Technical Feasibility of Water Soft Path Application in the Canadian Pulp and Paper Industry

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Abstract:

The application of the soft path concept towards water conservation in the Canadian pulp and paper industry is an approach that will decrease water usage and will promote water conservation. Freshwater availability, allocation and quality concerns are an increasing environmental issue for Canadians. The Canadian pulp and paper industry is one of the largest users of freshwater and so it is important to understand how and why the industry uses the amount and type of water it does. This paper examines the technical feasibility of water soft path application in the pulp and paper industry. It examines the pulp and paper process, the three dominant pulping methods and the differences in water use. It contrasts the water use and energy use of the pulping methods to the best available technologies. This paper examines how technologies create the feasibility of the use of the water soft path concept in planning and analysis of water use in the pulp and paper industry.

Introduction:

Freshwater availability, allocation, and quality concerns are increasingly at the forefront of issues for Canadians. Climatic variability, population pressures, contamination of aquifers and water distribution relative to population pressures are various indicators that there are increasing demands and competition for water resources. With increasing competition for water sources and inadequate management practices, water use and planning approaches are being re-examined across the Canadian landscape.

The Canadian pulp and paper industry is a major user of water and contributes to quality water issues where mills are located. This paper examines the technical feasibility of water soft path application in the pulp and paper industry. The water soft path concept is a method of analysis and a planning tool towards efficient and sustainable water use.

Rationale:

In Canada, several factors indicate growing stress on water resources, which makes water use management a growing concern. There is a "geographic mismatch" in Canada where 84 percent of the Canadian population lives along the southern border but 60 percent of the water supply flows north to the Arctic Circle, which compounds allocation concerns (Brandes et al., 2007, 282; Environment Canada (EC), 1998, 5). There are growing clusters of high population density, which are also sites of increasing demand for high quality fresh water for municipal-residential needs. Across Canada, water retention in soil is reduced due to urban sprawl or agricultural drainage. Excessive withdrawal of water from watersheds is affecting ecosystems and biodiversity of aquatic ecosystems. It can also impact drinking water quality because less water returned to the environment decreases dilution capabilities in rivers and lakes (Canadian Environmental Law Association, 2004). Yet, over-consumption continues, through residential, industrial, agricultural and commercial uses. If Canada's water sources continue to be used at current rates it is evident that growing stress on water resources will continue.

This research specifically focuses on the pulp and paper industry for several reasons. There is a major gap in academic knowledge of Canadian industrial water use. There is a lack of understanding of self-supplied users and sparse data reported on water use in the pulp and paper industry, an industry that has a great impact on water quality. Little government action at the provincial and federal level has exacerbated management issues on water use for industrial users.

According to Christie and McEachern (2000, 3) Canadian pulp and paper mills are the largest water users and create the most water pollution among all industries within Canada. Mills across the country are situated on rivers or lakes that are important to the watershed and therefore impact downstream uses. In certain provinces, such as British Columbia, Ontario and Quebec, some mills are located in more highly populated watershed areas and are in a unique socio-economic position as population pressures and competition for scarce water resources increase.

What is water soft path?

Soft-path analysis as an alternative analytical tool developed after the energy shortages of the 1970s by Amory Lovins (Brooks, 2004a). Amory Lovins (1977) wrote the ground breaking *Soft Energy Paths: Towards a Durable Peace* and provided the theoretical background of soft-path discussion. The soft-path concept requires a series of choices other than technical and economic, and is based in the socio-political structure of a resource system. The soft-path approach therefore leads us to a vital political difference from hard paths (Lovins, 1977).

The soft-path concept of water management stems from demand-side management and is a more holistic concept for the management of water resources. Demand-side management continues to focus on "how" water is used accepting current consumption patterns. Rather than focusing on "how" we use our water, the soft-path approach encourages an understanding and evaluation of "why" we use the quality and quantity of water for different services (Brookes, 2004). By understanding the services needed, the opportunities for alternative methods of providing those services are widened. The soft-path concept holds that demand for the resource is not for the resource itself but for the services it provides (Brooks, 2004a; Gleick, 1998; Lovins, 1977). This concept assumes ecological needs are met first and the planning approach of backcasting is used by working back from a future vision such as no "new water".

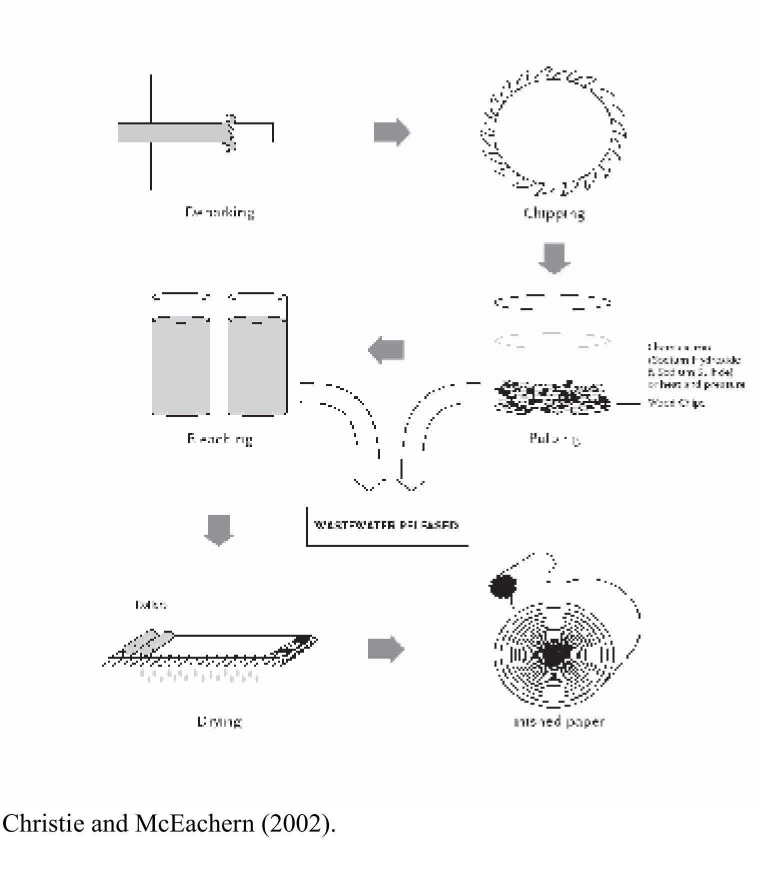
It is important to note that Lovins (1977) had two key insights into commonly-held assumptions about resource use. His first insight was that "energy is but a means to social ends; it is not an end in itself" (Lovins, 1977: 4). This insight alters how we look at what we want from the resource. Secondly, Lovins (1977: 7) disconnected economic growth from increased energy use, and the “relationship between energy use and prosperity”. This disconnection is vital when discussing resource management. The tie to economic growth has been severed, but historically both water and energy use were heavily relied on as indicators to track economic growth (Brooks, 2004).

Pulp and Paper Process

The process of turning trees into paper is conceptually fairly simple (Figure 1.0). Logs are debarked and chipped. By various pulping processes the wood chips are mixed with a solution, pressurized or placed under extreme heat until the wood is reduced to pulp, which is then bleached and rinsed several times. The bleaching process differs depending on the pulping method used. Finally, the pulp is pressed and made into paper.

Three different pulping processes are currently used in industry and they are: mechanical, chemical, and thermo-mechanical (or chemical-mechanical). Although they differ in the manner in which pulp is turned into paper, all pulping processes serve the same purpose—to separate the different fibres in the wood. Paper production uses both hard and soft woods but all pulping processes work to break the lignin. Lignin is the glue-like substance that holds the cellulose together in a tree and increases the rigidity. Cellulose is the long, strong fibre that forms the skeleton of the plant wall and is the ideal substance for paper making (Blum, 1996).

Figure 1: Schematic illustration of the pulp and paper industry



Christie and McEachern (2002).

Water plays a vital part of the pulp and paper production and is intrinsically linked to the process in various ways. There are three ways water can be examined in the industry. It provides services, particularly cooling. It is intrinsically linked to energy use because it requires energy to move any water brought into the industrial system. Water use is also intrinsically linked to water quality of the effluent being discharged at the end of the industrial process.

Services

There are four main services provided by water in pulp and paper. Water is used in chemical make up of solutions, transport and management of material flows, material separation, and in the cooling process (Boardley and Kinkhead, 2006; Scharf et. al, 2002 Browne, 2001). While water is used for the same purposes, it is important to recognize that there is not one uniform process used in the pulp and paper industry. The three pulping processes—chemical, mechanical, and thermo-mechanical—all use water for the same functions but to varying degrees and efficiencies. Within these three pulping processes there are innumerable factors that affect water use such as the age of the mill, product being produced, climatic variability, water availability, and technological availability. A key factor that affects water use is energy use and energy efficiency.

Water and Energy

Water reduction efforts are most often an effort to improve energy efficiency around the mill and operation costs. Much of the energy use in a typical pulp mill is for treating, heating and pumping water, so when water is conserved, reused or reclaimed, there are significant energy savings. Hellebust (2006, 11) explained the significant relationship of energy use and water: "Water is like hydrogen fuel in that it is not a source of energy but rather a carrier of energy…When assessing the efficiency of a service that water provides, the energy it took to put the water in that useful form must be stated". The same concept applies to the relationship of energy use and water consumption in pulp and paper mills. When done correctly, reducing water in a specific process increases the productivity of water and the efficiency of that process is increased and reduces the energy required to provide the specific service.

Reducing energy costs is a major driving force in reducing water use (CEO of Industrial Association, October, 2006). Ultimately, a reduction of demand will reduce resource use and allow for important cost savings (Boardley and Kinkhead, 2006). Water recycling is one of the most effective efficiency measures in the industry (Vickers, 2001).

Water Quantity and Water Quality

Besides the relationship between water and energy, there is also a complex relationship between water quantity and quality. Pulp and paper mills produce more water pollution than almost any other industry (Christie and McEachern, 2000; Delphi Group, 2004). Water input into the industrial system needs to be accounted for at the end of the production, in the form of effluent.

In 1992 the Canadian government enacted the *Pulp and Paper Effluent Regulations (PPER*), which implemented an environmental effects monitoring program as well as increased reporting requirements. This regulation attempts to control suspended solids, oxygen-consuming waste and fish toxic substances. Currently, there is at least some type of primary treatment at mills across the country. Secondary treatment is prevalent but not universal and less likely to be found are tertiary treatment systems (Browne, 2001).

As regulations on effluent discharge increase there will be more motivation for mills to move towards system closures and efficient technologies because those efforts are more economical than secondary treatment plants (Environmental Manager Ontario, June, 2006). Pulp and paper mills' dependency on large volumes of water only increases a company's responsibility and concern for process quality of resource input and output (CEO of Industrial Association, October, 2006). This responsibility becomes a driver to reduce dependency on large quantities of water. The relationship between quality of water discharged and quantity of water used in processes is interdependent. It is important to note that a consequence of reduced effluent can be increased concentration of effluent toxicity that requires more costs for treatment.

Findings

Quantity of water used in the pulp and paper industry is highly variable and based upon many factors. Water is used in every process from chipping to paper making. Factors that influence the quantity of water include: the type of the process (i.e., chemical or mechanical), the climate; and the geography of the mill. Water-saving technologies also vary with respect to pulping type, processes, and age of technology, physical geography and weather. For example, water used for cooling processes is considerably reduced in the winter from the summer.

In the literature there is a large range in data reported on water use, water consumption and gross water use. There were three explanations for the range: the variety of processes that impact resource use; inconsistent data collection methods; and terminology differences. Data varied by how it was measured (mcm/year; air dried tonne (adt) by tonne of paper or by tonne of pulp), and by what was measured such as water consumed, water productivity, and gross water use. The lack of standardized reporting scheme of water usage in Canadian pulp and paper mills leads to difficulties in accounting for water allocation.

Below are descriptions of the three most prominent pulping methods and the respective trends in water use, yields and energy use. Figures 2 to 4 show the water intake and consumption range of the three pulping processes, plotted against the years for which the data were reported. Due to the irregularity of the data reported over the years there are not a consistent number of data points for either years reported or consumption versus intake. Appendix A contains the data sources for Figures two to four.

Mechanical Pulping

Mechanical pulping uses machines and heat to break down the lignin and free the cellulose for paper making. Wood is pressed against grinders, at high temperatures, and the lignin and cellulose are physically separated (Christie and McEachern, 2000; Environmental Protection Agency (EPA), 1997). Of all the pulping processes, mechanical pulping uses much more energy (1 900 – 2 900 kilowatt hours of energy/tonne of pulp), but less chemicals and water (Christie and McEachern, 2000, 9), than other processes. Mechanical pulping produces a lower quality pulp because it is not as effective in removing the lignin. Due to the higher content of lignin the final paper product yellows when exposed to light (EPA, 1997). Unlike chemical pulping, mechanical pulping does not require the same chemical intensity. Mechanical pulping does produce great yields; the weight of the pulp is 90 – 98 % of the weight of wood chips (Christie and McEachern, 2000). Figure 1.1 illustrates the water intake and consumption for the mechanical pulping process.

.Figure 2: Water Intake and Consumption for Mechanical Pulping Process

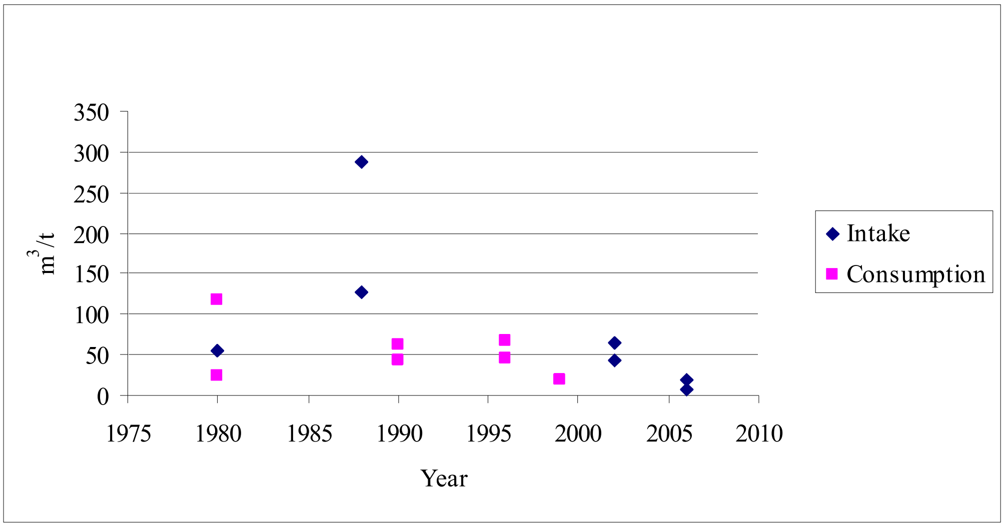


Figure 2 demonstrates the range of water intake and consumption through the years. It demonstrates a slow but steady decline in both water intake and water consumption in the mechanical pulping process as well as the decrease in range of intake and consumption.

Thermo-mechanical pulping

Thermo-mechanical pulping is the process in which both mechanical heat and chemicals are used to break down lignin. The wood is debarked, chipped and cleaned of any contaminants (metal) and sent to the thermo-mechanical refiners. The refiner process produces both heat (steam) and pulp. The process, simplified, is that the pulp enters the refinery and is pushed between two disks. While one disk lies stationary the other spins at speeds up to 3 200 RPM. Plates on the disks grind the wood fibres creating intense friction and boil the water instantaneously (Irving, 2004). Heat from the friction of the disks cause the wood chips to explode. The product is then sent on and the steam created from the process is sent to a cyclone machine. This cyclone machine separates the remaining fibres from the steam. The steam is recycled and the pulp carries on to a screening process. Fibres still too large are separated out and refined again (Irving, 2004). This process produces less yield than mechanical pulping but more yield than chemical pulping.

In terms of the water intake and consumption Figure 3 demonstrates the range and decline of water use in the process.

Figure 3: Water Intake and Consumption for Thermomechanical Pulping

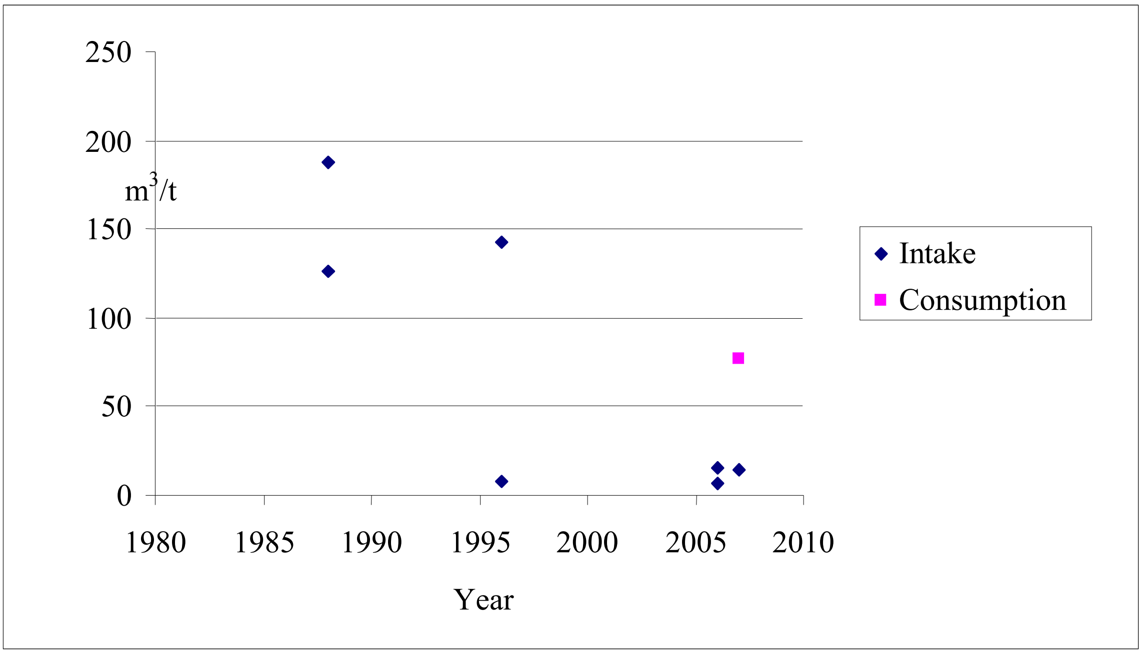


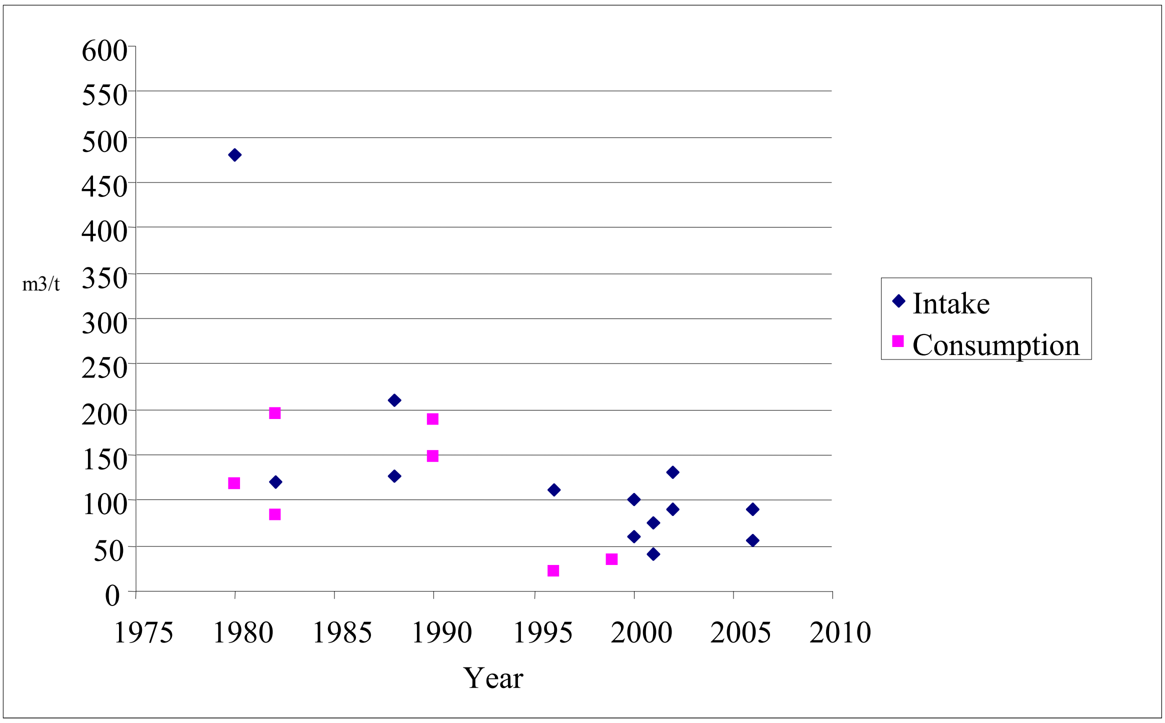
Figure 3 has fewer years reported because TMP is a newer pulping process that is replacing mechanical mills. The large range found in 2007 is the first year where a large number of TMP mills reported water intake or consumption data. Overall, the trend is decreased water consumption and intake as was the case in the mechanical and chemical pulping processes.

Chemical Pulping

Chemical pulping, as the term suggests, uses chemical processes to recover the cellulose. There is a wide range of chemical processes and chemicals that can be used. Kraft mills are the most common chemical pulping mill. In chemical pulping the wood or chips are 'cooked' in a digester, which contains a solution of chemicals that dissolve the lignin, leaving behind the cellulose (Christie and McEachern, 2000; EPA, 1997). It does produce a lower yield (40 -50% by weight) compared to mechanical pulping, but produces a stronger pulp (Christie and McEachern, 2000 9). While chemical use is high in both the pulping and bleaching process and water use overall is much higher, energy requirements are significantly lower, currently making it much more economically viable (Christie and McEachern, 2000).

As noted, the chemical pulping process uses much more water as is demonstrated in Figure 4.

Figure 4: Water Intake and Consumption for Chemical Pulping



In Figure 4 a similar decline in water intake and consumption as in the mechanical pulping can be observed. The decline is not steady but the overall trend is towards less water use over time.

In Canada, thermo-mechanical is the most commonly used technique because it provides an economically satisfying balance between input and output (Boardley and Kinkhead, 2006).

Process Trade off

It is important to note the trade offs in the choices of pulping methods. Table 1.0 illustrates the trade off between water use and energy use between each pulping process.

Table 1: Pulping Processes trade offs

	Mechanical	Chemical	Thermo-mechanical
Water Use	low water use	high water use	medium water use
Energy Use	highest energy use	low energy use	medium energy use
Yield	high yield	low yield (more organic waste)	medium yield
Quality of Yield	high quality	high quality	Higher quality

Adapted from Christie and McEachern, 2006; Boardley and Kinkhead, 2006.

Mechanical pulping, despite the high yield and low water use, is not the preferred pulping process. Due to high and increasing energy prices, it is the least profitable pulping technique. In Canada, thermo-mechanical is the dominant technique because it provides an economically satisfying balance between input and output (Boardley and Kinkhead, 2006).

There are technical advancements that allow appropriate quality process water and high recycling efforts. But, "product water" is different at various stages of the pulping process. Generally, 30 - 40% of the pre-processed logs, wood, and chips are composed of water. During the pulping process water content of the pulp is about 50% water, which rises to 99% on the wet end of the paper machine. When the product is ready for shipping it has about 9% water (Environmental Manager Ontario, personal communication, June, 2006). Water consumed in a product is a key loss that should be considered in water conservation strategies.

Best Practices

As discussed, there are external factors influencing conservation efforts beyond technology. Technical changes in processes occur as a means of reducing capital or operating costs for water supply or effluent treatment, improving energy efficiency, or expanding production (Browne, 2001). Serious considerations of the implementation of water efficient technological advances are motivated by reducing energy costs and resolving the water quality and quantity issues (Stratton and Gleadow, 2003).

Best practices are important to reducing total use and improving quality of discharged water but vital to these processes are quality of the process water. It is important that any process has a good recycle treatment system for quality of product (Environmental Manager, May, 2006). Two types of technology currently being used, reverse osmosis and advanced membrane technology, work as highly evolved water purifiers to maintain quality levels of process water. Another major thrust towards improving efficiencies was the improvement of the total chlorine free (TCF) bleaching sequence (Environmental Manager Ontario, June, 2006).

Some technologies that represent best practices include a closed loop system which, as the name suggests, are closed with high efficiency wastewater treatment and recycling systems. This technology also allows operations to reduce dependency on freshwater sources and lower effluent discharges. Another approach that reduces effluent discharges and wastewater treatment is zero liquid effluent. This process virtually eliminates effluent, reduces energy, and therefore water use.

Further improvements can be made by refining components within each process such as: high efficiency brown-stock washing and screening, improved spill controls, steam stripping and reuse of all pulping condensates, cooling water collection and reuse, digester-extended and/or oxygen delignification process to bleaching, elemental chlorine free or total chlorine free bleaching with alkaline filtrate recycle. Basic process improvements can improve productivity targets significantly for all processes, such as:

- Integrated mills - 12–20m^3/adt
- Mechanical or Chemi-mechanical - 15–20 m^3/adt
- Zero Effluent mills - 2 m^3/adt
- Bleached Chemical - 30–50m^3/adt
- Unbleached Chemical – 14–25 m^3/adt
  (Boardley and Kinkhead, 2006, 110)

Conclusion

There is an intrinsic link between water and energy in the pulp and paper industry. Water is an integral part in the process operations of transport, cooling, and material separation while energy is required to move water for these operations.

The pulp and paper industry is the largest industrial user of water but seeks to reduce water use to reduce capital costs of infrastructure, energy costs, or because there is a strain on availability. Over the past 27 years gross water use, intake and consumption have all declined. These declines can be attributed to the type of the process (i.e., chemical or mechanical); the climate; the geography of the mill; water saving technologies; and age of technology.

Review of process and technology shows the decline in water intake, gross water use and consumption has been occurring, but the inconsistencies in reporting and data make truly understanding water use in the industry difficult. The difficulties in the data, as well as the poor reporting mechanism, have greater implications for policy, regulation and long term industry planning.

Industry will continue to develop new water conservation technologies. Adopting analysis tools such as the soft path concept that will ideally seek to continually reduce water need in the industry are important. The success of these improvements will be uncertain as long as reporting and inconsistencies continue. But, the uptake of these improvements can be instituted with a long term planning concept such as the water soft path. The application of the soft path concept towards water conservation in the

Canadian pulp and paper industry is an approach that will decrease water usage and will promote water conservation.

Further research on standardized reporting mechanism would allow for better analysis to be understood on potential water savings. As a combined research piece dissemination methods for reported data could increase accessibility of industrial data for research and provide a better knowledge base of water takings.

Appendix A

Data were gathered from the following eight key sources:

1. *The NALCO Water Handbook* (Kemmer, 1988, 30.3) presents data as "net water use" (also known as gross water use) measured in gal/ton (the conversion factor is gal/ton x 0.0042 for m^3/t). The range of net water use was 126 – 288 m^3/t mechanical pulping; 126 210 m^3/t chemical pulping; and 126 -188 m^3/t. Kemmer (1988) produced this second edition handbook for North American industries using data from through the 1980s.

2. Kroesa (1990, 7) reported water consumption (not total use) range as 42 – 63 m^3/t mechanical pulping; and 147 -189 m^3/t chemical pulping. This report was produced by Green Peace intended to educate society on the impacts and processes of paper production and draws largely on data from the late 1980's.

3. Friends of the Earth (FOE, 1996), which cited the Kroesa (1990) data, used the term water use and gave a range of 45 – 68 m^3/t mechanical pulping and 160 -205 m^3/t chemical pulping. It is unknown why FOE reported different numbers than Kroesa, but provides generalized global data for the 1990s.

4. Christie and McEachern (2000, 11) reported a chemical pulping process range of 60 – 100 m^3/t for water use. The report produced by Christie and McEachern (2000) pertains specifically to Canadian mills and refers to data from 1996.

5. A report for the Canadian Council of Ministers of the Environment (CCME) by Kinkhead and Boardley (2006) differentiated terminologies. It uses "water conservation" and "water efficiency" interchangeably to describe actions for reduction in water loss, 85 waste or minimizing water used. Water use productivity is another term used in the report, defined as "water used to produce one unit of any good or service, e.g. m^3/tonne or m^3/$1,000 of shipment value. The lower the water input required, the higher the productivity" (Kinkhead and Boardley, 2006, 153). Water use of a Kraft mill (chemical pulping) with once-through cooling ranges from 55-90 m^3 per air dried tonne (adt) of product (Kinkhead and Boardley, 2006, 109). Mechanical pulping water use ranges from 6-20 m^3/adt (Kinkhead and Boardley, 2006, 109).

6. *The Pulp and Paper Journal of Canada* had the most data. The directory has been published for 133 years (Personal Communication, Pulp and Paper Journal manager April, 2007). It included data of mill, contact information, water use, source, production capacity, and environmental certification. Data were collected by surveys sent to mills. Four directories were selected to gain a range of water use: 1980, 1982, 1996, and 2007. The older volumes were selected based on availability, 1996 was selected because it could be cross-referenced with the Industrial Water Survey (2002), and 2007 was the most recent directory available. Data were reported in a variety of volume units including US gallons, litres, and metric tonnes, and time units of minute, day and years. All data were converted into cubic meters per tonne of product. In these directories "water

consumption" and "water use" are used interchangeably (Paprican Researcher, personal communication, 2007). Response rate for the 2007 directory was approximately 75%. Of the 111 applicable mills to this research only 36 reported both water use and production capacity.

7. Data for two mills were received from interviews. One tissue production mill withdrew only 15m^3/t and was one of two world-wide to withdraw so little for that product. The average identified in the research for tissue production is 40 – 150 m^3/t. The second mill reported 6.6 m^3/t water uses for a semi-chemical pulping process. Both mills cited best business case as motivation for water efficiency (Superintendent Ontario Mill, personal communication, June 15th, 2006). Both these mills provide examples of what is possible if the systems of influence play into water conservation.

8. FPAC (Forest Products Association of Canada) provided data collected from members (20 companies across Canada). There was a 90% response rate to the water use survey that was completed annually until 2001. Water consumption was reduced 34% from 1989 to 2001 FPAC (2004, 1). It is believed that reductions were being achieved through adoption of new technologies and manufacturing processes that permit recovery and reuse of process waters, and through tighter process controls and improved maintenance (CEO of Industrial Association, October, 2006).

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