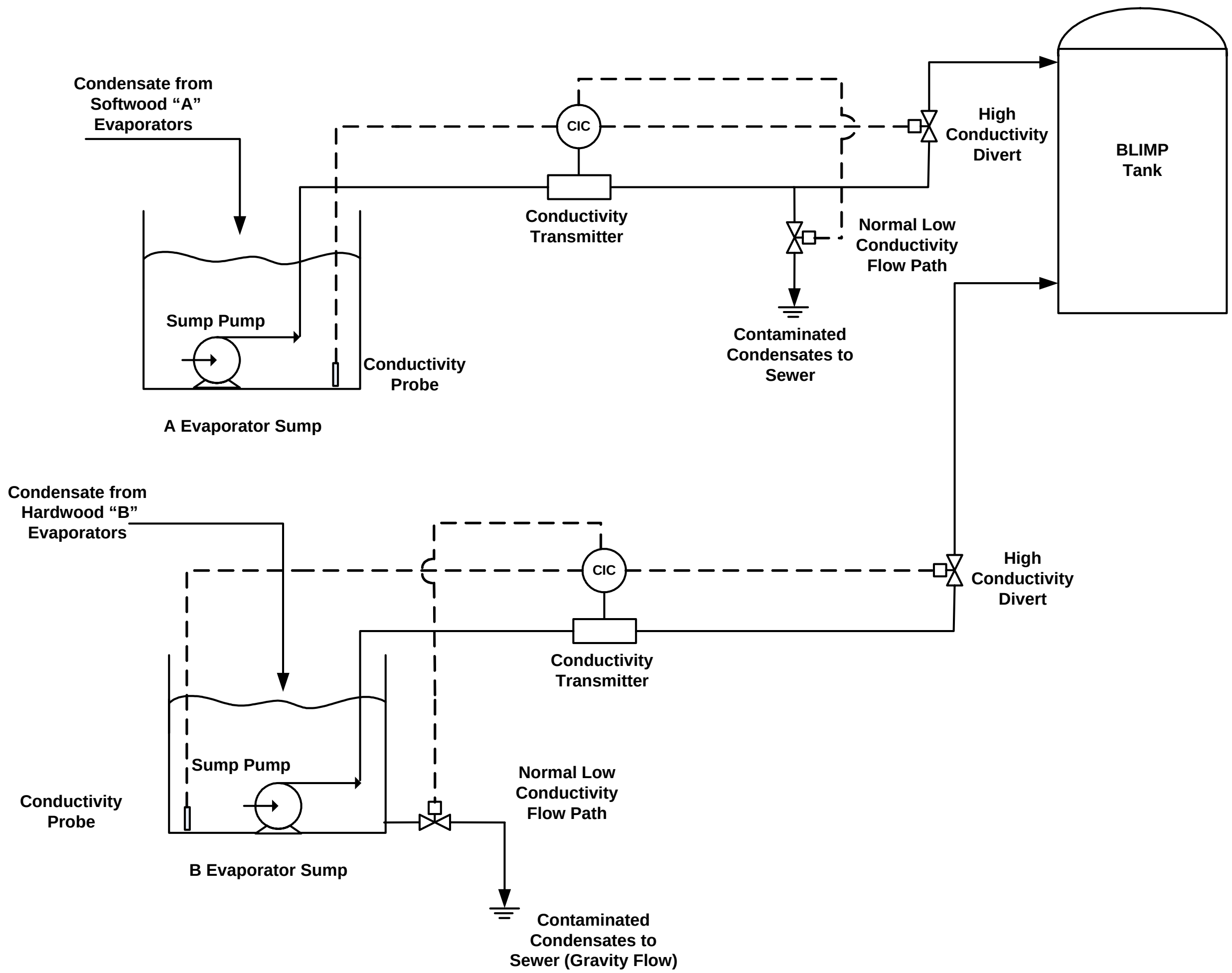

Figure 10. Schematic Representation of Evaporator Sump Control Project

OTHER EFFLUENT REDUCTION PROJECTS IMPLEMENTED OUTSIDE OF XL-2

Table 3 lists projects that were funded directly by IP that lead to effluent reductions during the period of the XL-2 Project. These projects involved reducing point sources of black liquor going to the sewer associated with knots and screening rejects and upgrading the softwood digester to permit more black liquor to be extracted from the digester and sending it to the recovery system.

"A" and "B" Side Knot Sluice Filtrate Projects

Clear paper machine filtrate "B" side and cyclone scrubber water "A" side were used to sluice knots collected from secondary vibratory flat screen in the screen room. Knots are discharged to the ground and then sent to landfill. These projects were initiated to close up the screen rooms in both the softwood ("A") and hardwood ("B") pulp mills. Figure 11 illustrates schematically the rudiments of these projects. These projects were completed prior to formal initiation of the XL-2 Project. The cost for these projects, mainly expended on piping changes, amounted to $4,000 on the "A" slice filtrate project and $5,000 on the "B" knot sluice filtrate project. Potential reductions in COD being discharged to the environment, since the knots are discharged on the ground outside the softwood ("A") and hardwood ("B") pulp mill buildings, was estimated to be 690,000 pounds per year on the softwood ("A") pulp mill and 1,100,000 pounds per year in the hardwood ("B") pulp mill.

Sluice Filtrate Project on Quaternary Screens in Hardwood ("B") Pulp Mill

The objective of the quaternary screens sluice filtrate project is to close up the screen room. It is very similar to the sluice filtrate project previously described for the softwood ("A") pulp mill. A schematic diagram for this project would look very much like that shown in Figure 4 for the softwood ("A") pulp mill except that Mill water was used in place of paper machine white waste. Here again a low COD water was substituted for Decker filtrate having a high COD value for conveying screen rejects to the sewer from the quaternary screens (Figure 4). This project was completed in 1999, prior to initiation of the XL-2 Project at a cost of about $3000, primarily for piping changes.

Table 3. Effluent Reduction Projects Completed by IP Outside of the XL-2 Budget

Source of Project	Description	Actual Cost (Dollars)	Comments
A-Side Knot Sluice Filtrate System in Softwood ("A")Pulp Mill	Use of cyclone scrubber mill water as an alternative to Decker filtrate to sluice knots in the softwood pulp mill.	$4,000	Project completed in 1999. All work was funded by IP outside of the XL-2 Project.
B-Side Knot Sluice Filtrate in the Hardwood ("B")Pulp Mill	Piping for substituting paper machine white water for Decker water to slice hardwood knots to the sewer.	$5,000	Completed in March, 2000. All work was funded by IP outside of the XL-2 Project.
B-Side Screening Sluice Filtrate in Hardwood ("B")Pulp Mill	Screening Sluice Filtrate on Softwood ("A") Pulp Mill. Piping for substituting paper machine white water for Decker water to slice hardwood knots to the sewer.	$3,000	Completed in 1999. All work was funded by IP outside of the XL-2 Project.
A-Side Digester Extraction Screens in Softwood ("A")Pulp Mill[(a)]	Improvements to the extraction screens in softwood digester. This permitted more black liquor to be extracted from the digester and reduced the Decker filtrate going to the sewer.	$140,000	Completed in Summer 2002. All work was funded by IP outside of the XL-2 Project.
Process Modification in Softwood ("A") Pulp Mill[(a)]	The softwood digester was modified so that more black liquor was extracted from the digester. This change, together with the softwood ("A") side digester screens, reduced the Decker filtrate going to the sewer.	$634,000	Completed in Summer, 2002.

(a) Installation of the extraction screens and the softwood digester modifications in the softwood ("A") pulp mill must be considered as a package.

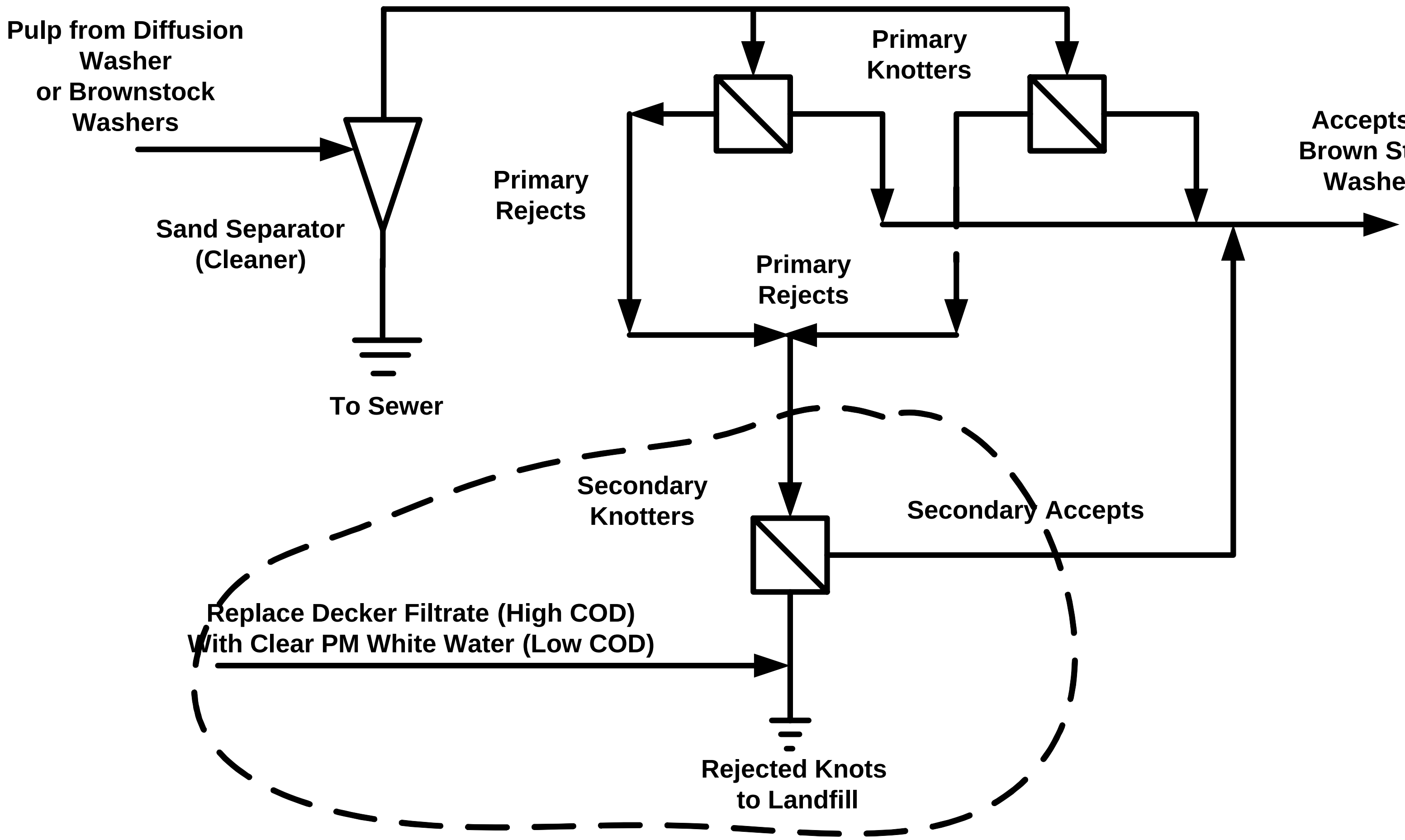

Figure 11. Schematic Representation of Knot Sluice Projects Undertaken in the Softwood ("A") and Hardwood ("B") Pulp Mill

It was estimated that implementation of this project would reduce the COD in the effluent going to the sewer in the hardwood screen room by about 510,000 pounds per year.

Changes to the Softwood ("A") Digester

The Mill undertook two projects that permitted additional black liquor to be extracted from the digesters in the softwood ("A") pulp mill, thus avoiding discharge of filtrate to the sewer at the softwood Decker. These projects were undertaken to improve the overall operation and efficiency in the softwood digester but had the side benefit of reducing the discharge of COD and color going to the wastewater treatment plant.

Black Liquor Extraction Screens in Softwood ("A") Digester. New diagonal black liquor extraction screens were added to the softwood digester, see Appendix Figure B4. The new diagonal screens have less pressure drop than the previous screens and the diagonal design helps avoid screen blinding. When taken together with the digester modification project, this permitted additional black liquor from the digester to be sent to the evaporators. Digester solids have high solids concentration and raise the capacity of the evaporators. The capital cost of the Black Liquor Extraction Screen project was $140,000 (Table 3).

Softwood Digester Process Modification Project. Digester modifications were made to the Kamyr Digester on "A" side. This project involved changing the plumbing in the digester and carefully controlling the alkali in the digester. This project reduced screen blinding and improved the pulp yield. It also allowed an increase in the removal of black liquor from the continuous digester, determined by an increase in the black liquor extraction ratio, which is the fraction of the black liquor moving with the chips that is extracted in the extraction zone of the digester. Wash liquor from the deck was being spilled to the sewer to maintain the water balance in the softwood ("A") pulp mill. This practice was discontinued after the installation of the new digester screens and the digester modification project. The installed cost of the softwood digester process modification project was $643,000. The softwood digester process modifications project was funded by IP and was outside of the scope of the XL-2 Project.

Effluent Reduction from the Digester Modification and Extraction Screens Projects. It is estimated that the digester modification and extraction screen projects resulted in approximately 400 gallons per minute of Decker filtrate not being diverted to the sewer, but rather being sent to the recovery system. Fifty samples of the Decker filtrate were tested for COD values over a 24 hour period (Table 4). The COD content was seen to vary considerably, from a low of 450 mg/liter to as high as 7,700 mg/liter with an average of 3,316 mg/liter. Using the average value for the COD and assuming that the displaced Decker liquid was 400 gallons per minute, it is estimated that the digester modification project resulted in the reduction of approximately 5.8×10^6 pounds per year of COD going to the wastewater treatment plant.

Table 4. Measured COD Values for Decker Filtrates

Parameters	**Value**
No. Samples	50
Average (X)	3316 mg/L
Std. Dev. (s)	2289 mg/L
Max.	7700 mg/L
Min.	450 mg/L
COD (s/X)*100	69%

FINANCIAL STATUS OF PROJECT

The financial status of the XL-2 Project is summarized in Table 3. Direct costs were those associated with the projects planned and implemented as part of the XL-2 Project. Ancillary costs were those associated with testing, consulting and reporting.

Projects Funded By XL-2 Project

The projects that were funded directly under the XL-2 Project are listed in Table 3 and included:

- Slotted screen baskets in the hardwood ("B") mill **($98K)**
- Sluice filtrate on the quaternary screens in the softwood ("A") pulp mill **(13 K)**
- Time dump cleaners in the hardwood ("B") pulp mill **($91K)**
- Oxygen delignification system upgrades in the softwood ("A") pulp mill **($571K)**

- Conductivity probes and the installation of the continuous monitoring program **($120K)**
- Tie-ins for flash steam condenser, **($19K)**
- Evaporator sump control system **($78K)**.

The cost of the projects directly funded under the XL-2 Project amounted to $990,000.

Costs for Testing, Consulting and Reporting

Several miscellaneous tasks were undertaken in support of the XL-2 Project. Approximately $29,000 was spent for COD and toxicity tests. This work was performed by Acheron Environmental Testing Laboratory, Newport, Maine. These charges were directly associated with the first[12] and second[13] Mill-Wide COD balances. Additionally, $5,000 was spent to conduct a laboratory project at the University of Maine to determine the potential for raising the percent delignification in the oxygen delignification system in the softwood ("A") pulp mill[14], thus reducing the discharge of COD and color going to the wastewater treatment plant. Lastly $30,000 was spent on consulting and preparation of the final report during the course of the XL-2 Project. Total cost for these ancillary activities was approximately $64,000.

Total Cost Associated with XL-2 Program

The total cost directly associated with the XL-2 Project was approximately $1,054,000 and involved $990,000 for direct project cost and $64,000 for testing and ancillary studies. IP spent untold engineering hours developing these projects and others in the initial stages of design and installation. These costs, which were significant, are not included in the total cost.

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[12] Genco, J. M. and van Heiningen, "Mill-Wide COD Balance to Identify Important COD Point Sources", October 18, 2000 (2nd report),

[13] Genco, J. M. and van Heiningen, "Second (2nd) Mill-Wide COD Balance to Identify Important COD Point Sources", December 21st, 2001 (7th report)

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[14] Genco, J. M., and van Heiningen, A., "Topical Report on XL-2 Project at IP, Jay, Maine Results of Laboratory O_2 Delignification Experiments", August 14, 2002.

Additionally, IP spent another \$12,000 closing up the screen room, \$140,000 for installation of the new diagonal digester screens and \$634,000 revamping the piping on the softwood digester cooking project. Although these funds were not allocated as part of the XL-2 Project, they had a direct impact in reducing COD going to the wastewater treatment plant.

COD PROCESS MONITORING DATA

Process monitoring data were obtained at thirteen different locations in the Androscoggin Mill as well as in the wastewater treatment plant. The process monitoring took place during the period January 1, 2004 to December 31, 2004. The objective was to monitor trends in the discharge of COD from important unit processes in the Mill and to monitor the COD in the influent and effluent from the wastewater treatment plant. It should be noted that insufficient data were taken to perform daily Mill-Wide COD balances and this was not an objective of the process monitoring task under the XL-2 Project.

Flow rate and composite samples were obtained from various sewer streams associated with the important unit processes within the Mill. These data were used to estimate the mass flow rates $(M_{COD})_i$ for soluble and insoluble COD for the various monitoring points by the equation

$$(M_{COD})_i = Q_i \, C_i \qquad (5)$$

where Q_i, is the measured flow rate (liters per day) and C_i is the concentration of COD in kg/liter.

Sample Locations and Frequency

Sewer samples were taken in the paper mill, Kraft pulp mills, recovery area and at the wastewater treatment plant.

Paper Machine. The paper machine sewer water discharges into the central sewer system, except for No. 1 and 2 paper machines which drain into both the central and caustic sewers (see Figure 2). Samples associated with the paper mill were taken and analyzed from the following five locations: combined sewer streams for the wet and the dry ends from the number 1 and 2 paper machines (2 separate locations); wet end for the number 3 paper machine; number 5 paper machine; and combined sewer for the number 4 and 5 paper machines. The samples that were taken permitted estimation of the total discharge of COD from all of the paper machine sources.

Black Liquor Cycle. In the black liquor cycle, samples were taken and analyzed from the following three locations: central sewer for the softwood "A" Kraft mill; central sewer for the hardwood "B" Kraft mill; and the contaminated condensates from the "A" and "B" evaporators, including the power plant, which are set by EPA in the Cluster Rules. These include the "A" side flash steam condenser, the "B" side flash steam condenser, the "A" evaporator's surface condenser, the "A" evaporators pre-evaporators, the "B" evaporators surface condenser and the "B" evaporators off the 6^{th} effect. Samples were not taken in the "A" and "B" caustic or acid sewers. Thus, the COD discharged from the softwood ("A") and hardwood ("B") Kraft pulp mills are missing these sources that originate in the bleach plants (Figure 2), which were are not including in the black liquor cycle.

Groundwood Mill. In the groundwood mill, samples were taken and analyzed from the following two locations: the west end sewer system; and the north end sewer system which includes a twin wire press which discharges material from the hydrogen peroxide (H_2O_2) bleach plant. These two samples permitted the total of all COD emanating from the groundwood mill to be estimated (Figure 2).

Wastewater Treatment Plant. In addition, samples were taken and analyzed from the following three locations in the wastewater treatment plant: the inlet to the bar screen; the lagoon inlet; and the final effluent. By taking samples at the inlet and outlet of the wastewater treatment plant (Figure 2), the change in concentration or efficiency of the lagoon for removing COD was estimated.

COD Sources Not Sampled. Samples were not taken from the wood room, ring barker, Otis Mill sewer, recaustization plant, PCC plant, the water treatment plant and the landfill leachate. COD from these sources would be included in samples taken at the bar screens.

Sample Frequency. Samples were obtained on a daily basis, although not all samples were taken on all days.

COD Test Methods

COD is a measure of the oxygen equivalent of that portion of the organic matter in a sample that is susceptible to oxidation by potassium dichromate ($K_2Cr_2O_7$), a strong chemical oxidant. It is often used as a general indicator of organic industrial pollution. A detailed description of the standard COD test is given in Standard Method 508 in the Standard Methods for the Examination of Water and Wastewater[15]. The COD samples obtained during the process monitoring period were analyzed by the Mill for unfiltered (total) COD by using a Hach kit, which closely follows EPA Standard Method 410.4. The total COD was measured by digesting the unfiltered organic matter in the samples with potassium dichromate. Each molecule of potassium dichromate has the same oxidizing power as 1.5 molecules of oxygen. The oxidizing equivalents of potassium dichromate that reacts with a standard volume of residual liquor are reported as milligrams of equivalent oxygen per unit volume. The amount of potassium dichromate consumed is determined by colorimetric methods. The complete method is documented by the Hach Company, 1987[16] .

Currently, there is no standard method developed to analyze for filtered (dissolved or soluble) COD, therefore, a filtering method was improvised by following procedures developed for color. For measuring filtered COD or soluble COD, the raw samples were filtered through a 1.2 micron fiberglass filter prior to analyzing COD using the Hach kit.

Color Test Method

Color measurements were made on the effluent from the Mill using NCASI Method 71.1. In this method, approximately 50 ml of the raw sample is filtered through

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[15] Method 508, Chemical Oxygen Demand (COD), Standard Methods for the Examination of Water and Wastewater, 14th Edition (1975), American Public Health Association, Washington, D.C.

[16] Gibbs, Charles R., Introduction to Chemical Oxygen Demand, Technical Information Series the Hach Company. Booklet Number 8 (1979)

a 1.2 micron fiberglass filter. The filtered sample was then adjusted to pH 7.6 by the addition of a buffer solution with caustic or acid, and then filtered a second time through a 0.8 micron fiberglass filter. The absorbance was then determined using a Turbidity meter set at a wavelength of 465 nanometers (nm), the absorbance wavelength for lignin. The color was then determined by comparing the test reading to a standard platinum cobalt standard curve given in PUC units per liter.

COD Data from Mill Unit Processes

A summary of the COD data are shown in the graphs in Appendix E. Inspection of the data in Figures E1 through E10 shows that there is considerable variability in the data; as one would expect from a complicated industrial process. Average values for the total and soluble COD are included in the figures and are summarized in Table 5. The average total COD for all unit processes was 215,664 pounds per day, of which 101,813 pounds per day was soluble COD or approximately 47.2% of the total COD was soluble COD.

Paper Machines. The paper mill is a major source and contributor of COD going to the wastewater treatment plant and validates the results obtained earlier in the two Mill-Wide COD balances. The data in Table 5 suggest that the No. 1 and 2 paper machines contribute approximately 60,514 pounds per day or roughly 54.3% of the COD loading from all paper machines (111,546 pounds per day). Figure 12 presents the distribution of COD emanating from the paper mill by machine.

The combined tonnage from Nos. 1 and 2 paper machine was about 595 tons per day, see Appendix Table B1. By contrast, No. 4 paper machine, one of the largest paper machines at the Mill having a capacity of 500 tons per day (Table B1), is relatively closed and only produced about 13.3% of the COD going to the wastewater treatment plant from the paper machines. Similarly, No. 3 paper machine, with a capacity of about 530 tons per day, produced only 26.5% of the total COD going to the wastewater treatment plant. No. 5 paper machine, a small machine, was a relatively small contributor to total COD going to the wastewater treatment plant during the process monitoring period.

Approximately 28% of the total COD from the paper machines was soluble COD. The range on the soluble COD varied between 12.8% for the No. 5 paper machine, which is a specialty machine, to 28.8% on the No. 1 and 2 machines which are fine paper machines which are rich in starch and other coating solids.

Table 5. Summary of COD Data Obtained During Process Monitoring [(a)]

Mill Location	COD Values (Lbs/Day)	
	Total COD	Soluble COD
Paper Mill		
No. 1 & 2 PM (Wet End)	52,919	14,007
No. 1 & No. 2 PM (Dry End)	7,594	3,133
(Total No. 1 and No. 2 PM)	**60,514**	**17,139**
No. 3 PM	**29,531**	**6,290**
No. 4 PM	14,869	3,741
No. 5 PM	6,633	851
(No. 4 and 5 PM)	**21,502**	**4,591**
Total All Machines	**111,546**	**28,021**
Kraft Pulp Mills		
Softwood (A) Pulp Mill	9,711	5,972
Hardwood (B) Pulp Mill	10,765	3,675
Total Monitored Sources	**20,476**	**9,647**
Groundwood Pulp Mill		
GW West End	11,459	2,084
GW North End Sewer & TWP	28,941	18,819
Total GW Mill	**40,400**	**20,903**
Power Plant/Contaminated		
Contaminated Condensates	**43,242**	**43,242**
Total All Monitored Sources	**215,664**	**101,813**

(a) Average Data Taken over the period January 1 through Dec. 31, 2004.

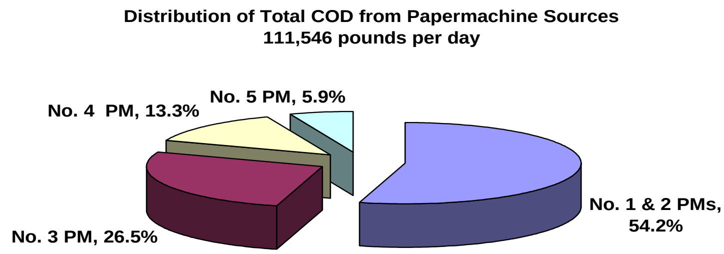

Figure 12. Distribution of COD by Paper Machine

Groundwood Mill. The groundwood mill also proved to be a major contributor of the total COD going to the wastewater treatment plant. The groundwood mill contributed 40,400 pounds per day of the total COD load from the process area that was monitored of which 20,903 pounds per day was soluble COD. Of the 40,400 pounds per day of total COD, 71.6% (28,941 pounds per day) originated from the North End Sewer which drains effluent from the twin wire press and the bleach plant. Approximately 90% of the North End Sewer (18,819 pounds per day) is soluble COD. This is to be expected since soluble organic material is released from the pulp during the hydrogen peroxide bleaching process which is conducted at high pH (10.5 to 11).

Black Liquor Cycle. In the Kraft mill the discharge of total COD to the general sewer was 20,476 pounds per day of which 47.1% or 9,647 pounds per day was soluble COD. The COD values for the Kraft Mill cannot be directly compared to those from the paper mill, the groundwood pulp mill, the power plant and contaminated condensates because discharge from the bleach plant was not monitored. The total COD from the power plant and contaminated condensates, also part of the black liquor cycle, was 43,242 pounds per day. The power plant and contaminated condensates consisted of six sources of COD: the "A" side flash steam condenser; the B" side flash steam condenser; the "A" side evaporator’s surface condenser; the "A" side evaporators pre-evaporator;

the "B" side surface condenser; and the "B" side evaporators 6th effect. Thus, the total black liquor cycle would consist of the Kraft pulp mill and contaminated condensates with a total COD of about 63,718 pounds per day. Of this total COD, about 52,889 pounds per day, or about 83%, was soluble COD.

Distribution of Total COD from Monitored Process Sources

The distribution of sources between the black liquor cycle, the paper machines, and the groundwood pulp mill is shown in Figures 13 and 14.

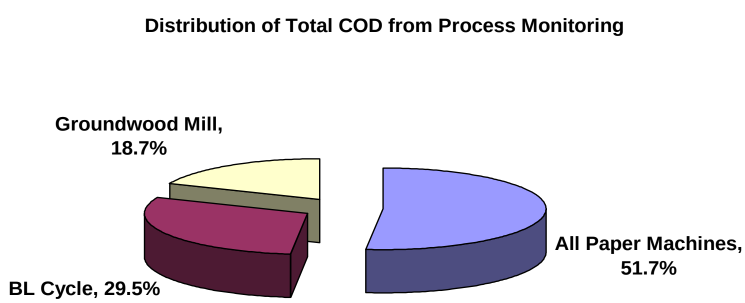

Figure 13. Distribution of Total COD (%) from Process Sources Monitored

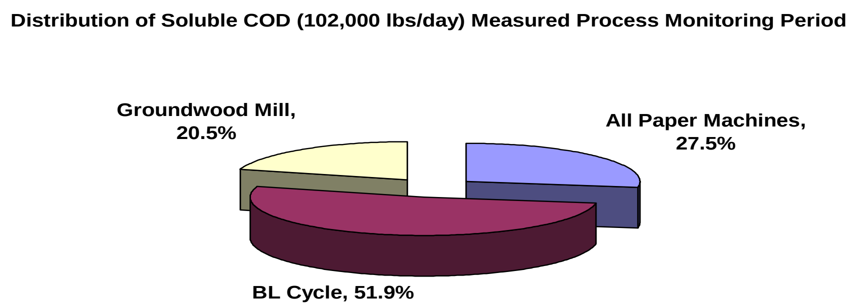

Figure 14. Distribution of Soluble COD (%) from Process Sources Monitored

The data in Figure 13 suggest that about 51.7% of the monitored COD originated from the paper mill, while 29.5% originated from the black liquor cycle, and 18.7% of the total COD originated from the groundwood mill. For soluble COD (Figure 14), the distribution was contrary to the total COD data with 51.9% coming from the black liquor cycle, 27.5% coming from the paper machines and 20.5% coming from the groundwood mill. It should be stressed that the bleach plant, which would be an important source of COD, was not monitored. These data, however, point out the fallacy of predicating the XL-2 Project goals solely on the production rate of unbleached Kraft pulp when there are many other sources of COD.

COD Data for Wastewater Treatment Plant

The COD monitoring data for the wastewater treatment plant obtained during 2004 are presented in Figures E11 through E15 in Appendix E. Figure E11 presents the data for the total COD measured at the bar screen. Please note that soluble COD was not monitored at this location within the wastewater treatment plant. The total and soluble COD for the inlet, presented in Figure E12, and the exiting, presented in Figure E13, flows from the lagoon, while Figures E14 and E15 present estimates for the removal efficiency for total and soluble COD, respectively, achieved in the lagoon. Average values of the data contained in these figures are summarized in Table 6.

Table 6. Summary of COD Data from Selected Wastewater Treatment Plant[(a)] Locations

Mill Location	COD (lbs/day)		Color (lbs/day)
	Total COD	Soluble COD	
Bar Screen	339,638	NA	NA
Lagoon Inlet	264,541	202,075	NA
Final Effluent	90,167	74,116	105,796
Efficiency (%) in Lagoon for COD Removal	65.9%	63.3%	NA
COD (kg/Tonne AD Unbleached Pulp)	35.6	28.7	NA
Color (lbs/Ton AD Unbleached Pulp)	NA	NA	83.8

(a) Average Data Taken from January 1 through Dec. 31, 2004.

Bar Screen. The measured value for the average total COD going to the bar screen was 339,638 pounds per day (Table 6). This may be compared to the total COD from all of the process sources given in Table 5, which was measured to be 215,664 pounds per day. The difference between the bar screen value and the process sources results from the other COD sources which were not monitored, namely the wood room, ring de-barker, Otis Mill sewer, the recaustization plant, PCC plant, the water treatment plant, the landfill leachate and the bleach plant as well as from sampling variability. Effluent from the bleach plant would constitute a significant source of COD going to the wastewater treatment plant from the black liquor cycle. Using the "A" Pulp Mill caustic sewer, the "B" Pulp Mill caustic sewer and the Acid Sewer data shown in Appendix D, Table D1 as a guide to approximate the bleach plant contribution shows that about 53% of the total COD and about 63% of the soluble COD is in the black liquor cycle. Though not all of this organic material would come from the bleach plant, a significant fraction would come from the bleach plant. No attempt was made to correct the monitoring data for bleach plant effluent since performing a sewer balance was not the intention of the monitoring program.

Also, please note that the contaminated condensates, 43,242 pounds per day of COD, are discharged directly into the aerated lagoon and bypass the bar screens. Therefore, the true difference between the bar screen value of 339,638 pounds per day and the sum of all process sources, exclusive of the source not monitored, is 175,264 pounds per day (i.e. 215,664 - 43,242 = 175,264). This difference further highlights the need to consider all sources of COD when trying to come up with a metric for regulatory purposes.

Lagoon Efficiency for Destruction of COD. The total COD entering the lagoon on average was estimated to be 264,541 pounds per day and that leaving the lagoon was estimated to be 90,167 pounds per day (see Table 6). The difference between the total COD measured at the bar screen (339,638 pounds per day) and that entering the lagoon (264,541 pounds per day) reflects that COD removed as suspended solids in the primary clarifier. A substantial portion of the primary sludge would be fiber fines and would be measured in the COD test.

Similarly, the soluble COD entering the lagoon was measured to be 202,075 pounds per day, and leaving was measured to be 74,116 pounds per day. Therefore the soluble COD constituted 76.4% of the total entering and about 82.2% leaving (see Table 6). The efficiency (η) for COD removal in the lagoon was estimated from the mass of COD entering $[(M_{COD})_{In}]$ and leaving the lagoon $[(M_{COD})_{Out}]$

$$\eta = \left[\frac{(M_{COD})_{In} - (M_{COD})_{Out}}{(M_{COD})_{Out}} \right] \qquad (6)$$

The efficiency of the lagoon for removing COD was found to be approximately 65.9% for the total COD and 63.3% for the soluble COD. This difference is so small as to be immaterial.

COD and Color in Mill Effluent during 2004 Monitoring Period

Using calculation methods proposed by the MEDEP, Figures 15 and 16 present the effluent discharge data for total COD and color, respectively, during the 2004 project monitoring period. The effluent data are calculated based upon the monthly average production data $(P_{monthly})$,

$$Effluent\ COD_i = \left[\frac{Q_i\ C_i}{P_{monthl\ \ j}}\right] = \left[\frac{kg / Day}{Tonne / Day}\right] = \left(\frac{kg}{Tonne}\right) \qquad (7)$$

where Q_i and C_i are the flow rate and concentration of the *"i-th"* sample during the *j-th* month. The calculations are based upon air dried tons of unbleached pulp and assume that the pulp contains 10% moisture, which is typical for dried market pulp. For example, on January 1, 2004 the flow rate (Q_i) and COD concentration (C_i) in the Mill effluent were measured and found to be 31.4 million gallons per day and 255 mg/liter, while the production rate for the month of January was 1,202 U.S. tons of air dried (10% moisture) unbleached pulp. Using these figures the COD in the Mill effluent on a metric tonne basis was estimated to be 27.7 kg/Tonne pulp for January 1, 2004.

$$Effluent\ COD_{Jan.1} = \left[\frac{\left(255\ mg \big/ liter\right) * \left(3.78\ liter \big/ gal\right) * \left(1\ kg \big/ 10^6\ mg\right) * \left(31.4x10^6\ gal \big/ day\right)}{\left(1202\ Ton \big/ Day\right) * \left(1Tonne \big/ 1.1\ Ton\right)}\right]$$

$$= \left(27.7\ kg \big/ Tonne\ Pulp\right) \qquad (8)$$

The data for the color in the effluent were estimated in a similar manner. The data for the maximum value was obtained by taking the maximum discharge in kg per day and dividing by the production rate for the month. Tables 7 and 8 summarize the statistics for the total COD and color in the Mill effluent. Data are presented for the average (X_{ave}), standard deviation (sd), sample size (n) and the two and three sigma limits.

Table 7. Statistics on COD in Mill Effluent for 2004 Process Monitoring Period

Item	Total COD (kg/metric Tonne AD Pulp)[(a)]	Maximum Value (kg/metric Tonne AD Pulp)[(a)]
Average	35.6	47.0
Std. Deviation (sd)	6.0	7.2
Sample Size (n)	300	12
X_{ave} + 2*sd	47.6	61.4
X_{ave} + 3*sd	53.6	68.6
X_{ave} -2*sd	23.6	32.6
X_{ave} -3*sd	17.6	25.4

(a) AD = Air Dry (10% moisture)

Table 8. Statistics on Color in Mill Effluent for 2004 Process Monitoring Period

Item	COLOR (lbs/US Ton AD Pulp)[(a)]	Maximum Value[(b)] (lbs/US Ton AD Pulp)[(a)]
Average	83.8	105.9
Std. Deviation (sd)	14.7	15.9
Sample Size (n)	204	12
X_{ave} + 2*sd	113.2	NA
X_{ave} + 3* sd	127.9	NA
X_{ave} - 2*sd	54.4	NA
X_{ave} - 3*sd	39.7	NA

(a) AD = Air Dry (10% moisture)
(b) Maximum value for color discharge in 2004 was 127.2 lbs/AD US Ton

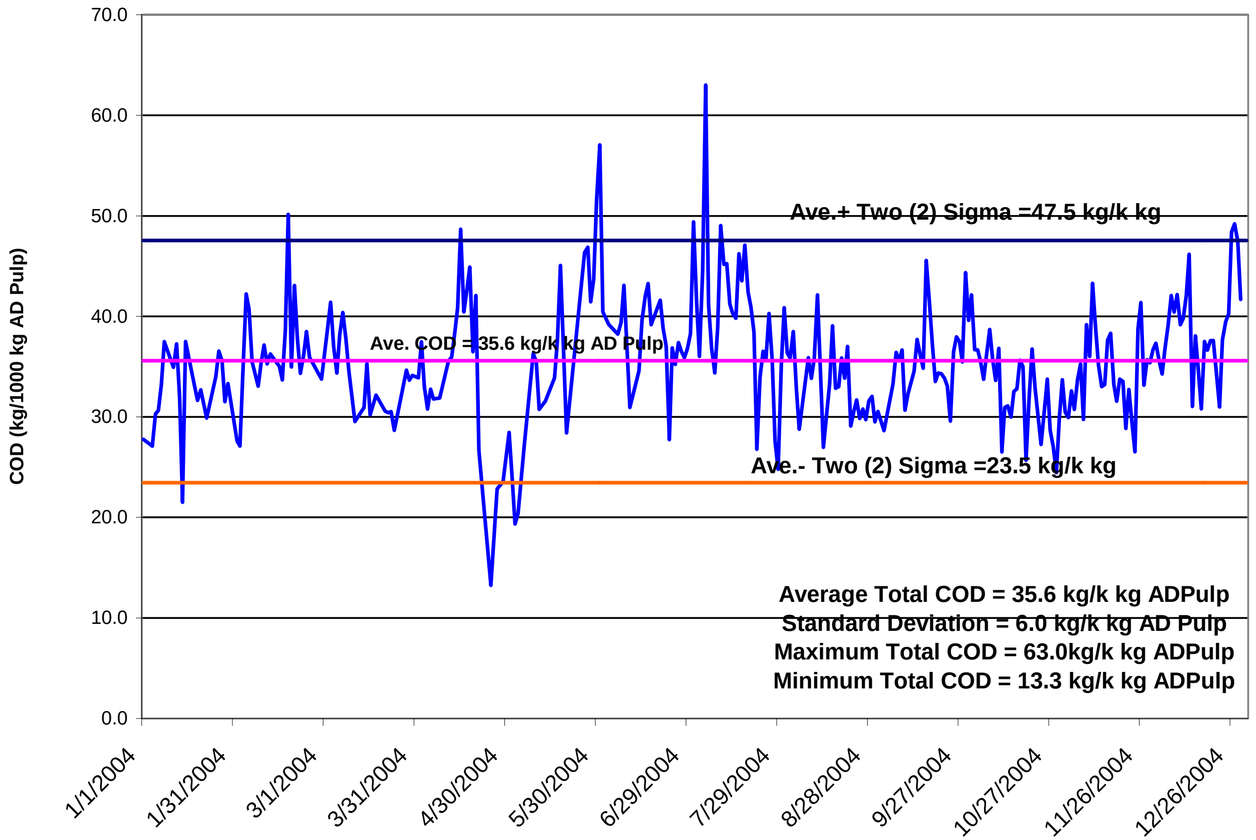

Figure 15. Total COD in Final Effluent in kg/1000 kg Unbleached Pulp

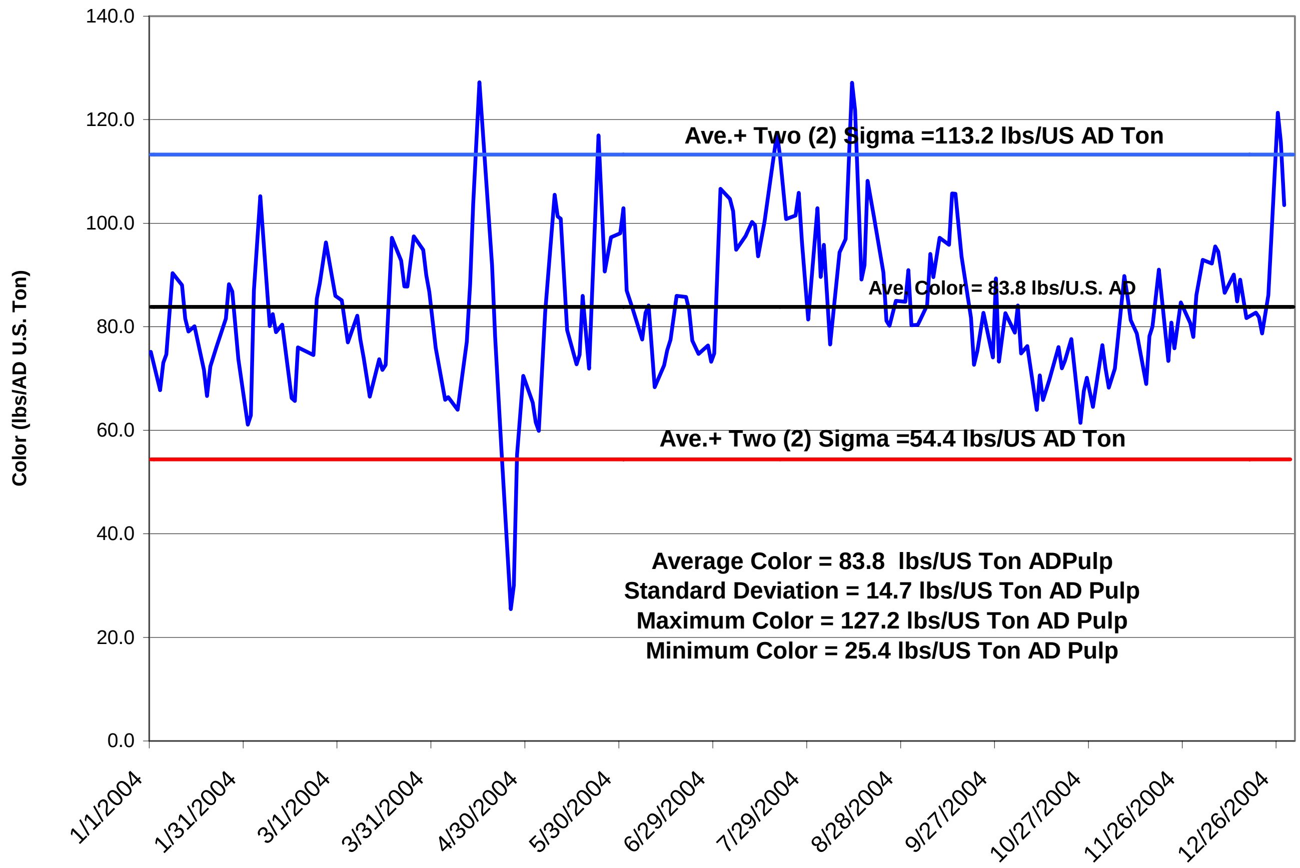

Figure 16. Color in Final Effluent in lbs per U.S. Ton AD Unbleached Pulp

Three hundred (300) samples for COD and two hundred and forty (240) samples for color were taken during the 2004 test period. These samples had a mean value for the effluent COD of 35.6 kg/metric ton of unbleached pulp and a standard deviation of +/- 6.0 kg/tonne (Table 7). Similarly the mean value for color was 83.8 lbs per US ton of unbleached pulp and a standard deviation of 14.7 lbs per ton (Table 8).

Recommended New COD and Color Discharge Limits

In the original agreement (Table 1) the proposed monthly average effluent discharge limit on COD was 50.7 kg per tonne. This value corresponds to the 95% percentile (2 sigma) values calculated from the mean value (X_{ave})[17]. Similarly, the daily maximum effluent limit in the original XL-2 agreement was 75 kg per tonne, and corresponds to the 99% percentile (3 sigma) applied to the data for the monthly maximum values.

New Monthly Average COD and Color Limits. Applying these criteria to the 2004 monitoring data, the two sigma limits for the monthly average COD limit would be 47.6 kg/tonne, and is the recommended limit for the monthly average. This may be compared to the proposed value for the monthly average effluent discharge limit of 50.7 kg per tonne specified in the XL-2 agreement (Table 1)[18]. Thus, using the method suggested by the ME DEP, the recommended value based upon the 2004 monitoring period represents a 6.1% reduction from the discharge limits specified in the original XL-2 agreement (50.7 kg per tonne).

Similarly, for color, the recommended new monthly average would be 113.2 lbs/US Ton AD pulp and corresponds to the two (2) sigma limit for the monthly averaged data (Table 8). This value may be compared to a value of 120 lbs/ton specified in the original XL-2 agreement, which represented the long term average of color effluent data (Table 1). The new recommended monthly average effluent limit (113.2) represents a 5.7% reduction in the monthly average color effluent limit relative to what was proposed in the original agreement.

[17] Wood, Gregory, Personal Communication (August 1, 2005).

[18] "International Paper XL Project: Effluent Improvements", Final Project Agreement, Androscoggin Mill, Jay, Maine. (June 29, 2000)

New Daily Maximum COD and Color Limits. Appling these same criteria to the daily maximum effluent limits, the three sigma (99% percentile) values would be 68.6 kg COD per tonne pulp and would be the recommended value for the maximum daily discharge limit. This may be compared to a value of 75 kg per tonne specified in the original XL-2 agreement. Thus, the recommended daily maximum discharge limit obtained using the 2004 process monitoring data would represent an 8.5% reduction from the value specified in the original agreement (75 kg per tonne). For color, taking the maximum value of color discharged in the effluent in 2004, the recommended new daily maximum color limit would be 127.2 lbs per US Ton AD pulp (see Figure 16).

Comparison of COD and Color Data in Monitoring to Base Periods

Data for the COD and color in the Mill effluent during the test period were compared to the data for the Mill effluent reported over the period from 1997 to 2004. These data are summarized in Figures 17 and 18 and given chronologically in Table 9.

Table 9. Average Daily Discharge of COD and Color by Year

Period	Total COD Discharge (kg/1000 kg UB AD Pulp)	Color (lbs/UB Ton AD Pulp)	Comments
1997	50.0	129.0	
1998	34.2	106.5	
July to Dec 1998	38.0	105.5	Base Period
1999	26.5	97.3	
2000	34.4	97.7	
2001	33.2	90.2	
2002	31.4	83.2	
2003	39.2	104.7	
2004	35.6	83.8	Test Period

The data in Table 9 vary considerably and reflect the operation of a large complex industrial plant which is constantly undergoing mill process and production changes driven by market conditions and available resources and operational issues. Operational issues during 2003 have been discussed by Cronin[19] in previous progress reports. One such operational problem occurred during the 4th quarter, 2002 and the 1st quarter, 2003 to the black liquor recovery boiler. The recovery boiler was out of service for a period of time, the boiler could not incinerate the black liquor, therefore, a portion of the black liquor was discharged to the wastewater treatment plant, in place of incineration, and this raised the COD and color in the Mill effluent. Also, during 2003 the new groundwood bleaching plant was started up and the No. 3 paper machine was rebuilt with increased production. Both of these mill process changes contributed considerable additional COD to the wastewater treatment plant.

The COD in the Mill effluent during the base period, July 1 to December 31, 1998, specified in Final Project Agreement[20] was 46.7 kg per tonne (Table 1). This value appears to be in error. Calculation of the COD in the base period using data provided by IP[21] gave a value of 38.0 kg per tonne unbleached pulp (Table 9). The total COD in the effluent samples for the 2004 testing period was 35.6 kg per metric ton of air dried unbleached pulp and compared favorably for the base period (38.0 kg per metric ton of air dried pulp), especially considering all of the changes and operational difficulties experienced by the mill. This represented a reduction of 6.3% relative to the base period and is modest on the face of the number.

$$\%\ COD\ \mathrm{Re}duction = \left[\frac{35.6 - 38.0}{38.0}\right] x100 = 6.3\% \qquad (9)$$

Similarly the data for color compared favorably for the test period during 2004 where color discharges averaged 83.8 pounds per air dried ton of unbleached pulp relative to the base period in June to December 1998 where the discharge was 105.5

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[19] Cronin, John, IP "Collaborative Team, XL-2 BMP Project 2003 Semi Annual Update and Meeting Minutes", (April 30, 2003), IP Collaborative Team 2003 Second Half, 2003 Semi Annual Update (October 31, 2003).

[20] "International Paper XL Project: Effluent Improvements", Final Project Agreement, Androscoggin Mill, Jay, Maine (June 29, 2000).

[21] Cronin, John, "COD and Color Excel Data Files COD_95_04 and Color_95_04.

pounds per air dried ton. Here the reduction in color amounted to 20.6% and reflects the numerous process modifications to the black liquor cycle.

$$\% \, Color \; Reduction = \left[\frac{83.8 - 105.5}{105.5} \right] x100 = 20.6\% \qquad (10)$$

The difference in the data between the COD and the color can be reconciled if we consider the numerous changes that have taken place in the Mill. The screen rooms in both Kraft mills were closed and the oxygen delignification system was improved; although only lately has it been operated at the higher temperatures that were envisioned at the time the improvements were made. These changes would naturally lead to reductions in both COD and color going to the wastewater treatment plant. But the paper mill increased production during the test period and major changes occurred in the groundwood mill. These changes would be expected to increase the discharge of COD going to the wastewater treatment plant, but not necessarily increase proportionally the color going to the wastewater treatment plant. Thus, we see a quantifiable reduction in color but a much smaller reduction in COD. This is especially true from an inspection of. the data in Table 9 which indicate that in 1999 the COD discharge was as low as 26.5 kg per metric ton of air dried pulp. This was about the time that initial steps were taken to reduce point sources of discharge of black liquor from the screen room.

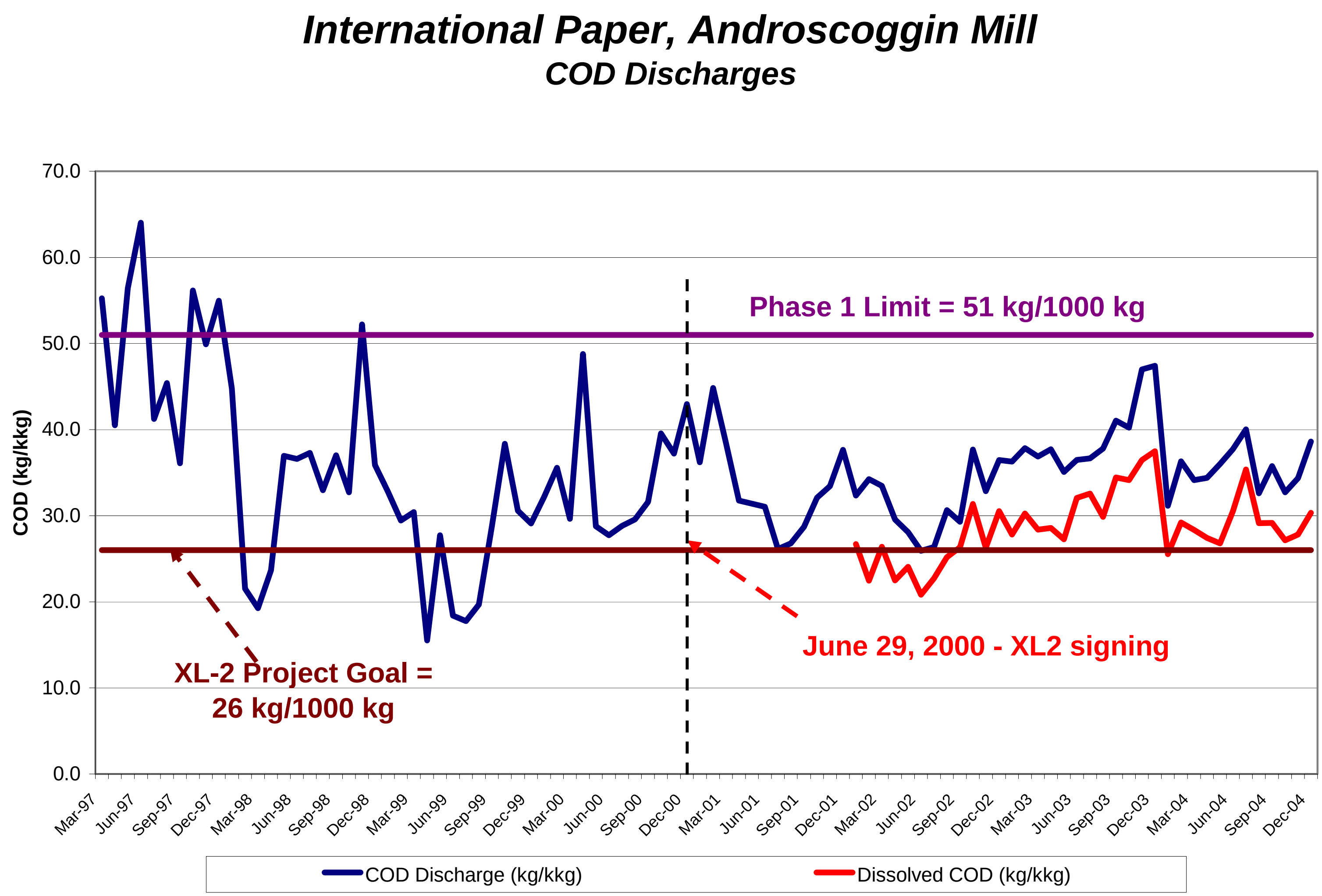

Figure 17. Effluent Discharge of COD from Androscoggin Mill During the Course of the XL-2 Project

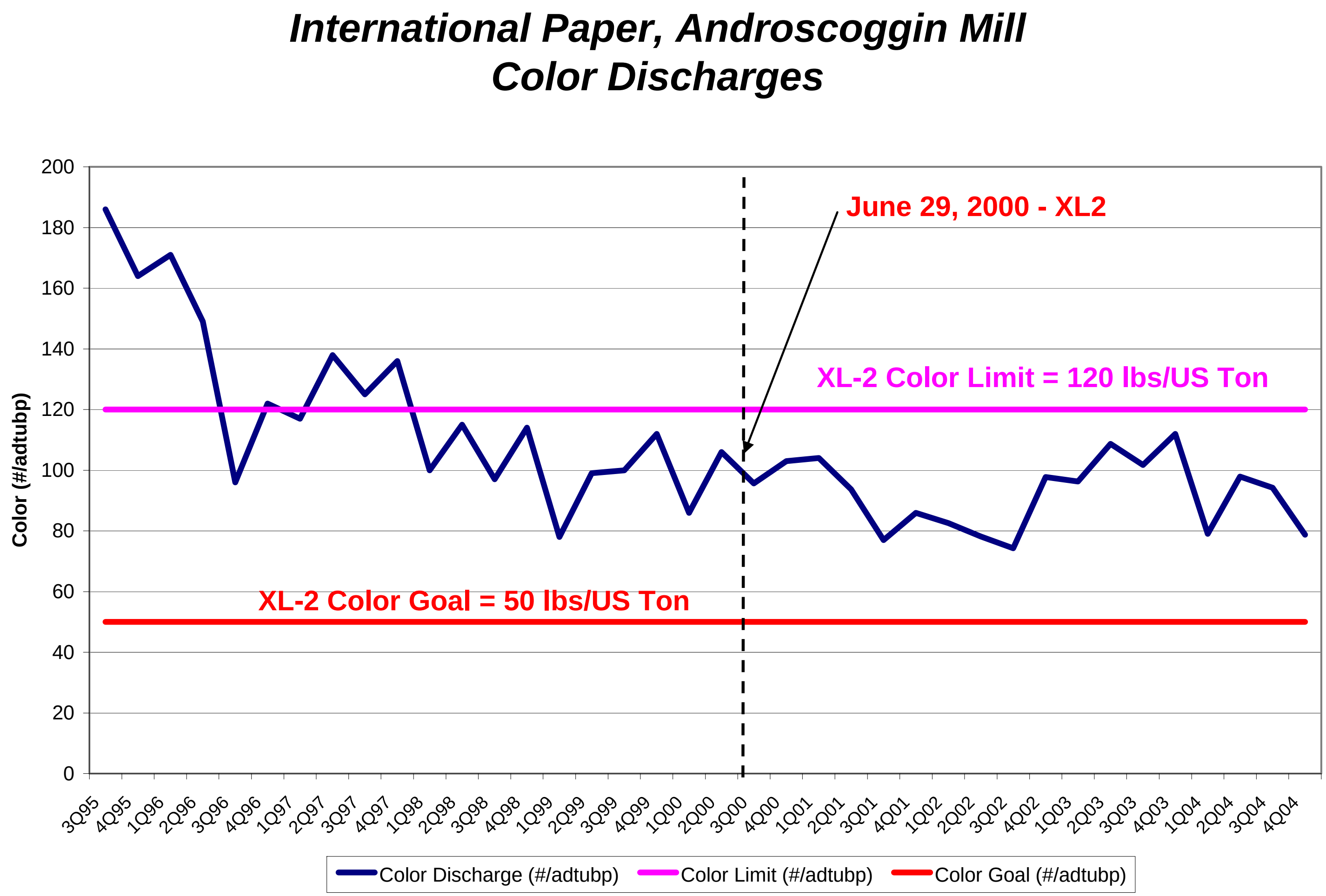

Figure 18. Effluent Discharge of Color from Androscoggin Mill During the Course of the XL-2 Project

DISCUSSION OF XL-2 PROJECT

Project Goals

The COD goal set forth in the Final Project Agreement following the three-year XL project was 26 kg COD per air-dried metric ton of unbleached pulp production (ADMT) based upon a monthly average while the COD discharge in the Mill effluent averaged 35.6 kg per ADMT during the test period (Figure 15). Similarly the long-term color goal for the project was 50 pounds per U.S. ton (air-dried) of Kraft pulp produced on a quarterly average basis. Color discharge from the Mill during the 2004 testing period was approximately 83.8 pounds per U.S. ton (Figure 16).

Although the project did not meet the original goals set forth in the Agreement, the XL-2 Project goals were stretch goals and difficult to meet given the limited capital funds available for the XL-2 Project. The original goal of 26 kg COD per was predicated upon a draft of the Cluster Rules and was not incorporated into the final EPA standards and had an estimated cost in the tens of millions of dollars; whereas the XL-2 Project had $780,000 of capital to spend. Rather, strides were made in reducing the spent cooking liquors being released to the wastewater treatment plant on a continual basis that were originally targeted by the BMP regulations.

Setting Goals

To set effluent reduction goals for a given mill is quite complex and depends very much upon the specific mill site. To have some semblance of setting achievable goals, the various COD sources would have to be identified based upon detailed sampling and COD balances performed for the site taking into account all of the sources. Reduction goals would then be selected by considering what sources of COD can be changed by process modifications at a reasonable cost. In the current program only the black liquor cycle was considered when the goals of the project were set and in reality all of the sources of COD should have been considered. In addition, to further reduce effluents the paper machines would also have to be considered and the capital budget would have to be expanded greatly.

Process Modification Projects

All of the projects that were invested were successful to some degree except for the funds expended on the tie-in piping for the proposed entrainment separator on the softwood ("A") pulp mill. The XL-2 funds ($990,000) were spent on process modifications in three areas (Table 10). Process modifications were related to reducing loss of black liquor to the sewer during pulp screening in the softwood ("A") and hardwood ("B") mills ($202,000), improvements to the oxygen system on the softwood pulp mill ($571,000) and projects related to process monitoring ($198,000). In addition, several IP internal projects also reduced COD discharge to the wastewater treatment plant, notably projects related to screen room closure ($12,000) and modifications to the softwood "A" side digester projects ($624,000).

Table 10. Summary of All COD Reduction Projects

Projects	XL-2 Projects		IP Internal Projects	
	Lbs COD/Year	$ (1000)	Lbs COD/Year	$ (1000)
Screen Room Closure	7.0×10^6	$202	2.3×10^6	$12
O_2 System Improvements	1.7×10^6	$571	NA	NA
Sewer Monitoring and Evaporator Sump Control Project	Not Quantifiable	$198	NA	NA
Digester Modification Project	NA	NA	5.8×10^6	$624
Tie Ins for Entrainment Separator	NA	$19	NA	NA
Totals	**(8.7×10^6)**	**($990)**	**(8.1×10^6)**	**($636)**

Screen Room Closure. Closing the screen rooms in the "A" and "B" pulp mills was clearly an important strategy for the Mill in reducing COD discharges to the wastewater treatment plant. A total of $214,000 was spent on this strategy; $202,000 under the XL-2 Project and $12,000 of internal funds. Although the actual reductions are hard to quantify, this strategy led to an estimated reduction of 9.3×10^6 pounds per year of total COD, one of the highest COD reduction projects undertaken and extremely cost effective.

Improvements to the O2 System. On the surface, the investment in the improvements to the oxygen delignification system was a relatively costly project, with the XL-2 Project team expending $571,000 on this project, and achieving only an estimated reduction in COD going to the wastewater treatment plant of about $1.7x10^6$ pounds per year. The low reduction in the COD results from limitations in the post oxygen washer being able to wash the pulp if higher levels of delignification were achieved. However, the improvements to O_2 system in the "A" pulp mill puts the Mill in a position to further close the "A" bleach plant if and when internal funds become available to refurbish or replace the existing post oxygen washers. The driving force for the oxygen delignification project was two fold: the reduction in the COD from the bleach plant and also a potential reduction in ClO_2 consumption in the softwood ("A") bleach plant.

Sewer Monitoring. Installation of the sewer monitoring program at a cost of $120,000 is considered one of the highlights of the XL-2 Project. The sewer monitoring project, although not quantifiable in terms of reductions in COD, permits continuous process monitoring and avoidance of black liquor going to the sewers. It is a tool being used by the operators on a daily basis to prevent black liquor spills which reduces soda and sulfur losses to the sewer that must be made up in the recovery area where the digester chemicals are recycled.

Evaporator Sump Control Projects The evaporator sump control project ($78,000), although difficult to quantify in terms of COD reductions, is an excellent example of environmental stewardship. Evaporator condensates are some of the foulest byproducts from the Kraft process and this project tries to minimize discharge of such materials to the wastewater treatment plant.

Softwood Digester Modification Project. The softwood digester modification project was not technically part of the XL-2 Project. However, it had a direct impact on the effectiveness of the XL-2 Project and is a good example of process modifications that leads directly to environmental benefits. Although the softwood digester modification project was relatively expensive ($624,000), it significantly improved the operation of the "A" digester and also reduced the level of COD going to the wastewater treatment plant an estimated $5.8x10^6$ pounds per year. This was the second most effective project undertaken for COD reduction from the black liquor cycle next to the screen room closure projects.

Observations Regarding the XL-2 Project

Several observations became apparent during the course of the XL-2 Project that are worth noting.

Pollution Abatement is Site Specific. Pollution abatement is mill specific. In the Androscoggin Mill, the pollutant under consideration was organic material characterized by the COD test. The discharge of COD will depend upon the pulping and bleaching facilities present at the site, the structure of the paper mill, and the support operations. These unit processes will obviously depend upon the grade(s) of paper being produced at the site. For example, you cannot compare the Androscoggin Kraft mill, which has both hardwood and softwood Kraft pulping operations plus a bleached groundwood mill to a simple one line fiber operation which, for example, only processes hardwood by the Kraft process. Likewise, it is difficult to compare a coated paper mill to an uncoated free-sheet paper mill or to a tissue mill.

Limitations of an Older Mill. It also became quite apparent that an older mill cannot be treated in the same manner that one would treat a new facility. In an older mill such as the Jay, Maine facility, space is limited; and retrofit costs will limit what process modifications can be made for pollution abatement. A good example of this at the Jay, Maine facility was the entrainment separator project; this project had to be abandoned because of space limitations which necessitated a high cost for the project. Items such as re-piping and building modifications make projects more complex and expensive. Also, at an older mill site, often the paper is produced on older, slower paper machines so that paper production is limited. Consequently, the ability to spread the cost of the pollution abatement for the mill complex to paper production will be limited by the volume of saleable product. Thus, there will be inherently higher pollution abatement costs and more reluctance to take on pollution abatement projects in an older facility.

Changing Business Environment. Another important lesson learned at the Jay, Maine facility was that business conditions changed during the XL-2 Project, which was reflected in changes to the product mix and the facilities required for producing the products at a completive cost. Some of the changes to the Mill were enumerated earlier in this report. The original goals on the Project were predicated upon a Mill configuration that existed in 1999. Changes such as the move to hydrogen peroxide bleaching in the groundwood pulping operation, conversion to higher production of coated paper, and increased production on the paper machines influenced the final outcome of the Project.

Soluble COD. The total COD test gives an indication of both soluble and insoluble COD and includes suspended pulp and other papermaking solids. Toxic substances originating from the bleach plant and black liquor cycle are more likely to reside as truly dissolved and fine colloidal material rather than as suspended solids. As such, toxic substances would most likely be detected in the soluble COD test. In the COD balances, high COD/BOD ratios of some of the coated machine effluents indicated persistence through the wastewater treatment plant. Small particulate size of some of the coating fillers, notably titanium dioxide, also resisted settling and had an effect on color measurements. These materials tended to be colloidal in nature and had much less effect on filtered test results. For this reason, soluble COD (sCOD) appeared to be a better indicator for spent cooking liquors targeted by the BMP regulation.

Revised COD Test Method. Currently, EPA Standard Method 410.4 does not address the filtration of the COD samples. A separate soluble COD test does not exist. While total COD may remain a good overall indicator of environmental pollution, soluble COD may be a better measure for process control and monitoring. The EPA may wish to revise the COD test to measure soluble more persistent substances.

COD Discharge Limits and COD Metric. In setting discharge limits for COD, regulator agencies may wish to consider basing discharge regulations on the final products being produced at the mill sites. Using the Androscoggin Mill as an example, the discharge metric is based upon the total production rate of unbleached Kraft pulp. This metric does not recognize the contributions from the numerous unit processes that exist in the paper mill and groundwood pulping facility. Also, the contribution from the Otis Mill to the COD load on the wastewater treatment plant should be considered. Perhaps a more appropriate COD metric would be to base the discharge limits on the dry tons of paper produced or a combination of dry tons of paper and market Kraft pulp with proper accounting for the contribution for the Otis Mill.

The effluent limits described in this report are production based standards and take into account the amount of unbleached Kraft pulp produced in establishing limitations. This standard, however, does not take into account the amount of groundwood pulp produced, which in the case of the Androscoggin Mill, is more than 25% of the total pulp produced.

CONCLUSIONS AND RECOMMENDATIONS

Meeting the Primary Goal

The primary goals of the XL-2 Project were to provide leadership in environmental stewardship and flexibility in regulation as an alternative to the command and control approach enumerated in the Cluster Rules. Under the Cluster Rules, the IP Mill would have been required to install additional dikes and berms to control spills of black liquor from black liquor storage tanks at the Mill. Since the Mill already had dikes and berms, and because black liquor spills from storage tanks are rare, adherence to the exact regulations clearly would have been a poor expenditure of capital resources. However, with the flexibility granted to the Mill under the XL-2 Project, monies were spent on a variety of process modifications projects that accomplished both process improvements at the Mill and reductions in the COD going to the wastewater treatment plant from the black liquor cycle. This was a win-win situation as the XL-2 Project conducted at the Androscoggin Mill has accomplished the intended goal and can serve as a model for similar programs at other mill sites, if there was interest.

Organic materials measured by the COD test from the assorted process areas often represent loss of raw materials with associated costs to mills. Because of potential benefits from the projects selected under the XL-2 Project, expenditures by the Androscoggin Mill on COD reduction projects exceeded the $780,000 required to build the dikes and earth berms under the command and control approach to regulation. All of the major projects undertaken under the XL-2 Project have led to process improvements and reductions in COD being discharged from the black liquor cycle. For example, closing up the screen room, and modifications to the softwood cooking process undertaken at the Androscoggin Mill outside of the XL-2 Project, reduces loss of wood solids and pulping chemicals, notably sodium and sulfur going to the sewer and the wastewater treatment plant. Recovery of wood solids and pulping chemicals improves the energy balance in the Mill and avoids purchase of costly makeup chemicals such as caustic in the recovery process. Similarly, installation of process modifications to the oxygen delignification system has led to smoother operation in the softwood fiber line and potential cost reductions for bleach chemicals as well as reductions in COD going to the wastewater treatment plant. Expenditure of funds on the mixing equipment in the oxygen delignification system lays the foundation for further economies in the bleach plant for reducing ClO_2 and initiates closure in the softwood ("A") side bleach plant. Installation of the sewer monitoring program is one of the highlights of the XL-2 Project, and led to monitoring raw material losses from the Kraft pulp mills and the Power Plant area, which go to the wastewater treatment facility as COD and dissolved solids. It should be pointed out that the process monitoring program instituted under the XL-2 Project had its origin in the Cluster Rules.

Advantages and Disadvantages of the XL Method

One notable advantage of the XL Method approach over the traditional command and control approach is that IP's engineers worked in concert with town, state and federal regulatory personnel to select projects that accomplished the intent of the regulations but also had positive economic benefit for the Mill. This flexible approach is extremely important to the paper industry in the current business climate where many paper companies are trying to survive tough competition and low prices for their products.

A disadvantage of the XL methodology is that it is very time consuming. Contrary to the command and control approach, COD balances and process analyses had to be performed prior to the identification and selection of the process improvement projects. The sewer COD balances and the subsequent process analyses then dictated which process improvement projects were selected for implementation. The engineering analysis, although time consuming, had positive benefits for the Project Technical Team, but could be a deterrent at sites and organizations with limited personnel.

Transferability

A notable conclusion drawn from the XL-2 Project is that the methodology employed in the current program should be transferable to other paper mill sites. Lessons learned on the XL-2 Project that are transferable to other sites are that pollution abatement is site specific and older mills cannot be treated the same way as modern mills. Also, since the XL approach takes time to come to fruition and the business climate changes rapidly, allowances must be made for changes at the mill necessitated by the business climate. This may conflict with the intended goals of the XL Project. Thus, flexibility in setting achievable goals and selecting practical projects is important. For example, in the present XL-2 Project, the potential projects were only apparent after the sewer balances and engineering analysis were performed.

Effluent Metric

Another conclusion drawn from the experiences of the XL-2 Project is that in setting discharge limits for COD and color, regulator agencies may wish to consider basing discharge regulations for COD and color on the final products being produced at the Mill site rather than on intermediate products such as unbleached Kraft pulp. A more appropriate COD and color metric would be to base the discharge limits on the dry tons of paper product produced or a combination of dry tons of paper and market Kraft pulp. Using the current unbleached Kraft pulp metric does not take into account for increasing paper production, which increases the COD release rate, if it occurs with constant, or near constant Kraft pulp production. Other examples include the case where the product mix changes, for example the conversion from uncoated to coated paper; or when different pulps are produced, which was the case at the Androscoggin Mill where additional groundwood was produced but is unaccounted in the metric. Thus, for a variety of reasons basing the metric on one intermediate product, in this case unbleached Kraft pulp, may not be the best metric.

Final Comments

This type XL Project may be appropriate for other industrial facilities. The facility must be amenable to a more time-consuming approach and have the commitment, integrality and disposition to work closely with the regulatory agencies. Clearly, this was the case in the current XL-2 Project where the IP management was committed to a more flexible approach to regulation.

APPENDIX A

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APPENDIX B

DESCRIPTION OF THE PULP AND PAPER PROCESS AT THE IP ANDROSCOGGIN MILL IN JAY MAINE AT THE INCEPTION OF THE XL-2 PROJECT

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DESCRIPTION OF THE PULP AND PAPER PROCESS AT THE IP ANDROSCOGGIN MILL IN JAY MAINE AT INCEPTION OF XL-2 PROJECT

Pulp Production at IP Androscoggin Mill in Jay Maine

The softwood ("A") and hardwood ("B") fiber lines are illustrated schematically in Figures B1 and B2. The production rate on the "A" fiber line is approximately 640 tons per day bleached softwood Kraft pulp on a dry basis or about 710 tons per day assuming 10% moisture. The production rate on the "B" fiber line is about 480 tons per day of bleached hardwood Kraft pulp or about 533 tons per day again calculated based on 10% moisture.

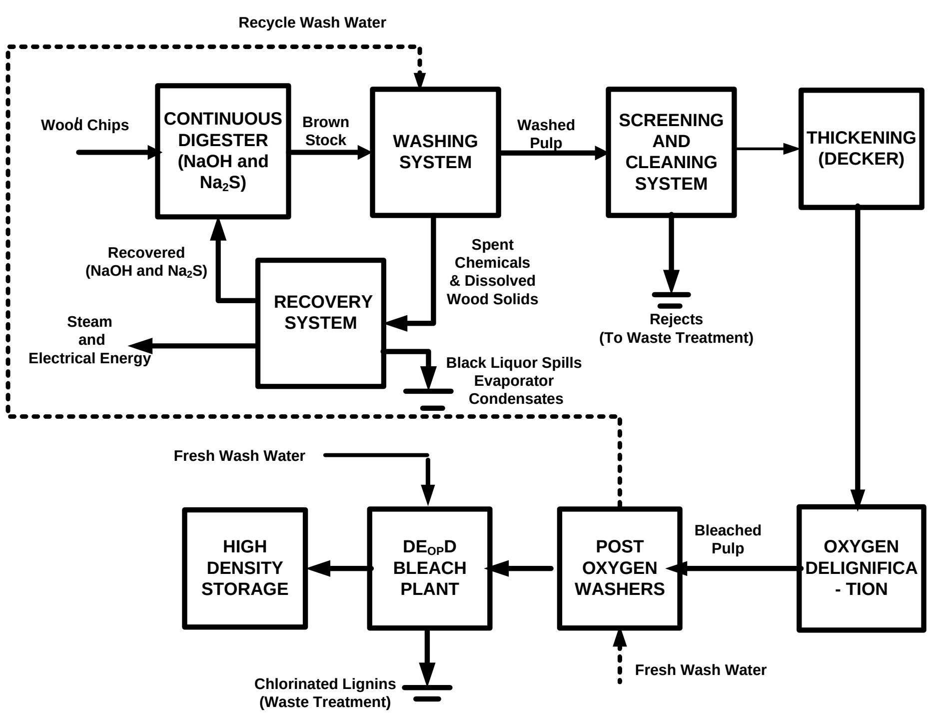


Figure B1. Schematic Diagram of the Softwood Kraft Mill (A Side) at IP Jay Maine

Softwood ("A") Fiber Line

In the softwood fiber line (Figure B1), chips are sent to a Kamyr continuous digester where the wood is macerated with white liquor consisting of sodium hydroxide

(NaOH) and sodium sulfide (Na_2S) as the active delignifying agents. After the continuous digester, the pulp is washed using rotary drum vacuum washers and screened and cleaned to remove oversized material and debris from the pulp and thickened prior to oxygen delignification system. The pulp is bleached in the bleach plant to 87.5 ISO brightness in a three-stage bleaching sequence ($DE_{OP}D$). In the bleaching process, the pulp is oxidized using chlorine dioxide (D), then extracted with caustic which has been reinforced with oxygen and hydrogen peroxide (E_{OP}), and finally oxidized again using chlorine dioxide (D). In all three of these stages, the brightness of the pulp is increased as the pulp proceeds through the bleach plant.

Water from the post oxygen washers is recycled back to the washing system where the filtrate is sent to the recovery system for recovery of dissolved solids in the form of steam and electrical power (Figure B1). The active chemicals comprising the white liquor are NaOH and Na_2S and are regenerated in the recovery cycle. The oxygen delignification process is a "mini" O_2 system and only has a 20 minute up-flow medium consistency tower rather than the conventional 60 minute tower or a two stage pressurized system. The use of an oxygen stage however, reduces the level of organic material in the waste streams emanating from the softwood bleach plant.

Hardwood B Line

The hardwood fiber line is illustrated in Figure B2 and is very similar conceptually to the softwood line except that the hardwood line does not contain an oxygen delignification system. The kappa number of the pulp leaving the digester is approximately 15. In the hardwood fiber line the pulp is bleached to 87.5 ISO brightness using the $DE_{OP}D$ bleaching sequence. Lack of an oxygen delignification system on the hardwood pulp mill would result in higher levels of residual lignin in the pulp going to bleach plant and thus, higher levels of organic solids in the effluent emanating from the bleach plant going to the wastewater treatment plant.

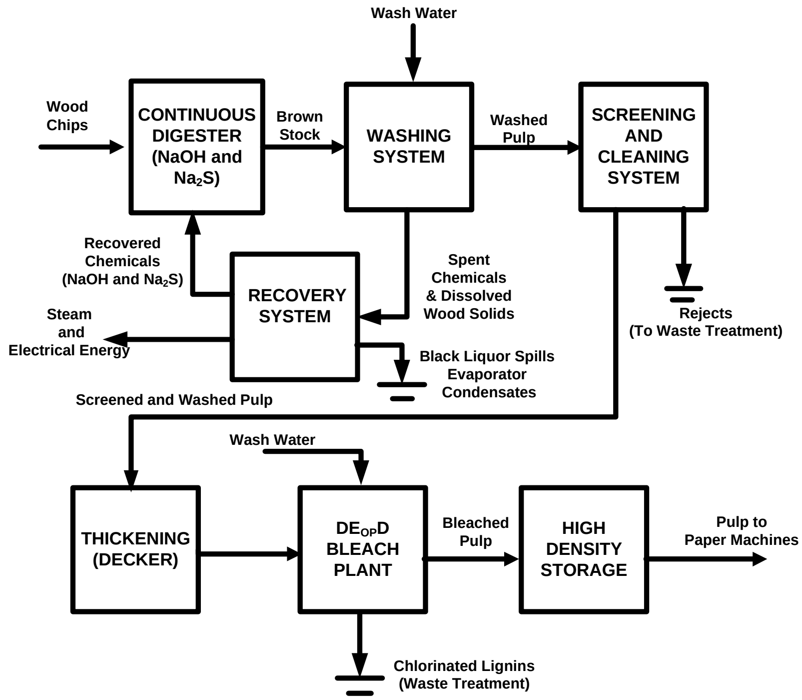


Figure B2. Schematic Diagram of the Hardwood Kraft Mill (B Side) At IP Jay, Maine

Kamyr Continuous Digesters

A schematic of the Kamyr continuous Kraft pulping systems used at the Androscoggin Mill is illustrated in Figure B3 and consists of a single-vessel hydraulic digester. The chips are continuously steamed initially in a chip bin at atmospheric pressure and then in a low pressure (20 psig) steaming vessel where turpentine and other volatile extractives are vented to a condenser (Figure B4). Chips and white liquor are fed to the top of the digester. The chips first pass through an impregnation zone where liquor is impregnated into the chips, the temperature is then raised to about 170 °C in a heating zone by circulating the white liquor through upper- and lower-zone heat exchangers. The chips are then held at constant temperature as they pass through a cooking zone. The delignification and some carbohydrate degradation reactions take place in the heating and cooking zones in the digester. The chips and pulping liquor move in co-current flow in the impregnation, heating, and cooking zones in the digester. After the cooking zone, the chips next pass continuously through to a countercurrent washing zone in the bottom of the digester.

The spent pulping solution, or black liquor, leaves the digester at the bottom of the cooking zone (Figures B3 and B4). The spent pulping liquor is extracted from the digester through screens located in the digester wall. The function of the screens is to extract liquor while keeping the chips in the digester. In a conventional hydraulic digester, lignin fragments and other wood solids in the chips are removed in the washing zone of the digester, where the chips and liquor pass in counter-current fashion, with the chips moving downward and the wash liquor moving upward. The wash liquor moving upward in the digester mixes with black liquor moving downward. The extracted black liquor is sent to flash tanks where water vapor and volatile organic compounds are removed and sent to a condenser and then to a sewer for treatment in the wastewater treatment plant. The chips exit the bottom of the digester through a blow valve or outlet device. The pressure drop across the blow valve provides sufficient force to fiberize the cooked chips. From the digester, the pulp is then washed further and sent to intermediate Brownstock storage. Pulp leaving the Kamyr digester on the softwood side has a kappa number of about 27.5, about 4.1% lignin, and on the hardwood side at about 15 kappa number, about 2.5% lignin.

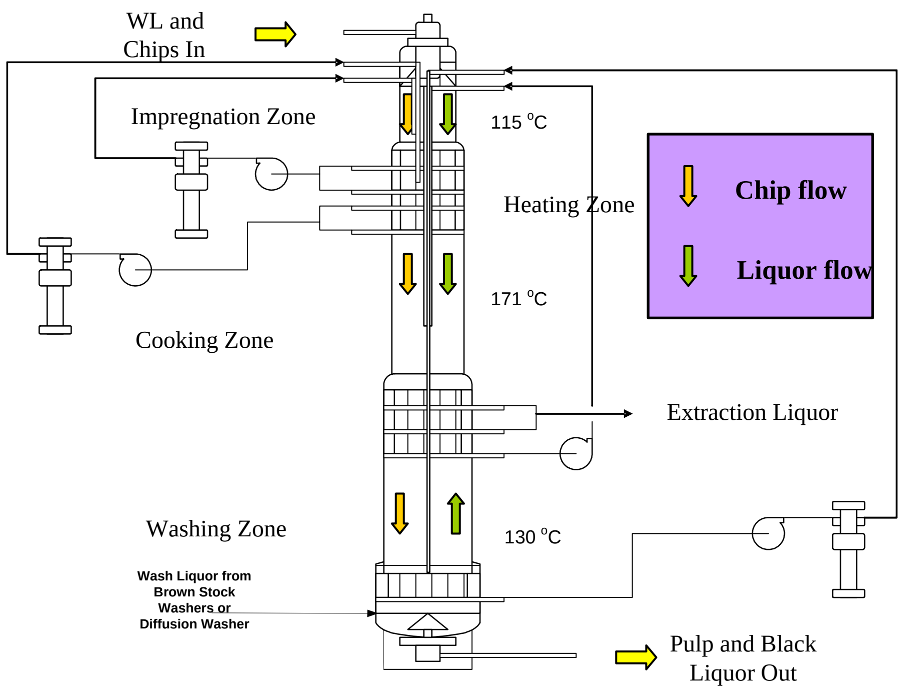


Figure B3. Kamyr Digester with Conventional Co-Current Washing

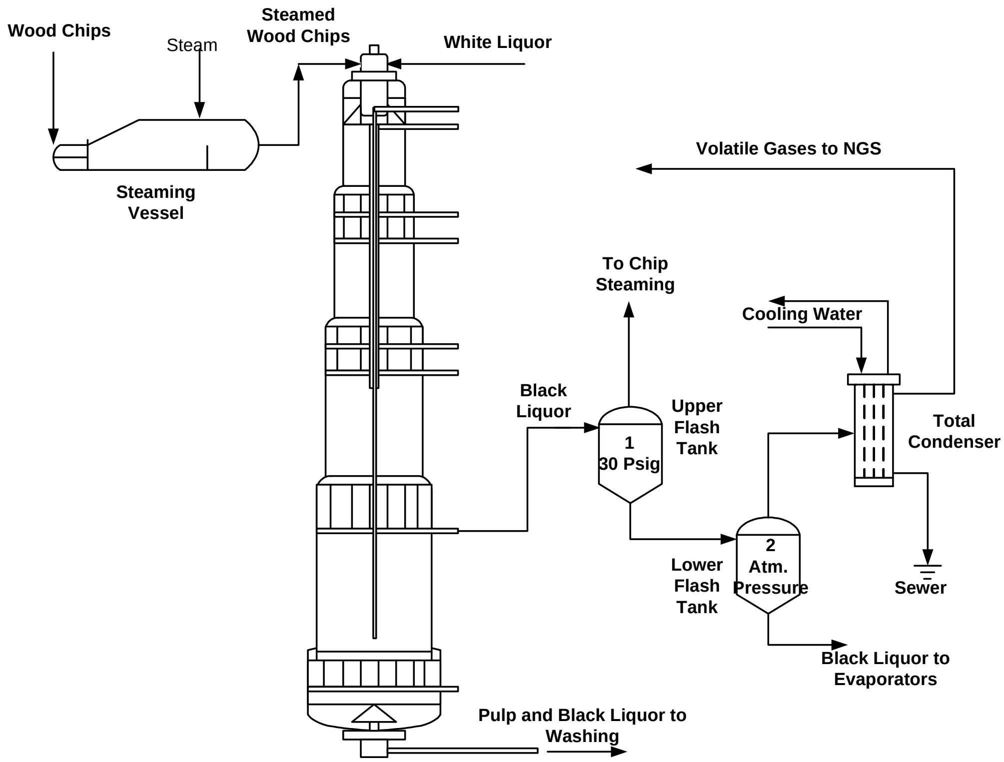
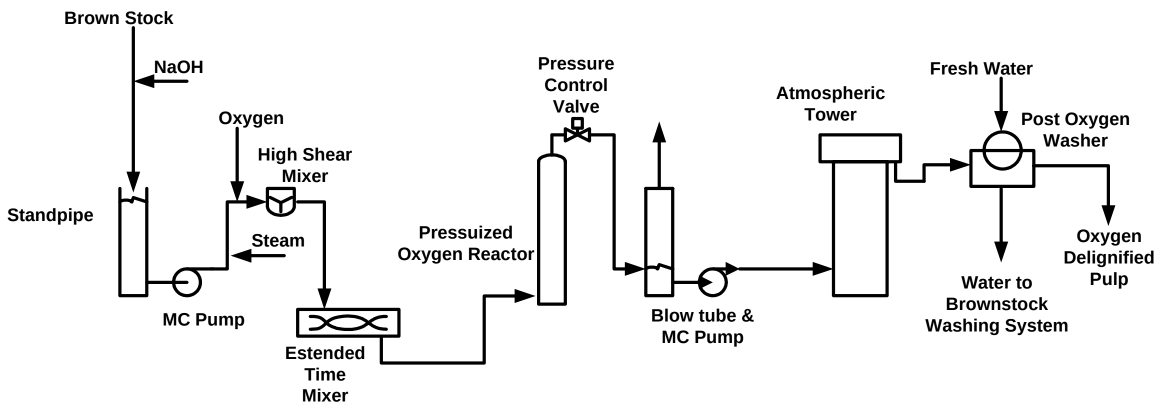


Figure B4. Extraction Zone for Continuous Kraft Digester

Mini-Oxygen System in the Softwood "A" Mill

The softwood pulp mill also has a "mini-Oxygen delignification system (see Figure B5). In this system, caustic is added to the Kraft Brownstock pulp, which has a Kappa number of approximately 26 to 28. From a standpipe, the pulp is pumped with a medium consistency pump through a high shear mixer and extended time mixer, in which the rotary elements have been removed. The pulp then flows through a pressurized reactor with a residence time of about 15 minutes. The pulp then is brought to atmospheric pressure in a blow tube and pumped through an atmospheric tower and then washed in rotary drum post-oxygen washers. The pulp is thickened in the rotary drum washer by using a vacuum created primarily by a falling leg of filtrate. Filtrate from the post oxygen washers is recycled back to the Brownstock washers and then to the digester where it is extracted and sent to the evaporators. The oxygen delignification system at Jay traditionally reduced the kappa number of the pulp by about 25%. Having an oxygen stage prior to a traditional bleach plant reduces the emissions of COD, BOD and color in the effluent going to the wastewater treatment plant[22]. The main disadvantage of an oxygen stage is that compared to chlorine dioxide stages (D), it has both lower reactivity and selectivity[23]. The other disadvantage is the high capital cost of installing an oxygen delignification system.



Softwood O_2 System at IP Androscoggin Mill

Figure B5. Oxygen Delignification System on Softwood ("A") Side

Chemical Pulp Bleaching at IP Jay

Elemental chlorine free bleaching (ECF) is practiced at the IP Jay, Maine pulp mill. The $DE_{OP}D$ bleach sequence is used in both the hardwood and softwood pulp mills (Figure B6). In the $DE_{OP}D$ bleach sequence, the pulp is bleached to 87.5 ISO brightness in three stages; an initial chlorine dioxide stage (D_1), an extraction stage that has been reinforced with oxygen and hydrogen peroxide (E_{OP}) and finally a second chlorine dioxide stage (D_2). In the first chlorine dioxide stage sulfuric acid (H_2SO_4) is added to the pulp to control the pH of the reaction mixture and chlorine dioxide (ClO_2) is added as the oxidizing agent to bring about delignification of the pulp. In the caustic stage, sodium hydroxide, oxygen (O_2), and hydrogen peroxide (H_2O_2) are added to remove

[22] Croon, I, and Andrews, D. H., "Advances in Oxygen Bleaching: 1. Demonstrations of its Feasibility and Scope", Tappi 54(11): 1983(1971).

[23] McDonough, T. J., "Kraft Pulping Bleaching Technology: A Brief Overview of Basic Principles and Current Trends", Institute of Paper Science and Technology Atlanta, GA (1992).

oxidation products formed in the D_1 stage and further oxidize the pulp with O_2 and H_2O_2. The function of the second D_2 stage is to raise the brightness of the pulp by further application of ClO_2. In all three stages, fresh wash water is added to the pulp washers. Filtrates from the D_1 and D_2 stage washers go to the acid sewer while filtrate from the E_{OP} washers is discharged to the alkaline sewer. These filtrates are large contributors to the COD and color load leaving the bleach plant.

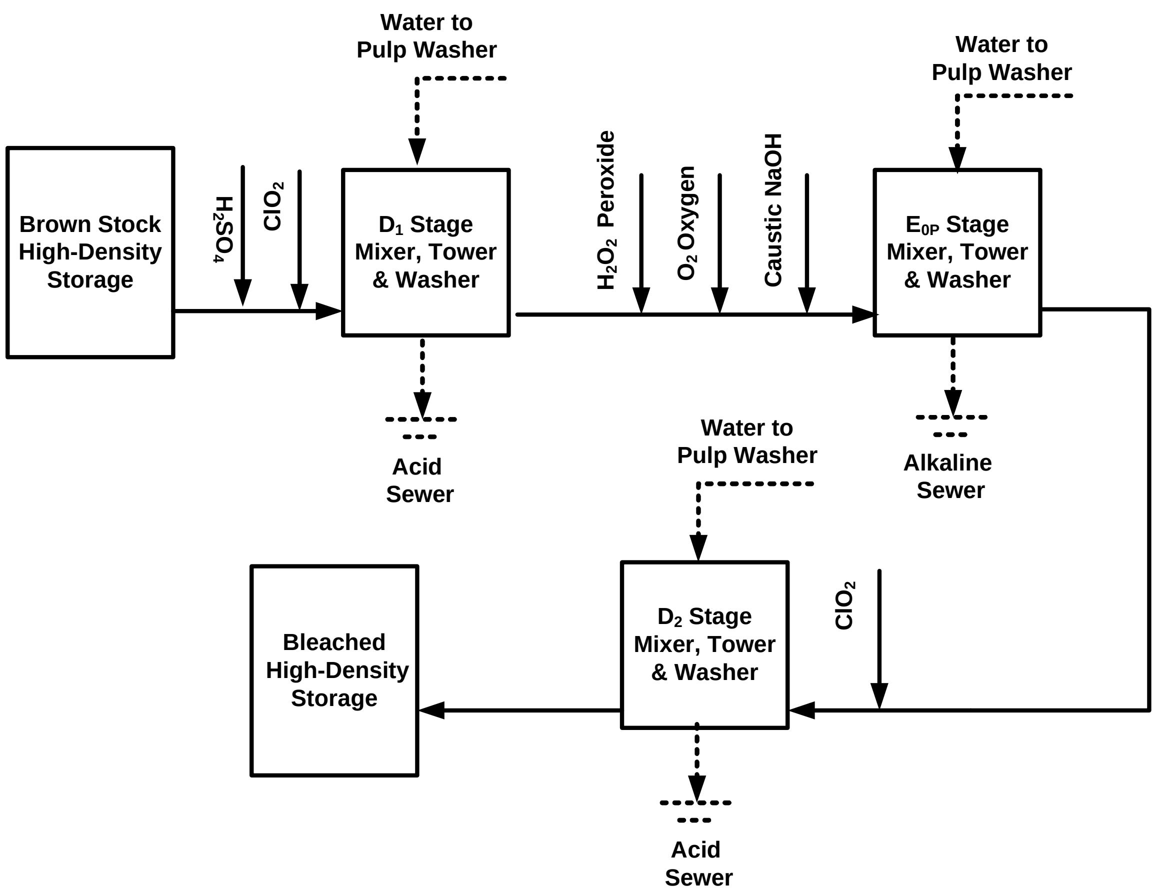


Figure B6. Schematic Diagram of IP Hardwood and Softwood Bleach Plants

Kraft Recovery Operations

Kraft pulping depends on its associated recovery process for producing the digestion liquor (NaOH and Na_2S) and recovering dissolved wood solids as steam for use in the Mill and as electrical power. The major steps in the Kraft recovery process practiced at IP Jay are illustrated schematically in Figure B7.

After washing, the black liquor is subjected to multiple effect evaporation where the "weak black liquor" or "spent liquor" obtained from the pulp washers is concentrated so that it can be burned economically and safely in the recovery furnace. In the evaporators, the water is evaporated and the dissolved wood solids and spent inorganic chemicals (NaOH and Na_2S) in the black liquor are concentrated. The evaporator condensates removed from the black liquor concentration step contain methanol and a variety of toxic Volatile Organic Compounds (VOC) that must be separated and treated in the wastewater treatment plant. The VOCs from the evaporator condensates are collected and burned.

The function of the recovery furnace is to burn the concentrated black liquor to recover the heating value of the dissolved wood solids. In the recovery boiler, generated steam and the salts in the black liquor are converted to sodium carbonate (Na_2CO_3) and sodium sulfide (Na_2S). Electrical power is extracted from the steam by sending it to a back-pressure turbine coupled to an electrical generator.

Molten smelt is removed from the furnace section of the recovery boiler and dissolved in water in a smelt tank to form green liquor, which is a mixture of sodium carbonate (Na_2CO_3) and sodium sulfide (Na_2S). The green liquor, after clarification, is then sent to a series of causticization reactors which convert the sodium carbonate (Na_2CO_3) in the green liquor into sodium hydroxide (NaOH), which is termed white liquor. In the causticization reactors, the sodium carbonate (Na_2CO_3) is reacted with slaked lime [$Ca(OH)_2$] to form the desired sodium hydroxide (NaOH). Following conversion of the green liquor into white liquor in the causticization reactors, the white liquor is clarified and sent to storage, after which it is recycled back to the digester. In the causticization reactions, calcium carbonate ($CaCO_3$), termed lime mud, is formed and is separated from the white liquor in clarifies and thickened by filtration. Lastly, lime (CaO) is regenerated from the lime mud by calcining or burning off carbon dioxide from the mud (CaCO3) in a kiln. The recovered lime (CaO) is reused in the causticization process.

It is important to note that the black liquor that is recovered, that is collected and sent to the evaporators and recovery boiler, does not go to the wastewater treatment plant. However, the evaporator and recovery systems are limited and can only evaporate a fixed amount of dilute or "weak" black liquor. As a frame of reference a "new" mill would more likely have additional capacity to accept more dilute or weak black liquor compared to a mature facility like the Androscoggin Mill.

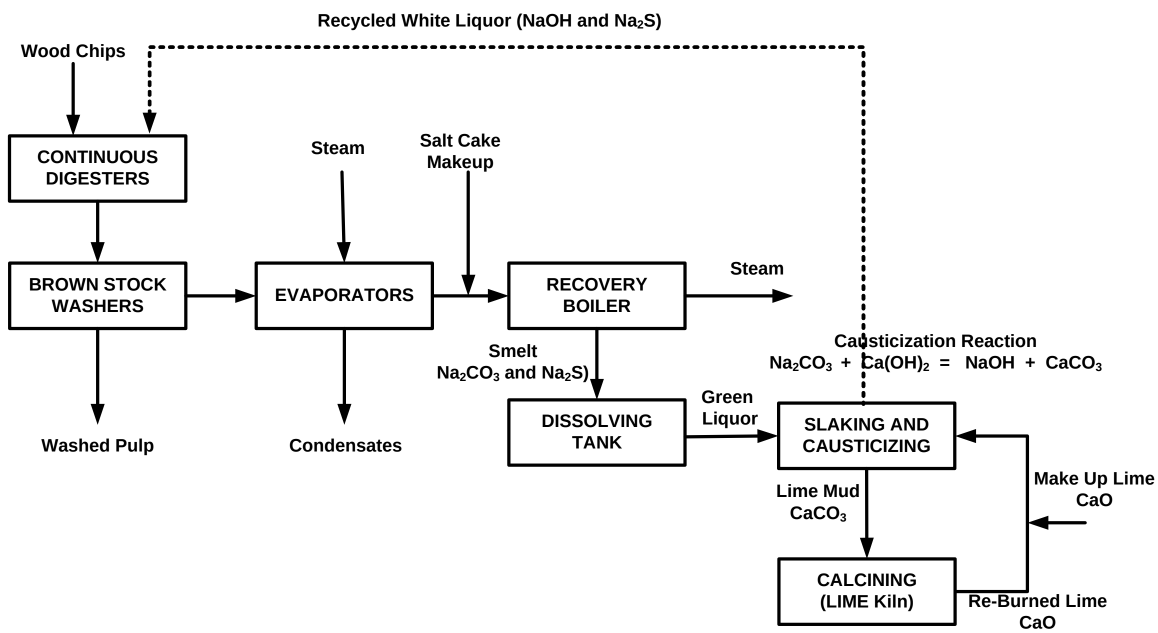


Figure B7. Schematic Diagram of the Kraft Recovery Cycle

Kraft Mill Closure

The intent of the XL-2 Project was to invest in process modification technology to close the "A" and "B" Kraft mills to minimize the discharge of COD and color from the process. Closing a Kraft mill to control color and COD involves: controlling black liquor spills, which was not a problem at the IP Jay, Maine facility; controlling the discharge of black liquor solids that go to the sewer on a continuous basis when rejects are discharged from the cleaning and screening systems, termed "closing up the screen room"; (3) controlling COD and methanol in evaporator condensates; and minimizing the discharge of chlorinated organic substances in the bleach plant effluent. This implies sending more black liquor to the evaporator and recovery sections of the Mill.

Groundwood Pulping and Bleaching

Figure B8 illustrates the configuration of the groundwood mill at the beginning of the XL-2 Project. In the groundwood pulping operation, debarked aspen round wood is ground to a coarse pulp using conventional atmospheric grinders. The pulp is then sent to coarse and fine screens to remove oversized material and cleaned in centrifugal cleaners to remove debris and thickened prior to bleaching. Rejects are thickened, refined, screened, and sent back to the main pulp accepts stream from the grinding operation. The pulp is then bleached to about 70 ISO brightness in a single stage bleaching process that uses sodium dithionite ($Na_2S_2O_4$) as a reductive bleaching agent. In reductive bleaching, the pulp is sent directly to groundwood storage, and often the bleaching is done directly in the storage tower. Because the ionic strength of the dithionite bleach is low, dissolved salts in the pulp do not have to be removed prior to sending the pulp to the paper machines.

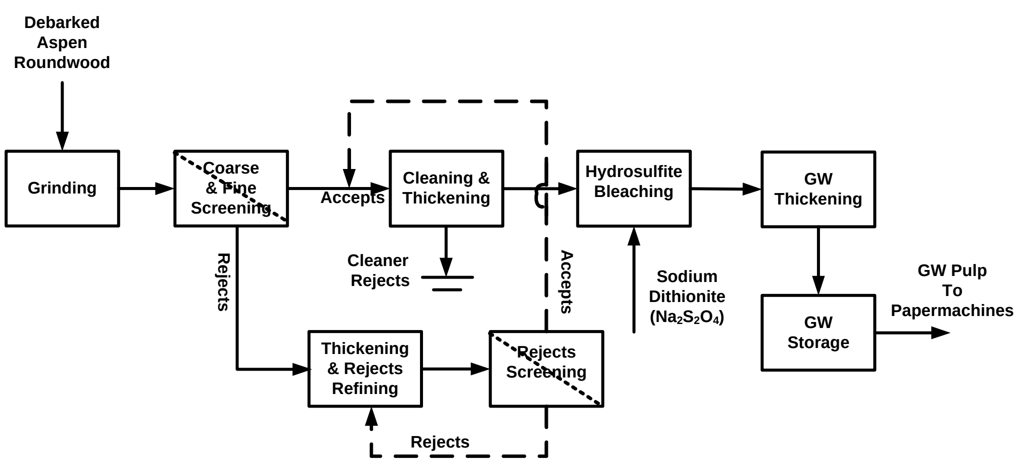


Figure B8. Groundwood Pulping and Bleaching Process at IP Jay in 2000

Paper Machine Production

International Paper operated five paper machines at the Jay, Maine Mill at the onset of the XL-2 Project. These five machines produce a variety of paper grades (see Table B1). At the inception of the XL-2 Project in 2000, paper production was approximately 545,000 tons annually of paper products (Figure B9). The paper products being produced at the Mill included uncoated freesheet (17%), coated groundwood primarily as lightweight coated publication papers (44%), coated freesheet as forms bond (27%), and specialty Kraft papers such as foil laminating and grease resistant papers (8%). In addition, the Mill produced market pulp for use at other IP papermaking facilities and amounted to about four percent (4%) of the 545,000 tons of paper at the IP Jay Mill in 2000. The No. 1 paper machine produced uncoated freesheet, while the No. 2 and 3 paper machines were producing light weight coated publication papers (LWC). At the inception of the XL-2 Project, the No. 4 machine produced uncoated freesheet while No. 5 paper machine was devoted to specialty Kraft papers.

Table B1

General Description of Paper Machines at IP Jay at Inception of the XL-2 Project

Paper Machine	Paper Grades
No. 1 PM (275 T/D)	Uncoated Freesheet (Forms Bond)
No. 2 PM (320 T/D)	Coated Groundwood (LWC – Offset Magazine and Catalog Paper)
No. 3 PM (440 T/D)	Coated Groundwood (LWC – Rotogravure Catalog Paper
No. 4 PM (500 T/D)	Uncoated Freesheet (Forms Bond) Converted to Coated Freesheet (Coated Magazine Papers)
No. 5 PM (125 T/D)	Specialty Kraft Papers (Foil Laminating, Grease Resistant Papers etc.)
Pulp Machine	Kraft SW Pulp

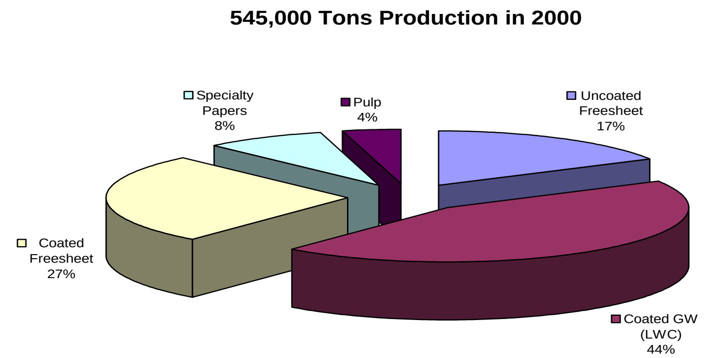


Figure B9. Paper Production at IP Jay in 2000

Paper Machine Operations

Figure B10 illustrates the processing that takes place on the five paper machines at IP Jay. The exact furnish will depend upon the grade of paper being produced. On the free sheet and specialty machines, hardwood and softwood Kraft pulp are refined to achieve the desired physical properties in the paper and entered into the stock preparation system. On the coated groundwood machines, stone groundwood and softwood Kraft pulp are used in the furnish. Here again the softwood Kraft pulp would be refined to achieve the desired physical properties. Broke or partially made paper from the various stages in the paper making process is dispersed in a series of hydro-pulpers, stored in a broke chest, and entered into the stock preparation system. Here the broke is mixed with the virgin pulps and various non-fibrous additives, which are added to achieve desired properties in the paper that cannot be achieved with the pulps. An assortment of manufacturing aids are also added to the furnish in the stock preparation system.

Stock from the stock preparation system (Figure B10) is sent to the machines thru the basis weight valve, after which it is diluted with recycled water and then sent to cleaning, air removal and screening systems. Water drained on the former is sent to a silo where it is reused on the wet end to make down fresh stock coming to the paper machine.

Water drained late in the forming process goes to a seal tank some of which is used as dilution in the cleaning and screening systems.

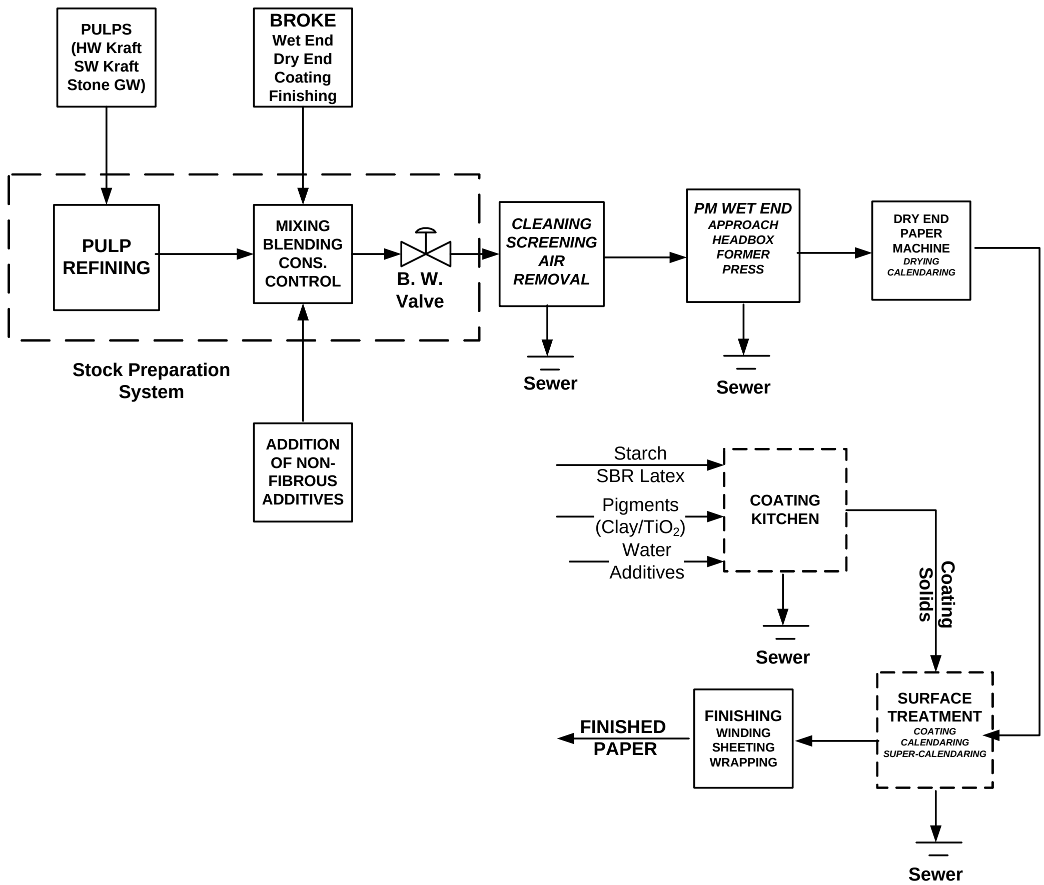


Figure B10. Schematic Diagram of Commercial Paper Machines

All paper machines operate with too much water since the pulp comes to the paper machines at about 4 to 4.5% consistency and the pulp leaves the press section between 40 and 45% and fresh water is added on the machine in critical showers. Thus, water must be purged from the paper machine through the saveall system (Figure B11). The saveall system recovers solids from the purge water which are sent back to the stock preparation system as saveall reclaim stock (Figure B11). The saveall filter recovers process water in the form of clear and cloudy filtrates. Cloudy filtrate is used on the wet end of the machine and for pulper dilution. Clear filtrate is used in showers on the wet end of the machine and for dilution where needed when cloudy whitewater is unavailable. Out of necessity, clear filtrate is exported from the paper machine system and sent to the pulp mill for reuse. Unfortunately, since fresh water is being used in critical showers and on paper breaks, considerable excess white water is produced and often is discharged to the sewer (Figure B11).

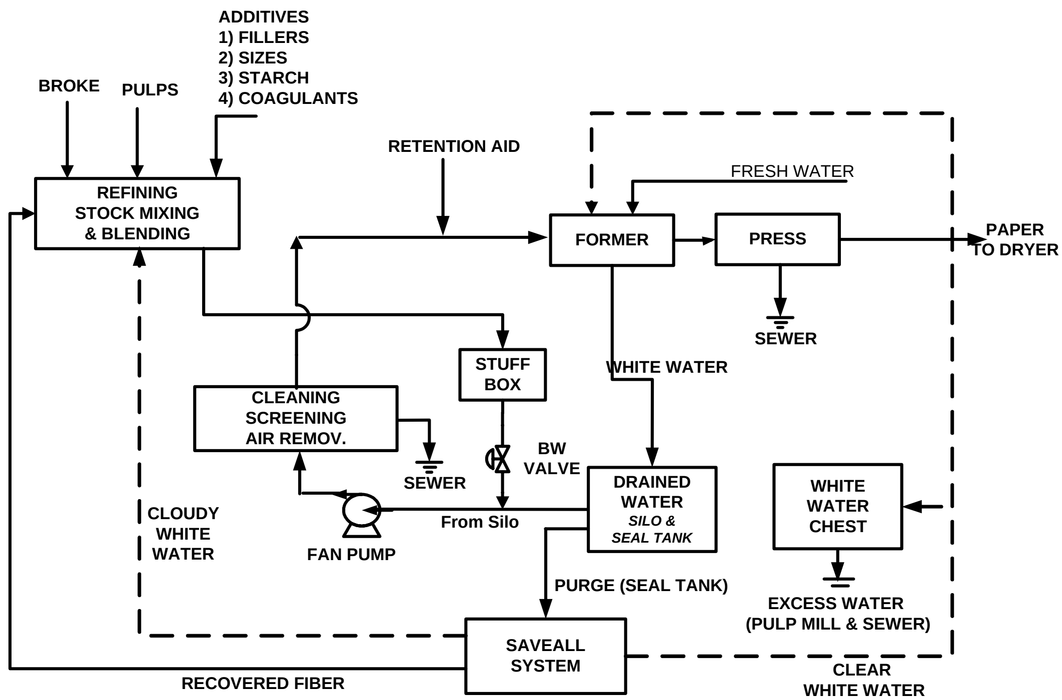


Figure B11. Paper Machine Wet End Showing Saveall System

The diluted stock that passes after the basis weight valve is processed in a multiple-stage centrifugal cleaning system to remove impurities that have a specific gravity greater than that of water. After the cleaners, the stock passes through an air removal system to remove air, which decreases the rate of drainage on the machine. Following the cleaning and air removal system, the stock passes through a multiple stage screening system to remove oversize particles, strings, slime and other impurities. The stock then passes through the flow approach system and the headbox to distribute the stock on the former. The function of the former is to filter the stock and form the paper. From the paper forming section of the machine, the paper is picked up on a felt and sent to the press section of the machine where the wet web is dewatered further. In the press section, water is removed from the paper. This water is often sent to the sewer (Figures B10 and B11) because it is contaminated with felt hairs and debris. Lastly the paper is dried in the dryer section and sent through an on-machine calendar to set the caliper or thickness of the paper and its smoothness.

Coated Paper. On coated paper machines, coatings (paints) are prepared in the coating kitchen. Paper coatings resemble common household paint and are formed from adhesives, traditionally starch and styrene butadiene latex (SBR), pigments such as clay, calcium carbonate ($CaCO_3$) and titanium dioxide (TiO_2), water which acts as a solvent, and a variety of additives to convey functional properties to the coating -- for example viscosity modifiers, dispersants, and the like. From the coating kitchen, coatings are pumped to the coater section of the machine where they are applied to the paper in blade and roll coaters. Sometimes paper is coated on off-machine coaters, or coaters which are not directly attached to the primary paper machine used to manufacture the base paper.

The coated paper is then calendared to achieve a very high level of smoothness and gloss. The paper, which is manufactured in "jumbo" rolls, is cut into smaller width and diameter rolls on a winder to the customers' specifications. The smaller rolls are then wrapped and sent to printers or specialty users. Alternatively, the paper can be converted into flat sheets, wrapped, and sold as sheet fed papers.

On coated paper machines, coating solids are sometimes sent to the sewer from the coating kitchen or coating preparation area. Coating solids also go to the sewer from the coater stations or areas of the machine where the coating is applied to the paper.

Discharge of COD and Color from Commercial Paper Machines

Sewer losses on commercial paper machines occur in a variety of locations. Chief among the continuous discharge points on the paper machine are the rejects from the last stage cleaners and last stage of the screening system. In addition, press water often is continuously discharged because it often is contaminated with felt hairs, fine fiber and filler particles, and detergents from felt cleaning. Another continuous discharge point on commercial paper machines is excess white water that is discharged through the saveall filter system. In addition there are continuous discharges of non-process water from vacuum pump seals, gland water from pumps, and cooling water from heat exchangers.

In addition to the continuous discharge points, there are spills from chests that overflow when the machine is operating improperly; that is "haying-out". Water high in suspended and dissolve solids is discharged during machine wash-ups and boil outs, which occur when the entire wet end of the machine is cleaned to remove the build-up of micro-biological organisms and debris. On coated machines, spills sometime occur when tanks and chests are cleaned in the coating kitchen. Also, sometimes coating losses occur during paper breaks in the coater section of the machine, when doctor blades are changed, and when coater heads are cleaned.

Wastewater Treatment Facilities. The IP treatment facility (Figure B12) provides primary treatment, biological treatment, and secondary clarification. The components of the facility consist of the following: two coarse mechanical bar screens; two 190-foot diameter primary clarifiers with skimmers; four influent pumps with provisions for chemical addition for pH adjustment and nutrient addition; a 70 million gallon aerated lagoon; two 255-foot diameter secondary clarifiers with polymer addition to enhance settling; four return activated sludge pumps; an 80-foot diameter gravity thickener and eight screw presses and two belt filter presses; a foam dissolving tank; an emergency spill basin with pumps (not shown); a heat exchanger; and a diffuser.

Collection of Wastewater. Storm water, cooling water, water treatment backwash water, landfill leachate, and wastewater generated in the pulp and papermaking process (including process wastewater from the SMI and Androscoggin Energy plants) are discharged into the Mill's General Sewer (caustic/neutral pH wastewater) by way of a series of collection pipes and sewers. The General Sewer flows through the mechanically raked bar screens to remove large objects. The screened objects are then sent to the landfill. Process wastewater from the Otis Mill is combined with the General Sewer after the bar screens. The combined wastewater then flows by gravity through a splitter box and into the two primary clarifiers.

Acid Sewer System. Acid process wastewater is collected separately from the caustic and neutral pH range wastewater. The sanitary wastewater from the Mill discharges into the process wastewater acid sewer. The sanitary waste is disinfected by reaction with the oxidants in the Acid Sewer coming from the bleach plant. Disinfection can also be done by using sodium hypochlorite, calcium chlorite, or other suitable oxidants when the Acid Sewer is unavailable for treatment. The acid wastewater, including sanitary wastewater, has few suspended solids that can be removed by screening or conventional primary clarification. Therefore, the Acid Sewer combines with the general wastewater effluent from the primary clarifies just downstream from the primary clarifier (Figure 2).

pH Adjustment. pH adjustments using lime, caustic or sulfuric acid on the combined wastewater occur in the collection box prior to flowing to the wastewater treatment plant's influent pump station. Four centrifugal pumps lift the combined wastewater from a wet well to the aerated lagoon through a 42-inch force main. Before the wastewater enters the lagoon, nutrients such as phosphoric acid, urea, and other suitable nutrients are injected into the force main, as needed, to provide phosphorous and nitrogen to enhance growth of biological solids.

Aerated Lagoon. The lagoon at IP Jay is an irregular shaped earth-berm structure with a volume of approximately 70 million gallons and an effective process volume of 24 million gallons. Fifty-five (55) aerators are used to entrain air and mix the solids and liquid in the aeration lagoon to promote biological treatment of wastewater. The aerators consume about 4200 horsepower of mechanical power.

Solids Settling. Wastewater exits the lagoon and flows over a weir and into a splitter box where the flow is split to the two secondary clarifiers. Cationic polymer is added, as needed, before the secondary clarifiers, to enhance settling of the suspended solids. The settled solids consist of active biological matter and are returned via return activated sludge pumps to the lagoon through a return line that discharges from two pipes within twenty-five feet of the influent from the lift pumps.

Sludge Thickening and Dewatering. The waste sludge pumps also remove excess solids from the secondary clarifiers to the gravity thickener. This waste sludge is then pumped to a sludge dewatering system consisting of screw and belt filter presses. Polymer is added to the sludge prior dewatering to increase floc size and aid in dewatering. After dewatering by the presses, the dewatered sludge is incinerated in the multi-fuel boiler waste fuel incinerator (WFI), or temporarily stockpiled and trucked to the Mill landfill site for disposal.

Discharge to the Androscoggin River. Defoamer is added at the overflow from the secondary clarifiers, as necessary, as it flows to a collection box for discharge to the Androscoggin River. The effluent is monitored at the collection box for compliance with Permit requirements. Before being discharged to the River, the effluent passes through a heat exchanger, which is operated during the winter months to recapture waste heat. The effluent then passes into a foam dissolving tank that allows for the physical separation of any foam from the effluent and then through a diffuser for discharge into the Androscoggin River.

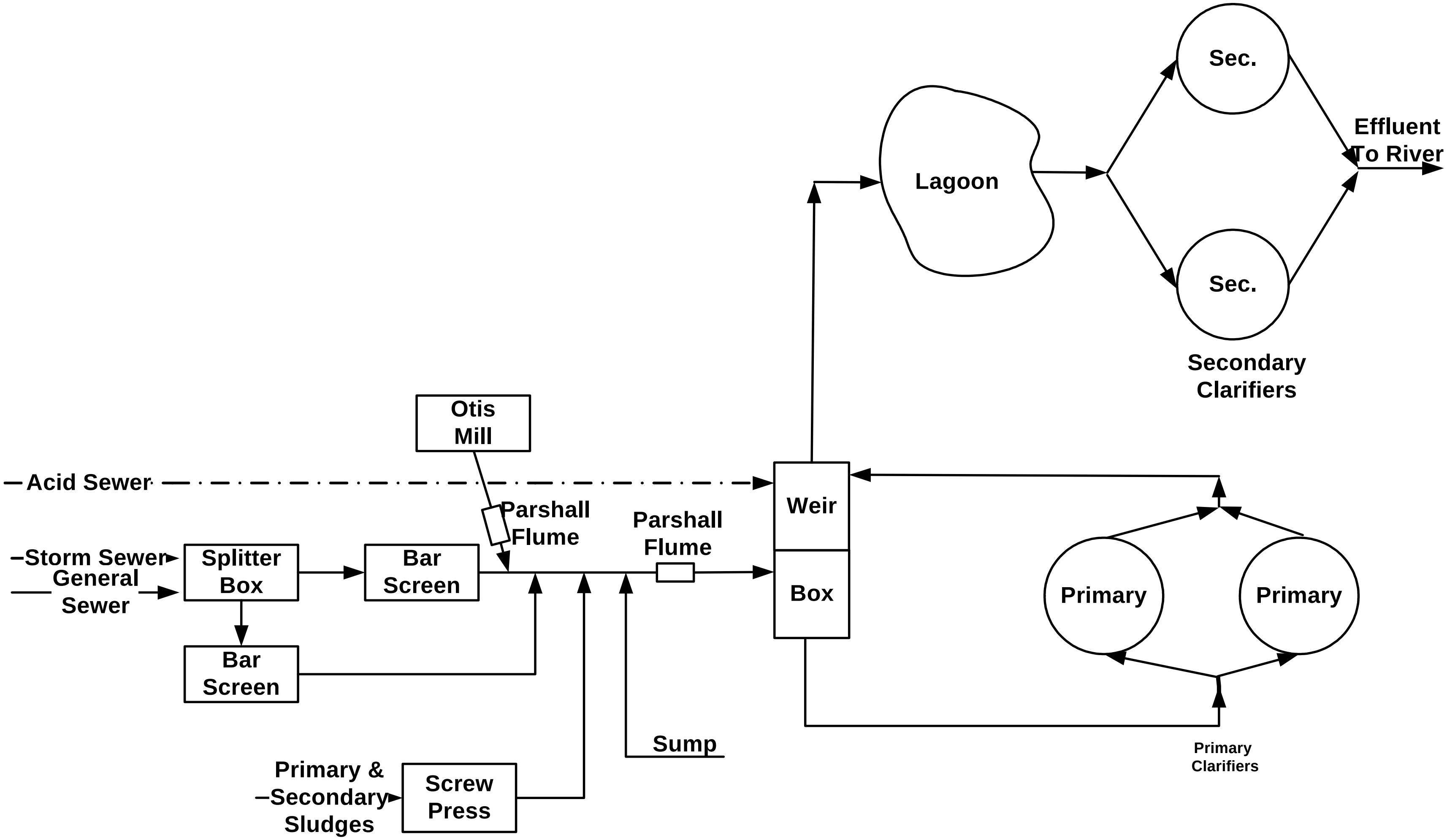


Figure B12. Schematic Diagram of Sewer System at Jay, Maine

APPENDIX C

CHANGES TO THE ANDROSCOGGIN MILL IN JAY, MAINE SINCE THE INCEPTION OF THE XL-2 PROJECT

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CHANGES TO THE ANDROSCOGGIN MILL IN JAY, MAINE SINCE THE INCEPTION OF THE XL-2 PROJECT

Process Modifications to the Softwood Kamyr Digester

A detailed list of the process changes made at the Androscoggin Mill is given in Table C1. Process modifications were made to the cooking process in the softwood ("A") fiber line during the XL-2 Project. These changes in the cooking process reduced the amount of overflow liquor that was being sent to the sewer in the Decker, which was estimated to be about 400 gallons per minute. The softwood ("A") pulp mill was limited in extraction flow and water was being spilled at the Decker or device that thickens the softwood pulp prior Brownstock storage. This change reduced the COD and toxic substances going to the wastewater treatment plant.

Changes to the Groundwood Mill

Two significant process changes were made to the groundwood mill during 2003 and the first quarter of 2004. Figure C1 illustrates the current configuration of the groundwood pulp mill at the Mill.

Capacity Increases. The capacity of the groundwood operation was increased by adding addition screening and rejects refining. The original groundwood mill did not wash the pulp prior to going to the paper machine. The production of groundwood at the Mill increased from approximately 170 tons per day before the rebuild to about 230 tons per day after the rebuild during the period of the XL-2 Project. The increase in production rate would be expected to raise the level of COD being discharged to the wastewater treatment plant because of increased pulp washing and addition of the hydrogen peroxide bleaching process.

Table C1

List of Changes to the Mill Completed During the XL-2 Project

Item	Comments on Modification
1) Increased production in the groundwood mill in 2003/2004	Increased production in the groundwood mill from 170 tons per day to 230 tons per day currently. Increased production would lead to increased COD and dissolved solids (DS).
2) Installation of hydrogen peroxide bleaching and twin wire press in the groundwood mill in 2003/2004.	Groundwood bleaching would lead to increased COD and dissolved solids because of decrease in pulp yield resulting from the peroxide bleaching. Installation of a twin wire press increases the discharge of dissolved solids and dissolved solids from the groundwood mill.
3) Increase in production of coated paper on the No. 4 paper machine	The production rate on the No. 4 paper machine was gradually increased during the period of time the XL- 2 project was being conducted.
4) Process Modifications to the Softwood ("A") Kamyr Digesters in 2003.	Process modifications to the softwood continuous digester lead to higher extraction rates of black liquor that goes to the evaporators and avoids sending black liquor to the sewer system. These modifications should potentially reduce COD and toxic substances going to the sewer and being discharged to the river.
5) Increased Production on the No. 3 paper coated groundwood machine in 2003/2004.	This would lead to increased COD, in the form of dissolved and suspended solids (TSS).
6) Condensate collection and installation of hard pipe system for control of CH_3OH for HAPS.	This change would result in collection and treatment of additional condensate which would lead potentially to increase COD.
7) Removal of suspended solids from the lagoon in 2003.	During the XL-2 Project, suspended solids were dredged from the lagoon.
8) Ashcrete project in 2001 and 2002.	For a period of time during the XL-2 Project Ashcrete was prepared and used to line the lagoon.

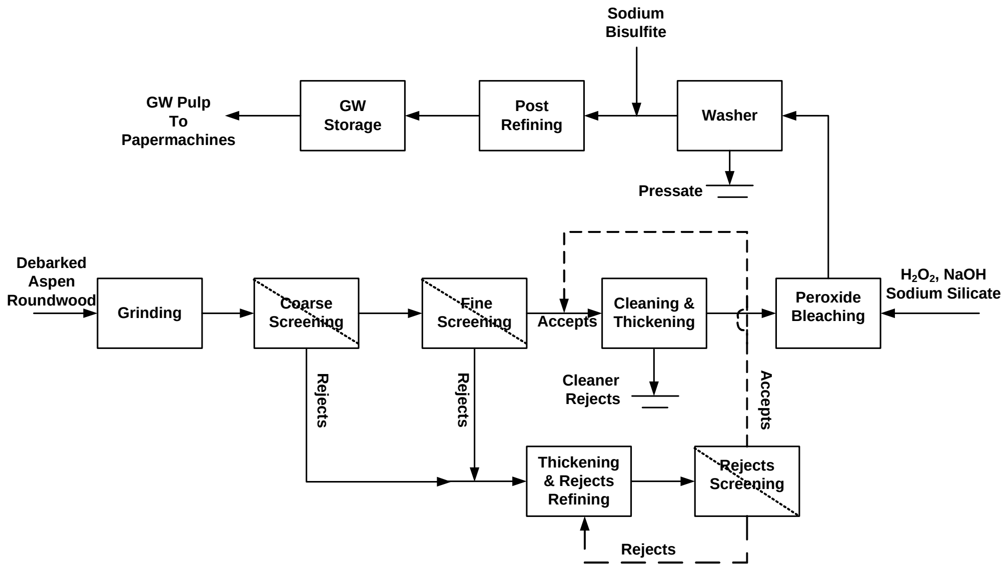

Figure C1. Schematic Diagram of the Groundwood Mill with Hydrogen Peroxide Bleaching in 2004

Peroxide Bleaching. The groundwood mill was converted from a simple single stage sodium dithionite ($Na_2S_2O_4$) bleaching process (see Figure B8) to a single stage hydrogen peroxide bleaching (H_2O_2). Hydrogen peroxide bleaching permits high brightness levels to be obtained with the groundwood. In hydrogen peroxide bleaching, a mixture of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) is added in addition to hydrogen peroxide to raise the pH to about 10.8 to bring about the desired bleaching reactions. Sodium silicate is added as a buffer to maintain the pH in the desired range. By contrast, conventional sodium dithionite, often termed sodium hydrosulfite, bleaching is conducted under neutral or slightly acidic conditions.

Bleach Plant Twin Wire Press. After bleaching the pulp is thickened to remove spent chemicals and the pH reduced and residual oxidant consumed by the addition of sodium bisulfite. As part of this project, a new bleach plant twin-wire press was added to the process between the groundwood mill and the paper machines. The twin-wire press discharges press liquid, termed pressate, which contains much of the ionic trash added during the bleaching process. Discharge of pressate protects the paper machines from dissolved solids being sent to the stock preparation system, which interferes with the retention chemistry on the machines. This strategy will send additional water and COD to the north sewer in the groundwood pulp mill.

Additional COD Discharge from the Groundwood Mill. The brightness targets were raised from 70 ISO brightness before the rebuild to 78 ISO brightness after the rebuild. The increase in brightness led to higher levels of discharge of COD and dissolved solids going to the wastewater treatment plant since the pulp yield is decreased. Typically, sodium dithionite bleaching would dissolve approximately 0.25% to perhaps 0.5% of the pulp during the bleaching process. This can be compared to hydrogen peroxide bleaching where 1% to 2% of the unbleached pulp is dissolved. In the groundwood operation about 2% of the wood would be expected to be dissolved during peroxide bleaching. This would amount to 8,000 pounds per day or about 2.8×10^6 pounds per year of an additional COD being discharged from the groundwood mill at the 78 brightness level.

Changes to the Paper Machines

Table C2 illustrates the production levels on the five paper machines at the end of the XL-2 Project. Significant changes occurred in the paper mill during the XL-2 Project. Notable among them was a gradual increase in production on the No. 4 paper machine which had previously been converted from an uncoated to a coated paper machine. With the conversion of the No. 4 paper machine to coated paper, there was an increase in production from about 500 tons per day of coated freesheet to 550 tons per day of coated paper. Also, there was an increase in production on the No. 3 paper machine from approximately 480 tons per day to 525 tons per day.

Another significant change that has taken place at the Mill was the shutdown of No. 1 paper machine in the 1st quarter of 2005, after the XL-2 Project, due to poor business conditions. The No. 1 paper machine produced uncoated freesheet papers and was one of the smaller machines at the Mill with a production rate of 275 tons per day. There was essentially no change to the No. 5 specialty freesheet machine and in pulp production.

The total production and mix of papers between the various grades of paper produced at the Mill is summarized Figure C2. The annual production on the paper machines increased from approximately 545,000 tons per day in 2000 at the inception of the XL-2 Project (Figure B9) to approximately 640,000 tons during the test period in

2004 (Figure C2). Also, the mix of papers being produced at the Androscoggin Mill facility shifted from about 71% coated paper at the inception of the project to 76% coated paper at the end of the project (Figure C2).

Increases in production of coated paper would increase the discharge of coating solids that contain high levels of starch, latex, inorganic fillers such as clay and titanium dioxide, which would then increase the discharge of COD. The exact amount would depend upon the degree of closure of the paper machine and the amount of water being discharged to the sewer.

Table C2

General Description of Paper Machines at IP Jay during Testing Period

Paper Machine	**Paper Grades**
No. 1 PM (275 T/D)	Uncoated Freesheet (Forms Bond) (Shut Down During Later Stages of Project)
No. 2 PM (320 T/D)	Coated Groundwood (LWC – Offset Magazine and Catalog Paper)
No. 3 PM (525- T/D)	Coated Groundwood (LWC – Rotogravure Catalog Paper
No. 4 PM (550 T/D)	Coated Freesheet (Coated Magazine Papers)
No. 5 PM (125 T/D)	Specialty Kraft Papers (Foil Laminating, Grease Resistant Papers etc.)
Pulp Machine	Kraft SW Pulp

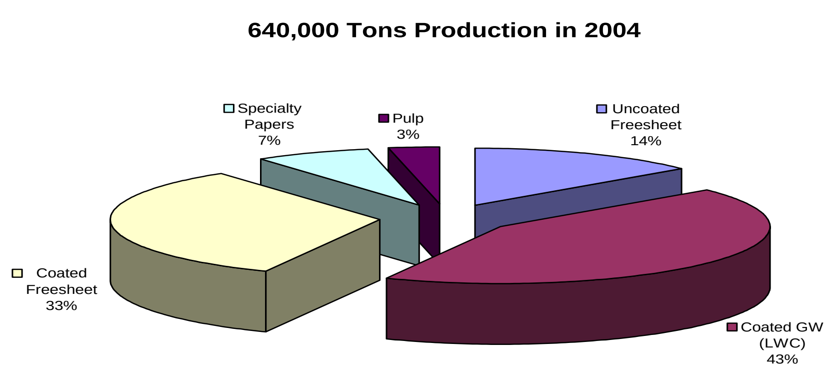

Figure C2. Paper Production at the Androscoggin Mill in 2004

Changes to the Wastewater Treatment Plant

Three changes took place in the wastewater treatment plant during the XL-2 Project and would be expected to influence the operation of the wastewater treatment plant.

Hard Pipe Option. The Cluster Rules hard piping option was implemented and evaporator condensates were sent to the wastewater treatment plant for destruction of methanol. The hard piping system was implemented in April 2002. Using the hard pipe option would increase the load of methanol and other VOCs going to the lagoon.

Ashcrete Trials. A second change was the trials performed in 2001 with Ashcrete, a mixture of boiler ash, cement kiln dust and green liquor dregs that had properties similar to that of Portland cement. Ashcrete was used to cover portions of the perimeter of the wastewater treatment plant where biological solids built had been deposited. This practice was discontinued after a period of time due to the fact that the Ashcrete was actually displacing the biological solids into the active area of the aerated lagoon.

Dredging Aerated Lagoon. Lastly, the aerated lagoon was dredged. The purpose of the dredging operation was to recapture some of the active area lost by the Ashcrete pilot project and reduce the volume of biological solids build up in other areas of the aerated lagoon. The biological solids build up varied from five to ten feet thick along the perimeter and bottom of the aerated lagoon. This buildup of solids over the years had significantly reduced the volume of the aerated lagoon and led to short circulation of the wastewater, eventually, reducing biological treatment. After the dredging process was completed new flow currents were formed in the aerated lagoon causing the suspension of inert solids which interfered with the biological treatment and reduced the performance of the wastewater treatment plant. Once the flow path through the aerated lagoon stabilized and the additional solids discharged were captured and dewatered the performance of the wastewater treatment plant stabilized and improved.

APPENDIX D

SUMMARY OF MILL-WIDE COD BALANCES

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Experimental Methods

In performing the COD balances, the Mill was divided into three areas:

1. Paper machines and coating preparation facility;
2. Unit operations associated with the black liquor cycle; and
3. Other miscellaneous process areas.

The paper machine area included the five paper machines and the coating preparation facility. Unit operations associated with the black liquor cycle encompassed the digesters, bleach plant, and recovery cycle. The miscellaneous process areas included wastewater from both the groundwood facility and the Otis Mill, as well as backwash coming from the water treatment plant. These areas were selected based upon the 2000[24] sewer survey of streams that had sizeable quantities of COD going to the wastewater treatment plant.

Measurements were made for the total volumetric flow rate, BOD, COD, suspended solids, dissolved solids, specific conductance, pH, and color. Samples were taken for seventeen sewer streams comprising the Mill. The selected streams were those thought to be the most likely to contain sizable quantities of COD being discharged to the wastewater treatment plant. The samples were sent to Acheron Laboratory, an environmental testing laboratory located in Newport, Maine. BOD and COD measurements were made for composite samples obtained directly from the various sewer streams and also after filtering through a 0.8-micron fiberglass filter. The filtered samples were thought to measure dissolved and sub-micron colloidal. Results from the August 2001 sewer survey are summarized in Table D1.

[24] Genco, J. M., and van Heiningen, A. "Mill-Wide COD Balance to Identify Important COD Point Sources", October 18, 2000.

Table D1

Average Daily Emissions (lbs/Day) for Measured Quantities For Aug. 2001 Sewer Survey

		Total		Filtered		Solids			color
	Flow Rate	BOD	COD	BOD	COD	Susp.	Diss.	Est. Total	
Location	(gpm)	(#/Day)							
(2) Raw Water - Grab	29028	6170	21305	5821	13155	4773	30152	34925	2328
(8) PM #3 & Coating Prep - Composite	3492	4565	74780	2591	6134	47346	21384	68730	6750
(9) PM #4 & #5 - Composite	2065	5747	44715	629	4157	24941	5548	30489	18383
(7) PM #1& #2 - Composite	5036	7574	54691	2100	5453	34313	24316	58629	929
Paper Mill Total	10592	17885	174185	5320	15743	106600	51248	157848	26062
(12) A Pulp Mill (general) - Composite	1836	3881	17911	3174	13831	759	23516	24274	16018
(11) A Pulp Mill (caustic) - Composite	630	5789	23296	5748	22184	222	41918	42140	14162
(18) B Pulp Mill (General)- Composite	223	2479	14885	481	2578	10347	2931	13278	5475
(14) B Pulp Mill (caustic) - Grab	656	8998	18496	7014	16391	800	17943	18743	4025
(13) Acid Sewer - Grab	2620	6431	24252	5769	21793	462	65568	66031	10245
(15) A Evaporators - Grab	800	9051	16459	8422	12577	64	603	667	337
(16) B Evaporators - Grab	494	937	2088	644	1320	38	164	202	258
(17) B Evaporators 6th & SC - Grab	310	4998	7410	4066	6652	5	469	474	298
BL Cycle Total	7075	41627	122709	34674	96006	12659	152948	165607	50561
(10) Groundwood - Composite	274	551	2140	517	1153	4269	578	4847	798
(5) Otis - Composite	2371	10842	30823	4698	9701	6486	10899	17385	618
(3) River Waste - Grab	347	33	1421	15	85	3010	1546	4556	153
Others Total	2993	11427	34384	5231	10939	13765	13023	26788	1569
(6) Mill Sewer (Bar Screen) - Composite	25717	87774	313139	46001	143367	212988	311282	524270	133053
Sum Paper Mill, BL Cycle, Others minus Acid Sewer and B Evaporators	18040	64508	307026	39456	100895	132562	151650	284213	67946
(1) Mass Closure at Bar Screen (%)	29.9	26.5	2.0	14.2	29.6	37.8	51.3	45.8	48.9
Mill Effluent - Composite	29537	3672	73328	1895	55559	11491	367115	378606	89439

(mg/L)(X)[flow(gpm)]=(#/day)
where x= 0.012032

Total Flows by Areas

Figure D1 shows the flows divided between the three major areas of the Mill. The calculated total flow was 29.75 millions gallons per day in the August 2001 sewer survey. The total flow was estimated to be divided as 51% from the paper mill, 34% from unit operations comprising the black liquor cycle, and 15% from the other areas. By comparison, the flow measured in the 2000 sewer survey from the paper machine area was 66% of the total flow.

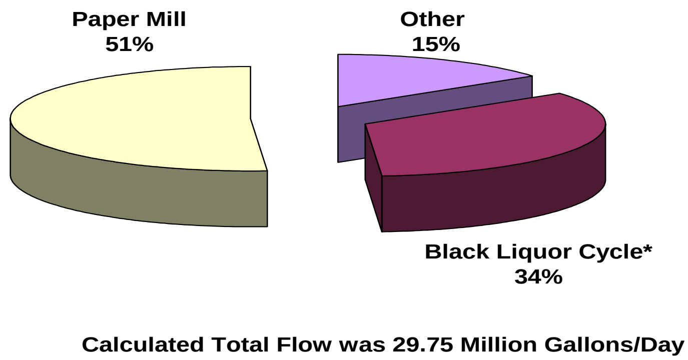

Figure D1. Percentage Flow by Area Measured in August 2001 Sewer Survey

COD Release by Area

The COD release by area is summarized in Figures D2. The impact of the various parts of the Mill is seen in the difference between the incoming raw water and the Mill effluent. Data from the 2001 sewer survey indicated that the raw water being taken into the Mill at the raw water pump house was 21,300 pounds per day, compared to the Mill effluent which was 73,300 pounds per day. Thus, the net total COD going to the Androscoggin River was 52,000 pounds per day and resulted from the pulp and paper processing taking place at the Mill.

$$Net\ Total\ COD = (73{,}300 - 21{,}300) = 52{,}000\ pounds\ per\ day$$

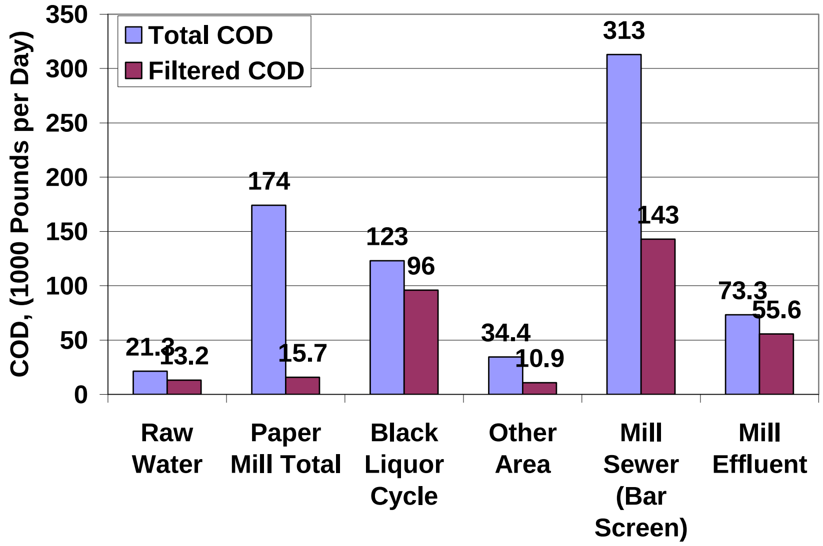

Figure D2. Comparison of Total and Dissolved COD for Various Areas of Mill for 2001 Sewer Survey

Of the total 52,000 pounds per day of total COD that are added to the River, approximately 42,400 pounds per day are added as dissolved or soluble COD.

In the 2001 sewer survey, considerable total COD going to the wastewater treatment plant originated from both the paper mill (174,000 pounds per day) and the black liquor cycle (129,000 pounds per day) but the dissolved/soluble COD originated primarily from the black liquor cycle (96,000 pounds per day) compared to the paper mill (15,700 pounds per day). In the 2001 sewer survey, 53% of the total COD came from the paper mill while 37% of the total COD came from the black liquor cycle and 10% from the other miscellaneous areas of the Jay Mill (see Figure D3). By contrast, 78% of the dissolved/soluble COD originated from the black liquor cycle compared to only 13% from the paper mill and 9% from the other miscellaneous areas of the Mill (see Figure D4). Similar results were obtained for color (Figure D5).

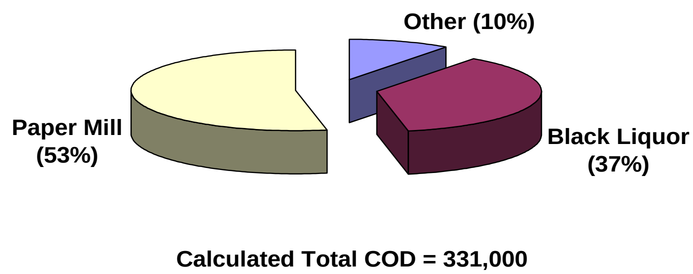

Figure D3. Total COD Originating from Process Areas in the Mill from the 2001 Sewer Survey

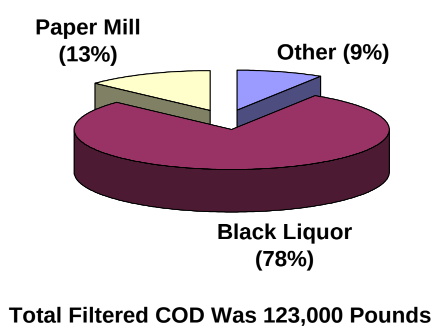

Figure D4. Total Dissolved/Soluble COD Originating by Area Measured in 2001 Sewer Survey

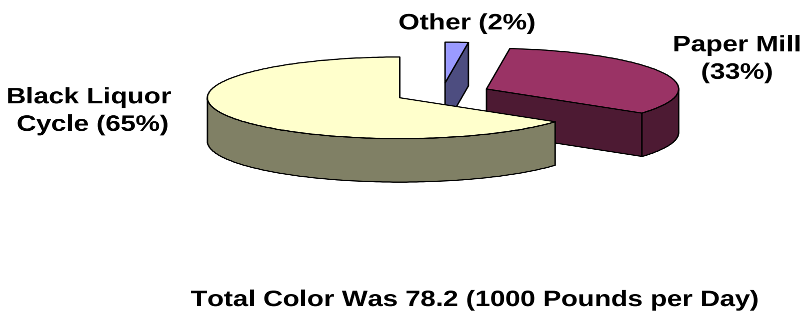

Figure D5. Color Originating By Area Measured by 2001 Sewer Survey

These results show further that the total COD measurement is not a particularly good parameter for process monitoring. Most of the total COD comes from the paper mill as suspended solids, which are settled and removed in the wastewater treatment plant. To assess the true impact of the Mill processes on the environment it would appear that the dissolved/soluble COD may be a more appropriate parameter for process monitoring.

The bleach plant and the "A" Pulp Mill effluent were the largest contributors to the total discharge of dissolved/soluble COD and color from the black liquor cycle. The bleach plant contribution to the black liquor cycle was 63% for dissolved/soluble COD and 55% for color. The relatively large discharge by the "A" Pulp Mill was thought to be related to incomplete closure of the screen room and black liquor carry-over from the undersized flash tanks.

COD in Raw Water

The data in Table D1 suggest that there is considerable total COD in the raw water. In the second COD sewer balance, approximately 21,305 pounds of total COD per day came into the Mill in the form of the raw water. Of this amount, 13,155 pounds per day or 62% was dissolved/soluble COD. The raw River water is treated in the water treatment plant and solids collected on sand filters are back flushed off the filter and sent to the wastewater treatment plant. Thus, the incoming total COD in the raw water amounts to about 7% of the total COD measured at the bar screen, or about 29% total COD measured in the effluent.

$$\%\ COD\ \ from\ Raw\,Water = \left[\frac{COD\ \ Raw\,Water}{COD\,at\ \ Bar\,\text{L}\,Screen}\right] = \left[\frac{21{,}305\ lbs\,/\,day}{313{,}139\,lbs\,/\,day}\right] = 6.8\% \quad \text{(D1)}$$

$$\%\ COD\ \ from\ Raw\,Water = \left[\frac{COD\ \ Raw\,Water}{COD\,in\ Effluent}\right] = \left[\frac{21{,}305\ lbs\,/\,day}{73{,}328\,lbs\,/\,day}\right] = 29.0\% \qquad \text{(D2)}$$

Since the total COD in the raw water is a significant portion of the COD being discharged to the Androscoggin River, it would appear prudent to take into account the COD coming into the Mill with the raw water when calculating the metric used to set the effluent regulations.

Efficiency in Wastewater Treatment Plant

Efficiencies for removal in the waste water treatment plant were estimated for the total and soluble BOD, total COD, soluble COD, color, Total Suspended and Dissolved Solids and Total Solids.

Dissolved/Soluble Solids. The efficiency for the process variable was estimated from the mass flowing to and from the wastewater treatment plant using an equation of the form:

$$\eta_i = \left(\frac{m_{Influent} - m_{Effluent}}{m_{Influent}}\right)_i * 100 \qquad \text{(D3)}$$

The removal efficiencies in the wastewater treatment plant are summarized in Table D2 based upon the second sewer survey.

The removal efficiencies in the wastewater treatment plant are high for total BOD, soluble BOD and Suspended Solids, respectively 96, 96 and 95% (see Table D2). The removal efficiencies for total and soluble COD were significantly lower at 76% and 66% respectively. The removal efficiency for color was only about 38%. This value is typical for biological treatment of pulp and paper wastewater, and may be due, at least partially, to the formation of new colored groups when ECF bleach effluents are oxidized in the treatment system.

Table D2.

Removal Efficiencies in Waste Water Treatment Plant

VARIABLE	INFLUENT (1000 lbs/day)	EFFLUENT (1000 lbs/day)	REMOVAL EFFICIENCY(%)
Total BOD	94	3.7	96
SolubleBOD[(a)]	51.8	1.9	96
Total COD	337	73	78
Soluble COD[(a)]	165	56	66
Color	143	89	38
Total Suspended Solids (TSS)	214	11.5	95
Soluble Solids (SS)	377	367	2.6
Estimated Total Solids	590	379	36
Flow (million gallons/day)	40.8	42.5	

(a) Samples were filtered through a 0.8 micron filter

Toxicity Measurements

Toxicity data were taken in conjunction with the 2001 sewer survey. The toxicity data were determined using (Ceriodaphnia Dubia) A-NOEC and LC-50 (see Table D3).These data show that the "A" Pulp Mill (Caustic) effluent was more toxic than the Acid Sewer, while the effluent from the No. 3 paper machine effluent was non-toxic. The combined effluent at the Bar Screen was intermediate in toxicity.

Table D3.

Summary of Toxicity Data

SAMPLE DATE	LOCATION	A-NOEC	LC-50
9/4/2001	Bar Screen	35%	47.5%
9/7/2001	No. 3 PM	100%	>100
9/4/2001	A Caustic Sewer	<5%	4.7%
9/10/2001	Acid Sewer	25%	40%

APPENDIX E

PROCESS MONITORING DATA FOR SELECTED STREAMS DURING THE PERIOD JANUARY 1, 2004 THROUGH DECEMBER 31, 2004

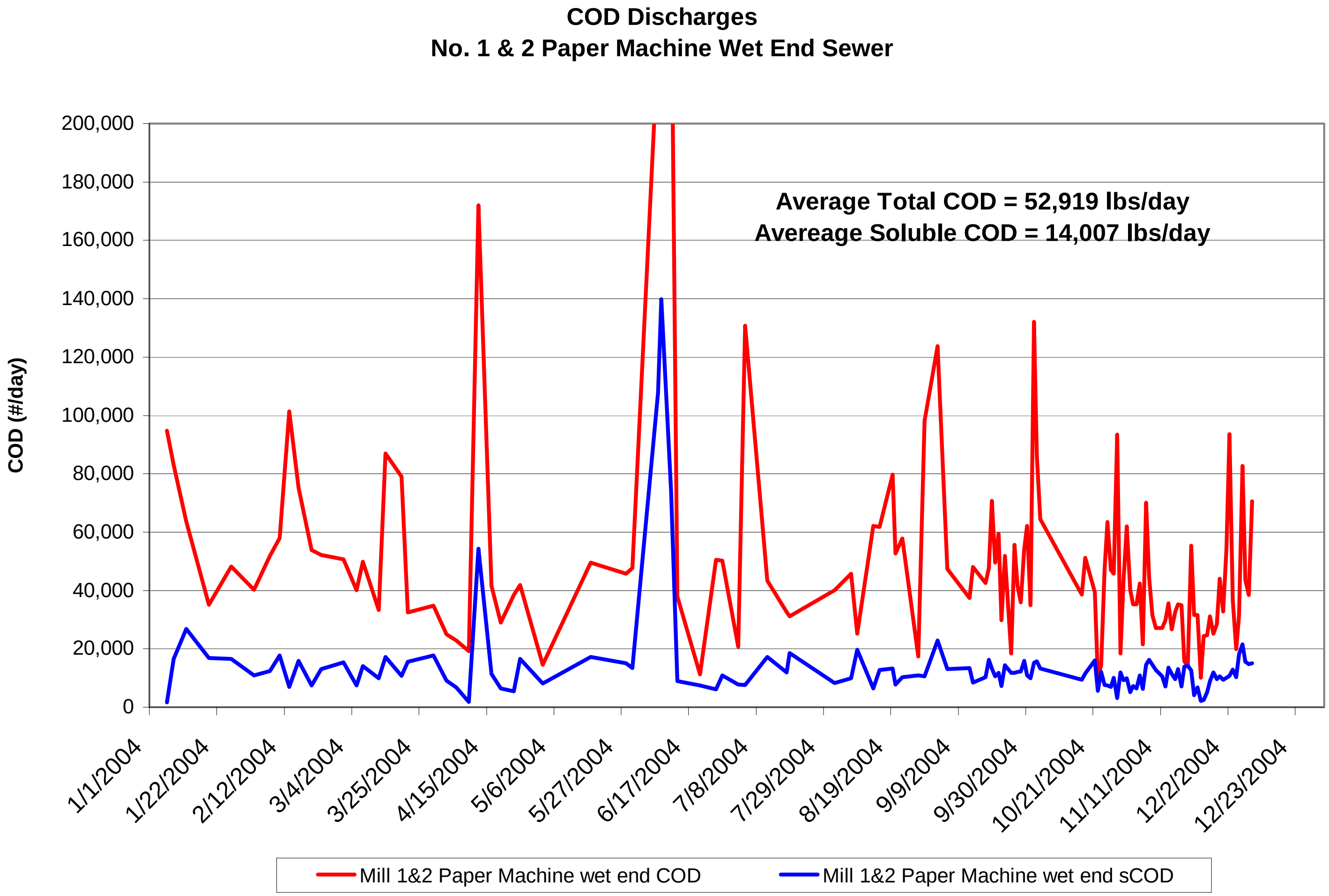

Figure E1. COD Discharges from the No. 1 and 2 Paper Machines Wet End Sewer

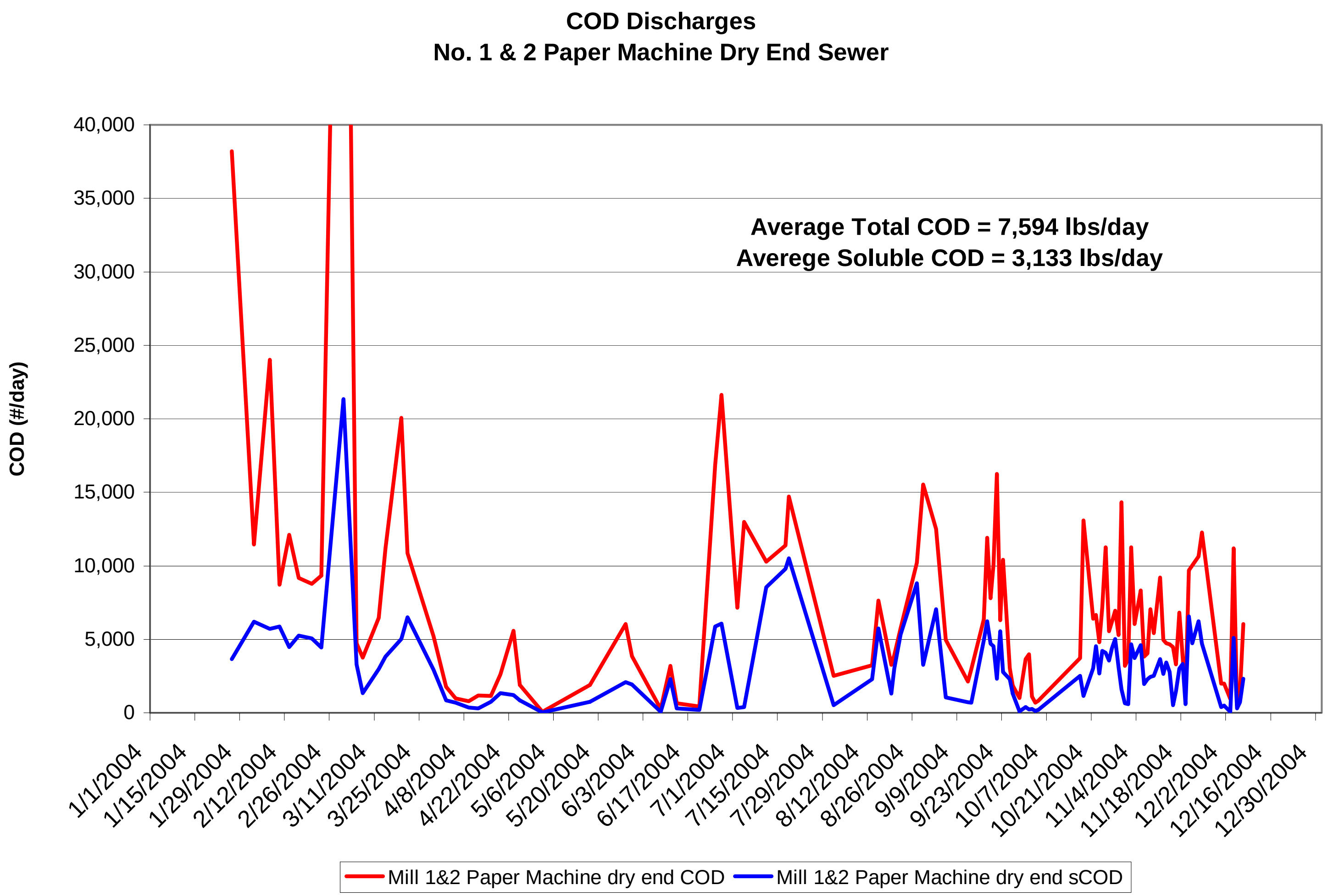

Figure E2. COD Discharges from the No. 1 and 2 Paper Machines Dry End Sewer

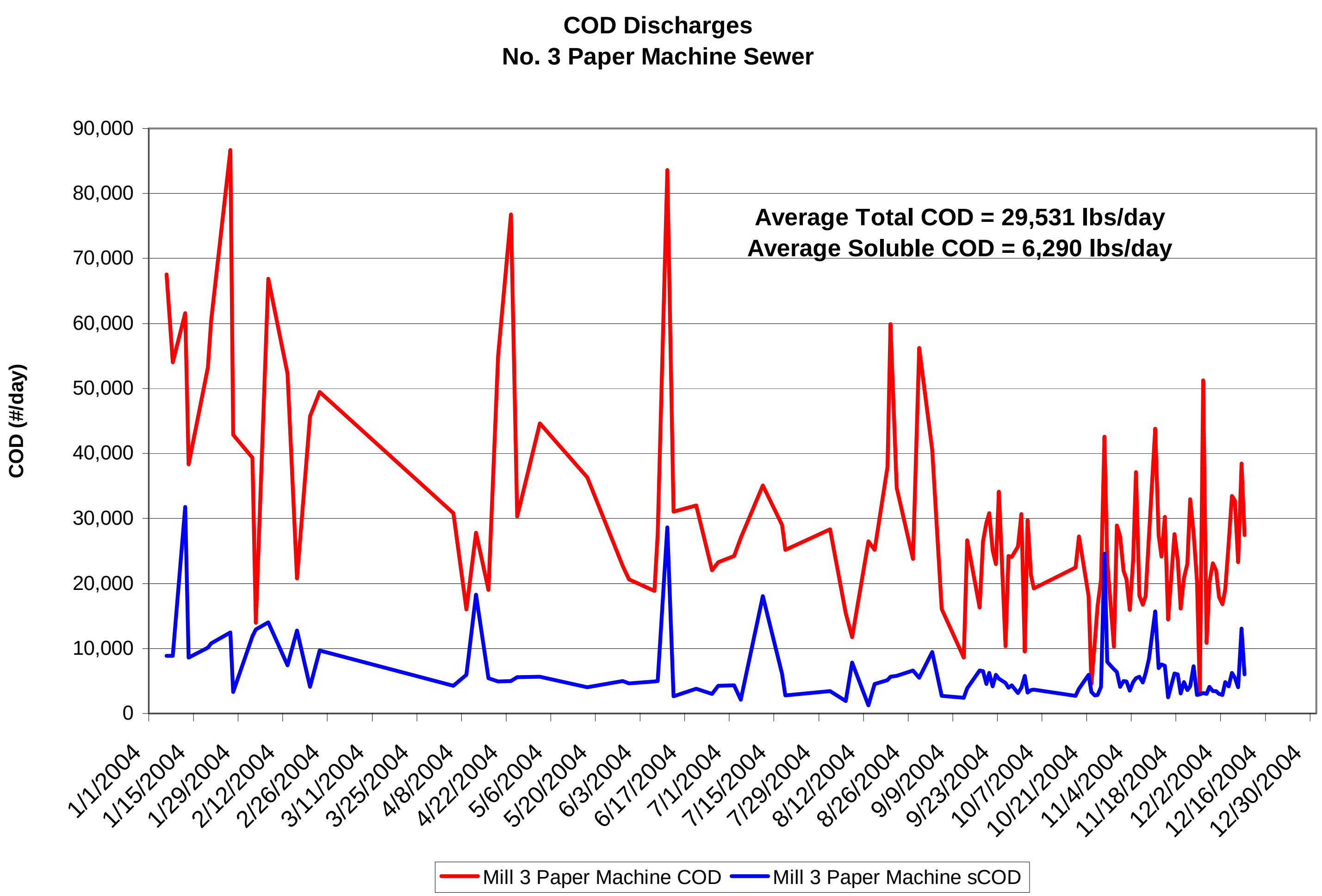

Figure E3. COD Discharges from the No. 3 Paper Machine Sewer

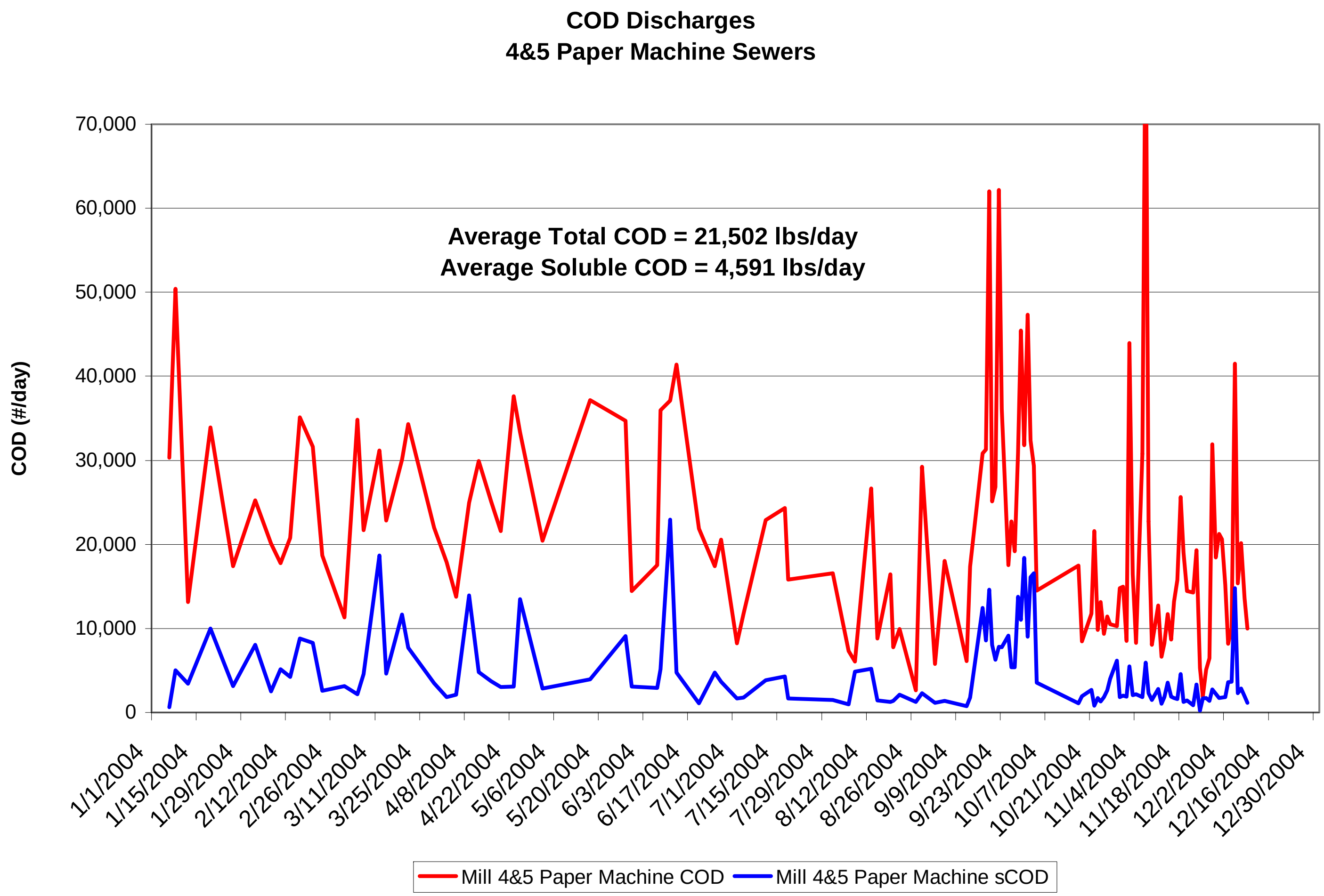

Figure E4. COD Discharges from the No. 4 and 5 Paper Machine Sewers

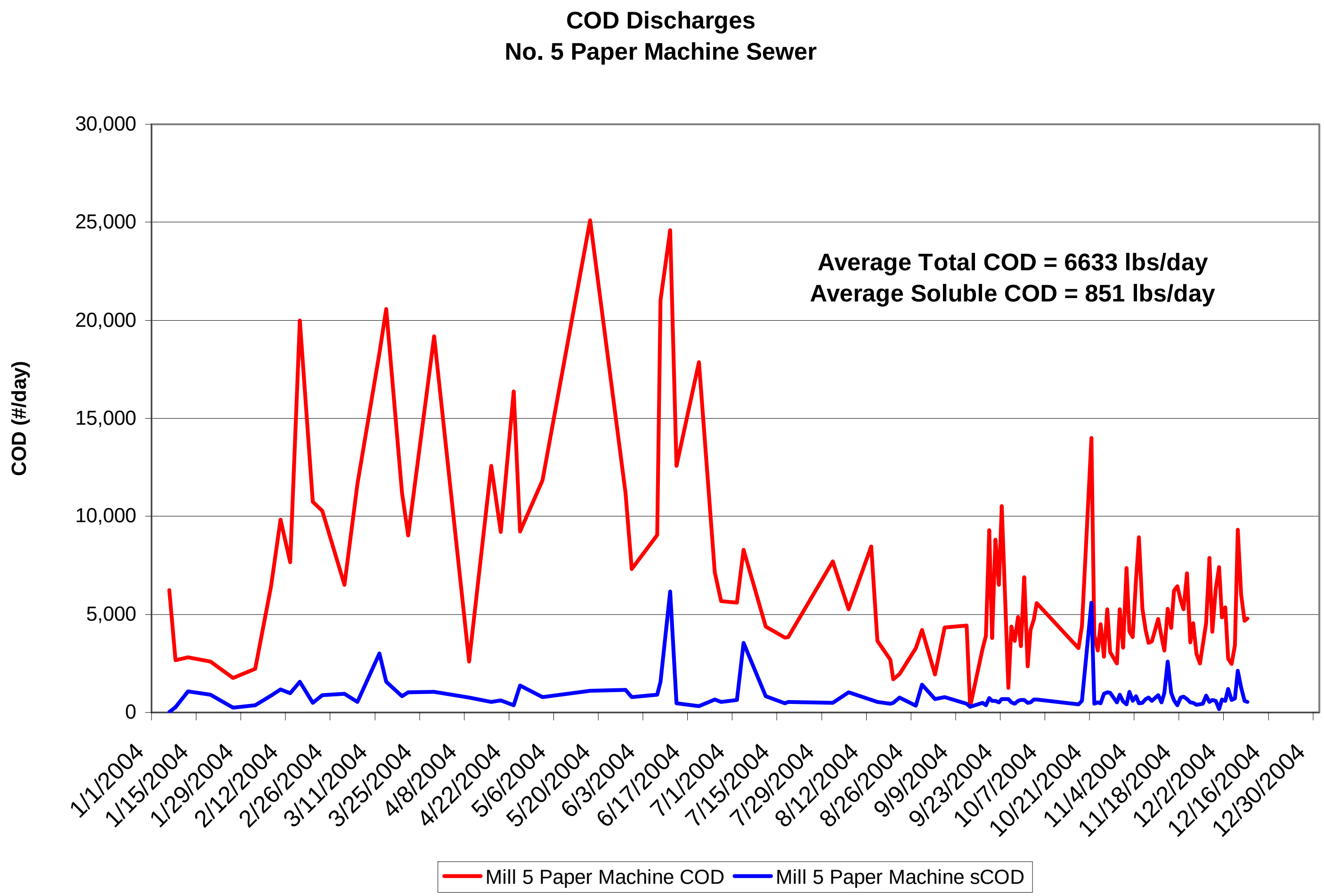

Figure E5. COD Discharges from the No. 5 Paper Machine Sewer

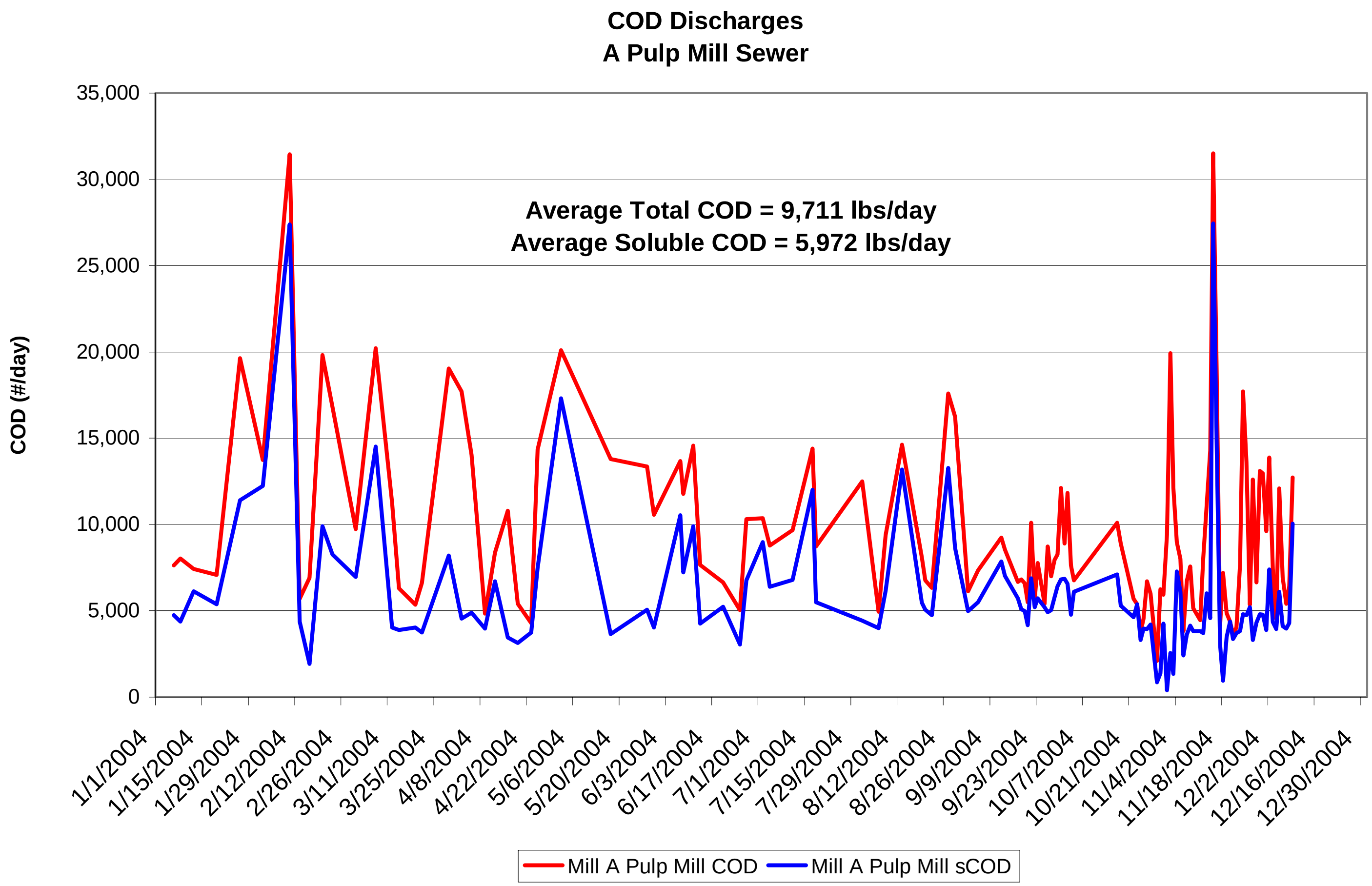

Figure E6. COD Discharges from the Softwood ("A") Pulp Mill

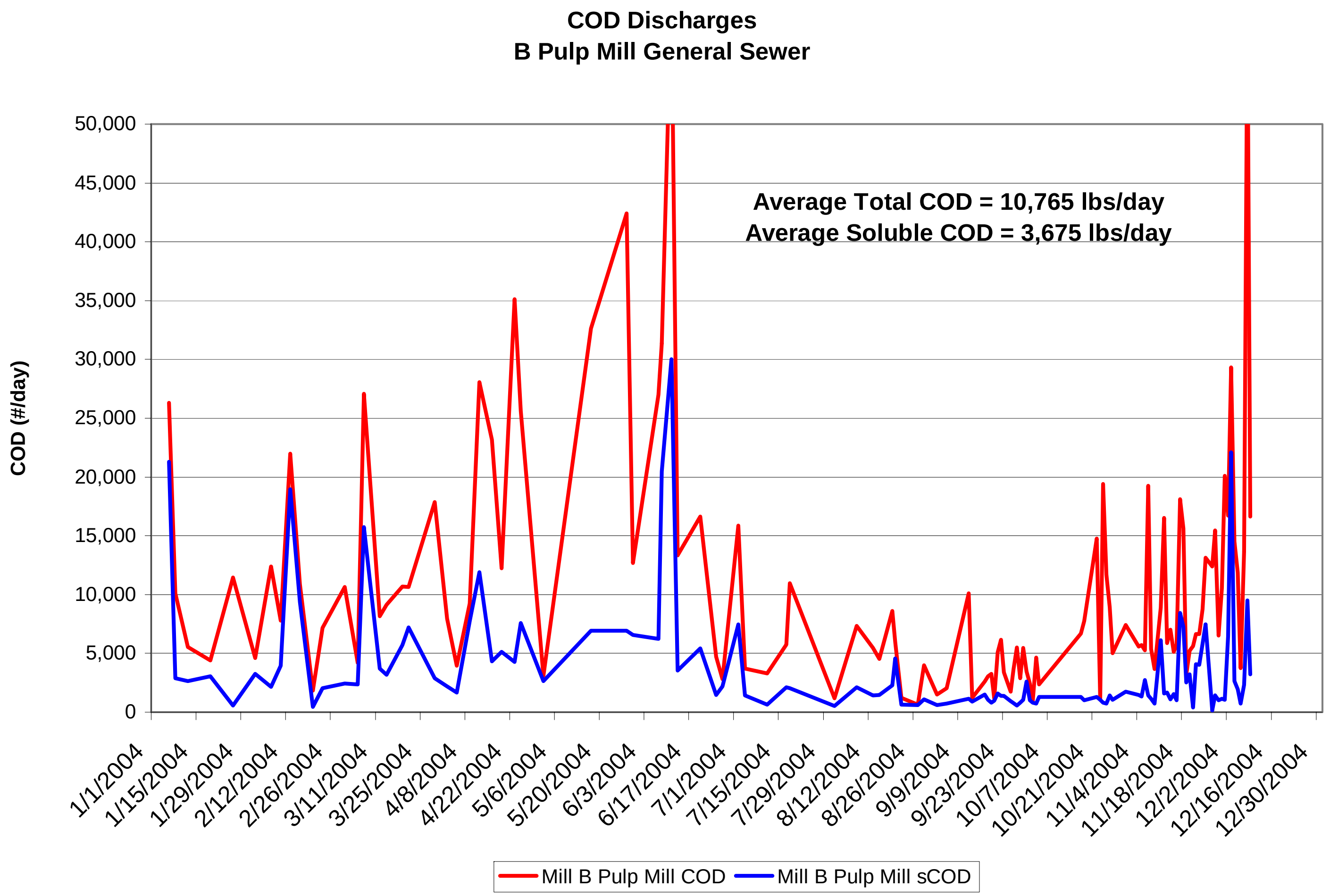

Figure E7. COD Discharges from the Hardwood ("B") Pulp Mill

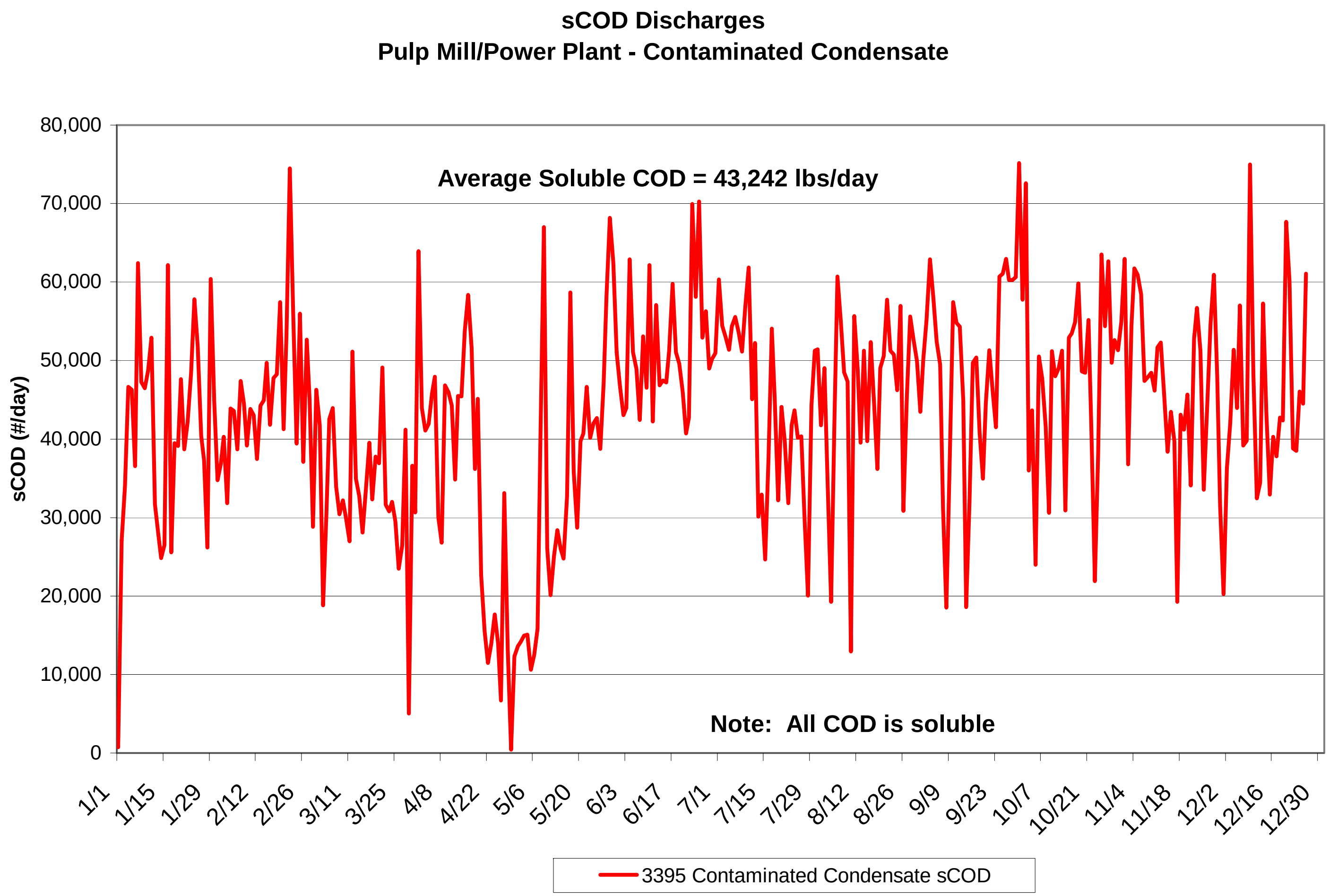

Figure E8. Filtered (Soluble) COD Discharge from the Pulp Mill/Power Plant Contaminated Condensate

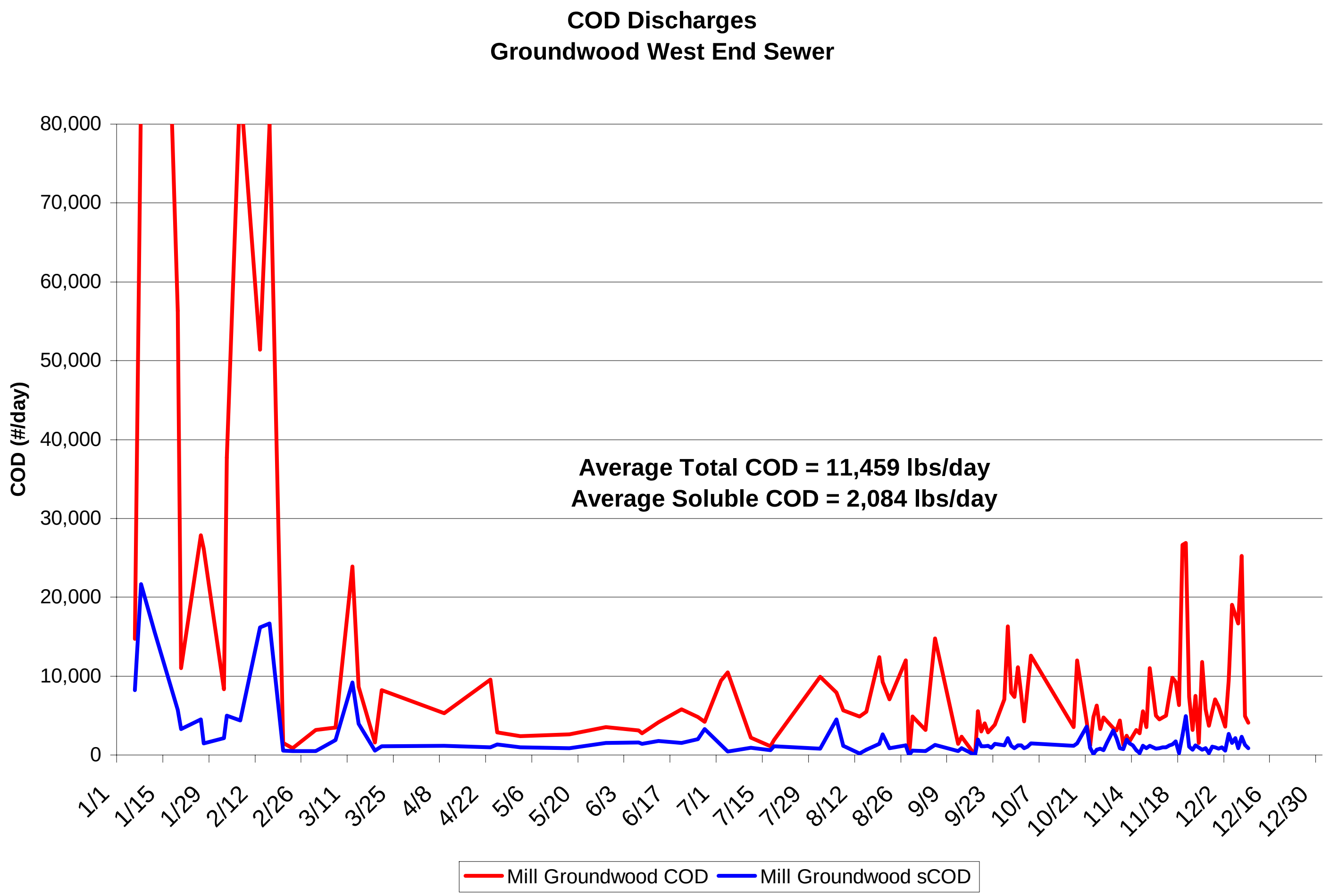

Figure E9. COD Discharges from the Groundwood Mill West End Sewer

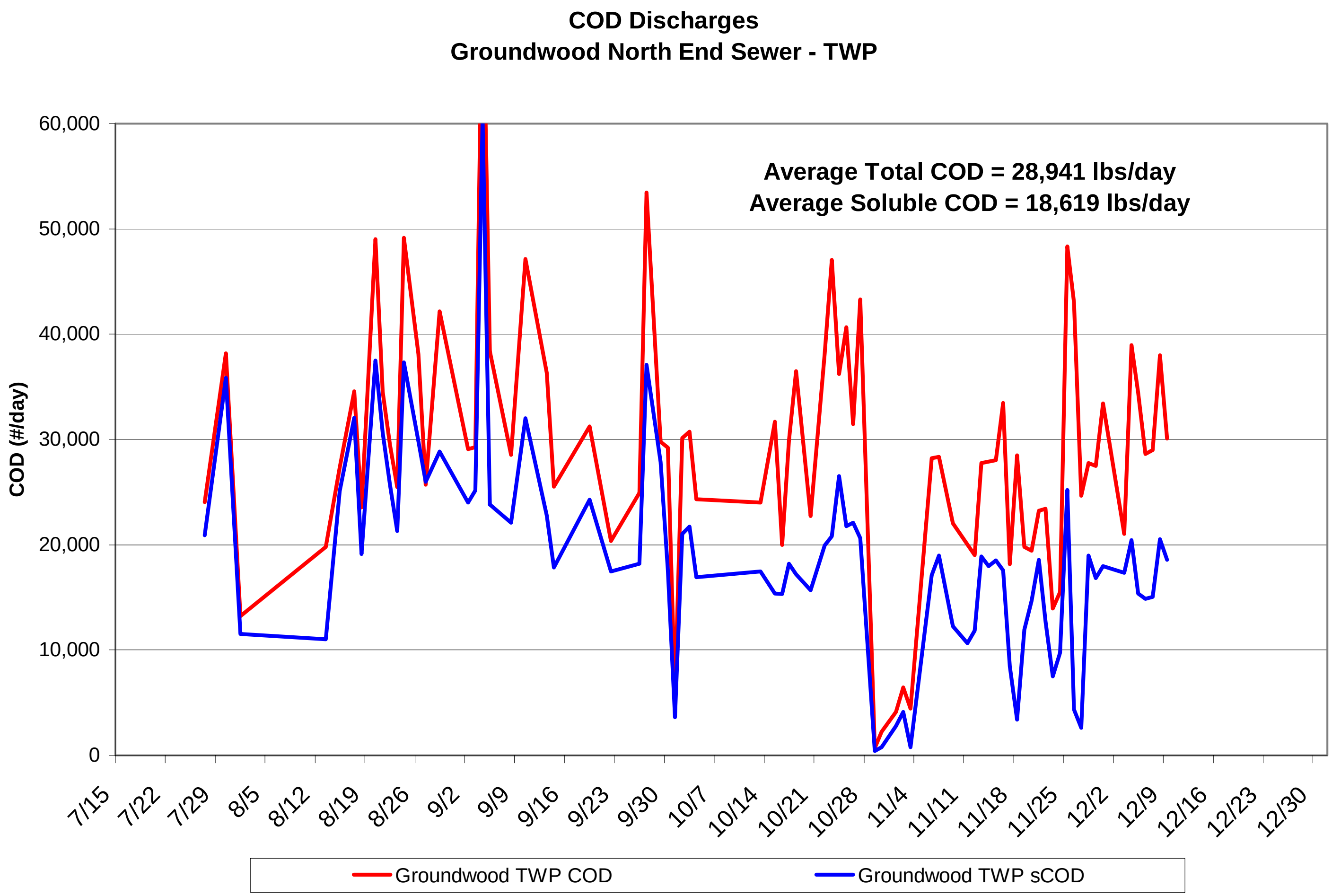

Figure E10. COD Discharges from the Groundwood North End Sewer Including Twin Wire Press

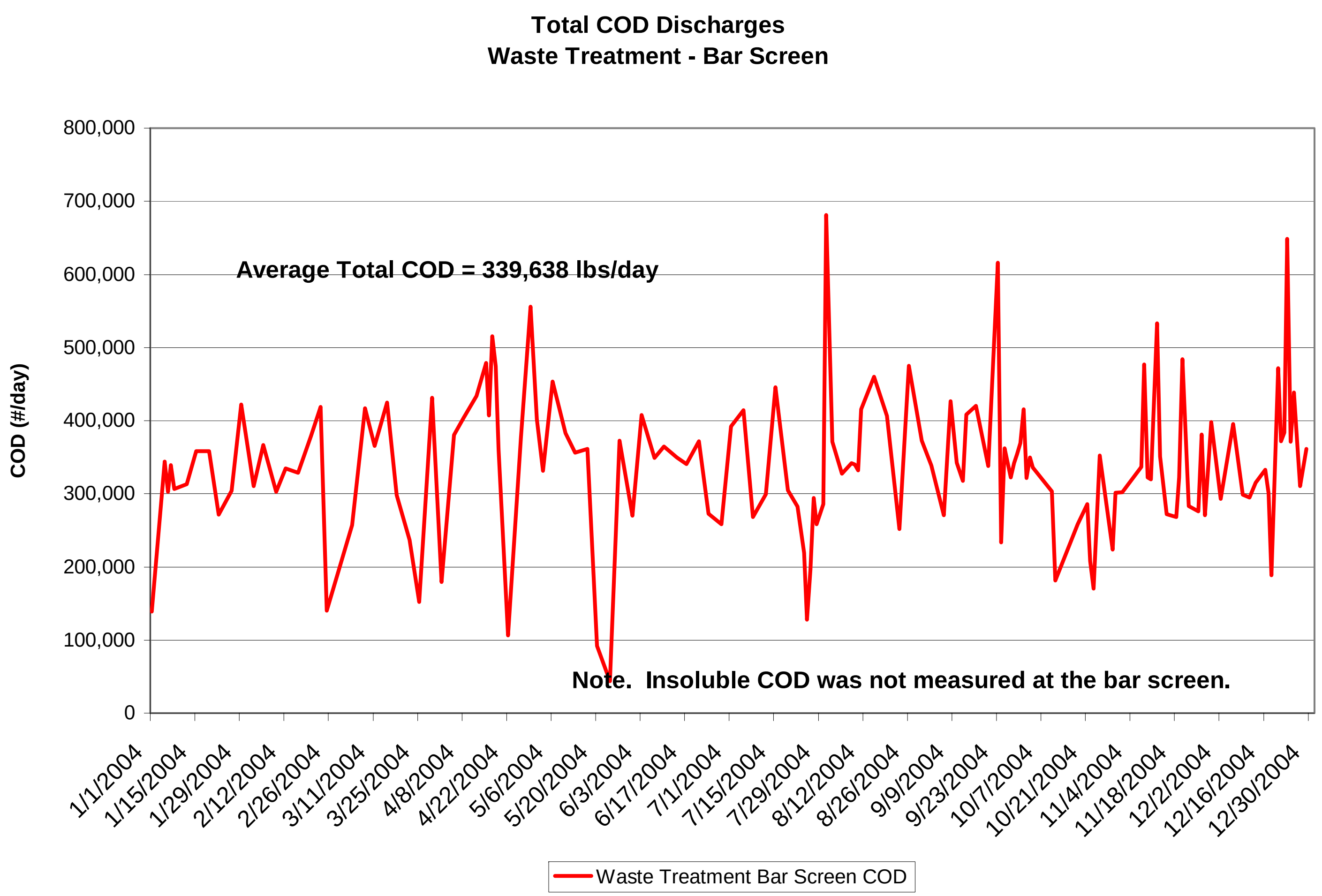

Figure E11. Total COD Discharge at the Bar Screen in the Waste Treatment System

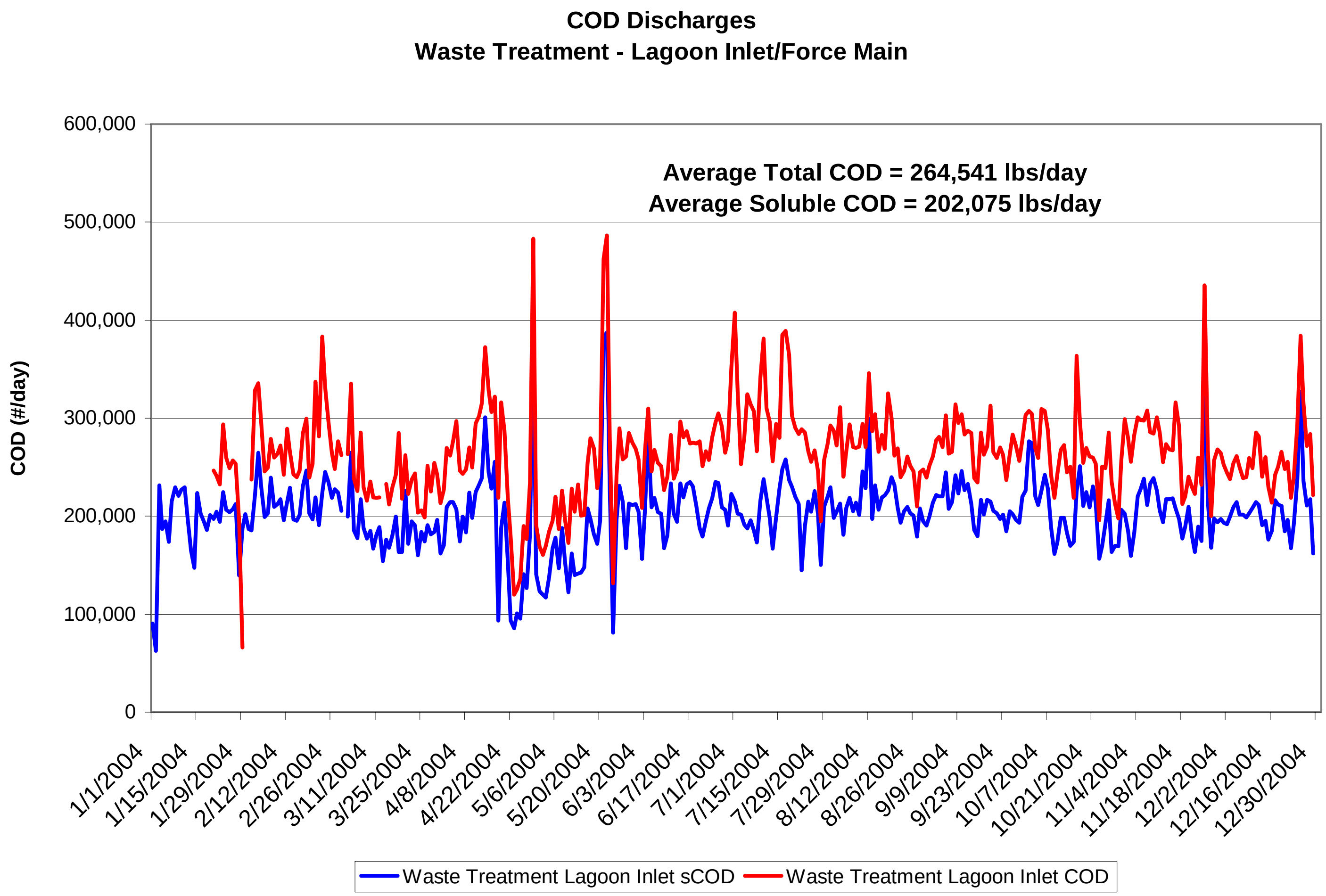

Figure E12. COD Discharges at the Lagoon Inlet in the WastewaterTreatment Plant

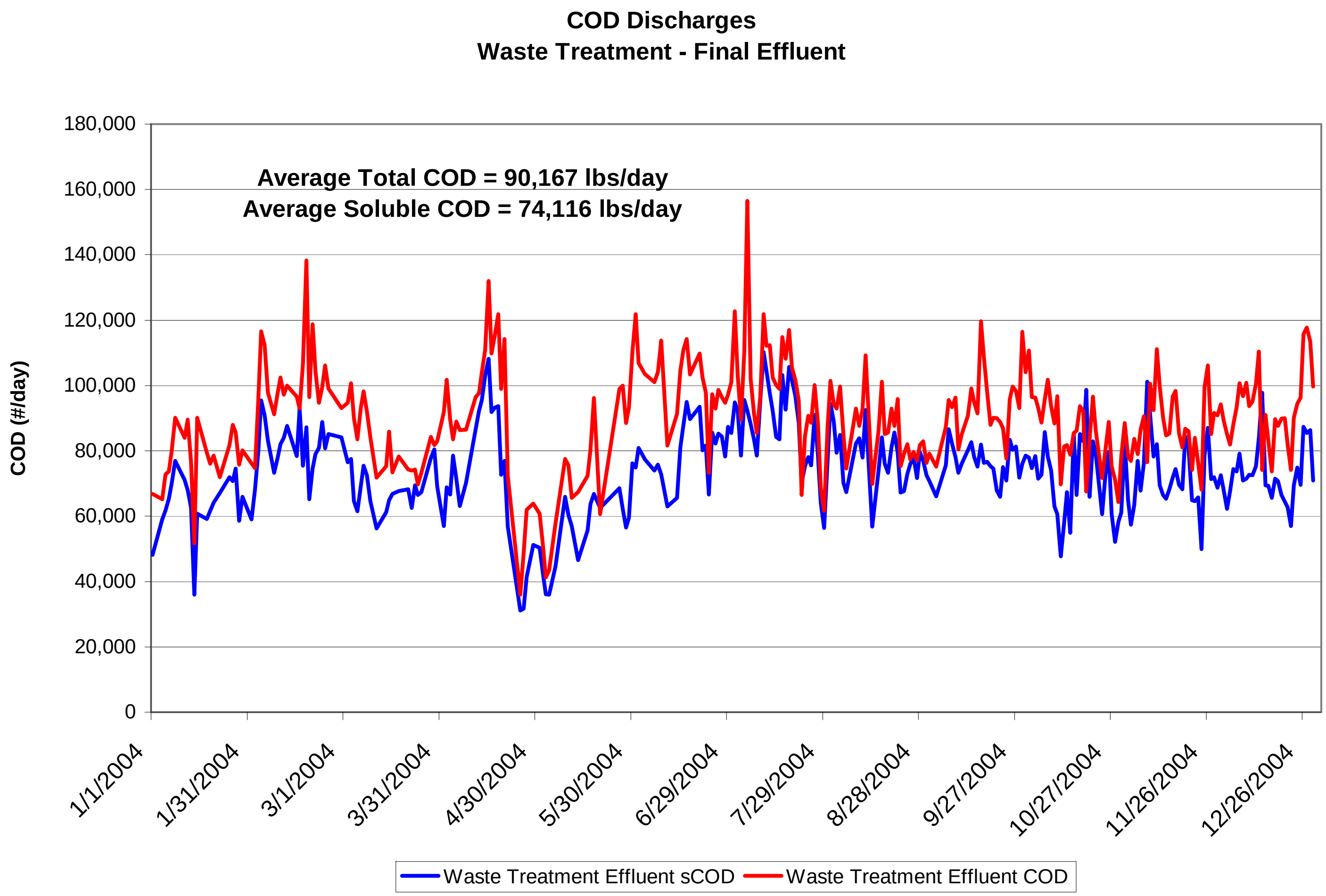

Figure E13. COD Discharge in the Final Effluent Leaving the Waster Treatment Plant

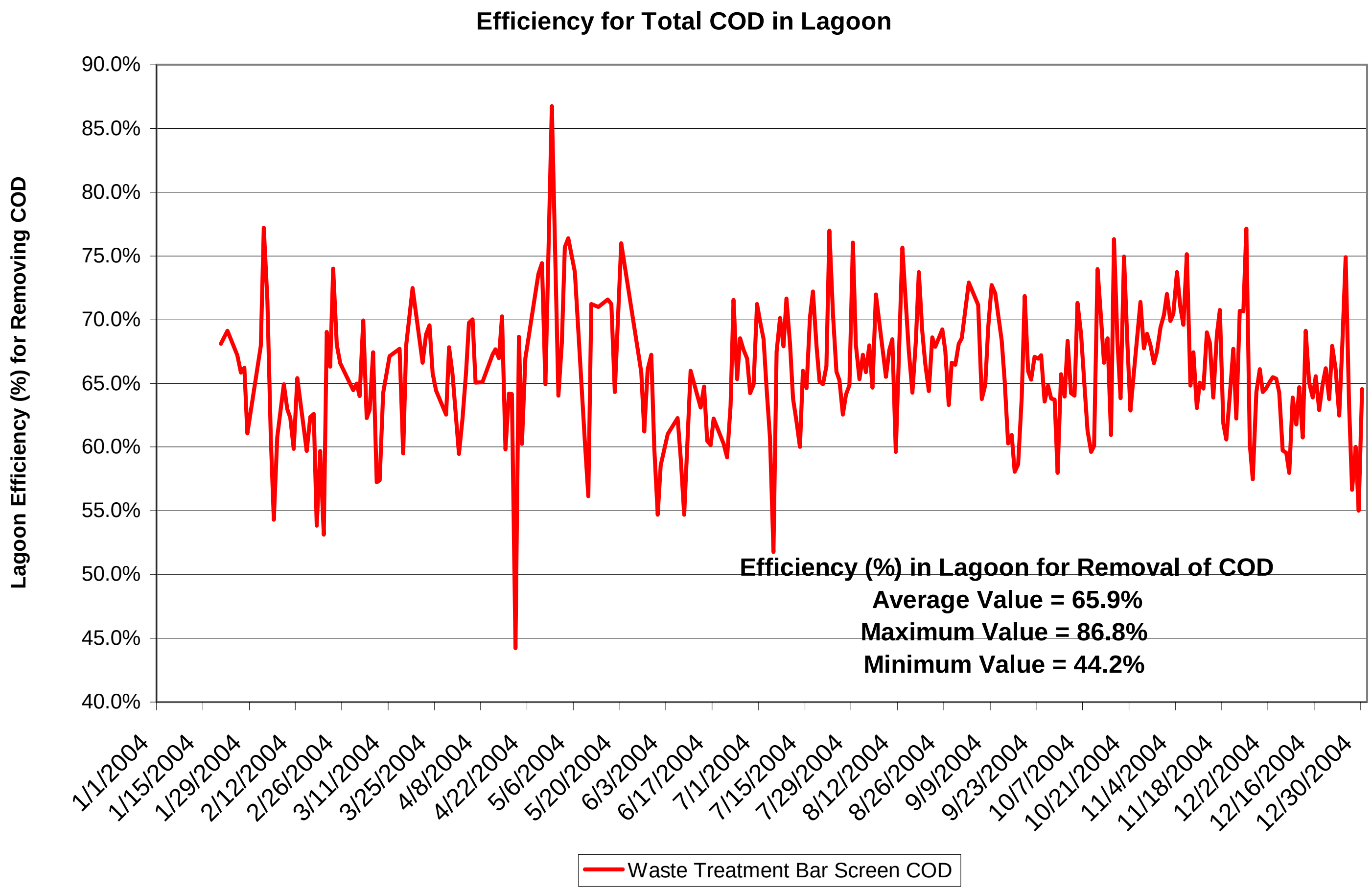

Figure E14. Efficiency in the Lagoon for Removing COD

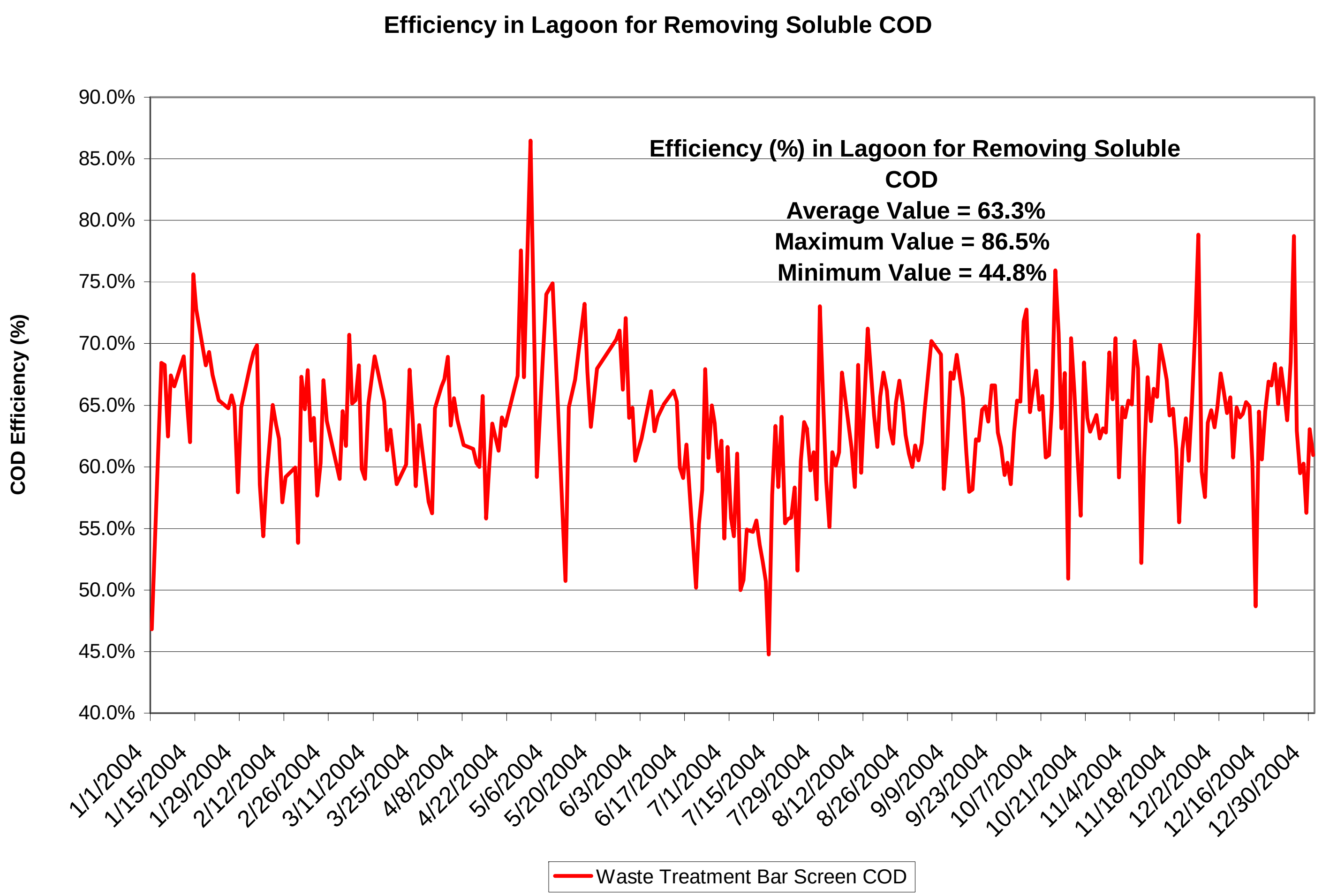

Figure E15. Efficiency in the Lagoon for Removing Soluble (Filtered)