Installation of a Deinking Plant to Increase Paper Machine Production:

Financial Analysis and Final Report

Prepared for Carolina Pulp and Paper

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Engineering Design Firm 3

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Executive Summary

CPP's Raleigh, North Carolina uncoated freesheet mill has expressed the need for a capital project to generate incremental free cash flow in the coming decades. Two different capital project alternatives were proposed to CPP. The high-capital alternative involves installing a flotation deinking plant to supplement the mill's virgin fiber and increase production. The low-capital alternative involves installing a hydropulper makedown system and purchasing market deinked pulp (MDIP) to increase production.

In each case, the primary changes to the mill would be to the paper machines, waste treatment system, and effluent treatment system; there would be only limited effects to other mill operations (woodyard, bleaching, pulping, and recovery). The production off of each paper machine would increase by approximately 11% in each of the envisioned scenarios. Effluent generation would increase in both cases, more significantly in the case of flotation deinking. Flotation would also generate almost 40,000 ODt/yr of deinking sludge that would have to be landfilled. Each project would require significant additional energy (both to dry the incremental paper and to run the pulpers or deinking plant) and fresh water. The increases in energy and fresh water usage were larger in the case of flotation deinking, as per the WinGEMS model developed for this report.

The total installed capital (TIC) cost of each of the proposed projects was estimated. Given the relative simplicity of the low-capital alternative, each individual piece of equipment was priced and a factored capital cost estimation method was used to estimate the TIC at around \$2,400,000. Since the proposed flotation deinking plant would require numerous types of equipment for which reference quotes were unavailable, the Consulting Firm sought an all-inclusive vendor quote in the interest of accuracy. The total purchased equipment cost from the most pertinent quote (\$6,900,000) was input into a factored capital cost estimator and the TIC of the high-capital investment was estimated at just under \$28,000,000.

Separate FEL-0 level financial analyses were completed for each of the two proposed capital projects. It was quickly found that the low-capital alternative of purchasing MDIP would not be profitable or feasible for the mill, with an IRR of around -17% and an NPV of approximately -\$50,000,000. The high-capital alternative of flotation deinking, on the other hand, had a much more financially feasible IRR of 10% and an NPV of approximately -\$3,400,000.

The Consulting Firm believes that, given CPP's need for incremental free cash flow in the coming decades, it would be in CPP's best interest to commission an FEL-1 analysis of the proposed flotation deinking plant investment. The FEL-0 analysis discussed in this report is accurate only to within ±40%, so it is possible that the information gathered by completing an FEL-1 analysis could indicate better financial performance. In addition, the Firm suggests that CPP no longer pursues the low-capital alternative (MDIP usage) given its extremely poor financial performance.

Project Background and Description

Current Mill Situation

The Carolina Pulp and Paper Mill in Raleigh, North Carolina is recovery limited, with the recovery boilers operating at over 120% of their designed operational capacity and at their actual maximum capacity. Table 1 provides a summary of key recovery boiler information.

Table 1: Key Recovery Boiler Information (1)

	RB1	RB2
Startup Year	1985	1990
Operating Pressure (psig)	800	1,000
Total Rated BLS Capacity (tons/yr)	507,270	
Total Operating BLS Capacity (tons/yr)	638,867	
Percent Over Rated Capacity	25.94%	

It is also worth noting that the mill's two digesters are operating at around 90% of their maximum capacity. Figure 1 shows the maximum and design operational capacities for several key systems within the mill.

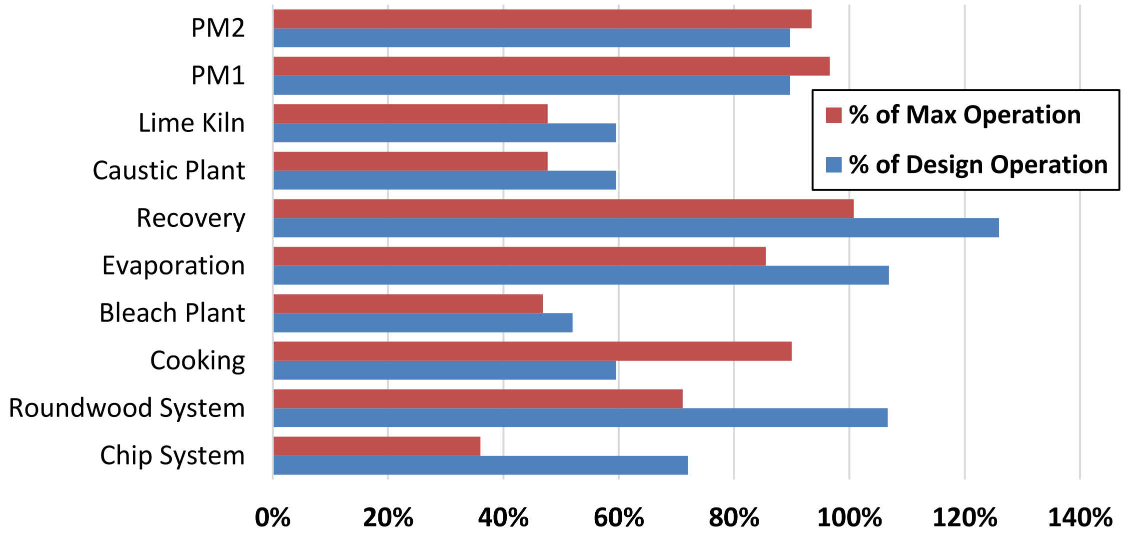


Figure 1: Current Operating and Max Capacities (1)

The mill has two paper machines, one producing uncoated freesheet in roll form and one producing sheets. The bottleneck analysis shows that the machines both have excess capacity that is currently unable to be used. Together, the machines produce just over 505,000 FT/year at the current recovery limit. If the recovery limit removed, the machines would be able to produce over 563,000 FT/year, an increase of 11.5%. Table 2 contains information about each of the mill's two paper machines.

Table 2: Paper Machine Specifications (1)

	PM1	PM2	Totals
Startup Year	1985	1990	
Product	UCF Rolls	UCF Sheets	
Basis Weight (lb/1300 ft^2)	24	20	
Effective Width	266	333	
Rated Speed	3000	3500	
Actual Production with Recovery Limit (FT/yr)	236,712	268,684	505,396
Production Without Recovery Limit (FT/yr)	263,801	299,495	563,296
Percent Increase Immediately Possible	11.4%	11.5%	11.5%

Figure 2 shows the free cash flow generated by the mill since construction began in 1982. The mill has been generating positive free cash flow for years, but it is forecasted to steadily decrease in profitability until the free cash flow becomes negative in 2028.

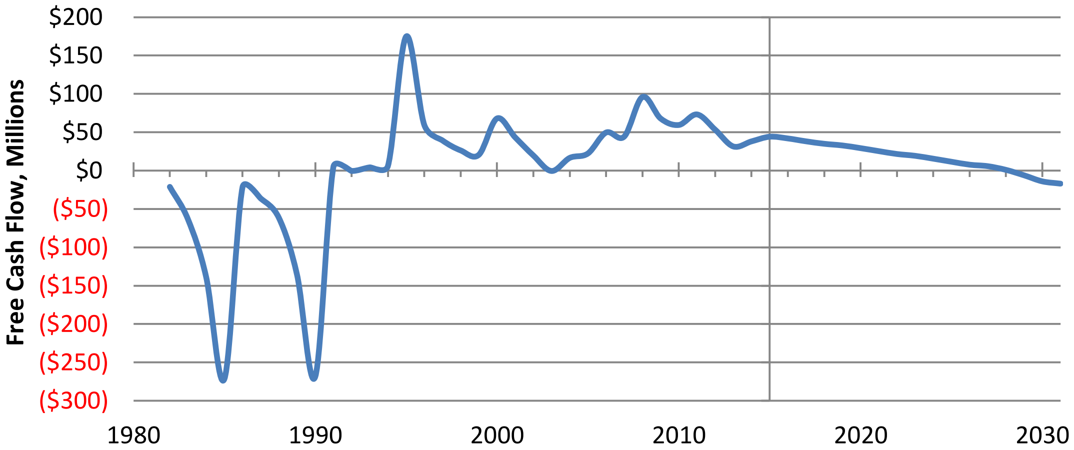


Figure 2: Projected Mill Free Cash Flow until 2030 (1)

As the mill is projected to decline in profitability, several strategic capital projects have been proposed to increase the mill's free cash flow and make it more cost-competitive again.

Proposed Capital Projects

Each of the proposed capital alternatives is discussed in detail in the Scope of Work, Decisions, and Project Options section.

One of the potential strategic capital projects proposed by the mill is to install a deinking facility to allow greater paper machine production without upgrading the recovery boiler. Many mills around the world use deinking technologies to reuse secondary fiber in papermaking. Given that more than half of all paper produced worldwide comes from recycled fiber, this technology is well-proven (2). The proposed alternative project is to install hydropulpers and purchase market deinked pulp (MDIP), which would require significantly less capital but would require the purchase of a more expensive fiber source.

Incorporating wastepaper into the furnish would be an excellent way to supplement virgin pulp production. Given that the mill's recovery boiler is at capacity and its digesters are operating near their max capacities, deinking or purchasing MDIP could be an excellent option for the Raleigh, North Carolina mill, yielding significant increases in production from both machines. Using recovered fiber on the machines does not add load to the digesters, which is also desirable given that they are operating close to their maximum capacity.

Supporting Information

Much of the information presented in this section was taken from the "Key Concepts" section of Deliverable 1. In the interest of brevity, supporting information not included in the body of this report can be found in Appendix A1.

Wastepaper Supply, Demand, and Cost

The availability of raw material, be it recovered paper or deinked market pulp, will play a key role in the financial performance of each investment. Given the mill's relatively urban location in Raleigh, North Carolina, it is believed that there is adequate supply of wastepaper to fit the mill's needs. In speaking with a Carolina Pulp and Paper representative, it was determined that the wastepaper being generated in Raleigh is all currently purchased (3). This means that the mill would likely pay a premium over existing wastepaper users to be able to acquire wastepaper from the current local market if it chose to install a deinking plant.

For this application, a sorted office paper (SOP) feedstock was chosen as the best balance of availability and quality. Considering the urban location of the mill, it was assumed that the large number of local sorting facilities would be able to supply the required amounts of this material. SOP is typically used in the production of printing and writing papers from recycled fiber, as these grades have strict requirements of high brightness and low dirts count. The sorting process removes the majority of groundwood and unbleached fiber, though each sorting cycle increases the cost of the grade. Alternatively, the mill could utilize unsorted mixed office waste (MOW) and implement its own sorting line, selling the rejected, lower-quality wastepaper to other manufacturers that are seeking cheap sources of fiber as filler or for bulk (e.g., linerboard mills). The use of unsorted wastepapers will, however, increase other operating costs due to increased chemical requirements and the more complex contaminant removal systems needed (4). The feasibility of the latter approach depends on the amount and type of contaminants in the MOW supply and the local demand for low-quality papers.

Deinked market pulp is not widely produced in North America. According to the RISI Mill Asset Database, only those mills listed in Table 3 produce deinked market pulp (5). The nearest deinked market pulp producer, Resolute Forest Products, is located over 400 miles from Raleigh in Fairmont, West Virginia. This mill also happens to produce dried MDIP, which is much cheaper to transport than wet-lap, meaning it would likely be a preferable MDIP supplier for the Raleigh mill.

Table 3: List of North American Companies Producing Deinked Market Pulp (5)

Parent Company	Mill Location	Relevant Product
Cascades	Auburn, Maine, USA	Deinked Pulp - Wetlap
Rolland Enterprises Inc.	Breakeyville, Quebec, CAN	Deinked Pulp - Wetlap
Kruger	Crabtree, Quebec, CAN	Deinked Pulp - Wetlap
Fox River Fiber	De Pere, Wisconsin, USA	Deinked Pulp - Wetlap
Verso	Duluth, Minnesota, USA	Deinked Pulp - Wetlap
Resolute Forest Products	Fairmont, West Virginia, USA	Deinked Pulp - Dried
Georgia-Pacific	Halsey, Oregon, USA	Deinked Pulp - Wetlap
Resolute Forest Products	Menominee, Michigan, USA	Deinked Pulp - Dried

Figure 3 shows the locations of these MDIP producers, illustrating the significant distance across which the pulp would have to be shipped to Raleigh, North Carolina.

Figure 3: Locations of MDIP producers in North America (5)

Figure 4 shows the apparent consumption, imports, exports, and consumption of recovered paper in the United States since 1992 (6). Exports of recovered paper have increased since around 2002, whereas apparent consumption and production both dropped starting in 2007. The fact that recovered paper exports are increasing indicates that production is remaining relatively stable despite decreased apparent consumption. Given that over a third of the recovered paper generated in the US is exported, there is likely more than enough capacity in the US for another mill to begin deinking.

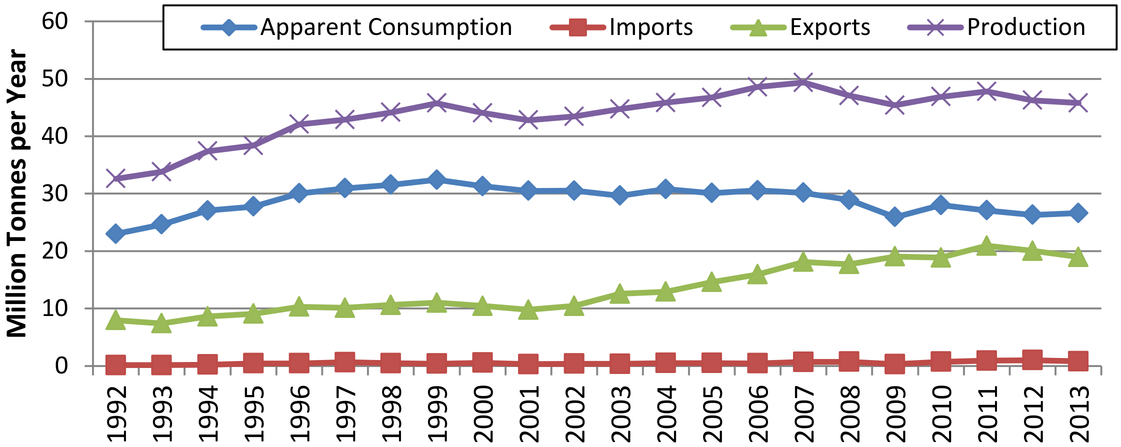


Figure 4: Recovered paper statistics since 1992 (6)

It is worthy of note that the database used to acquire these figures does not support queries for more specific grades of recovered paper. The term "recovered paper" is actually quite broad and includes both white and brown grades, the latter of which are increasingly being exported to China. It is possible that the proportion of white recovered paper grades exported is significantly lower than indicated by Figure 4, but given the scarcity of information and the relatively low volume of wastepaper required by the proposed deinking plant, it is believed that there is adequate ledger wastepaper supply to satisfy the needs of the modified Raleigh mill.

The price of the raw material (wastepaper vs. MDIP) will play a key role in the financial performance of each of the proposed investments. Figure 5 shows the costs of some key wastepaper grades throughout recent years, highlighting the premium price the Raleigh mill would have to pay for MDIP. The RISI Market Price Database states that the price of deinked market pulp (MDIP) is around $750/ton, significantly higher than that of any of the wastepaper grades shown in Figure 5 (7).

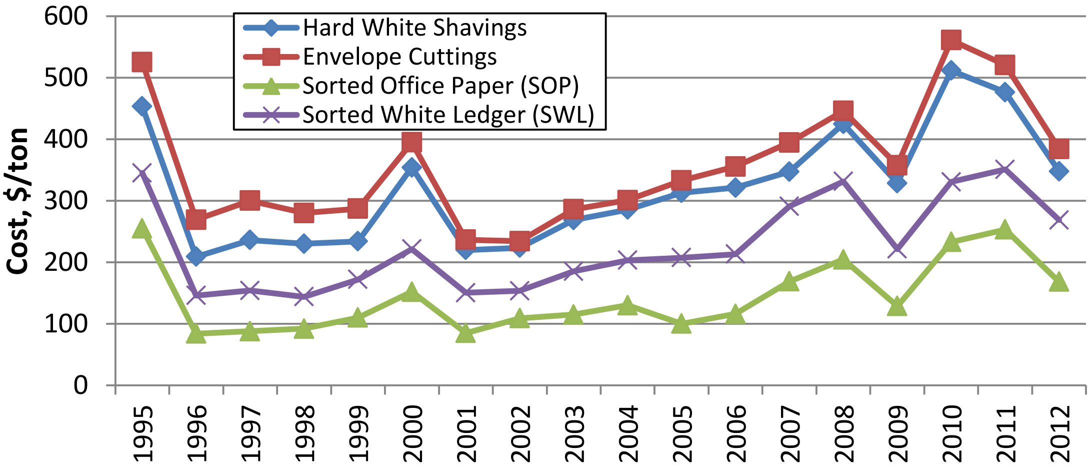


Figure 5: Costs (FOB seller's dock) of relevant wastepaper grades (8)

In addition, the price of recovered paper appears to be decreasing in the US Southeast. These trends are supported further by the data previously discussed in Figure 4. Unfortunately, historical pricing data beyond the previous two years was not available for MDIP. It is clear from Figure 5 that the price of recovered paper is declining, which favors the installation of a deinking plant over the installation of pulpers for MDIP use. Sorted office paper (SOP), the most likely candidate for use in the proposed deinking plant, will likely cost under $200/ton if it continues to follow the trend shown in Figure 5. Since fiber cost is the largest variable cost of production, the major difference in the costs of MDIP and recovered paper sources will play a key role in determining which of the two proposed solutions yield better financial performance. More detailed financial analyses are in development.

It should also be noted that on October 31, 2012, Mississippi River Pulp closed down their Natchez MDIP mill, decreasing North American MDIP production by 131,000 annual tonnes (9). Given the relatively few MDIP producers remaining in North America (as shown in Figure 3 and Table 3), this major decrease in supply likely means the price of MDIP will remain stable or even increase in the next few years. Although it is not immediately clear which of the two proposed solutions would yield better financial performance, the high price and low supply of MDIP do not bode well for the low-capital alternative of installing hydropulpers and purchasing deinked market pulp. Although installing a flotation deinking facility would require significant capital, the Raleigh mill would enjoy significantly reduced variable cost of production on the incremental tons of paper produced.

Process Steps in the Deinking of Ledger Wastepaper Grades

Repulping (2, 10)

The first and arguably most important step in the deinking of recovered paper is repulping. Furnish (baled or loose) is converted into a slurry, ink is detached from fibers, and large contaminants are removed from the stream. The temperature, pH, residence time, consistency, chemical load, fiber type, and contaminant composition during the pulping stage strongly affect the efficiency of the separation of fibers and contaminants during the latter stages of deinking (11).

Decontaminating (2, 10)

A designated screening section in a drum pulper removes large contaminants before the pulp is discharged and moves further into the deinking process, so a separate detrashing unit is not necessary. The advent of drum pulpers has greatly improved removal efficiency and pulp quality, and this technology is almost always used in new and upgraded deinking plants. While these units are more expensive than vat pulpers and require more space, they consume approximately half as much power and have far lower maintenance costs than rotor rebuilds.

Lightweight contaminants such as stickies are removed in the pressure screens, which operate based on differences in size and shape between the contaminants and the fibers. These devices are equipped with slotted baskets that are designed to filter out individual fibers from contaminants and rotors that create pressure pulses to prevent the slots in the baskets from plugging. The coarse screens have wider slots and are typically set up in a feedforward configuration to maximize fiber yield. The fine screens have baskets with narrower slots and usually operate in a countercurrent mode (where accepts from later stages return to feed an earlier stage) to maximize separation efficiency. Over the past ten years, the slot size in the screen baskets has decreased by about half, allowing for decreased residual refuse size and improved separation of stickies from the exiting pulp stream. Stock consistency and temperature, pH, contaminant composition, pressure drop, and slot size can influence the effectiveness of both the fine and coarse screening operations.

Kneading and dispersion are crucial steps in the removal of ink and dirt from the pulp, as well as the size reduction of stickies. These units operate similarly to refiners, but kneaders rotate at slower speeds and with a larger plate gap to avoid fiber cutting. Kneaders increase final brightness via further separation of contaminants. They typically precede flotation and washing steps, and contaminants exit at a size that flotation cells can efficiently remove. Dispersers run at high speeds with smaller plate gaps. Debris and visible ink particles still present in the pulp are reduced, resulting in a more uniform sheet but decreasing brightness. Dispersers are usually placed near the end of the process, prior to pulp storage. Both of these units typically operate at around 35% consistency, so a belt or screw press is usually used upstream to thicken the stock. Peroxide bleaching is often more effective at this point in the process due to the increased pulp consistency. In kneaders and dispersers alike, the consistency, pH, temperature, power, plate design, and rotational speed determine the overall performance of the unit.

Deinking

Flotation cells remove hydrophobic contaminants (primarily ink particles) via the injection of air into the pulp slurry. The contaminants adhere to the air bubbles, rather than the pulp, and float to the surface of the unit where they can be removed. Flotation aids, such as soaps and surfactants, are typically added before flotation cells to improve the adhesion between the air bubbles and contaminants and to strengthen the bubbles so they reach the surface of the unit. The size distribution of these bubbles is also important for effective ink removal, in that bubbles that are too large or too small compared to the contaminants can lead to fiber loss or contaminant carryover, respectively. Water hardness is an important determinant in the effectiveness of the flotation stage. Lime milk is often added to impart hydrophobicity to ink particles and ensure a correct size distribution (12). In addition to residence time, water hardness, pH, consistency, particle size, and temperature in the flotation unit, the upstream pulper conditions also affect the ink removal efficiency during flotation. Figure 6 is an illustration of an Andritz flotation cell.

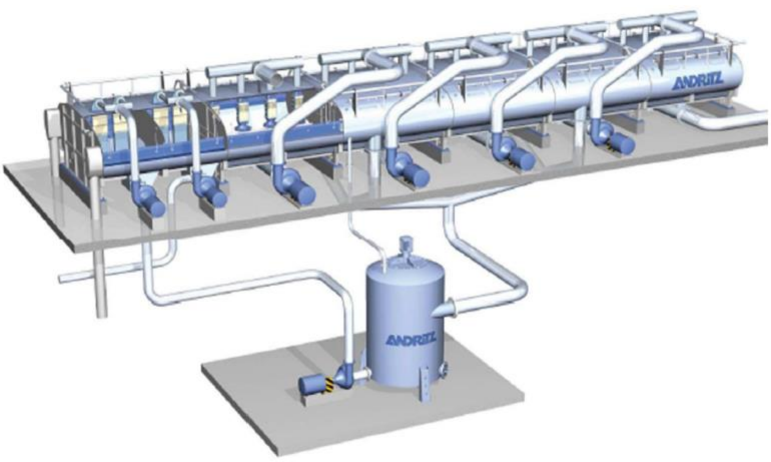


Figure 6: Andritz flotation cell (2)

Sophisticated deinking plants typically have two to three loops, with flotation and washing stages within each, for maximum deinking efficiency and pulp brightness. The advent of new flotation cell designs and more effective recycling chemicals has decreased the need for washing as a separate, independent pulp cleaning operation. As such, new flotation cells are typically installed alongside vacuum, drum or belt washers, which, though less effective than their predecessors at removing ink and other contaminants, exhibit much less dramatic yield loss.

The effectiveness of deinking is influenced by the type of ink being removed, the printing technique and conditions, the age of the print, and the paper surface properties. The key findings of a study of the effects of different printing processes and drying parameters on deinkability are summarized in Table 4. (13)

Table 4: Influence of printing process and drying mechanism on deinkability (13)

Printing process	Drying mechanisms	Deinkability
Offset newspaper **Letterpress** **Offset sheet fed** **Offset heat-set**	Absorption (and oxidation) Absorption and oxidation Absorption, evaporation, and oxidation	Good if not aged. After aging, bad ink detachment, smeared pulp, and specks
Rotogravure	Evaporation	Good, possibility of colored pulp (dyes)
Laser printers, copiers **U.V. and I.R.**	Radiation curing	Bad toner detachment, strong speck contamination

In addition to mechanical forces, there are numerous chemicals that can aid in the deinking process. Chelating agents have been used to aid in the deinking of papers printed with flexographic printing ink. Flexographic printing ink is an electrostaticallystabilized, colloidal dispersion and is thus extremely stable within the alkaline pH range (14). Since conventional deinking processes operate under alkaline conditions, this is problematic (2, 13). Some researchers have found that flexographic inks can be flocculated and more easily removed via reduction of steric stabilization forces when ink particles are chelated with cupric chloride (II) (14). This method is similar to others in that it utilizes salts, but it stands out in terms of its effectiveness.

Another chemical treatment common in deinking processes is the addition of non-ionic surfactants during the pulping stage to control issues caused by hydrophilic, sub-micron-sized ink particles (15). The rationale behind such treatments is that adding a surfactant can strengthen air bubbles so they can carry more ink particles upwards and out of the bulk liquid, where the ink can be efficiently removed. Further, non-ionic surfactants can help prevent fibers from attaching to air bubbles, potentially increasing deinking yield (15).

The extent and efficiency of deinking are very sensitive to a number of process parameters, from the pulping of the recovered paper to the characteristics of the flotation cell itself. Some of the parameters with dramatic effects on deinking are the pulping conditions, the relative ink and fiber sizes in the recovered paper and the pH, temperature, air bubble size, water hardness, and duration of flotation.

One study found the optimal pulping conditions with respect to deinking efficiency to be 2% consistency, 50 °C, 1 minute duration, and pH 3.5 with 60 rpm agitation (16). Increasing the duration of pulping detaches more ink but reduces the size of the particles, making them more difficult to remove during deinking.

The quality of the recovered paper used in the process has a significant effect on deinking. Deinking is less effective, overall, when the feedstock is a mix of papers printed with different types of ink. When the wastepaper mix includes papers printed with liquid toner inks, the total dirt speck area after flotation increases dramatically (17).

The size of the air bubbles generated within a flotation cell can have an effect on the quality of deinking. Small air bubbles are generated at the bottom of flotation cells. These air bubbles move slowly upwards, sometimes agglomerating with other bubbles and increasing in size. Only very small particles can attach to these tiny air bubbles long enough to rise into the frothy area at the top of a flotation cell, where they are removed. These particles are typically hydrophobic in nature and include inks, fillers, contaminated fines, and extractives. However, if the air bubbles are too large, entire fibers can become attached to them. Attachment of fibers and fines to air bubbles is the main cause of deinking yield loss, often over 25%. If air bubble size and velocity are not controlled effectively, deinking yield can suffer dramatically, substantially increasing the price per finished ton of production. (18)

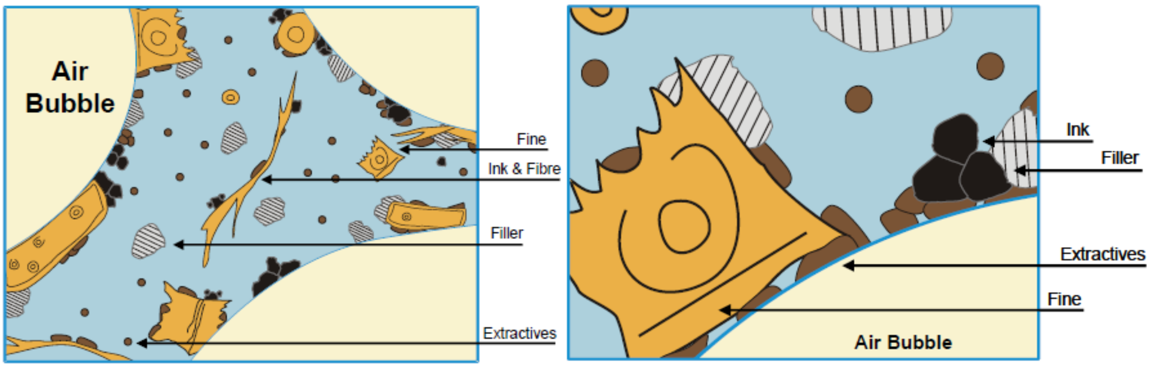


Figure 7: Illustration of particles on air bubbles in flotation cell (18)

Figure 7 illustrates the attachment of different kinds of particles to air bubbles during the flotation process. As shown by the image on the right, smaller particles more readily attach to air bubbles due to their size and hydrophobicity. However, as shown in the picture on the left, larger particles like fibers usually do not attach to air bubbles unless the bubbles are quite large or the fibers are heavily contaminated with hydrophobic particles (18).

The pH must also be controlled during deinking. Pulping at an alkaline pH allows for better toner removal, but pulping at a slightly acidic pH allows for more thorough separation of aluminum- and titanium-based ink particles (19). Under these parameters, flotation is most efficient when carried out at a relatively neutral pH, between 6 and 7. Caustic addition during pulping may facilitate fiber swelling, helping to detach ink particles from fibers because the ink cannot swell (19). In another study, the optimum deinking efficiency was achieved at a pH of around 8 (20). Small pH variations can have major effects on the degree of ink removal, so careful pH control is necessary to achieve uniform, bright deinked pulp. Figure 8 illustrates the effects of varied flotation pH on dirt removal.

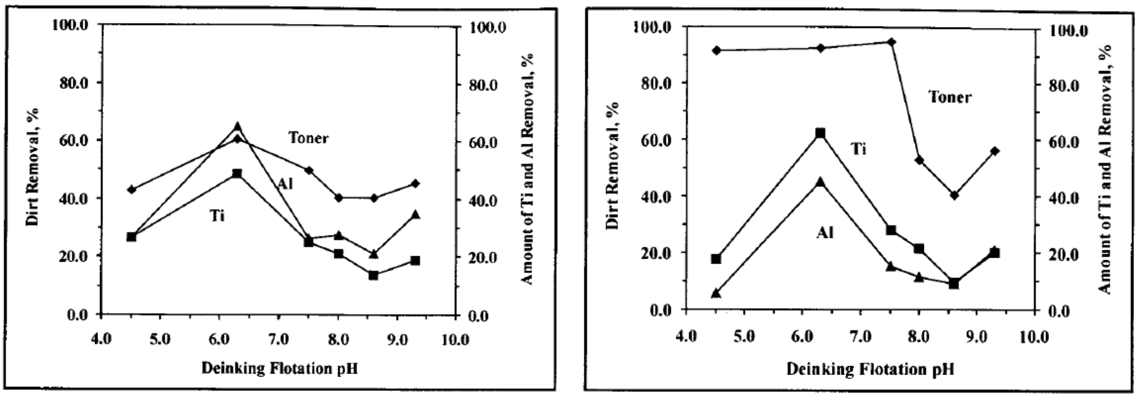


Figure 8: Dirt removal vs. flotation pH for alkaline-pulped wastepaper (19)

Temperature also affects deinking, especially when using enzymes. Operating flotation cells at hotter temperatures can increase the reaction rate and facilitate better ink removal, but at too high a temperature the peroxide used for bleaching can decompose and inhibit brightness development. Moreover, when soaps and fatty acids are used within a flotation cell, a relatively high temperature must be maintained so they remain soluble. When reactive chemicals are used in a flotation cell, careful attention must be paid to the effects of temperature on chemical effectiveness and deinking efficiency. (18)

The calcium ion concentration (i.e., the hardness) in the water used during pulping and flotation often has an effect on deinking. Studies have shown that calcium can interfere with the action of nonionic surfactants via the common ion effect, in which soaps and sodium silicate “compete” for calcium ions (21). Controlling the calcium ion concentration in the dilution water used in pulping and flotation processes can allow for better chemical activity and reduce the dosage of nonionic surfactants required to achieve the same degree of ink dispersion (22).

Perhaps the most important parameter during deinking is the duration of flotation. Longer periods of flotation increase ink removal but decrease yield (18). There is a discrete point at which enough ink has been removed but the yield has not been jeopardized. Operating at this optimum point is essential to cost-effective, thorough deinking. By effectively monitoring and controlling the other parameters mentioned, a deinking operation can minimize the flotation duration required to reach their brightness targets and thus maximize yield and throughput.

Case Studies and Precedents

A number of pulp and paper mills across North America have undergone projects to either introduce secondary fiber use in the mill or expand systems already in place. The mills researched installed pulping, flotation, washing, cleaning, and screening equipment to process the recycled fiber for appropriate further use. Incentives include reducing solid waste sent to landfills, reducing energy consumption, and increasing production capacity. While some mills cite pressure from governmental regulations to use recycled fiber in their products, most admit that economic factors were the key drivers for their implementation of deinking. (23)

Internationally, many deinking plants demonstrate impressive results, especially those producing printing and writing grades. The installation of a Thermo Black Clawson system at a Sun Paper mill in China has enabled it to use 80% recycled fiber in its product without problems with dirt specks or stickies (24). Both the Sun Paper mill and an Aspex Paper Mill in Indonesia use a flotation-dispersion-flotation system, each achieving exceptional finished stock quality. Developments in the Metso Paper MuSTCell allow pulp to flow between each aeration stage based on density differences between the inner and outer sectors, meaning no pumps are required. In addition to energy savings, better brightness and flotation are possible through careful control of bubble size, internal flows, reject removal, and air-to-pulp ratio. This high degree of control allows operators to adjust the deinking system according to changes in the raw material supplied to the plant, which translates to excellent deinking and higher pulp quality. Similarly, the Voith EcoCell has proven itself invaluable to manufacturers seeking continuous capacity increases because of its modular design. The simple addition of multiple cells allows for increases in deinked pulp processing. (25)

Recent deinking plant installation case studies have proven difficult to acquire as many mills have chosen not to disclose much information about the execution and performance of their capital projects. However, in the past, mills have been more generous with their information. Georgia-Pacific installed a flotation deinking facility in one of their Michigan mills in as early as 1976 (26). The nineties were also a period during which many North American mills looked to deinking – Boise Paper installed a deinking mill in Jackson, Alabama and International Paper started up a deinking plant using proprietary technology in Selma, Alabama (27, 28).

The Kalamazoo, Michigan flotation deinking startup by Georgia-Pacific was one of the first large-scale North American deinking operations. G-P installed two Voith 55-tpd deinking lines and started them up in late 1976. Interestingly, Voith was one of the key suppliers responsible for popularizing flotation deinking in North America (29). Since this startup nearly four decades ago, the basic concepts behind flotation deinking have changed little, but the technologies associated with each unit operation have been vastly improved, allowing significantly better deinking yield and efficiency at a fraction of the cost and space. (26)

More recently, International Paper spent $325 million on a project including a 400-tpd deinking plant installation at their Riverdale mill in 1995. At the time, the company stated that they recognized that an increase in their reprographic paper production capacity would be required in order for them to remain competitive in that market. The deinking plant was installed to reduce the amount of bleached kraft market pulp required to run the two existing machines, producing approximately 1800-tpd uncoated printing papers containing a fraction of recycled paper. With the capacity added by the new deinking plant, IP ultimately decided to install a brand new paper machine, Riverdale 16, rated for 1,090 tpd production at 4,000 fpm. (27)

Just as International Paper was installing significant deinking capabilities and new paper machine capacity, Boise Paper looked to deinking as a driver of future revenue. Their Jackson, Alabama deinking plant started up in April of 1995. With added deinking capacity and the excess virgin pulping capacity available at the Jackson facility, Boise Paper was able to build a new paper machine, “J3”, to fully utilize its deinking capacity. Again, the process by which the pulp was deinked was largely the same as it is today. As mentioned previously, deinking technologies have been significantly improved throughout the past years, but the general concepts have remained relatively constant. (28)

Scope of Work, Decisions, and Project Options

Much of the information presented in this section was previously discussed in Deliverable 2. In the interest of brevity, some additional information not included in the body of this report is included in Appendix A2. Table 5 shows a summary of the decisions and assumptions made in the process of creating this report.

Table 5: Decisions Made as a Result of Discussions with CPP

Decision	Reasoning
Assume that a premium will need to be paid to purchase wastepaper in Raleigh, NC	All wastepaper is likely already being purchased; consulted with CPP representative
Will not further pursue agglomeration deinking	Too much technological risk involved; consulted with CPP representative
Consider *CPP.xlsx* values to be actual mill data	Consistent to use 1 data source for calculations
Assume no changes to woodyard, bleaching, digesters, recovery system	Addition of deinked pulp only affects machines and effluent/waste treatment unit operations
Not going to consider clippings/shavings use	Uncertainty of local clippings/shavings supply
Capital cost for flotation deinking plant could not be estimated on a piece-by-piece basis	Reference quotes for cleaners, screens, flotation cells, etc. unavailable
More rejects handling equipment required for flotation deinking alternative	Literature suggests the need for additional reject handling capacity with added deinking

High-Capital Solution: Flotation Deinking

The installation of a full-scale deinking plant is significantly more complicated than the aforementioned low-capital solution. Figure 9 shows the process flow through the proposed deinking plant. These process steps were determined according to several recent references containing generalized flow diagrams (2, 26, 28).

To begin the process, wastepaper is added to the high-consistency drum pulper. This is accomplished using a conveyor much like those mentioned in the description of the proposed hydropulper system. An operator loads wastepaper bales onto the conveyor, removing the baling wire in the process. The conveyor is controlled to automatically move forward at certain intervals to maintain the specified production rate. The drum pulper is equipped with screens at its lower end which remove some large contaminants. These large contaminants are sent to a compactor. Several other process streams enter the same compactor and will be discussed in more detail further into this subsection.

After the wastepaper is pulped, it is routed to high-density cleaners that remove medium- and large-sized contaminants, particularly those denser than fiber. These cleaners use centripetal force to separate contaminants from the fibers based on density differences. Typically, the rejected contaminants exit out of the bottom of the conical bodies of the cleaners. The rejects from the cleaners are sent to the compactor and the accepts are sent forward into the process to a coarse screening system.

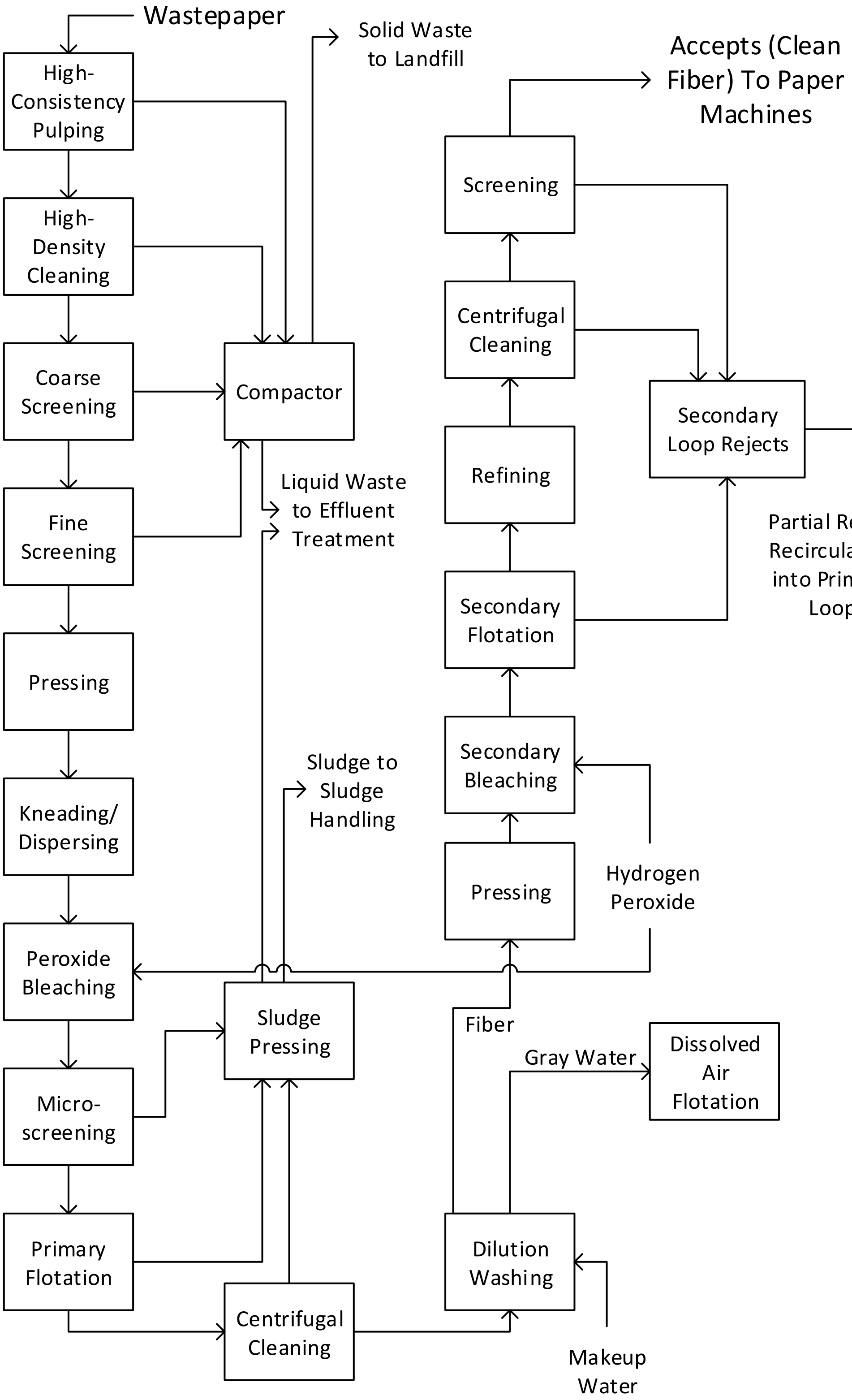


Figure 9: Process flow through proposed deinking plant

The coarse screening system is efficient at removing medium- and large-sized contaminants and consists of primary, secondary, and tertiary levels, as illustrated in Figure 10. The screens are organized in a feedforward configuration: the accepts from each level of screening (primary, secondary, and tertiary) are combined and sent to fine screening. The primary rejects are sent to the secondary screen and the secondary rejects are sent to the tertiary screen. The rejects from the tertiary coarse screen are sent to the compactor mentioned earlier. Each successive screen is smaller.

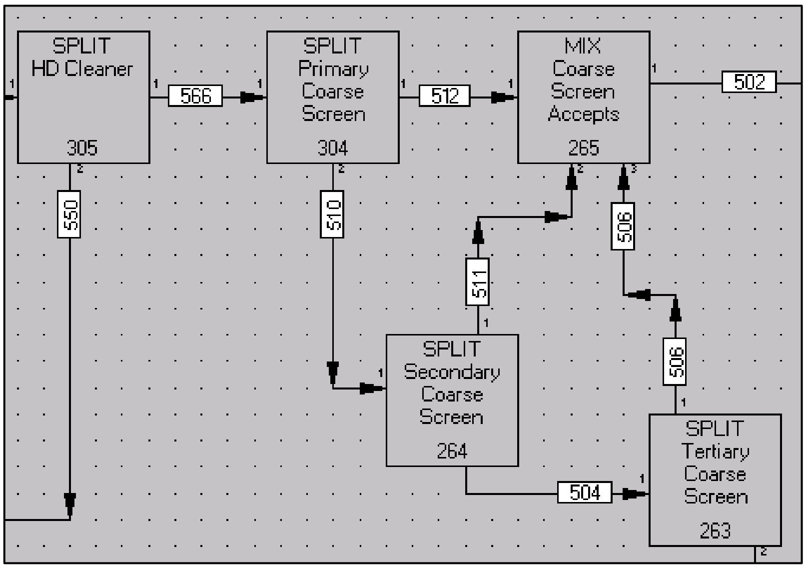


Figure 10: WinGEMS representation of coarse screening system

The accepts from the primary, secondary, and tertiary coarse screens are routed to a fine screening system designed to filter out even smaller particles. The fine screening system consists of primary, secondary, and tertiary levels, as illustrated in Figure 11. Unlike the coarse screens, the fine screens are arranged in a feedback configuration to minimize the amount of small dirts carried further into the process. Given the small slot size in these screens, fiber loss is expected to be small.

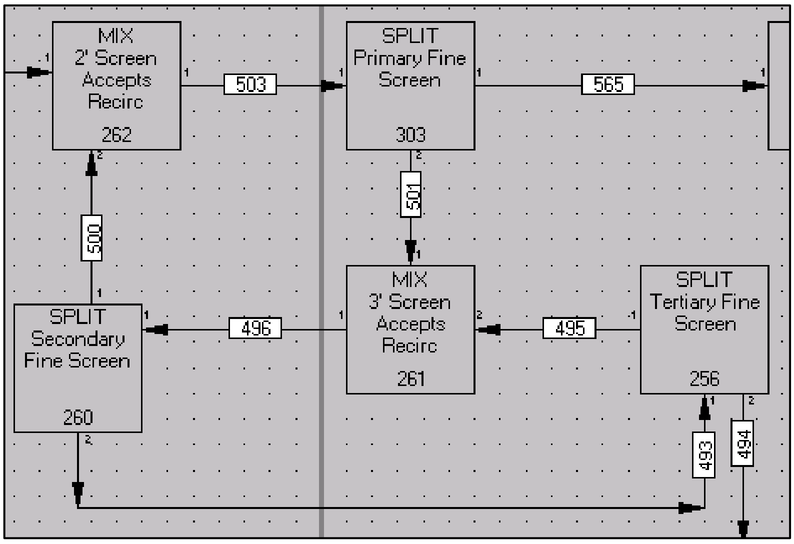


Figure 11: WinGEMS representation of fine screening system

The rejects from the primary fine screen are routed to the secondary fine screen. The accepts travel further into the deinking process and are pressed, kneaded, and dispersed. The secondary fine screen accepts are fed back to the primary fine screen and the secondary rejects move to the tertiary fine screen. The tertiary screen rejects are sent to the previously mentioned compactor and the tertiary accepts are routed back to the second screen. This configuration means that the primary fine screen is the largest and the secondary and tertiary screens are smaller and the smallest, respectively.

The rejects from the drum pulper, high-density cleaners, coarse screening system, and fine screening system are compacted. The compactor achieves a solids content of roughly 50% and the dewatered rejects are sent to the mill's landfill. The liquid removed from the compacted rejects is sent to the mill's effluent treatment system.

The primary fine screen accepts are pressed to relatively high solids content and are then kneaded and dispersed. This is a common unit operation in flotation deinking operations because it breaks down large- and medium-sized ink particles. When high brightness is required (as in the case of the Raleigh pulp mill), hydrogen peroxide bleaching is applied in or immediately following the kneader. This is because excellent chemical usage efficiency can be achieved when bleaching at higher solids content (2). The pulp is hydrogen peroxide-bleached following kneading and is then microscreened for small contaminants removal.

Microscreening removes the smallest-sized contaminants that flotation cannot easily remove. Flotation cannot remove contaminants smaller than fibers without significant fiber loss, so efficient microscreening is essential to maintaining deinking yield (2). The accepts from the microscreen are sent to flotation and the rejects are sent to a sludge press.

The primary flotation cells are fed by the microscreen accepts. Ideally, the feed to the flotation cell contains primarily fiber and medium-sized contaminants, which flotation selectively removes. The flotation stage generates significant amounts of sludge overflow (effectively, flotation rejects) which is routed to the sludge press. The accepts stream, which contains mostly fiber and small contaminants detached from fibers during flotation, is further cleaned and washed. The WinGEMS representation of the unit operations from kneading and dispersion through flotation, cleaning, and washing is shown in Figure 12. The washing stage is the last part of the so-called "primary loop." The "secondary loop" begins with pressing and secondary bleaching.

The cleaners following flotation remove the remaining medium- and large-sized contaminants that the prior flotation stage was unable to remove. The successive washing stage removes small ink particles via dilution and dewatering. Makeup water is added to the system here for the ink wash water dilution. The ink-rich water from the washing stage is subjected to dissolved air flotation (DAF), which uses microscopic air particles to slowly remove microscopic ink particles and clarify the ink-rich "gray water" for reuse in the process (2).

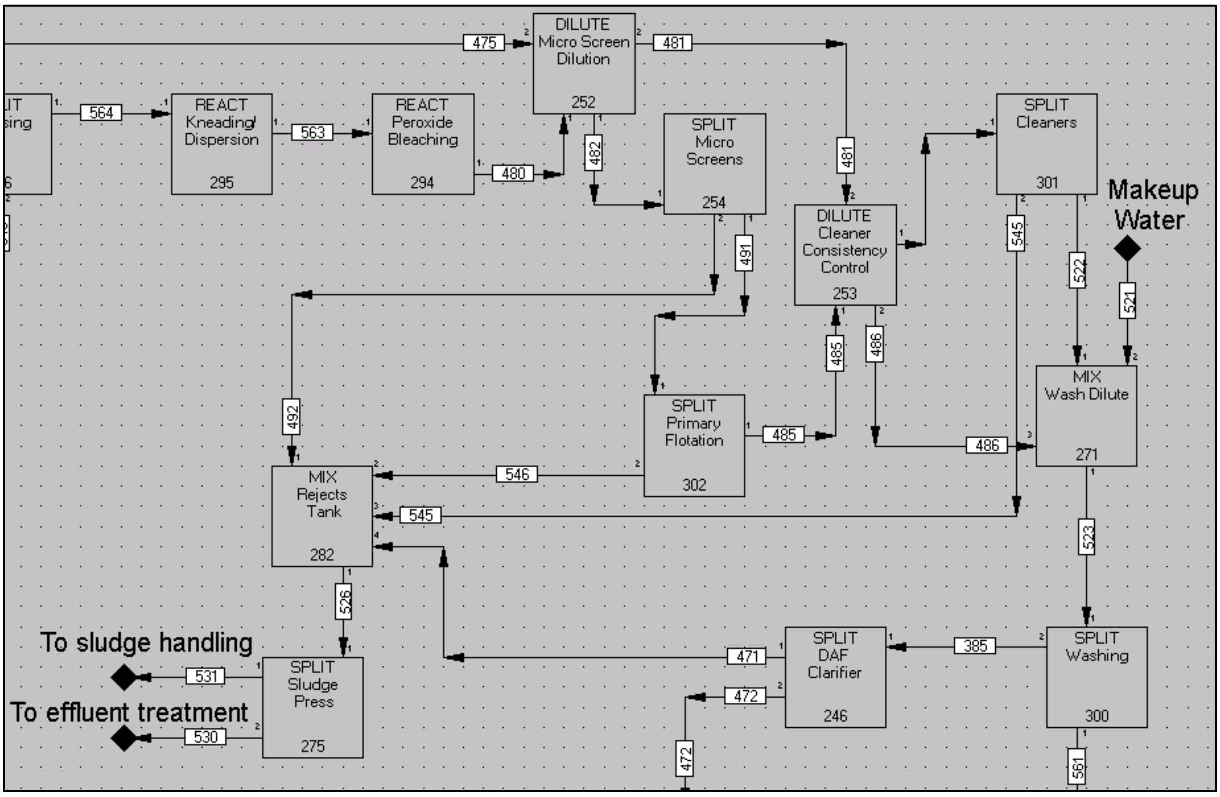


Figure 12: WinGEMS representation of kneading through washing unit operations

After washing, the pulp is pressed and bleached, marking the beginning of the secondary deinking loop. The press filtrate (gray water) is reclaimed and used elsewhere in the deinking process for consistency control. The thickened pulp is subjected to a second hydrogen peroxide bleaching stage. Depending on the brightness target, this stage can be balanced with the primary hydrogen peroxide bleaching stage earlier in the process to minimize chemical costs. After the thickened pulp is bleached, it is diluted using reclaimed gray water and routed into the secondary flotation cells.

The secondary flotation cells are effectively identical to the first. However, they are operated differently in that there are much fewer contaminants remaining in the pulp slurry when it enters secondary flotation. This flotation stage again targets medium-sized ink particles and contaminants and is not very effective at removing large- or small-sized contaminants. The secondary flotation sludge (a much smaller quantity than the primary flotation sludge) is combined with other secondary loop rejects and rerouted into the primary loop to maximize fiber retention and overall deinking yield. The flotation accepts are sent to a refiner.

The refiner located after the secondary flotation cells is mechanically identical to a refiner found in a virgin paper mill but is operated much more gently. The purpose of this refiner is to break up fiber flocs and grind residual large- and medium-sized contaminants into smaller ones rather than to introduce fibrillation. After refining, the pulp slurry is routed to a final cleaner bank and screen before it is sent to storage.

The secondary loop cleaners are, much like the previously described cleaners, designed to remove medium- and small-sized contaminants from the pulp slurry before it is routed to storage and mixed into the two machine chests. The rejects are combined with the secondary flotation rejects and rerouted to the primary deinking loop. The accepts are sent forward to the final dirt removal stage in the deinking plant.

The dirt removal in the deinking plant is performed by a set of screens. These screens provide a final effort to remove large contaminants remaining in the pulp slurry. The pulp is relatively clean at this point in the process, so the screens are somewhat of a precautionary unit operation. The main contaminants that may still be present in the pulp at this point are stickies, which can extrude through screen openings and are difficult to remove in flotation and centrifugal cleaning steps because their density is similar to that of water. These contaminants can create troublesome deposits further downstream if they are not efficiently removed (10). Secondary loop screening rejects are partially rerouted to the primary deinking loop to maximize deinking yield. Secondary loop screening accepts are sent to deinked pulp storage, from which the deinked pulp is appropriately proportioned and added to the respective machine chests of PM1 and PM2. Figure 13 shows the WinGEMS representation of the secondary deinking loop, from bleaching and secondary pressing to the final screening stage before storage and use on the paper machines.

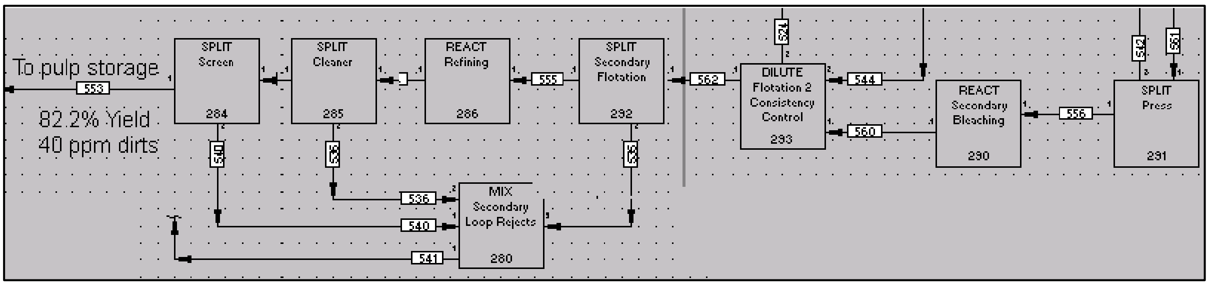


Figure 13: WinGEMS representation of secondary deinking loop

Low-Capital Solution: MDIP Usage

Figure 14 is a very basic process flow diagram describing the process by which deinked market pulp is made down with a hydropulper system and sent to the paper machines. This configuration would likely require two hydropulpers running in parallel, each with their own dilution water systems and MDIP conveyors. Figure 15 shows the (also simple) WinGEMS representation of this system.

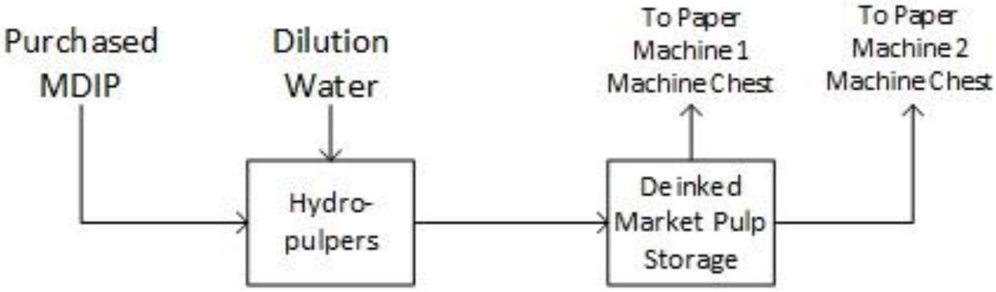
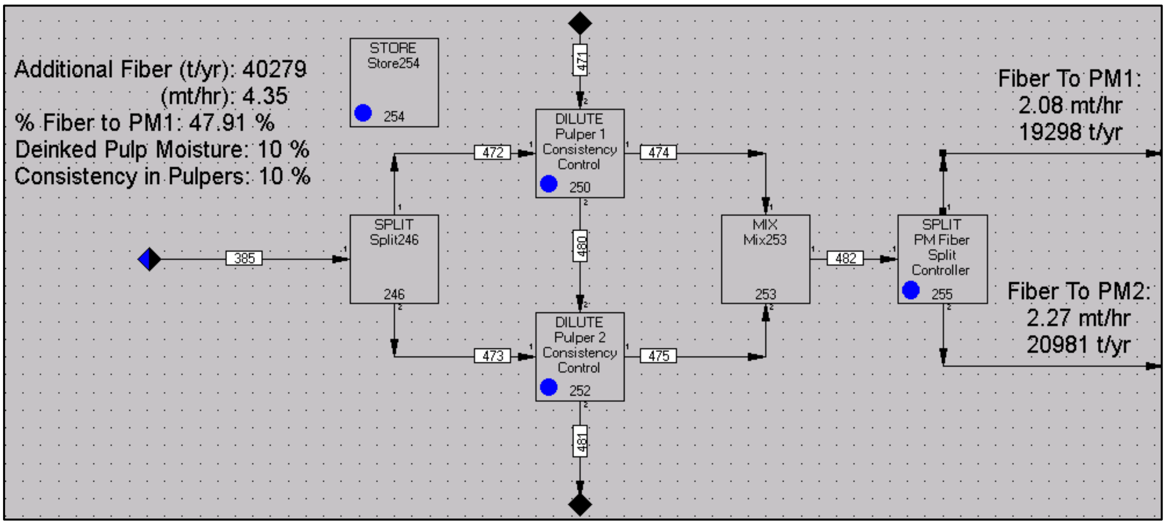


Figure 14: Flowsheet for MDIP repulping

This process is simple. Purchased MDIP comes in bales, much the same as virgin market pulp does. An operator driving a fork truck or loader of some sort loads a bale onto the conveyor leading to one of the pulpers, removing the baling wire in the process. The conveyor automatically moves at certain intervals to maintain the specified production rate.


Additional Fiber (t/yr): 40279
(mt/hr): 4.35
% Fiber to PM1: 47.91 %
Deinked Pulp Moisture: 10 %
Consistency in Pulpers: 10 %

Fiber To PM1:
2.08 mt/hr
19298 t/yr

Fiber To PM2:
2.27 mt/hr
20981 t/yr

Figure 15: WinGEMS representation of pulper makedown system

This process is repeated until there are enough bales on the conveyor for one pulper cycle, at which point the conveyor rotates and drops all of the MDIP into the pulper as the requisite dilution water is dispensed. After the pulpers complete their makedown cycles, large pumps transfer their contents into a deinked market pulp storage tank at 8-10% consistency. This tank is agitated to prevent stagnant spots from developing, which could potentially lead to microbial growth issues.

Results of Process Modeling

A full-mill WinGEMS model was provided to the consulting firm by CPP. Modifications were made to the base case model to create new models for each alternative case. The key inputs and outputs of each model were summarized in the Second Deliverable and can be provided again upon request. Since the Second Deliverable Presentation, some changes have been made to the WinGEMS models and corresponding analysis as per data kindly provided by an industry representative (30).

Before continuing with the analysis, it was important to verify that the model was in agreement with the mill operational parameters provided by CPP, to the extent possible. Table 6 shows that the WinGEMS model was in agreement to within 0.2% with the provided mill data in most cases. There were some irreconcilable differences between WinGEMS metrics and the mill data. In these cases, mill data from the CPP spreadsheet was considered to be more accurate.

Table 6: Reconciliation of WinGEMS Model with Mill Data

	Mill Data	Model Output	% Difference
Hardwood Roundwood, bdt/yr	567,613	567,613	0.00%
Softwood Roundwood, bdt/yr	290,782	290,680	0.04%
Purchased Chips, bdt/yr	163,055	163,055	0.00%
Bleached HW Fiber to PMs, bdt/yr	237,262	237,262	0.00%
Bleached SW Fiber to PMs, bdt/yr	129,191	129,191	0.00%
PM1 Production, ft/yr	236,712	236,690	0.01%
PM2 Production, ft/yr	268,684	268,286	0.15%

The inerts content in the SOP fed to the modelled flotation deinking plant was increased significantly to account for the inorganic filler content of the wastepaper. This resulted in a larger amount of sludge being generated in the flotation case, which is discussed in more detail in the Environmental Impacts section. This also lowered the overall deinking yield to more believable numbers. Finally, individual unit operations were altered such that they were in better agreement with the unit operations described in the report provided by Voith (30). These changes have resulted in an, overall, much more accurate representation of the propose flotation deinking facility.

Environmental Impacts

The WinGEMS model offers insight into the environmental impacts of both of the proposed alternative cases. The biggest environmental considerations for both of these projects are the increased fresh water demand and the increased liquid effluent generation. In the case of the deinking plant, increased production of solid waste in the form of sludge is also worth considering.

Pertinent information from the WinGEMS model regarding environmental changes is summarized in Table 7 and Table 8. Table 7 contains information regarding to the low-capital deinked market pulp alternative and Table 8 refers to the high-capital flotation deinking alternative. Deinking would generate 38,500 ODt/yr of landfilled sludge.

Table 7: Summary of Environmental Effects of MDIP Usage

MDIP	Dimensions		Current Mill		Modified Mill		%Diff. (+/-)
	per FT	per Year	per FT	per Year	per FT	per Year	
Inputs							
Fresh Water	MM gal	MMM gal	0.01	4.28	0.01	4.51	5.3%
Outputs							
Effluent	M gal	MMM gal	8.20	4.15	8.10	4.56	10%
Solid Waste	yd^3	MM yd^3	2.87	1.45	2.60	1.45	0%

Table 8: Summary of Environmental Effects of Flotation Deinking

Flotation	Dimensions		Current Mill		Modified Mill		%Diff. (+/-)
	per FT	per Year	per FT	per Year	per FT	per Year	
Inputs							
Fresh Water	MM gal	MMM gal	0.01	4.28	0.01	5.22	21.9%
Outputs							
Effluent	M gal	MMM gal	8.20	4.15	8.50	4.71	13.2%
Solid Waste	yd^3	MM yd^3	2.87	1.45	2.60	1.49	3%

Fresh Water

There will be a significant increase in the fresh water demand of the mill if either alternative is pursued. This is especially true in the deinking plant case. It is currently unknown what the legal limit on fresh water usage by the mill is. It must be verified that the mill possesses the relevant permitting to utilize additional fresh water, if needed. If the mill lacks permission to access the incremental fresh water needed, it may be possible to utilize other water sources from within the mill if their quality is deemed sufficient for repulping or deinking. Communication with local and state governments to clarify fresh water usage limits prior to moving forward would be advantageous.

Effluent

Effluent is a second major environmental concern involved with both of the proposed solutions. The WinGEMS models project 10 and 13.2% increases in the liquid effluent generation in the MDIP and flotation cases, respectively. The effluent treatment system is not included in the provided WinGEMS model and the capacity of the Raleigh mill’s effluent treatment system is unknown. CPP should ensure that their most up-to-date permitting allows for the noted increases in effluent discharge. Furthermore, the effluent from deinking differs from that typical to virgin pulping operations. Given the relatively small quantity of deinking effluent introduced, it is not expected that this effluent will be very difficult for the existing wastewater treatment system to purify.

Solid Waste

There will be an increase in solid waste production in the case of flotation deinking. The increase in solid waste generation cited in Table 8 is significant. This waste will likely have to be landfilled or shipped to nearby municipal landfill facilities, depending on the mill's solids disposal capabilities. Some alternatives to landfilling were discussed in the Effects of Flotation Deinking on Solid Waste and Wastewater Treatment section found in Appendix A2. In addition to sludge, trash from the pulper, high-density cleaners, and screens will have to be disposed of. These two refuse streams combined represent around 20,000 OD tons per year of solid waste, based on the WinGEMS model, an increase of 38,500 total tons per year over the base case.

Throughput Impacts

Low-Capital: Deinked Market Pulp Usage

As the deinked pulp production facility is relatively stand-alone, there will not be significant throughput changes to the wood yard, digesters, or bleach plants. The paper machines and the effluent treatment system will be subject to the greatest throughput changes. The incremental pulp production equates to a roughly 11% increase in production from each machine in each case. Figure 16 illustrates some of the key process parameter changes, according to the WinGEMS model, with the installation of the hydropulpers as proposed.

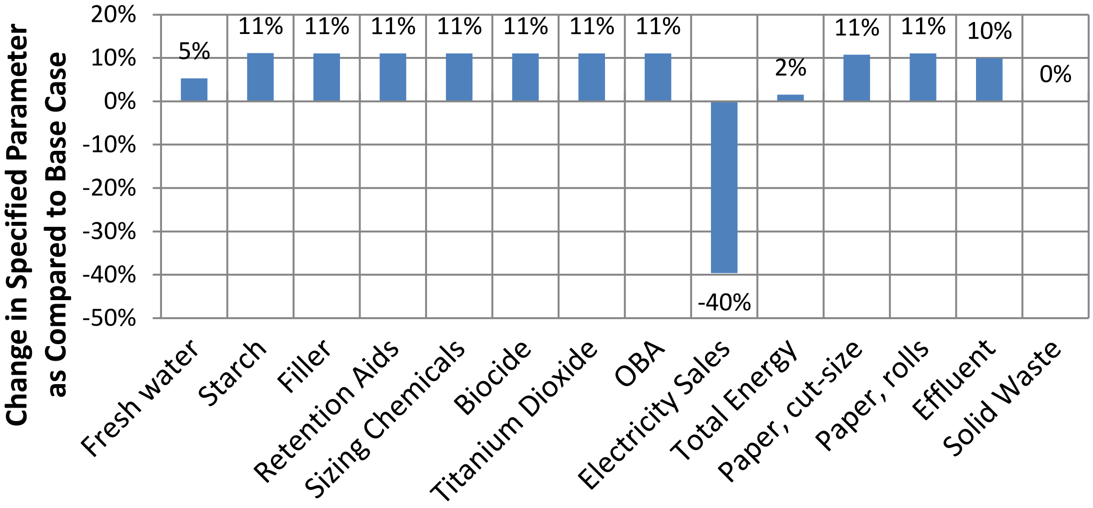


Figure 16: Parameter Changes for Low-Capital Alternative

Again, the paper machine is subject to the greatest increases in throughput. Mill data states that the paper machine drives can accommodate the speed increase achieved with the use of deinked pulp, but the mill must ensure that the headbox and whitewater systems can tolerate 11% throughput increases. Specifically, it must be verified that the headbox can dispense the additional pulp without adverse effects on formation, drainage, or wet web strength. This could be achieved with a mill trial.

The mill must do a trial to determine if the presses can achieve the same solids level without overly densifying or crushing the sheet. If the presses are not able to achieve the same solids without adversely affecting sheet quality, the proposed change will not be possible as it is described.

There will be increased demand for steam by the dryers with greater production. It must be verified that the mill's multi-stage extraction turbines can provide enough additional steam to meet the increased drying demand. The energy used to dry the incremental tons and the energy required to run the new pulpers, unfortunately, will significantly decrease excess power generation by the mill, decreasing energy sales by around 40%.

Increased liquid effluent generation is expected with increased paper production. The WinGEMS model indicates a roughly 10% increase in the amount of liquid effluent generated by the mill. Before moving forward, it must be verified that the Raleigh mill has adequate wastewater treatment capacity to handle a 10% increase in effluent discharge. It is not expected that solid waste treatment will be adversely affected because it was assumed that the deinked market pulp purchased would be used as-is.

High-Capital: Deinking Plant Installation

Figure 17 shows some of the key process changes associated with installing the proposed flotation deinking facility.

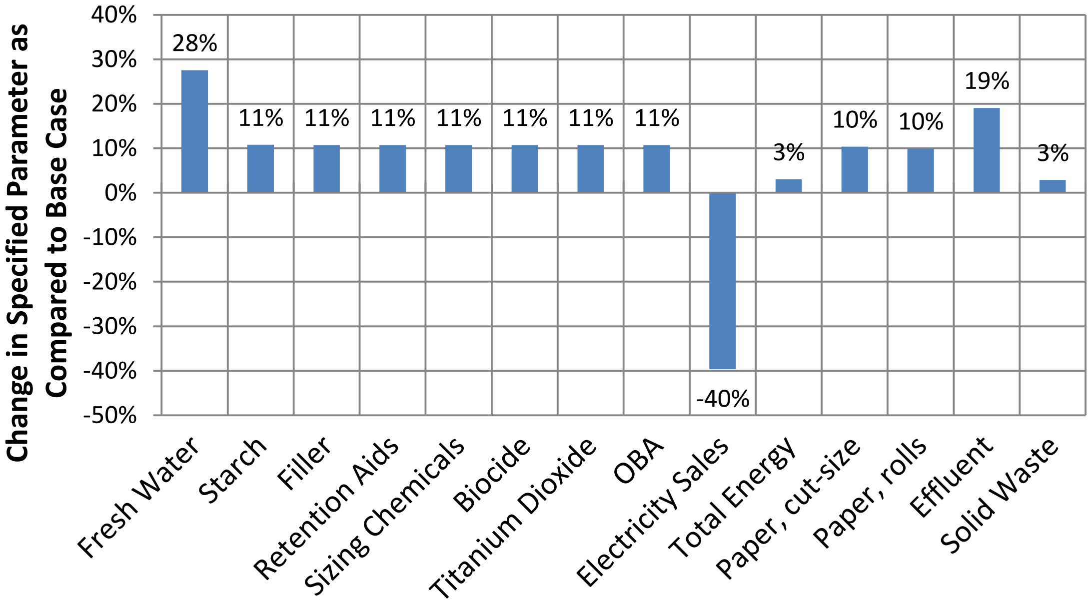


Figure 17: Parameter Changes for High-Capital Alternative

Again, the paper machine throughput will increase by roughly 11%, so the mill must verify that the PM1 and PM2 headboxes, presses, and the dryer steam generation system have enough excess capacity to handle the proposed incremental production.

In terms of throughput, one key difference between the high-capital and low-capital alternatives is the additional solid waste generation from the flotation deinking plant. Although the WinGEMS model indicates that solid waste generation will only increase by 3%, this waste must be landfilled. The Raleigh team must make sure that their solid waste treatment systems can handle the added waste. It is theoretically possible that the sludge from flotation could be incinerated, but this would likely require additional capital to prevent excessive boiler tube scaling and fouling, so it was conservatively assumed that the waste would be landfilled.

Running a flotation deinking plant requires a lot of water, so the mill fresh water usage is estimated to increase by approximately 22%. Although there is not a large cost associated with this extra water usage, a throughput increase this significant should not be overlooked. It is possible that excess whitewater or other relatively clean effluent streams from elsewhere in the mill could be used instead of fresh water in the deinking plant, but it was conservatively assumed that fresh water will be required.

Quality Impacts

Using recycled fiber will affect the quality of the final product sold to customers in several ways. The primary quality considerations made in this report are with respect to the sheet strength, runnability on the machines, and the optical properties of the sheet. Each of these are typically affected by the inclusion of deinked pulp in the furnish, but unfortunately, cannot easily be quantitatively modeled using WinGEMS.

Strength

With increased dirts and other contaminants content stemming from the use of recycled fiber, inter-fiber bonding will be diminished. Bonding strength will also decrease due to the irreversible hornification that recycled fibers have undergone. This influences both machine runnability (discussed more in the following subsection) and the end uses of the sheet itself. For example, uncoated free sheet in roll form requires excellent tensile strength or it will be susceptible to breaks during offset printing operations, which often run at very high speeds. Cut-size sheets are also subject to substantial tensile stresses inside of printers and copy machines, and poor strength and curl properties can cause tearing and jamming in these applications as well.

There are numerous chemicals available to offset the potential decreases in strength. Careful evaluation of the mill’s wet-end chemistry could help to determine the appropriate strength aids to apply, if any. Unfortunately, it will be difficult to predict exactly how much strength loss will be associated with the use of deinked fiber because there is no good way to run a machine-scale trial with deinked pulp.

Runnability

Paper machine runnability will suffer as a result of recycled fiber usage in the sheet. Including deinked pulp in the furnish will reduce the strength of the web on the wet end of the machine, causing more frequent breaks and reducing availability. More stickies and deposits should also be expected. The anticipated decrease in availability was accounted for in the WinGEMS model by increasing production losses due to breaks by 2%. Given the nonhomogeneous nature of recycled paper, it is unlikely that these breaks will be consistent, so the mill should be prepared for relatively unexpected breaks in the event that particularly contaminated wastepaper is introduced into the process. This issue could largely be alleviated by adequate monitoring of the quality (i.e., the approximate stickies and dirts contents) of the recovered paper being introduced into the deinking plant. In addition, detackifiers like talc could prove useful for the mill, by eliminating deposits and stickies, in the event that breaks become an issue. If microbial growth becomes a problem, the mill could also increase the dosage of biocide on the paper machine.

Accurate tracking of breaks, with comparison to the quality of the recycled material, should be maintained if a deinking plant is installed. Correlations between recycled material properties and break frequency will allow CPP process engineers to better predict when and why breaks will occur.

Optical Properties

Another point of concern is the dirts content in the post-consumer waste-containing sheet. It is uncertain to what degree this will affect the optical properties of the final sheet. The dirts content in the sheet will undoubtedly increase, but the WinGEMS model indicates that it will be by only a few parts per million. It is essential that customers are made aware of the change in the furnish in advance and that the mill closely monitors the brightness of the sheet when deinked pulp is introduced.

It is likely that the final sheet brightness will decrease as a result of the increased dirts content. If this becomes problematic, the mill can dose more titanium dioxide or optical brightening agent (OBA) to counteract some of the brightness loss. Accurate prediction of the brightness with the incorporation of deinked pulp has proven difficult, but the consulting firm does not expect any major brightness decrease at the given sheet dirts content. The mill must bear in mind the fact that the WinGEMS model cannot be used to quantitatively model brightness.

Economic Evaluation

Capital Cost Estimation

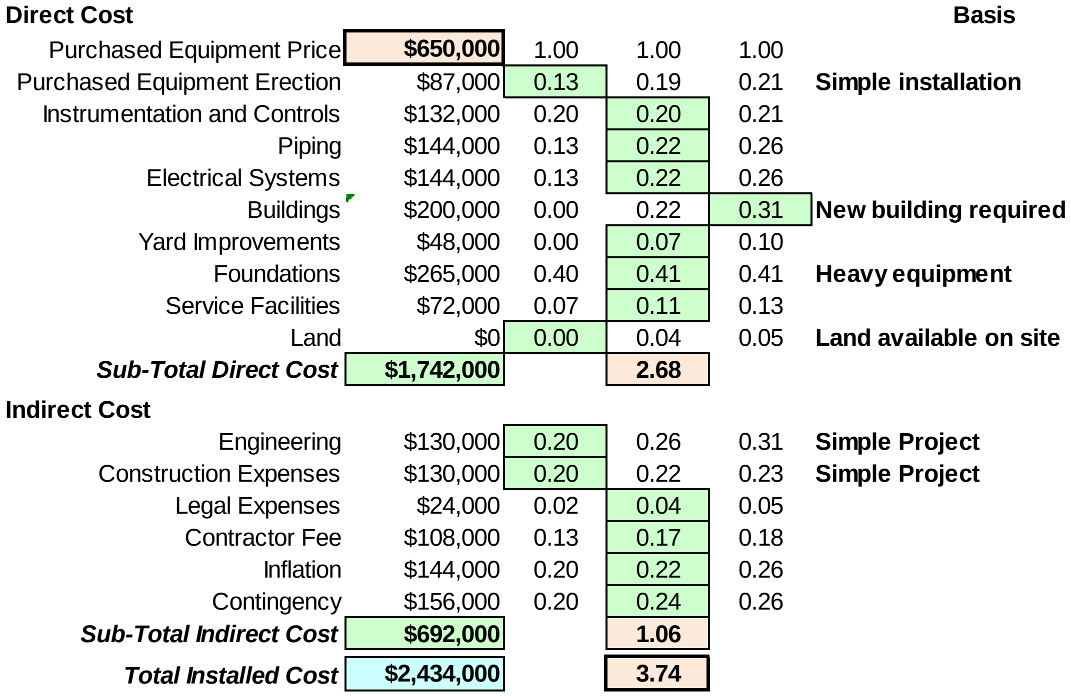
Low-Capital Solution: MDIP Usage

Estimating the capital cost of the MDIP usage project was relatively simple given that there were very few pieces of equipment involved. Table 9 shows the expected delivered costs for the equipment associated with the proposed low-capital solution, each estimated using the Peters and Timmerhaus online tool (31).

Table 9: Equipment List with Delivered Costs for Low-Capital Alternative (31)

Eq. #	Quantity	Description	Deliv. Cost ($)
1	2	Wastepaper Conveyors into Pulpers, 40 m	297,000
2	2	Pulper Dilution Water Pumps, 3000 gpm	29,000
3	2	Hydropulper, 10000 gal, ~1000 AD lb batches every 15 min	220,000
4	2	Pulper Discharge Pumps, 3000 gpm	33,000
5	1	Repulped MDIP Storage Tank, 40000 gal	56,000
		TOTAL	635,000

Given the estimated delivered equipment cost of around $650,000, the Phillips' factored cost estimation method was used to estimate the total installed capital cost (TIC) of the project to be approximately $2,400,000 (32). Figure 18 shows this spreadsheet.

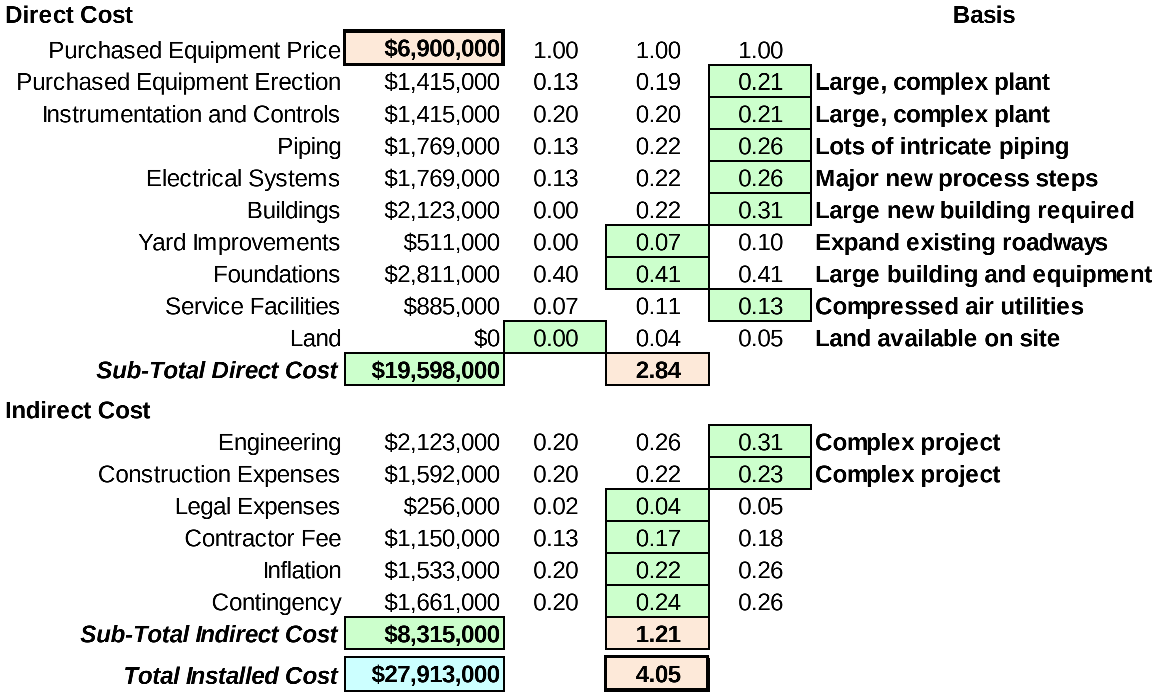


Direct Cost					**Basis**
Purchased Equipment Price	**$650,000**	1.00	1.00	1.00	
Purchased Equipment Erection	$87,000	0.13	0.19	0.21	**Simple installation**
Instrumentation and Controls	$132,000	0.20	0.20	0.21	
Piping	$144,000	0.13	0.22	0.26	
Electrical Systems	$144,000	0.13	0.22	0.26	
Buildings	$200,000	0.00	0.22	0.31	**New building required**
Yard Improvements	$48,000	0.00	0.07	0.10	
Foundations	$265,000	0.40	0.41	0.41	**Heavy equipment**
Service Facilities	$72,000	0.07	0.11	0.13	
Land	$0	0.00	0.04	0.05	**Land available on site**
Sub-Total Direct Cost	**$1,742,000**		**2.68**		
Indirect Cost					
Engineering	$130,000	0.20	0.26	0.31	**Simple Project**
Construction Expenses	$130,000	0.20	0.22	0.23	**Simple Project**
Legal Expenses	$24,000	0.02	0.04	0.05	
Contractor Fee	$108,000	0.13	0.17	0.18	
Inflation	$144,000	0.20	0.22	0.26	
Contingency	$156,000	0.20	0.24	0.26	
Sub-Total Indirect Cost	**$692,000**		**1.06**		
Total Installed Cost	**$2,434,000**		**3.74**		

Figure 18: Factored Estimate for MDIP Usage Alternative (32)

High-Capital Solution: Flotation Deinking

Unfortunately, it was impossible to estimate the delivered equipment costs of the individual pieces of equipment required for the proposed flotation deinking plant. For this reason, contact with an industry vendor was made. This vendor provided a quote indicating a total purchased equipment cost of around $6,900,000 for a similarly-sized system that would, in his opinion, provide excellent-quality deinked pulp suitable for CPP’s application (30). This purchased equipment cost was input into the factored cost estimation sheet pictured in Figure 19, suggesting a total installed capital cost of just under $28,000,000. More details from the quote provided by this vendor, including a comprehensive equipment list, are included in Appendix A3.



Direct Cost					**Basis**
Purchased Equipment Price	**$6,900,000**	1.00	1.00	1.00	
Purchased Equipment Erection	$1,415,000	0.13	0.19	0.21	**Large, complex plant**
Instrumentation and Controls	$1,415,000	0.20	0.20	0.21	**Large, complex plant**
Piping	$1,769,000	0.13	0.22	0.26	**Lots of intricate piping**
Electrical Systems	$1,769,000	0.13	0.22	0.26	**Major new process steps**
Buildings	$2,123,000	0.00	0.22	0.31	**Large new building required**
Yard Improvements	$511,000	0.00	0.07	0.10	**Expand existing roadways**
Foundations	$2,811,000	0.40	0.41	0.41	**Large building and equipment**
Service Facilities	$885,000	0.07	0.11	0.13	**Compressed air utilities**
Land	$0	0.00	0.04	0.05	**Land available on site**
Sub-Total Direct Cost	**$19,598,000**		**2.84**		
Indirect Cost					
Engineering	$2,123,000	0.20	0.26	0.31	**Complex project**
Construction Expenses	$1,592,000	0.20	0.22	0.23	**Complex project**
Legal Expenses	$256,000	0.02	0.04	0.05	
Contractor Fee	$1,150,000	0.13	0.17	0.18	
Inflation	$1,533,000	0.20	0.22	0.26	
Contingency	$1,661,000	0.20	0.24	0.26	
Sub-Total Indirect Cost	**$8,315,000**		**1.21**		
Total Installed Cost	**$27,913,000**		**4.05**		

Figure 19: Factored Estimate for Flotation Deinking Alternative (32)

Project Impacts on Operating Costs and Earnings

All unit costs were taken directly from the CPP.xlsx mill model provided to the Firm, unless otherwise noted (1). The Firm will provide the exact sources of each of these unit costs to the reader upon request. The costs of fiber (SOP and MDIP) were estimated according to statistics from the RISI Market Price Watch database and through communications with industry representatives (7).

Low-Capital Solution: MDIP Usage

The low-capital solution appears quite unprofitable in its current state. Table 14 in Appendix A4 shows a year-by-year cost and revenue summary via the FEL-0 analysis.

The total gross profit over the project lifetime is estimated at around -$126,000,000. Figure 20 shows a comparison of all of the projected incremental direct and indirect costs, totaled over the project's lifetime, associated with using MDIP.

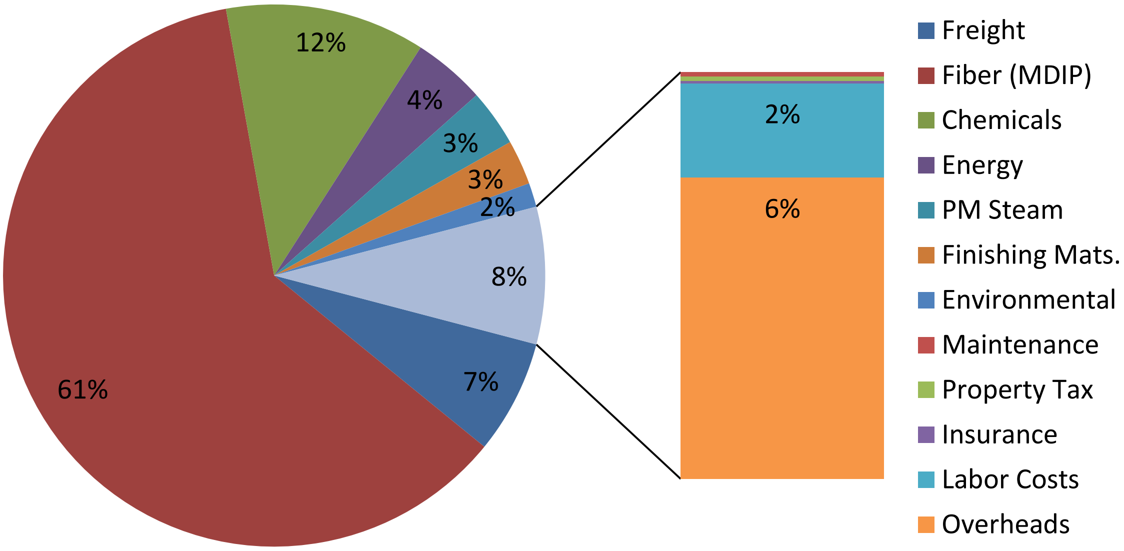


Figure 20: Incremental Cost Summary for Low-Capital Alternative (MDIP)

The indirect costs account for only 8% of the total cost, and fiber (MDIP) makes up over 60% of the total cost. This highlights why the financial performance of this capital alternative is so poor: MDIP costs so much that the incremental revenue from the increased production cannot offset its cost.

Because the projected financial performance of this investment is low (IRR under -15%), the Consulting Firm feels that further discussion would not be of very much interest or value to CPP. If this is not the case, the Consultants would be happy to answer any further questions during the Final Presentation on April 22nd, 2015.

High-Capital Solution: Flotation Deinking

Table 15 in Appendix A4 shows a year-by-year summary of the projected incremental costs, revenues, and gross profit for the high-capital alternative, flotation deinking. This project, even at first glance, appears much more lucrative than the low-capital alternative. A total gross profit of around $75,000,000 is estimated over the project's lifetime. Figure 21 shows the incremental costs over the project lifetime (10 years) for the flotation deinking case.

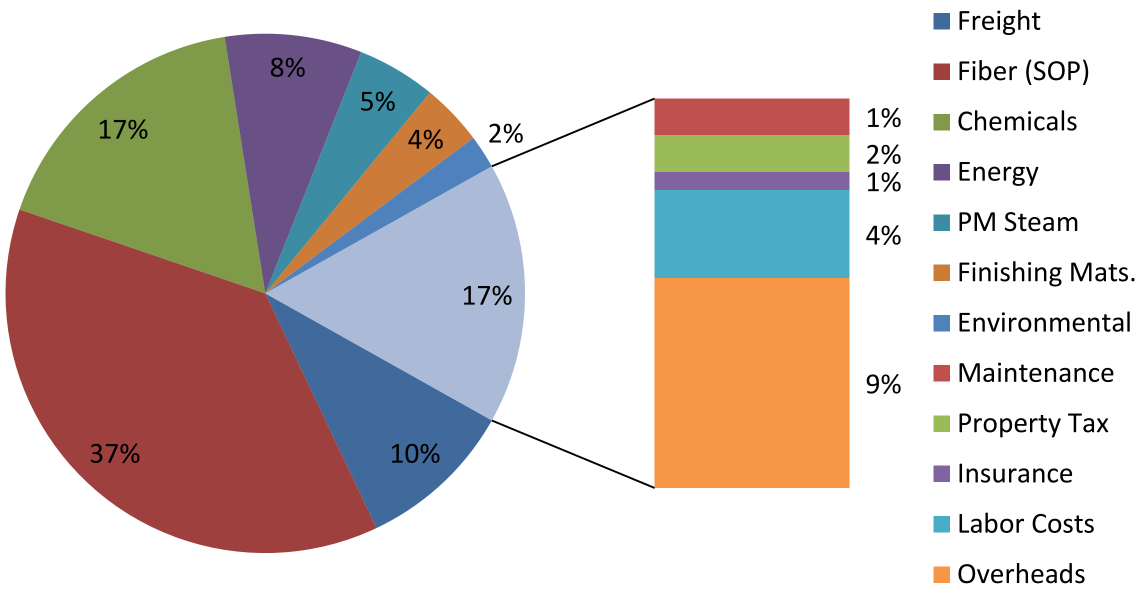


Figure 21: Incremental Cost Summary for High-Capital Alternative (Flotation)

The incremental cost structure associated with installing flotation deinking capabilities is markedly different than that of the MDIP alternative. Fiber (SOP) accounts for a much smaller fraction of the total incremental costs in this case, and chemicals account for a larger fraction.

Chemical costs were set at $17/deinked ton in the deinking plant financial analysis, as per a FisherSolve query of current deinking operations and a quote from an industry representative (33, 34). Indirect costs make up 17% of the total incremental costs, and of that 17%, finishing materials account for over half.

Profitability and Sensitivity Analysis

Low-Capital Solution: MDIP Usage

A summary of key financial indicators for the low-capital solution is included in Table 16 in Appendix A4. It should be noted that all numerical entries are in thousands of dollars. With all sensitivities set to 1.00, the financial performance of this project is abysmal, as discussed in the previous section. The cost of MDIP, even when liberally estimated at a very low $600/ton and without inflation, is simply too high to be offset by the incremental revenue from the added production. Figure 22 shows a sensitivity analysis for the MDIP usage case. Table 17 in Appendix A4 shows the numerical values graphed in Figure 22.

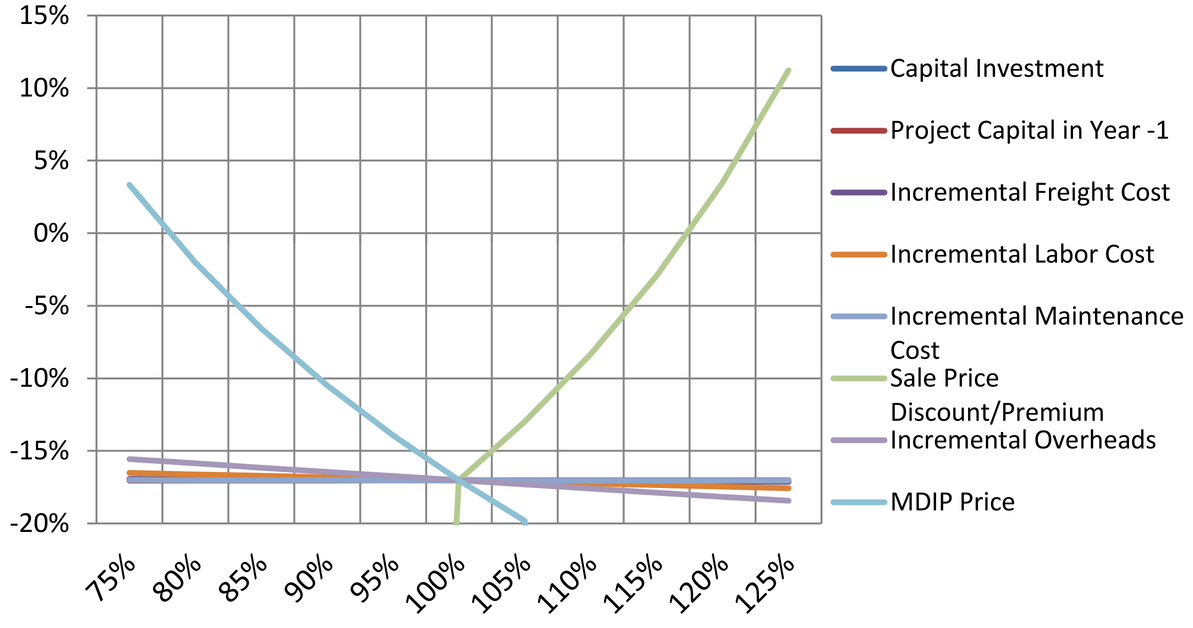


Figure 22: Sensitivity Analysis for Low-Capital Alternative

As shown in the sensitivity analysis, the IRR (shown on the vertical axis) is extremely low in almost all cases. The only things that had appreciable positive effects on the IRR were applying a premium to the product sale price or decreasing the MDIP sale price well below $600/ton. In either case, the IRR still remained quite low.

Given the sensitivities examined in this report, the Consulting Firm recommends against going forward with the proposed low-capital alternative project.

High-Capital Solution: Flotation Deinking

A summary of key financial indicators for the high-capital solution is included in Table 18 in Appendix A4. It should once again be noted that all numerical entries are in thousands of dollars. With all sensitivities set to 1.00, the financial performance of this project is much better than that of the low-capital alternative, at around 10%. Figure 23 shows a sensitivity analysis for the MDIP usage case. Table 19 in Appendix A4 shows the numerical values graphed in Figure 23.

The key parameters affecting the financial performance of this investment are the sale price discount/premium, deinking yield, and SOP price. Not surprisingly, increasing the sale price premium or deinking yield had significant positive effects on the IRR of the investment. Higher-than-expected SOP prices would hinder the project’s financial performance. Incremental overheads and labor also had noticeable influences on the project’s IRR and overall financial performance.

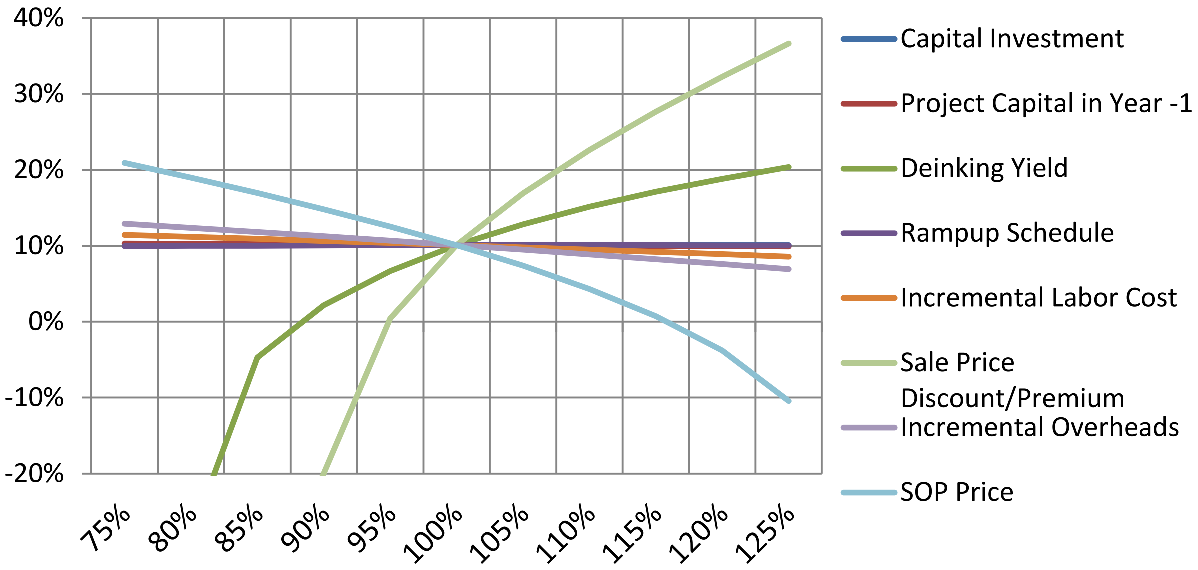


Figure 23: Sensitivity Analysis for High-Capital Alternative

Figure 24 shows the base case and project case free cash flows associated with the installation of the proposed flotation deinking facility.

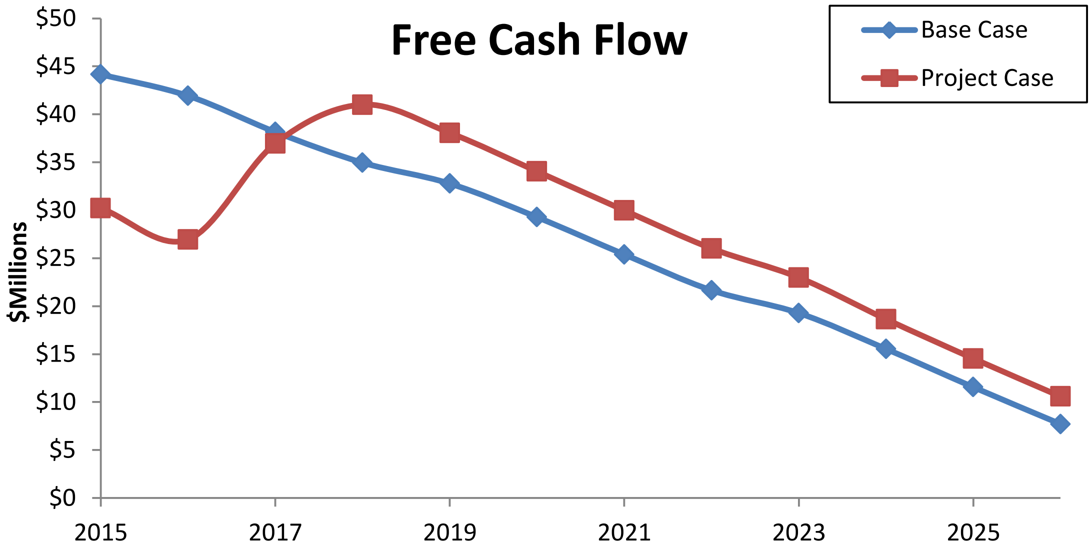


Figure 24: Free Cash Flow for High-Capital Alternative

As expected, this capital project would initially decrease the free cash flow beneath that of the base case, but would provide incremental cash flow in each subsequent year starting in 2018. The incremental free cash flows, over the 10-year project lifetime, are worth an estimated net present value (NPV) of around $-3,400,000. Unfortunately, this project does not appear very profitable for the mill either. Figure 25 shows the incremental revenue, cost, and EBITDA for the high-capital alternative case in each year of the project's 10-year lifetime.

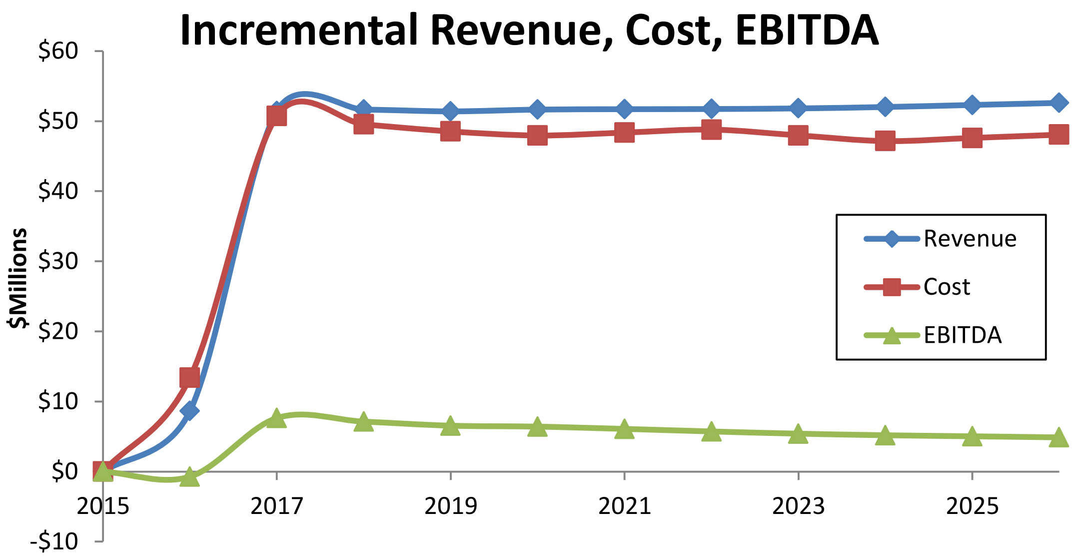


Figure 25: Incremental EBITDA for High-Capital Alternative

It is estimated that this project would generate just under $10,000,000 of incremental EBITDA each year, starting in 2017. The incremental EBITDA is expected to decline slightly throughout the project lifetime due to steadily increasing operating costs, as forecasted by CPP in the mill data spreadsheet provided (1). As mentioned previously, the incremental revenue comes entirely from additional offset roll and cut-size sheet sales and the incremental cost is as a result of numerous factors, the most significant of which being fiber and chemicals.

Discussion

The financial performance of the low-capital alternative (MDIP usage) was extremely poor in all cases. Although the process impacts of such a small capital project would be minimal and the construction would be simple, CPP would almost certainly forfeit a considerable amount of free cash flow if it chose to pursue this option. Given the unimpressive financial performance of this alternative, no further discussion will be provided unless requested by CPP.

The internal rate of return of the high-capital alternative (flotation deinking), however, is approximately equal to the CPP-specified discount rate of 12%. Given that the FEL-0 is a ±40% estimate of the financial performance of a project, there is definitely potential for improvement in the NPV and IRR of the proposed investment as more information becomes available.

The process impacts of installing a flotation deinking facility have been discussed in some detail in the Results of Process Modeling section. Minor effects on sheet quality are expected, and CPP should be prepared to deal with more breaks due to the increased deposits associated with incorporating wastepaper into their furnish. Significantly more solid waste (around 38,500 ODt/yr) will be generated in the form of deinking sludge. More fresh water will be required to run the flotation deinking plant and more liquid effluent will be generated at the increased production rates. In addition, the headboxes and press sections of each paper machine must be capable of withstanding throughput increases of around 11% without jeopardizing sheet quality or machine runnability. The machine drives are rated to operate safely and effectively at the new speeds required to achieve the cited 11% incremental production. The Consulting Firm does not anticipate that there will be any process impacts prohibitive to the installation of a flotation deinking plant as described in this report.

Installing the proposed deinking plant has been proven to be logistically feasible. A startup date of October 1, 2016 would be possible given the research conducted in creating this report. Many mills in similar positions have installed deinking plants much like the one in question, as shown in the Case Studies and Precedents section. In addition, the quote received from Voith describes a deinking plant almost identical to the one that would be required by CPP (30). Another quote received from Valmet also indicates that many mills are pursing similar options, which suggests that installing deinking capability is logistically feasible (35). The Consulting Firm believes that this project is logistically feasible and recommends that CPP commission an FEL-1 analysis, should the Company be satisfied with the estimated financial performance.

The economic feasibility of installing the proposed deinking plant is, unfortunately, in question. Given that the investment has an IRR of around 10% (versus the CPP-specified discount rate of 12%), the project is 2% below “profitable.” However, given the ±40% accuracy of the FEL-0, the Consulting Firm believes that the project should be tentatively considered worth pursuing. The sensitivity analysis in the previous section showed several scenarios in which the proposed flotation deinking plant would be appreciably more profitable. It is also possible that more specific information, gathered during an FEL-1 analysis, could alter the estimated financial performance of the project.

Conclusions

Installing a pulper makedown system to use MDIP to generate incremental production is not at all financially feasible. On the other hand, installing a flotation deinking plant to take advantage of low-cost SOP could prove lucrative for the CPP Raleigh mill. A preliminary FEL-0 level analysis indicates an internal rate of return of just over 10% for the proposed high-capital alternative project.

Installing a deinking plant would impact the paper machines, waste treatment, and effluent treatment systems significantly. The impacts on the woodyard, digesters, bleach plants, recovery boilers, and power generation would be negligible. In the Second Deliverable Presentation, a CPP representative requested that a summary table with some of the key performance indicators for each capital project be included in the Conclusions section. Table 10 illustrates some of these financial performance indices.

Table 10: Summary of Key Performance Metrics

	Flotation Deinking	MDIP Usage
Total Installed Capital (TIC)	$28,000,000	$2,400,000
Estimated Internal Rate of Return (IRR)	10%	-17%
Estimated Net Present Value (NPV)	-$3,400,000	-$50,000,000
Complexity of Process & Construction	High	Very Low
Overall Feasibility for CPP	Intermediate	Very Low

Recommendations

Given the unimpressive financial performance of the low-capital alternative of MDIP usage, the Consulting Firm recommends that CPP no longer pursues this project.

The financial performance of installing the proposed flotation deinking plant, however, is nearly high enough to justify the project in its current state. Even though the IRR of the project is currently estimated at just over 10% (versus a discount rate of 12%), the Consulting Firm feels that the Raleigh mill’s need for additional free cash flow, as well as the uncertainty associated with the FEL-0 analysis, justify an FEL-1 level analysis to evaluate the installation of deinking capability in more detail.

The Consulting Firm also recommends that CPP continue to work with existing customers throughout the investment planning process. As shown by the sensitivity analysis in the Profitability and Sensitivity Analysis section, it is of paramount importance that the mill estimate future product sale prices as accurately as possible. The mill must also develop more rigorous estimates of the price of wastepaper throughout the 10-year project lifetime (and perhaps beyond).

CPP must also contact the relevant officials to ensure that they can legally landfill an additional 38,500 ODt/yr of solid waste (deinking sludge), especially given that this number has changed significantly since the Second Deliverable.

Future Work

The Consulting Firm believes that continued market analysis and economic forecasting would prove beneficial to CPP. Completing an FEL-1 level analysis, although costly, would eliminate some of the uncertainty associated with the results discussed in this report.

It would also be of benefit for the mill to reconcile the numerous discrepancies between the provided WinGEMS and Excel models.

In addition, an investigation into the changes required to allow the mill's existing biomass boiler to incinerate deinking sludge could dramatically alter the IRR of this project. This would reduce the amount of waste landfilled and increase the amount electricity sold to the grid. This consideration would be especially important if the mill's current permitting does not allow for the disposal of the additional solid waste that would be generated by the flotation deinking plant. Andritz sells both bubbling fluidized bed (BFB) and circulating fluidized bed (CFB) boilers able to combust deinking sludge, as well as CFB gasifiers that can create syngas from rejects usable in the lime kiln (36). Voith’s controlled thermal conversion (CTC) technology can be used to process deinking sludge; extracts minerals, such as kaolin and carbonate, for sale to other industries; and generates steam that can be sent elsewhere in the process or used to generate power (37). Both of these nonconventional options for handling the mill's incremental refuse streams represent potential additional revenue and cost savings.

Literature Cited

1. Phillips, R. B. (2015). “CPP.xlsx,” Excel Spreadsheet. Provided by Carolina Pulp and Paper Company. Accessed Wednesday, March 4th, 2015.
2. Bajpai, P. (2013). "Recycling and Deinking of Recovered Paper," Elsevier, Waltham, MA.
3. Venditti, Richard. (2015). *Personal Communication*. Monday, February 23, 2015. North Carolina State University, Raleigh, NC.
4. Erkenswick, J. L. (1994). "Sorted Office Paper Definitions Facilitate Collection, End Use," *Pulp & Paper* 68(4), 67-69.
5. RISI. (2015). “Mill Asset Database,” online database. Accessed February 23, 2015 at <http://www.risiinfo.com/millassets/millLanding.html>.
6. RISI. (2015). “RISI Global Industry Statistics Database,” online database. Accessed February 23, 2015 at <http://www.risiinfo.com/content-gateway/pricewatch/northamerica.html>
7. RISI. (2015). “Market Price Watch,” online database. Accessed February 23, 2015 at <http://www.risiinfo.com/content-gateway/globalIndustryStatisticsDatabase.html>
8. Phillips, R. B. (2015). *Personal Communication.* Excel Spreadsheet containing pricing, supply, and demand data. Wednesday, March 4th, 2015.
9. RISI Editorial Staff. (2012). “Mississippi River Pulp to Close 131,000 tonnes/yr MDIP Mill at Natchez,” *RISI Pulp and Paper Week,* Friday, October 26th, 2012.
10. Ferguson, L. (1999). "Tutorial: Recycling and Deinking 101," TAPPI Pulping Conference Proceedings. American Fiber Resources, Fairmont, WV.
11. Jiang, C., and Ma, J. (2000). "De-Inking of Waste Paper: Flotation," Enzymatic Deinking Technologies, Norcross, Georgia; Academic Press, pp. 2537-2544.
12. Moe, S. T., and Røring, A. (2001). "Theory and Practice of Flotation Deinking," Sixth Research Forum on Recycling, Magog, Quebec, Canada.
13. Carre, B., Magnin, L., Galland, G., and Vernac, Y. (2000). “Deinking Difficulties Related to Ink Formulation, Printing Process, and Type of Paper,” Centre Technique du Papier, Domaine Universitaire, Grenoble, France.
14. Fernandez, E. O., and Hodgson, K. T. (2013). “Deinking Flexographic-Printed Papers: Destabilization of Flexographic Ink Dispersions with Copper Compounds,” TAPPI Journal 12(11): 29-35.
15. Hsieh, J. (2012). “Deinking of Inkjet Digital Nonimpact Printing,” TAPPI Journal 11(9): 9-15.
16. Lee, C. K., Ibrahim, D., Omar, I. C., and Rosli, W. D. W. (2011). “Pilot Scale Enzymatic Deinking of Mixed Office Wastepaper and Old Newspaper,” BioResources 6(4): 3809-3823.

17. Hirsch, G., Voss, D., Putz, H. J., and Schable, S. (2014). "Effect of Poorly Deinkable Paper on Deinked Pulp Quality," TAPPI Journal 13(9): 41-48.

18. TAPPI. (2011)."Deinking Review," Progress in Paper Recycling 20(1): 1-43.

19. Azevedo, M. A. D., Drelich, J., and Miller, J. D. (1999). "The Effect of pH on Pulping and Flotations of Mixed Office Wastepaper," Journal of Pulp and Paper Science 25(9): 317-320.

20. Lee, C. L., Darah, I., and Ibrahim, C. O. (2007). "Enzymatic Deinking of Laser Printed Office Waste Papers: Governing Parameters of Deinking Efficiency," Biores. Tech. 98: 1684-1689.

21. Pauck, J., and Marsh, J. (2002). "The Roles of Sodium Silicate in the Deinking of Newsprint at Mondi Merebank," Website. Accessed November 23, 2014 <http://www.tappsa.co.za/archive/Journal_papers/The_role_of_sodium/ the_role_of_sodium.html>.

22. Pauck, J., and Marsh, J. (2002). "The Role of Sodium Silicate in Newsprint Deinking," Website. Accessed November 23, 2014 <http://www.tappsa.co.za/archive /APPW2002/Title/The_role_of_sodium_silicate/the_role_of_sodium_silicate.html>.

23. McMillan, M., Bettis, S., Proznik, L., & Graham, R. (1991). In J. R. Thrift (Chair). Impact on steam and power requirements when secondary fiber capacity is added to an existing mill. TAPPI Proceedings Engineering conference.

24. James, R. (2014). "Sorting out the latest DIP news," Pulp and Paper International. May 2000: n. page. Web. 26 Nov. 2014.

25. Jewitt, C. (2014). "Deinking orders dazzle industry suppliers." Pulp and Paper International. Apr 2001: Web. 26 Nov. 2014.

26. Hanson, J. P. (1977). "GP Starts up Flotation Deinking Lines at Kalamazoo, Mich., Mill," Pulp & Paper July 1997, 98-100.

27. Ferguson, K. H. (1995). "IP Focuses on Reprographic Market with World's Largest Machine at Selma," Pulp & Paper 69(6): 47-52.

28. Finchem, K. J. (1996). "Boise Designs Jackson Deinking Mill for Low-Quality Fiber, High-Quality Pulp," Pulp & Paper 70(5): 101-107.

29. McKinney, R. (1998). "A Better Insight Could Help Flotation Technology Take Off," Pulp and Paper International: June.

30. Spielbauer, J. (2015). Personal Communication. Monday, March 30, 2015. Voith Paper Inc., Appleton, WI.

31. Peters, M. S., Timmerhaus, K. D., and West, R. E. (2002). "Equipment Costs: Plant Design and Economics for Chemical Engineers," Online. Accessed Monday, March 2nd, 2015 at <http://www.mhhe.com/engcs/chemical/peters/data/>.

32. Phillips, R. B. (2015). "Phillips Installed Cost Estimator.xlsx," Excel Spreadsheet. Provided by Carolina Pulp and Paper Company. Accessed Monday, March 2nd, 2015.

33. Lenski, M. J. (2015). "Deinking Chemical Costs 2014_Q2," Excel Spreadsheet. Sourced from FisherSolve Software. Accessed Thursday, April 2nd, 2015.

34. Buchanan, J. (2015). *Personal Communication.* Monday, March 2, 2015. Akzo Nobel Pulp and Performance Chemicals Inc., Marietta, GA.

35. Belair, B. (2015). *Personal Communication*. Monday, March 30, 2015. Valmet Inc., Norcross, GA.

36. Andritz. (2011). "From Trash to Treasure," Website. Accessed April 7, 2015 <http://spectrum.andritz.com/index/iss_23/art_23_31.htm>.

37. Voith. (2011). "Greater added value thanks to CTC technology," Website. Accessed April 7, 2015 <http://voith.com/en/twogether-article-32-en-60-ctc-technologie.pdf>.

38. Carroll, W. P., and McCool, M. A. (1990). "Pressurized Deinking Module", TAPPI Pulping Conference Proceedings. Beloit Corporation, Dalton, MA.

39. Vashisth, S., Bennington, C. P. J., Grace, J. R., and Kerekes, R. J. (2011). "Column Flotation Deinking: State-of-the-art and Opportunities," Resources, Convservation and Recycling 55, 1154-1177

40. Pala, H., Mota, M., and Gama, F. M. (2004). "Enzymatic Versus Chemical Deinking of Non-Impact Ink Printed Paper," Journal of Biotechnology 108: 79-89.

41. Welt, T., and Dinus, R. J. (1994). "IPST Technical Paper Series Number 542: Enzymatic Deinking – A Review," Institute of Paper Science and Technology, Georgia Institute of Technology, Atlanta, Georgia.

42. Goto, S., Tsjui, H., Onodera, I., Watanabe, K., and Ono, K. (2014). "Cavitation-Jet Deinking: A New Technology for Deinking of Recovered Paper," TAPPI Journal 13(9): 9-17.

43. Goto, S., Tsuji, H., Onodera, I., Watanabe, K., and Ono, K. (2014). "Pilot-Scale Development of Cavitation-Jet Deinking," Progress in Paper Recycling 13(9): 19-25.

44. AkzoNobel EKA. (2014). "Deinking Chemicals," Website. Accessed November 17, 2014 <https://www.akzonobel.com/eka/products/pulp_chemicals/ deinking_chemicals/>.

45. Buckman. (2014). "Deinking," Website. Accessed November 17, 2014 <http://www.buckman.com/ core-businesses-paper/paper-technologies/paper-applications/deinking>.

46. EDT. (2014). "Deinking - Enzymatic Treatments for Processing Recovered Paper," Website. Accessed November 17, 2014 <http://www.edt-enzymes.com/deinking.html>.

47. Kemira. (2014). "Fennoflot for Enhanced Ink Removal," Website. Accessed November 17, 2014 <http://www.kemira.com/en/industries-applications/Pages/fennoflot.aspx>.

48. Thiele Kaolin Company. (2014). "DEKA Deinking Products," Website. Accessed November 17, 2014 <http://www.thielekaolin.com/index.php/markets/paper/dekadeinkingprods>.

49. Andritz. (2014). "Deinking Systems," Website. Accessed November 17, 2014 <http://www.andritz.com/products-and-services/pf-detail.htm?productid=12079>.

50. Kadant. (2014). "Deinking," Website. Accessed November 16, 2014 <http://www.kadant.com/en/products/deinking>.

51. Voith. (2014). "Flotation," Website. Accessed November 17, 2014 <http://www.voith.com/en/ products-services/paper/process-steps/stock-preparation/flotation-10647.html>.

52. Borchardt, J. K., Matalamaki, D. W., Lott, V. G., and Grimes, D. B. (1997). “Pilot Plant Studies: Two Methods for Deinking Sorted Office Paper,” *TAPPI Journal* 80(10), 269-277.

53. Chen, H. (2014). “Process Development and Fundamental Study on Enzymatic Hydrolysis of Cellulosic Biomass to Fermentable Sugars for Ethanol Production,” *PhD Dissertation*. Accessed online February 23, 2015 at <http://repository.lib.ncsu.edu/ir/bitstream/1840.16/9673/1/etd.pdf>.

54. Woodward, T. W. (1996). “Water Reuse Levels, Solids Buildup Barriers to Deinking Plant Closure,” *Pulp & Paper*. February 1, 1996. Accessed online February 23, 2015 at <http://www.risiinfo.com/db_area/archive/p_p_mag/1996/9602/96020127.htm>.

55. Economides, D. G., Vlyssides, A. G., Simonetis, S. I., and Philippakopoulou, Th. L. (1998). “Reuse of Effluent from a Wastepaper Wash-Deinking Process,” *Environmental Pollution* 103(2-3), 229-237.

Appendix

Appendix Contents

Appendix A1 – Additional Supporting Information from Deliverable 1
Appendix A2 – Additional Supporting Information from Deliverable 2
Appendix A3 – Additional Information from Voith Deinking Plant Quote
Appendix A4 – Oversized Economic Analysis Tables

Appendix A1

Additional Supporting Information from Deliverable 1

Relevant Flotation Deinking Technologies

Although flotation is arguably the most common modern method of ink removal, there are numerous technologies by which ink can be removed. The most well-known methods, and their relative effectiveness, are predicated by the size of the ink particles being removed, as summarized in Table 11.

Table 11: Common removal methods for various ink particle sizes (2)

Particle Size	Removal Method
> 100 µm	Screening & centrifugal cleaning
10 - 100 µm	Flotation
< 10 µm	Washing

Figure 26 illustrates the removal efficiencies of these methods for varying particle sizes.

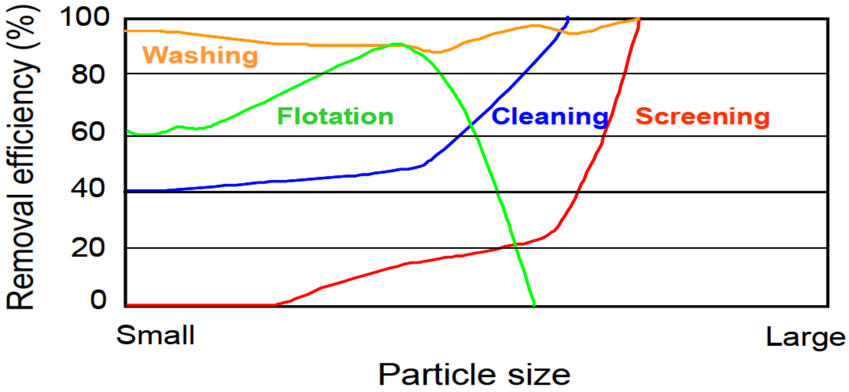


Figure 26: Removal efficiency of different deinking method versus particle size (18)

Washing is most effective for removing the smallest ink particles, whereas flotation most selectively removes medium-sized particles. Cleaning is effective for medium-to-large particles and screening is effective for even larger particles.

To achieve thorough deinking, a combination of these technologies is required. As shown in the previous section, a modern deinking plant contains a pulper, a deflaker, screens, centrifugal cleaners, washing stages, and different types of flotation cells. Each of these targets specific ink and contaminant particles to achieve bright, clean pulp before use on the paper machine.

Pulping

There are three typical choices of pulping equipment for deinking plants: low-consistency batch or continuous pulpers, high-consistency batch pulpers, and high-consistency continuous drum pulpers.

The first two approaches employ large vats with rotors at or near the bottom that break up the recovered paper and disperse fibers and contaminants. These contaminants include numerous different types of inks, dirt, stickies, extractives, and others. Low-consistency pulpers use more aggressive shear action, reducing the contaminants to as small a size as possible. This approach makes these contaminants easier to remove via washing, but the introduction of flotation cells, which are more efficient at removing somewhat larger particles, has made high-consistency pulpers the preferred choice for new installations. High-consistency pulping utilizes gentler fiber-to-fiber rubbing action, allowing contaminants to remain larger in size, generating fewer fines, and decreasing the need to charge the pulper with steam or chemicals. Exceptionally large contaminants can be removed from vat pulpers in a subsequent detrashing step.

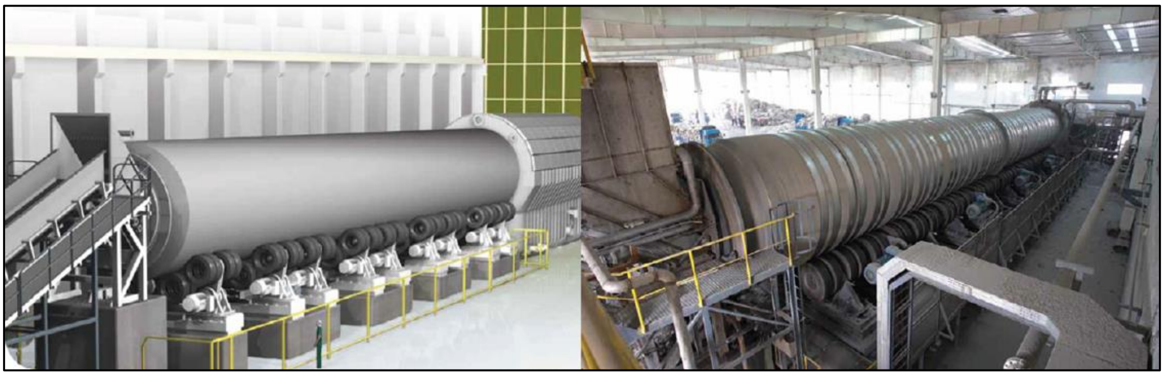


Figure 27: Illustration of Metso drum pulper (2)

Drum pulpers are geometrically similar to lime kilns in that they are inclined, revolving, cylindrical units. Figure 27 illustrates a Metso drum pulper. Paper, water, and chemicals are added to one end, and the contaminants are separated from the paper by successive drops as the shell rotates. This action is gentler than that of a high-consistency vat pulper, resulting in less contaminant size reduction and allowing for more efficient removal from the pulp in unit operations further downstream. Vat pulper rotors typically improve ink detachment, while drum pulpers maintain ink particles of larger sizes, allowing for easier removal in flotation cells.

Deflaking

After leaving the pulper, the stock is sent to a deflaker, which better disperses the bundles of fibers or paper remaining in the pulp (from recycled grades with wet strength). Deflakers use fiber-to-fiber rubbing via impact and shear forces to break down these structures, rather than passing stock between rotating plates as in refiners. The efficiency of the deflaking operation is highly dependent on the amount of contaminants still present in the stock. These units can easily become blocked by trash, so effective upstream refuse removal is essential. Recalcitrant paper grades require more aggressive deflaking, though the efficacy of the process can be improved by treating the stock with certain chemicals at elevated temperatures. For stock that contains residual contaminants, the implementation of disk screens is typically more effective than using deflakers. Disk screens reduce reject rates but suffer diminished deflaking effects.

An Andritz deflaker is shown in Figure 28. Deflaking technology is relatively simple and is similar to refining: stock enters the top of the chamber, is subjected to the shear forces described, and leaves the top of the chamber. Deflakers can usually be equipped with a variety of different plates tailored to specific applications.

Figure 28: Andritz deflaker (2)

Cleaning and Screening

Any heavy debris, such as staples, paper clips, and large grits, which remain in the pulp after deflaking are removed by centrifugal cleaners. The stock enters the conical bodies of the cleaners tangentially, and the devices use centrifugal force to remove the undesirable materials based on density differences compared to that of the stock itself. Some contaminants, such as stickies, have densities near that of water, making them difficult to remove in the cleaners. Thus, various other separation methods are required in a deinking plant. Separation efficiency in the cleaners is dependent upon the consistency of the stock, temperature, rejects composition, pressure drop across the cleaner body, and a myriad of other factors. Figure 29 shows a Metso cleaner.

Figure 29: Illustration of a Metso cleaner (2)

Typically, cleaners are used in conjunction with screens to ensure adequate refuse removal. Figure 30 shows a Metso fine screening system in which the screens are run in series and Figure 31 shows fine and coarse screens made by Andritz. These screens contain slotted baskets that rotate, allowing acceptable fibers to pass through and, ideally, rejecting all unwanted contaminants. Modern, world-class screens have 0.004-inch slots, through which very few contaminants can pass.

Figure 30: Metso fine screening system (2)

The number and configuration of screens can be customized to meet the needs of a particular deinking operation; an ONP deinking operation would have very different cleaning and screening needs than an OCC deinking operation. Screening and cleaning systems have improved radically in recent years, meaning that smaller cleaners and screens can now allow much greater process throughput than ever before.

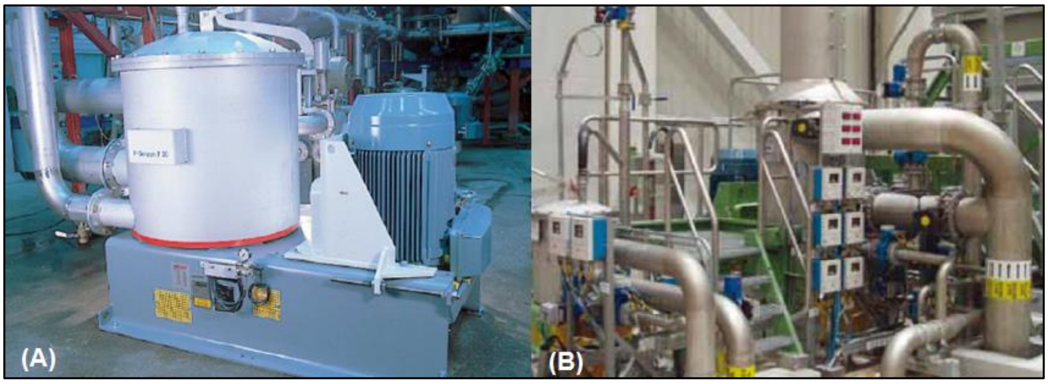


Figure 31: (A) Andritz coarse screen and (B) Andritz dual fine and coarse screen (2)

Flotation

Many consider flotation the key unit operation in deinking. There are a variety of different types of flotation cells, most of which are now pressurized to allow for better control of bubble characteristics (38). Beloit-Jones Corporation was the first to experiment with pressurized deinking modules in the eighties and early nineties, finding that they could tailor the air bubbles created to different wastepaper streams when the pressure of the flotation vessel could be adjusted.

There are alternatives to the typical flotation cells, as shown in Figure 6. Column flotation has become popular in the past few decades and is overtaking many other methods of ink removal due to its flexibility and effectiveness. In countercurrent column flotation, the pulp is gently introduced into the top of the column and air bubbles are created at the bottom, floating up, attaching to ink particles, and ultimately being removed. This type of deinking offers excellent deinking efficiency, but poor air bubble-ink particle adhesion can cause issues. Some cocurrent cells have also been designed to combat problems with poor ink-bubble adhesion. These are shown in Figure 32. (39)

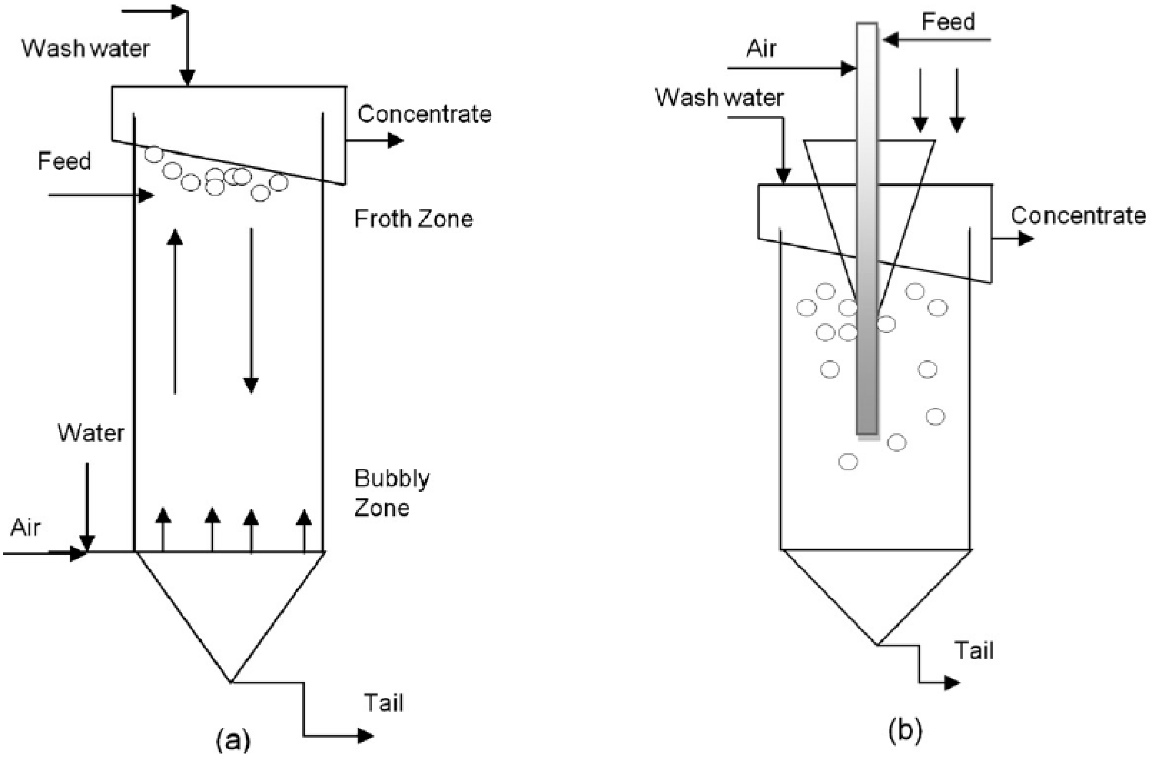


Figure 32: Illustration of (a) countercurrent and (b) cocurrent flotation columns (39)

Some Recent Developments

EDT and Buckman now offer specialized enzymatic deinking solutions to interested mills. One drawback of enzymatic deinking is that it must be optimized for each individual deinking operation, or the quality of the final product could suffer (40, 41). If effectively implemented, many researchers believe that enzymatic deinking could displace a large quantity of traditional deinking chemicals, making it a lucrative deinking strategy (40).

One group of deinking researchers has recently developed a novel method of ink removal called “cavitation-jet deinking”. This method of deinking uses a special nozzle to inject pulp into a tank filled with water at such a velocity that cavitation occurs, forming many small air bubbles. These bubbles collide with fibers with enough force to detach ink particles, binders, and various other unwanted contaminants from the more valuable fibers (42). Using this technique, the dirt count in the pulp was significantly reduced without the need for detachment chemicals or high temperatures. The treatment also increased the strength of the resulting sheet (42). This technology has been successfully employed at both the laboratory and pilot scales (43) and has promise to simplify deinking processes if it is proven effective at the industrial scale. Figure 33 shows the dispersion of and reduction in deposits achieved via cavitation-jet treatment.

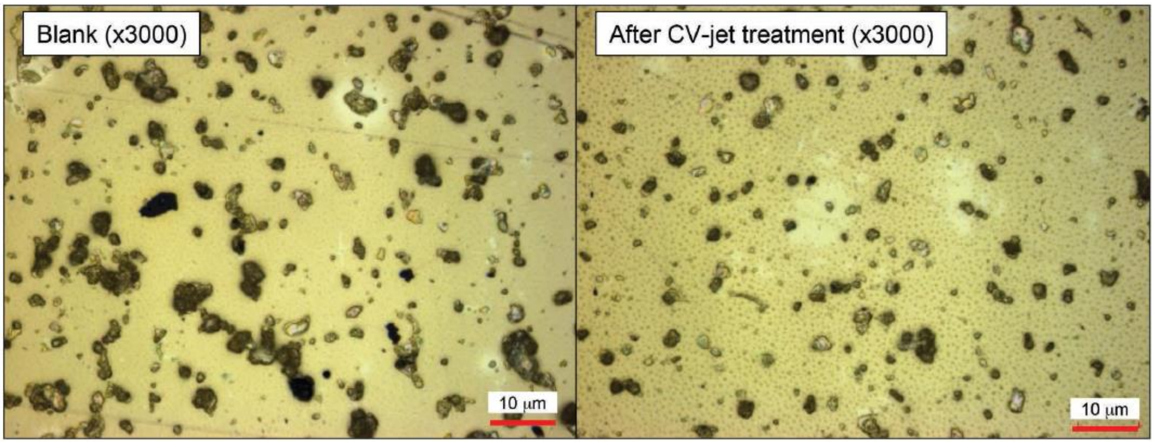


Figure 33: Photomicrographs of deposits before and after cavitation-jet treatment (42)

As this process has not yet been successfully demonstrated on the industrial scale, it is not of immediate interest to the Company, but should certainly be considered if the project is delayed and reexamined in the future.

Major Technology, Equipment, and Service Providers

Deinking Chemicals

AkzoNobel, a specialty chemical supplier for the pulp and paper industries, sells numerous chemicals used in deinking. Their Eka brand of chemicals is devoted to the bleaching of pulp, including deinking pulp. Their Eka RF series of chemicals, aimed specifically at deinking recovered fibers, includes a replacement technology for sodium silicates and a variety of fatty acids, surfactants, and enzymes. Their trademarked “S-Quad” technology is used in neutral pH deinking. AkzoNobel also supplies less specialized chemicals, including hydrogen peroxide and caustic, which are also used throughout the deinking process. (44)

Buckman, another prominent chemical supplier for the pulp and paper industries, supplies a variety of deinking chemicals aimed at maximizing yield and the brightness of deinked pulp. Some of their trademarked deinking chemical brands include BRD surfactants, Optizyme enzymes (stickies and contaminants control), Busperse dispersants and chelants (deposit control and brightness stability), Busan microbiocides, and Bufloc coagulants and flocculants (stickies control and water clarification). (45)

Enzymatic Deinking Technologies (EDT) supplies enzyme formulations intended to help detach ink particles from fibers without yield loss. Their trademarked Enzynk brand of enzyme formulations is the most relevant of their products to deinking. (46)

Kemira, a chemical supplier for water-intensive industries including pulp and paper, oil and mining, and municipal and industrial water treatment, offers some deinking chemicals. Their Fennoflot modified inorganic particle (MIP) deinking agent is designed to outperform traditional soap and surfactant technology. (47)

Thiele Kaolin Company offers separate formulations for washing and flotation deinking applications. Their deinking chemicals are modified kaolin particles bound with deinking surfactants. The DEKA2000 product line is tailored for flotation deinking applications and the DEKA3000 product line is tailored for wash deinking applications. Thiele Kaolin Company advertises that their deinking product lines aid in ink particle collection and stickies control. (48)

Deinking Equipment

Andritz has the capability to supply equipment for all aspects of the flotation deinking process, starting at pulping and storage and extending through sludge and reject treatment. The specific unit operations for which Andritz can provide equipment include pulping (drum pulpers, low-consistency pulpers, and high-consistency pulpers); screening (their ModuScreen product family); cleaning (a family of centrifugal cleaners); bleaching (towers and associated equipment); dewatering (pulp screw presses); dispersing (combined heating and feeding screws); flotation (SelectaFlot flotation cell); thickening (disc filter, drum thickener, disc thickener, and various screens); ash washing (rotary and drum washers); sludge dewatering (gravity-based and screw press); and reject treatment. (49)

Kadant offers technology called the “MAK-C Compact Flotation Cell”, which they laud as offering the maximum achievable deinking yield and efficiency. This technology is a combination of multi-stage tank flotation and column flotation and does not require secondary cells (i.e., it is standalone). Kadant claims that the MAK-C flotation cell can accept a varied feed without detrimental effects on its performance. (50)

Voith offers several more specialized flotation cells for deinking. These include a two-cell design trademarked “InjectaCell”, a more compact, single-cell design called “InjectaCompact”, and a low-energy deinking unit called “LowEnergyFlotation”. They also can provide a lab-scale flotation cell called the “Delta25 Laboratory Flotation Cell”. Their products are tailored to remove ink, stickies, and wax from the fiber slurry with minimal loss of valuable fiber. (51)

Appendix A2
Additional Supporting Information from Deliverable 2

Rationale for Choosing Flotation over Agglomeration

Given the relatively untested nature of industrial-scale agglomerative deinking, the risks associated with installing poorly understood technology, and the excellent results achieved by traditional flotation deinking, it is believed that the best technology choice for the Raleigh mill would be a more traditional flotation deinking operation.

In the previously cited pilot-scale study (52), both flotation and agglomeration deinking were shown to produce pulps of acceptable quality. Although industrial-scale agglomeration deinking facilities do exist, their technologies appear to be proprietary and it has been difficult to find information beyond the pilot scale. One pilot-scale study discusses some of the issues with scaling up the agglomeration deinking processes they examined: energy consumption and the physical size of the equipment required to perform agglomeration deinking on the industrial scale are major technical questions that are yet unanswered (19). This study further emphasizes the dependence of the performance of agglomerative deinking on the choice of separators. Because the mechanisms of agglomerative deinking are not thoroughly understood, accurately forecasting the degree of ink removal achieved with a certain unit operation is difficult (19). Choosing the wrong unit operations, or using them in a suboptimal order, could prove catastrophic.

Given the wealth of information available regarding both the technology and excellent performance of modern flotation deinking, it is believed that there would be substantially less risk involved with flotation deinking than with agglomeration deinking. The previous deliverable report contained information on some of the few publically-available deinking plant case studies. These flotation facilities were all shown to have achieved excellent deinking yield and product quality (24, 26, 27, 28).

Flotation cells are typically modular. They can be effectively bolted together, and additional cells can be added in the event of additional deinking requirements. The flexibility of flotation deinking is another advantage that it possesses over agglomeration deinking.

Effects of Flotation Deinking on Solid Waste and Wastewater Treatment

The deinking of pulp generates significant quantities of solid waste. The composition of the sludge generated during deinking varies widely, but one study of numerous sludge samples from deinking-bleaching operations indicates that sludge is roughly 30-35% solids, 35% of which are glucan (fiber), as shown in Table 12. The ash content in this sludge is quite high, on the order of 30%. This ash contains large amounts of calcium salts which can cause scaling in boilers and complicate solid waste and wastewater treatment, making sludge incineration complicated. (53)

Table 12: Compositions of Several Deinking, Bleached Sludge Samples (53)

Sludge Sample	Composition		
	Solids (%)	Glucan (%)	Ash (%)
1	30.11	28.83	28.33
2	32.94	34.99	21.83
3	29.82	24.98	34.41
4	30.03	22.86	48.5
5	32.6	67.25	7.2
6	33	30	Unknown
Average	31.4	34.8	28.1

Sludge yields are usually between 5 and 20% of the mass of the wastepaper entering a deinking facility, varying according to the recovered paper being used and the grade being produced (i.e., brightness and quality requirements) (2). A mill producing a lower-quality product can leave more ink in the sheet than a mill producing uncoated freesheet like the Raleigh mill. Unfortunately, sludge is difficult to dewater to above about 50% solids, so when landfilled, it occupies a lot of volume and imparts additional waste disposal costs (2). These costs will be considered in future financial analyses.

Burning the sludge in a boiler is desirable in that some of the residual heating value of the glucan in the sludge can be realized and that its volume can be reduced prior to landfilling. Given the major fraction of inorganics in the sludge, burning it in an inappropriately designed or unsuited boiler could cause fouling and scaling. Sludge generation via deinking can be limited by dissolved air flotation (DAF) cells, which are expensive but efficient auxiliary units to primary flotation cells that use microscopic air bubbles to reclaim the smallest particles from wastewater streams. One positive is that, with the public’s growing desire for sustainability, sludge is increasingly being utilized in other applications like brick and cement manufacture. (2)

In addition to the issues with solid waste treatment stemming from deinking, the mill should also expect some complications to their wastewater treatment system. It is often difficult or impossible to completely close the water loop of a deinking system due to the buildup of solid contaminants, particularly ash and inks (54). To achieve a high degree of deinking plant water loop closure, complex contaminant removal systems are required. These systems typically involve at least two stages of gravity clarification separated by activated sludge treatment and cooling (54). If too much water is recycled without adequate contaminant removal, serious runnability and quality problems will ensue.

At least one group of researchers has studied of the effects of the deinking wastewater recycling ratio (defined as the mass flow of recycled wastewater divided by the mass flow of water into the deinking process) on deinking effluent characteristics. Not surprisingly, they found that increasing the ratio of wastewater recycled caused the biological oxygen demand (BOD), chemical oxygen demand (COD), and solids content of the sludge to increase with each iterative recycle. The increases noted in the effluent COD and solids content are illustrated in Figure 34. (55)

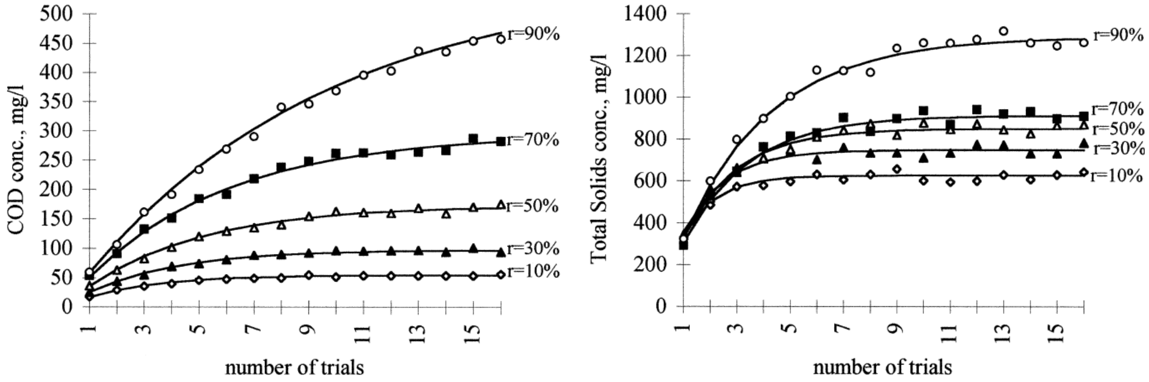


Figure 34: COD and solids content of recycled deinking effluents (55)

As the recycling ratio, *r*, increased, the COD and solids content of the deinking effluent stabilized at higher values. At higher recycling ratios, it also took more trials (iterative recycles) for the COD and effluent solids to stabilize, indicating a slower-reacting process. This study illustrates the importance of effective waste treatment and careful wastewater reuse to the stable operation of a deinking facility.

Appendix A3
Additional Information from Voith Deinking Plant Quote

Table 13: Voith Deinking Plant Quote Information (35)

ID#	Quant.	Description
		Pulping and Detrashing System
3.1	1	MMH-FC-1500-S Pulper Feed Slat Conveyor
3.2	1	MMH-DMOB-2000 Mobile Bale Dewiring Machine
3.3	1	MMH-WCOI Wire Coiling Machine
3.4	1	High Consistency Pulper, Model HDC 24
3.5	1	Contaminex, Model CMS 500
3.6	1	Drum Screen, Model STR 5F
		HD Cleaning
3.7	1	High Density Cleaner, Model HCC-AR 300-152
		Coarse Screening
3.8	1	MultiSorter, Model MSM 05/05
3.9	1	Combisorter, Size 12
		IC Fine Screening
3.1	1	MultiScreen, Model MSS 08/08
3.11	1	MultiScreen, Model MSS 05/05
3.12	1	High Density Cleaner, Model HCC 170-95
3.13	1	MultiScreen, Model MST 04/03
		Fine Cleaning
3.14	1	HCL5 Cleaner System with EcoMizer – 3 Stage
		LC Fine Screening
3.15	1	MultiScreen, Model MSS 15/15
3.16	1	MultiScreen, Model MSS 08/08
3.17	1	MultiScreen, Model MST 05/05
		Loop 1 Washing and Fiber Recovery
3.18	2	Compact Washer, Model CW 2000
3.19	1	Conustrenner, Model CT 150
3.2	1	Conustrenner, Model CT 60
		Loop 1 Clarification
3.21	1	Tauro, Model TAL 11.2
		Pressurized Dispersion
3.22	1	Thune Screw Press, Model SP 45SLP
3.23	1	Speed Heater, Model PMLS 24
3.24	1	Disperger, Model KRD 60-LC
		Flotation
3.25	1	EcoCell Flotation System, Model ECC 2/38 LEF
		Loop 2 Washing and Fiber Recovery
3.26	1	Compact Washer, Model CW 2000
		Loop 2 Clarification
3.27	1	Tauro, Model TAL 11.1
		Deinking Plant Water Lock
3.28	1	Thune Screw Press, Model SP 45SL
		Dilution Screw
3.29	1	Dilution Screw, Model SFV 300-700.6000
		Water, Sludge, and Reject Handling
3.3	1	Ecompax, Model EX 50
3.31	1	Screenex, Model SX 60-5-25
3.32	1	Sedimator, Model SM 28.2
3.33	1	BlueDrain, Model BDL 3XL
3.34	1	Sludge Screw Press, Model RSP 80
3.35	1	Tauro, Model TAL 6.1

Total Estimated Equipment Cost:

$6,942,000

Appendix A4
Oversized Economic Analysis Tables

Table 14: Cost and Revenue Summary Table – Low-Capital Solution (MDIP Usage)

(Note that all dollar amounts are in thousands)

	Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	Total
Direct Costs	Freight	$0	$791	$3,938	$4,029	$4,122	$4,218	$4,315	$4,415	$4,518	$4,623	$4,731	$4,842	**$44,542**
	Fiber (MDIP)	$0	$8,093	$39,387	$39,387	$39,387	$39,387	$39,387	$39,387	$39,387	$39,387	$39,387	$39,387	**$401,963**
	Chemicals	$0	$1,401	$6,966	$7,117	$7,271	$7,428	$7,590	$7,756	$7,926	$8,100	$8,279	$8,462	**$78,296**
	Energy	$0	$571	$2,780	$2,780	$2,780	$2,780	$2,780	$2,780	$2,780	$2,780	$2,780	$2,780	**$28,371**
	PM Steam	$0	$449	$2,183	$2,183	$2,183	$2,183	$2,183	$2,183	$2,183	$2,183	$2,183	$2,183	**$22,279**
	Finishing Mats.	$0	$309	$1,538	$1,575	$1,614	$1,653	$1,694	$1,737	$1,780	$1,825	$1,871	$1,918	**$17,514**
	Environmental	$0	$189	$921	$921	$921	$921	$921	$921	$921	$921	$921	$921	**$9,399**
Indirect Costs	Maintenance	$0	$28	$49	$50	$52	$53	$55	$56	$58	$60	$62	$63	**$586**
	Property Tax	$0	$28	$49	$50	$52	$53	$55	$56	$58	$60	$62	$63	**$586**
	Insurance	$0	$14	$24	$25	$26	$27	$27	$28	$29	$30	$31	$32	**$293**
	Labor Costs	$0	$620	$1,083	$1,104	$1,126	$1,149	$1,171	$1,195	$1,218	$1,242	$1,267	$1,292	**$12,467**
	Overheads	$0	$807	$3,908	$3,873	$3,855	$3,874	$3,878	$3,880	$3,886	$3,901	$3,923	$3,945	**$39,730**
Revenue	Sheet Sales	$0	$5,937	$28,538	$28,127	$27,837	$27,741	$27,579	$27,404	$27,264	$27,175	$27,125	$27,085	**$281,812**
	Roll Sales	$0	$4,828	$23,562	$23,507	$23,556	$23,906	$24,125	$24,325	$24,554	$24,842	$25,182	$25,520	**$247,907**
	Gross Profit	**$0**	**-$2,535**	**-$10,726**	**-$11,460**	**-$11,996**	**-$12,079**	**-$12,352**	**-$12,665**	**-$12,926**	**-$13,095**	**-$13,190**	**-$13,283**	**-$126,307**

Table 15: Cost and Revenue Summary Table – High-Capital Solution (Flotation Deinking)

(Note that all dollar amounts are in thousands)

Year		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	Total
Direct Costs	Freight	$0	$635	$3,888	$4,029	$4,122	$4,218	$4,315	$4,415	$4,518	$4,623	$4,731	$4,842	**$44,336**
	Fiber (MDIP)	$0	$2,735	$16,358	$16,570	$16,570	$16,570	$16,570	$16,570	$16,570	$16,570	$16,570	$16,570	**$168,223**
	Chemicals	$0	$1,125	$6,877	$7,117	$7,271	$7,428	$7,590	$7,756	$7,926	$8,100	$8,279	$8,462	**$77,931**
	Energy	$0	$625	$3,740	$3,788	$3,788	$3,788	$3,788	$3,788	$3,788	$3,788	$3,788	$3,788	**$38,457**
	PM Steam	$0	$360	$2,155	$2,183	$2,183	$2,183	$2,183	$2,183	$2,183	$2,183	$2,183	$2,183	**$22,162**
	Finishing Mats.	$0	$248	$1,518	$1,575	$1,614	$1,653	$1,694	$1,737	$1,780	$1,825	$1,871	$1,918	**$17,433**
	Environmental	$0	$152	$909	$921	$921	$921	$921	$921	$921	$921	$921	$921	**$9,350**
Indirect Costs	Maintenance	$0	$326	$575	$592	$610	$628	$647	$667	$687	$707	$728	$750	**$6,917**
	Property Tax	$0	$326	$575	$592	$610	$628	$647	$667	$687	$707	$728	$750	**$6,917**
	Insurance	$0	$163	$288	$296	$305	$314	$324	$333	$343	$354	$364	$375	**$3,459**
	Labor Costs	$0	$826	$1,444	$1,473	$1,502	$1,532	$1,562	$1,593	$1,624	$1,656	$1,689	$1,723	**$16,624**
	Overheads	$0	$648	$3,857	$3,873	$3,855	$3,874	$3,878	$3,880	$3,886	$3,901	$3,923	$3,945	**$39,520**
Revenue	Sheet Sales	$0	$4,768	$28,172	$28,127	$27,837	$27,741	$27,579	$27,404	$27,264	$27,175	$27,125	$27,085	**$280,277**
	Roll Sales	$0	$3,878	$23,260	$23,507	$23,556	$23,906	$24,125	$24,325	$24,554	$24,842	$25,182	$25,520	**$246,655**
Gross Profit		**$0**	**$477**	**$9,248**	**$8,625**	**$8,042**	**$7,910**	**$7,585**	**$7,219**	**$6,905**	**$6,682**	**$6,532**	**$6,378**	**$75,603**

Table 16: Profitability Summary Table – Low-Capital Alternative (MDIP Usage)

(Note that all dollar amounts are in thousands)

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Revenue	$0	$10,765	$52,100	$51,634	$51,394	$51,647	$51,704	$51,730	$51,818	$52,017	$52,307	$52,604
Costs	$0	$14,004	$63,414	$63,521	$63,700	$63,956	$64,290	$64,631	$64,878	$65,141	$65,525	$65,919
Gross Profit	$0	-$2,898	-$10,726	-$11,461	-$11,994	-$12,079	-$12,353	-$12,665	-$12,928	-$13,096	-$13,189	-$13,285
Depreciation	$0	$341	$588	$427	$312	$231	$233	$236	$132	$28	$29	$29
Taxes	$0	-$1,134	-$3,960	-$4,161	-$4,307	-$4,308	-$4,405	-$4,515	-$4,571	-$4,593	-$4,626	-$4,660
Net Profit After Taxes	$0	-$2,105	-$7,354	-$7,727	-$7,999	-$8,001	-$8,181	-$8,386	-$8,489	-$8,530	-$8,592	-$8,654
Cash Flow	$0	-$1,764	-$6,766	-$7,300	-$7,687	-$7,771	-$7,948	-$8,150	-$8,357	-$8,502	-$8,563	-$8,625
Change in Working Capital	$0	$2,590	$9,968	-$75	-$38	$41	$9	$4	$14	$32	$46	$48
Free Cash Flow	-$1,181	-$5,559	-$16,758	-$7,250	-$7,674	-$7,838	-$7,985	-$8,182	-$8,400	-$8,564	-$8,640	$24,421

Discount Rate	12%	NPV	-$49,255	IRR	<< -15%

Table 17: Sensitivity Analysis IRR Values for Low-Capital Alternative (MDIP Usage)

	75%	80%	85%	90%	95%	100%	105%	110%	115%	120%	125%
Capital Investment	-16.95%	-16.97%	-16.98%	-17.00%	-17.02%	-17.03%	-17.05%	-17.06%	-17.08%	-17.10%	-17.11%
Project Capital in Year -1	-17.04%	-17.04%	-17.04%	-17.03%	-17.03%	-17.03%	-17.03%	-17.03%	-17.03%	-17.03%	-17.03%
Incremental Freight Cost	-16.93%	-16.95%	-16.97%	-16.99%	-17.01%	-17.03%	-17.05%	-17.08%	-17.10%	-17.12%	-17.14%
Incremental Labor Cost	-16.52%	-16.62%	-16.72%	-16.83%	-16.93%	-17.03%	-17.14%	-17.24%	-17.35%	-17.46%	-17.57%
Incremental Maintenance Cost	-17.01%	-17.02%	-17.02%	-17.02%	-17.03%	-17.03%	-17.04%	-17.04%	-17.05%	-17.05%	-17.05%
Sale Price Discount/Premium	Too Low	Too Low	Too Low	Too Low	Too Low	-17.03%	-12.98%	-8.33%	-2.92%	3.49%	11.22%
Incremental Overheads	-15.56%	-15.86%	-16.16%	-16.45%	-16.74%	-17.03%	-17.32%	-17.60%	-17.88%	-18.16%	-18.44%
MDIP Price	3.34%	-2.02%	-6.56%	-10.49%	-13.94%	-17.03%	-19.83%	Too Low	Too Low	Too Low	Too Low

Table 18: Profitability Summary Table – High-Capital Alternative (Flotation Deinking)

(Note that all dollar amounts are in thousands)

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Revenue	$0	$8,645	$51,433	$51,634	$51,394	$51,647	$51,704	$51,730	$51,818	$52,017	$52,307	$52,604
Costs	$0	$13,395	$50,738	$49,545	$48,530	$47,955	$48,366	$48,791	$47,969	$47,156	$47,606	$48,068
Gross Profit	$0	-$721	$7,640	$7,132	$6,551	$6,417	$6,092	$5,728	$5,412	$5,189	$5,038	$4,884
Depreciation	$0	$4,029	$6,945	$5,044	$3,688	$2,725	$2,754	$2,790	$1,563	$328	$338	$348
Taxes	$0	-$1,662	$243	$731	$1,002	$1,292	$1,168	$1,028	$1,347	$1,701	$1,645	$1,588
Net Profit After Taxes	$0	-$3,087	$452	$1,358	$1,861	$2,400	$2,170	$1,910	$2,502	$3,159	$3,055	$2,949
Cash Flow	$0	$942	$7,397	$6,401	$5,549	$5,125	$4,924	$4,700	$4,065	$3,487	$3,393	$3,296
Change in Working Capital	$0	$1,678	$8,312	$55	-$38	$41	$9	$4	$14	$32	$46	$48
Free Cash Flow	-$13,957	-$14,972	-$1,203	$6,050	$5,282	$4,770	$4,591	$4,362	$3,707	$3,102	$2,982	$24,421

Discount Rate	12%	**NPV**	-$3,379	**IRR**	10.08%

Table 19: Sensitivity Analysis IRR Values for High-Capital Alternative (Flotation Deinking)

	75%	80%	85%	90%	95%	100%	105%	110%	115%	120%	125%
Capital Investment	10.08%	10.08%	10.08%	10.08%	10.08%	10.08%	10.08%	10.08%	10.08%	10.08%	10.08%
Project Capital in Year -1	10.27%	10.23%	10.19%	10.16%	10.12%	10.08%	10.04%	10.01%	9.97%	9.93%	9.90%
Deinking Yield	10.08%	10.08%	10.08%	10.08%	10.08%	10.08%	10.08%	10.08%	10.08%	10.08%	10.08%
Rampup Schedule	9.96%	9.98%	10.00%	10.02%	10.07%	10.08%	10.09%	10.08%	10.07%	10.05%	10.02%
Incremental Labor Cost	11.44%	11.18%	10.91%	10.64%	10.36%	10.08%	9.79%	9.49%	9.19%	8.88%	8.57%
Sale Price Discount/Premium	Too Low	Too Low	Too Low	Too Low	0.43%	10.08%	16.92%	22.60%	27.63%	32.26%	36.62%
Incremental Overheads	12.90%	12.36%	11.81%	11.24%	10.67%	10.08%	9.48%	8.86%	8.23%	7.58%	6.91%
SOP Price	20.90%	18.97%	16.95%	14.81%	12.54%	10.08%	7.38%	4.32%	0.73%	-3.80%	-10.45%