CHAPTER 4

CELLARS

4.1 INTRODUCTION AND BACKGROUND

The wort prepared in the brewhouse is transferred to the cellars where fermentation, maturation and filtration of the beer are among the important unit processes. The characteristics unique to a beer are established in this section, thus requiring good process control and cleanliness. A flow diagram of the cellars section is shown in Figure 4.1. The cellars operations include wort cooling, yeast pitching, fermentation, racking, maturation and temporary storage, prior to packaging.

4.1.1 Wort cooling

The wort prepared by the brewhouse is cooled in the wort coolers, the first process in the cellars section, to the correct temperature to facilitate the functioning of the yeast cells. After all the wort is cooled to the correct temperature and transferred to the fermentation vessels, water is used to transfer any wort remaining in the transfer lines to the fermentation vessels. Before the transfer of wort from the wort coolers to the fermentation vessels, water is also transferred through the lines to prevent the uptake of dissolved oxygen into the beer which may cause, *inter alia,* taste problems. The water used before and after the transfer of the wort to the fermentation vessels is discharged to the drains. The wort coolers also undergo a regular CIP clean to prevent the build-up of dirt which may decrease the effectiveness of the heat transfer.

4.1.2 Yeast pitching

During the transfer of wort to the fermentation vessels, yeast and oxygen is added, or pitched, to the wort. The yeast is carefully prepared in a separate yeast area and used in a fermentation vessel for up to six generations, whereafter it is scrapped (also termed wasted). During scrapping the wasted yeast is transferred to the scrap yeast plant where the dried yeast is packed into bags and sold to farmers as a nutritional supplement for their animals. When the yeast is withdrawn from a fermentation vessel and reused, the yeast is said to be cropped. New yeast enters the propagation vessels and is allowed to multiply before being pitched into the fermentation vessels. To prevent microbiological contamination, the yeast vessels and pipelines are cleaned on a regular basis.

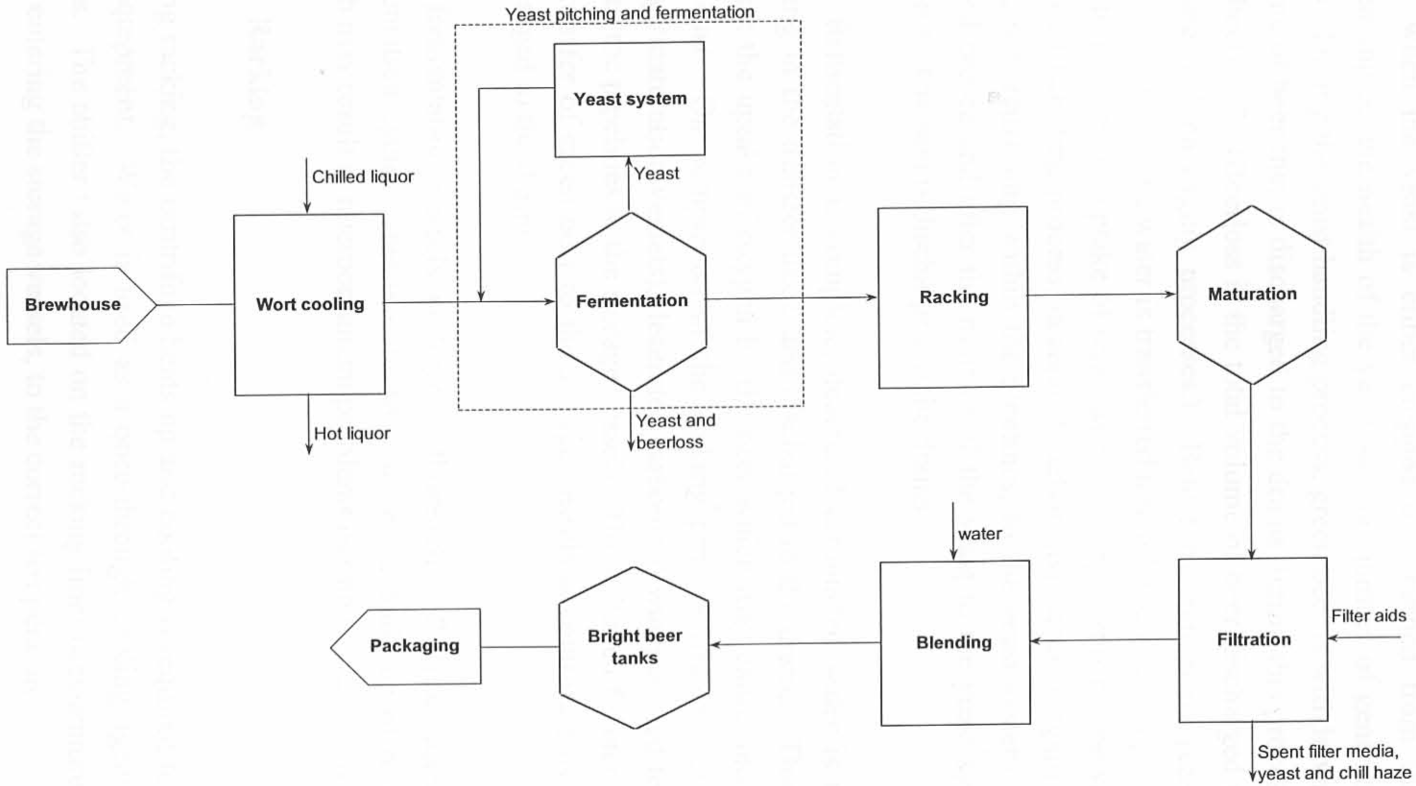


Figure 4.1 Flow diagram of the cellars section at the Rosslyn plant.

4.1.3 Fermentation

During the fermentation process, yeast is withdrawn from the fermentation vessels as explained in Section 4.1.2. At the Rosslyn plant, this happens only once per fermentation cycle when the yeast is either cropped or scrapped from the fermentation vessels (depending on the health of the yeast and the number of generations the yeast has been used). During the yeast handling process, green beer is withdrawn with the yeast and the volume of beer that is discharged to the drains during this process, is considered part of the "beerloss". (Beerloss is the total volume of beer discharged to the drains during the brewing and packaging processes.) Before the return of yeast to the yeast system, deaerated carbonated water is transferred through the yeast cropping or scrapping transfer lines to prevent the uptake of unwanted microorganisms by the yeast. On completion of the yeast handling process, deaerated carbonated water is again utilised to transfer any yeast, still remaining within the pipelines, to the yeast system. The volume of water utilised before and after the transfer of the yeast to the yeast system is controlled by a timing system and is discharged to the drains.

Once fermentation is complete, deaerated carbonated water is used to remove the air residing in the transfer lines, and discharged to the drains. This practice is adopted to prevent the uptake of oxygen by the beer which may cause, *inter alia,* flavour stability problems. On completion of the racking process (transfer of the green beer to the storage/maturation vessels), deaerated carbonated water is used to transfer any remaining beer in the pipelines to the storage vessels. The volume of water utilised before and after the transfer of green beer to the storage vessels is controlled by a timing system and is discharged to the drains.

The fermentation vessels undergo a thorough CIP clean after the completion of a fermentation cycle. This is done to remove the build-up of residue within the vessels which may result in microorganism problems during the next fermentation.

4.1.4 Racking

During racking, the centrifuge heats up and cooling is required to prevent any damage to the equipment. Water is used as a once-through cooling agent and discharged to the drains. The chiller (also located on the racking line) uses ammonia in cooling the green beer, entering the storage vessels, to the correct temperature.

4.1.5 Maturation (storage vessels)

During storage, maturation of the beer takes place and the beer remains in the storage vessels for several days, until the beer flavours have been developed. On completion of maturation, and before the beer is transferred to the filtration system, deaerated carbonated water is used to remove air residing in the transfer lines. This prevents the uptake of oxygen by the beer which may cause beer spoilage. After all the beer is transferred to the filtration system, deaerated carbonated water is again utilised to transfer any beer still remaining in the line to the filtration system. The volume of water utilised before and after the transfer of beer to the filtration system is controlled by a timing system and is discharged to the drains.

As with the fermentation vessels, the storage vessels undergo a thorough CIP clean after each maturation cycle to prevent the build-up of residue within the vessels, which could result in microorganism problems.

4.1.6 Filtration

During filtration, impurities in the beer are removed in the filtration system by using filter aids. (The filter aids, prepared in a separate plant, are added to the beer before filtration to form a suitable filter bed.) Before transfer of the beer from the storage vessels, the filtration system is filled with deaerated carbonated water to prevent the uptake of air by the beer. As the beer enters the filters, it displaces the water which is discharged to the drains. The filtered beer product is transferred to the filtration buffer tanks.

The filters, filtration buffer tanks, filter aid make-up tanks and filtration lines undergo a weekly CIP clean. The filters are also backwashed once the allowable pressure drop across a filter is exceeded. At the Rosslyn plant, backwashing occurs after each filter has treated approximately 5 000 hl of beer and this water is discharged to the drains. During backwashing, a small fraction of beer, which forms a part of the beerloss over the brewery, is discharged to the drains with the spent filter aids. Prior to backwashing, the filtration system is completely filled with deaerated carbonated water to transfer any beer still residing within the system to blending. This water is controlled by a timing system and discharged to the drains.

4.1.7 Blending and bright beer tank cleaning

Deaerated carbonated water is blended at a 44 % volume to volume ratio with filtered beer downstream of the filter buffer tanks. This blending, which represents the final product, is then transferred to the bright beer tanks (BBTs).

At the Rosslyn plant, the BBTs form part of the packaging section. However, the water utilised for their weekly CIP cleaning is supplied by the cellars section and will thus be addressed under this section.

4.2 WATER USE IN THE CELLARS

The general flow diagram of water utilised in the cellars section is shown in Figure 4.2. The cellars section consists of batch and continuous processes. The fermentation, maturation and temporary storage units are batch processes, while the racking and filtration units are continuous.

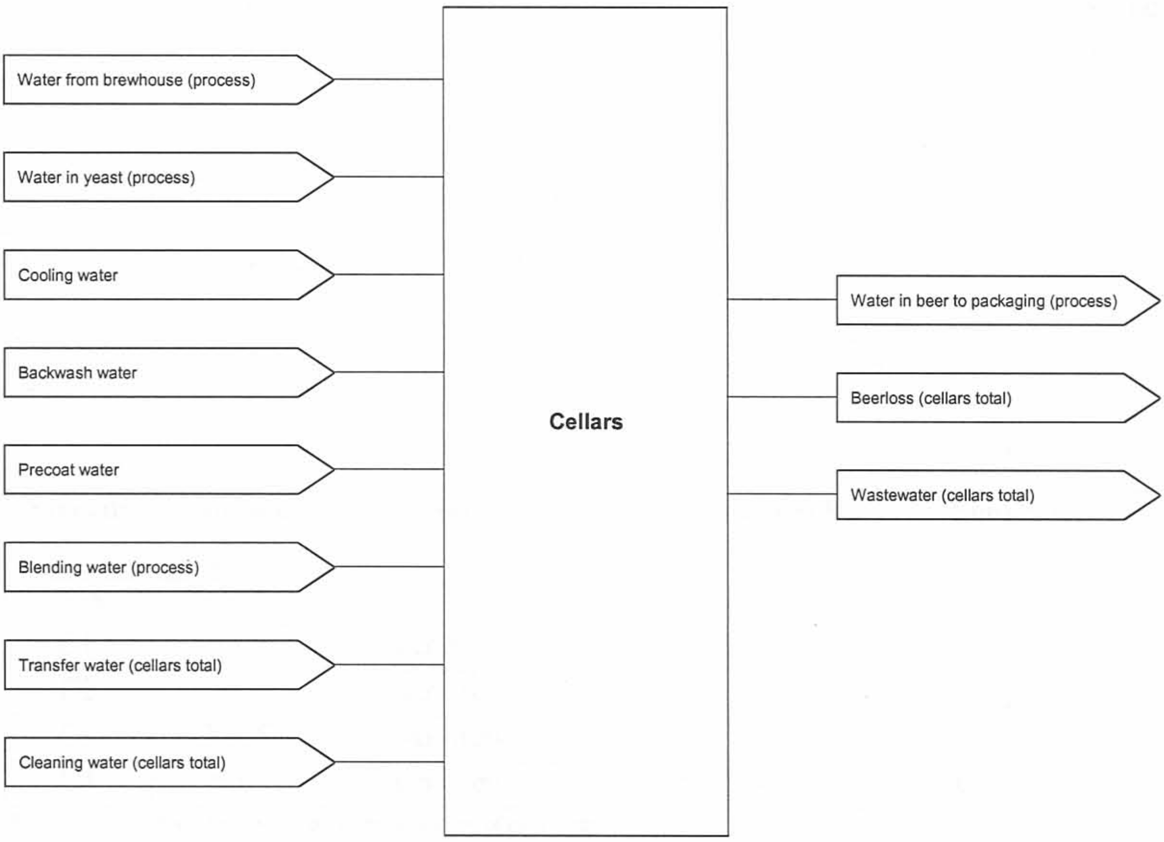


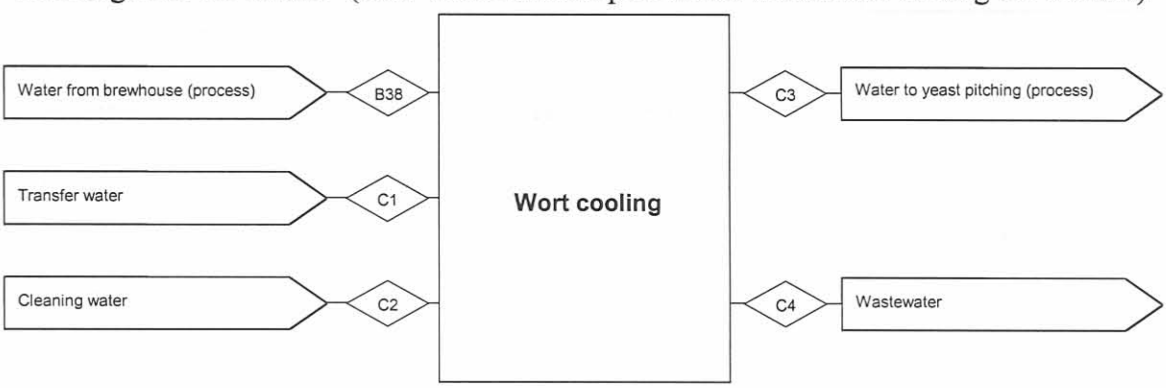
Figure 4.2 Simplified water balance over cellars.

Cooling of the various unit processes in the cellars section is mostly effected by ammonia, obtained from the utilities section. During wort cooling, however, chilled water is used. (The hot liquor produced from wort cooling is used in brewhouse operations, as discussed in Chapter 3.)

Water used for the cleaning of the vessels and the lines forms a large portion of the water used within the cellars section. A water balance was completed over the unit processes to define the volumes of water used by each process. A basis of 2 500 hl, equivalent to one brew (comprising of one brew from brewhouse 1 and one brew from brewhouse 2) produced within the brewhouse section, will also be used within the cellars section.

4.2.1 Wort cooling

The water balance for wort cooling is shown in Figure 4.3. Before the transfer of the wort to the fermentation vessels, 160 hl of water per brew is transferred through the transfer lines to prevent the uptake of microorganisms (Van der Merwe, 2000). On completion of a transfer, 80 hl of water per brew is used to transfer any wort remaining in the lines to the fermentation vessels (Van der Merwe, 2000). Therefore 240 hl of water is used before and after the transfer of the wort to the fermentation vessels per brew and discharged to the drains. (This water forms a part of the wastewater exiting the cellars.)



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
B38	2 205	per brew	70 560	-
C1	240	per brew	7 680	S3
C2	367	per brew	11 744	S4
C3	2 205	per brew	70 560	B38
C4	607	per brew	19 424	C1 + C2

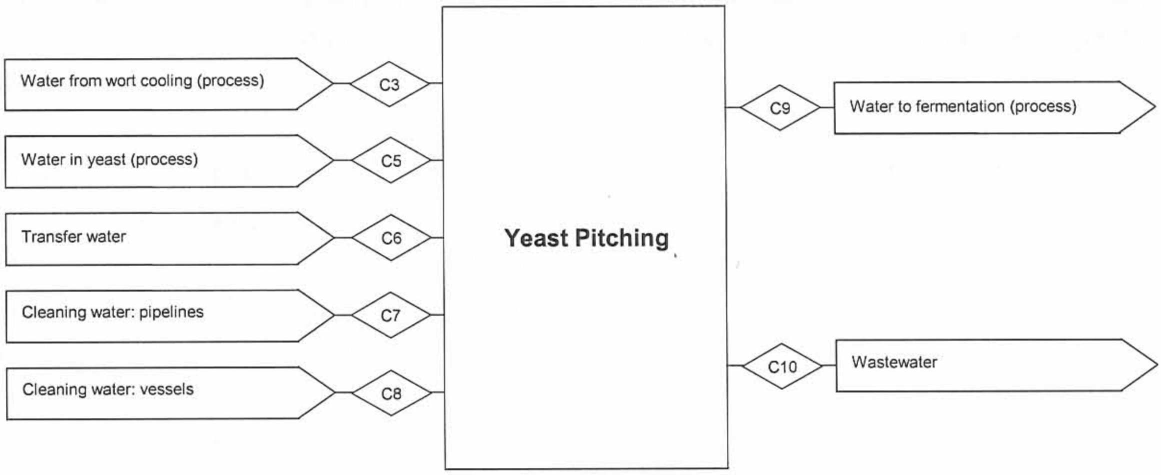
⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 4.3 The water balance for wort cooling.

The wort coolers undergo a CIP clean after each brew at a rate of 1 100 hl/h for approximately 20 minutes. The resultant 367 hl of water used per brew for CIP cleaning is discharged to the drains.

4.2.2 Yeast pitching

The water balance for yeast pitching is shown in Figure 4.4. At the Rosslyn plant, the fermentation vessels have a volume of 3 000 hl and are used to accommodate one brew produced in the brewhouse section (comprising one brew from brewhouse 1 and one brew from brewhouse 2). The yeast required for fermentation is pitched through one pitching pipeline to the wort during its transfer to the fermentation vessels. Before and after the transfer of the yeast from the yeast pitching vessels (per brew), water is transferred through the transfer lines at a rate of 1 400 hl/h for a total time of 210 seconds and discharged to the drains (Van der Merwe, 2000). Therefore 82 hl of water is utilised before and after yeast pitching per brew and discharged to the drains.



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
C3	2 205	per brew	70 560	-
C5	15	per brew	480	S6
C6	82	per brew	2 624	S3
C7	1 555	per week	1 555	S4
C8	2 250	per week	2 250	S4
C9	2 220	per brew	71 040	C3 + C5
C10	-	-	6 429	C6 + C7 + C8

⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 4.4 The water balance for yeast pitching.

Approximately one kg of a yeast solution (containing on average 50% water and 50% yeast) is pitched per hl of wort mixture (water and wort solids) from the brewhouse (Bradfield, 2001). Therefore, if the solution has a density of 1 000 kg/m^3 (Bradfield, 2001) and the wort mixture from the wort coolers has a solids content of 26% (Isaacs, 2001), 15 hl of water is added to each brew during yeast pitching.

There are four yeast pipelines for the transfer of yeast, two within the yeast plant and two for pitching to the fermentation vessels. The pipelines are cleaned once every two days at a rate of 250 hl/h for 20 minutes. Therefore 833 hl of water is used per week to clean the four yeast pipelines and discharged to the drains. There are also two yeast cropping lines which undergo a thorough CIP clean twice every three days, whilst the two yeast scrapping lines undergo a CIP clean, on average, once per week. These lines are cleaned at a flowrate of 250 hl/h for 20 minutes. Therefore 722 hl of water is used per week for CIP cleaning of the cropping and scrapping lines and discharged to the drains. In total, 1 555 hl of water is used for CIP cleaning of the yeast system pipelines and discharged to the drains.

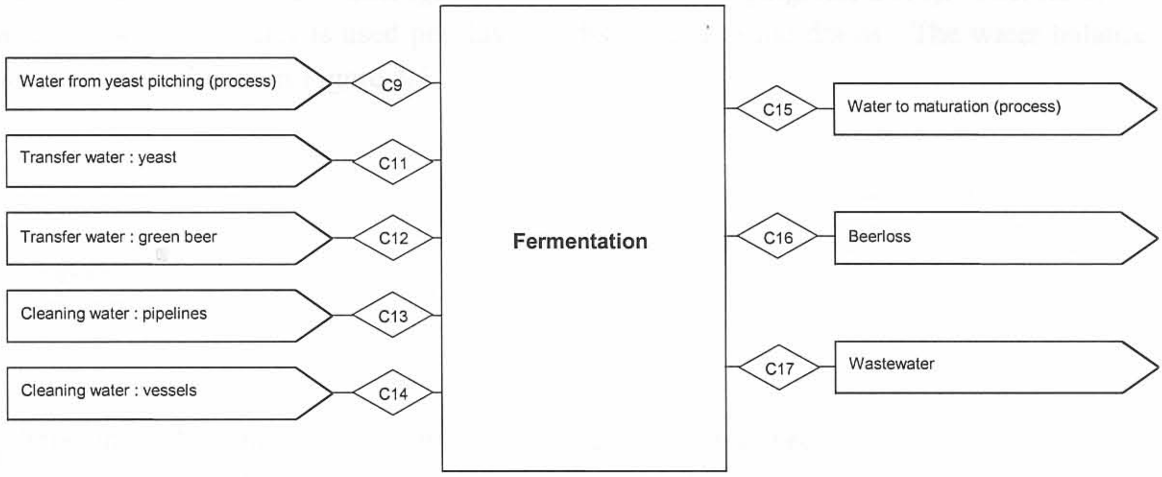
At the Rosslyn plant, the yeast plant consists of 18 yeast vessels for the propogation, scrapping, cropping and pitching of the yeast. Each vessel undergoes a CIP clean once every two days at a rate of 150 hl/h for 20 minutes to prevent microbiological contamination. The resultant 2 250 hl of water used for CIP cleaning of the yeast vessels per week is discharged to the drains.

4.2.3 Fermentation

The water balance for fermentation is shown in Figure 4.5. Yeast is cropped or scrapped from the fermentation vessels only once during a fermentation cycle, as explained in Section 4.1.3. A single cropping or scrapping line is used for this yeast transfer. Before and after the return of yeast to the yeast system, water is transferred through the cropping or scrapping lines at a rate of 200 hl/h for a total time of 475 seconds (Van der Merwe, 2000). The resultant 26 hl of water used per brew during the yeast transfer forms part of the wastewater exiting the cellars. The yeast cropping and scrapping pipelines undergo a CIP clean, as discussed in Section 4.2.2.

When yeast is withdrawn from the fermentation vessels, a small volume of beer is lost with the cropped (or scrapped) yeast, as discussed in Section 4.1.3. It is estimated that 3% of the beer contained within the fermentation vessels, on a volume basis, is lost with the yeast (Naik, 2001). Therefore, approximately 67 hl of process water exits the vessels with the yeast (for disposal from the yeast plant) and constitutes beerloss from the process.

Before and after the transfer of green beer to the storage vessels (maturation), deaerated carbonated water (at a rate of 600 hl/h and a total time of 360 seconds) is used to remove air residing in the transfer lines (Van der Merwe, 2000). The resultant 60 hl per brew is discharged to the drains.



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
C9	2 220	per brew	71 040	-
C11	26	per brew	832	S3
C12	60	per week	1 920	S3
C13	292	per day	1 460	S4
C14	187	per brew	5 984	S4
C15	2 153	per brew	68 896	C9 – C16
C16	67	per brew	2 144	S7
C17	-	-	10 196	C11 + C12 + C13 + C14

⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 4.5 The water balance for fermentation.

The transfer lines between the fermentation vessels and the storage vessels (racking pipelines) undergo a CIP clean on average once a day at a rate of 700 hl/h for 25 minutes (Van der Merwe, 2000). Therefore 292 hl of water is used per day for CIP cleaning of the racking lines and is discharged to the drains. Once a fermentation cycle is complete, the vessels undergo a CIP clean at a rate of 350 hl/h for 32 minutes. Since each fermentation vessel accommodates one brew, 187 hl of water per brew is used for CIP cleaning of the vessels and is discharged to the drains.

4.2.4 Racking

The centrifuge, located on the racking line, removes yeast from the green beer before maturation. To prevent damage to the centrifuge, water is continuously transferred through the shell of the centrifuge at a rate of 2 hl/h (Appelgrein, 2000). Therefore, on average, 48 hl of water is used per day and discharged to the drains. The water balance for racking is shown in Figure 4.6.

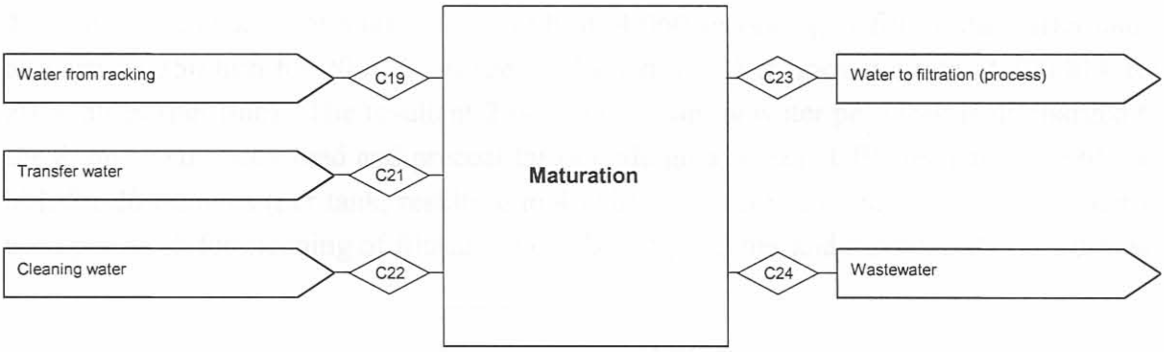
Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
C15	2 153	per brew	68 896	-
C18	48	per day	240	S8
C19	2 153	per brew	68 896	C15
C20	48	per day	240	C18

⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 4.6 The water balance for racking.

4.2.5 Maturation (storage vessels)

The water balance for maturation is shown in Figure 4.7. After the transfer of beer to the filtration system, water is used at a rate of 700 hl/h for a total time of 300 seconds to transfer any remaining beer in the lines to the filtration system (van der Merwe, 2000). Therefore 58 hl of water is utilised for beer transfer per brew and discharged to the drains. Each storage vessel accommodates one brew prepared by the brewhouse and after the completion of the maturation cycle, the vessels undergo a CIP clean at a rate of 350 hl/h for 32 minutes. The resultant 187 hl of water is discharged to the drains.



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
C19	2 153	per brew	68 896	-
C21	58	per brew	1 856	S3
C22	187	per brew	5 984	S4
C23	2 153	per brew	68 896	C19
C24	245	per brew	7 840	C21 + C22

⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 4.7 The water balance for maturation (storage vessels).

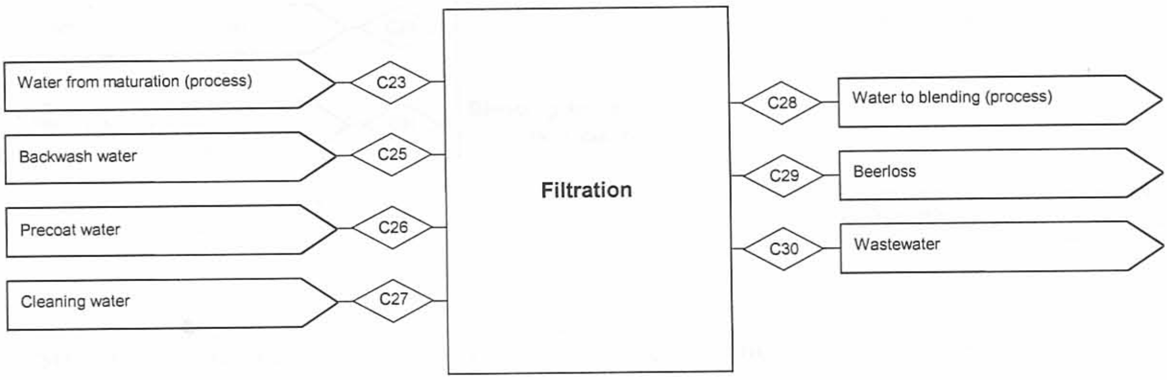
4.2.6 Filtration

The water balance for filtration is shown in Figure 4.8. The Rosslyn plant uses two kieselguhr filters for the filtration of the beer. Each filter treats 5 000 hl of beer before being backwashed resulting in approximately 14 backwashes in total for the two filters per week. Each filtration backwashing cycle uses 250 hl of water (Van der Merwe, 2000) and the resultant 3 500 hl of backwash water is discharged to the drains. According to Van der Merwe (2000), once the backwashing cycle is complete and before intake of the beer, 251 hl of water, containing body feed and precoat material, is used to precoat the filters and to prevent the uptake of oxygen by the beer. In total, 3 514 hl of water is utilised per week for precoating of the filters and is discharged to the drains.

It is estimated that 1,5% of the beer (on a volume basis) is lost during filtration (Naik, 2001). The resultant 32 hl of water per brew constitutes beerloss from the process and is discharged to the drains with the body feed and precoat material during the backwash cycle.

The filtration system at the Rosslyn plant consists of two filters, a pre and post filter buffer tank, a body feed and four precoat tanks and two filter transfer lines. The filters, pre and post filter buffer tanks and the two filter lines undergo a CIP clean once a week.

The filters are cleaned at a rate of 864 hl/h for 4 060 seconds (per filter), the buffer tanks at a rate of 350 hl/h for 20 minutes (per tank) and the filter lines at a rate of 700 hl/h for 20 minutes (per line). The resultant 2 649 hl of cleaning water per week is discharged to the drains. The body feed and precoat tanks undergo a weekly CIP clean at a rate of 240 hl/h for 20 minutes (per tank, resulting in 400 hl per week). In total, 3 049 hl of water is used per week for cleaning of filtration vessels and pipelines and discharged to the drains.



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
C23	2 153	per brew	68 896	-
C25	3 500	per week	3 500	S3
C26	3 514	per week	3 514	S3
C27	3 049	per week	3 049	S4
C28	2 121	per brew	67 872	C23 – C29
C29	32	per brew	1 024	S7
C30	-	-	10 063	C25 + C26 + C27

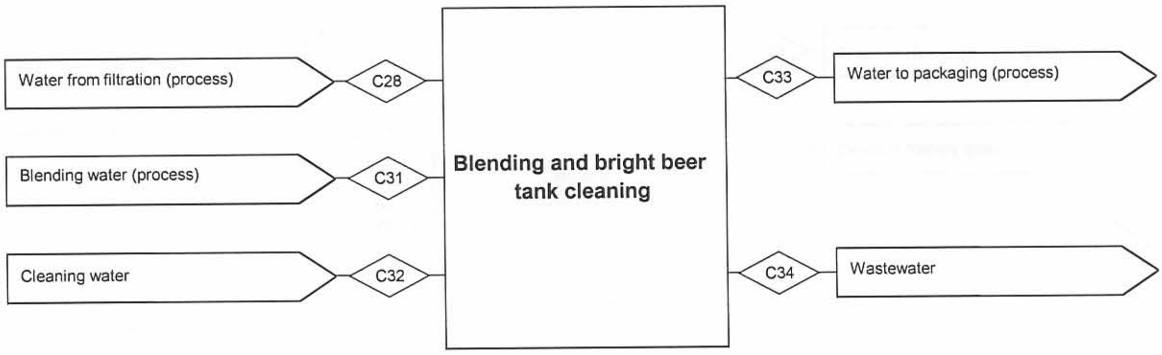
⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 4.8 The water balance for filtration.

4.2.7 Blending and bright beer tank cleaning

The water balance for blending and bright beer tank cleaning (BBT) is shown in Figure 4.9. During the transfer of beer to the bright beer tanks (BBTs), deaerated carbonated water is blended with the beer at a ratio of 0,44 hl of water per hl of filtered beer (a mixture of process water and alcohol). Since the beer mixture contains 7,2 % alcohol (Roseveare, 2001), 2 286 hl of beer mixture is blended with 1 006 hl of deaerated water per brew, resulting in 3 292 hl of beer (containing 3 127 hl of water per brew) being transferred to the bright beer tanks per brew.

At the Rosslyn plant, the bright beer tanks can accommodate one brew and the vessels undergo a CIP clean after the transfer of beer to packaging. The water utilised for cleaning of the tanks is supplied by the cellars section at a rate of 350 hl/h for a total of 32 minutes. Therefore 187 hl of water is used per brew to clean the bright beer tanks and is discharged to the drains.



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
C28	2 121	per brew	67 872	-
C31	1 006	per brew	32 192	S1 + S9
C32	187	per brew	5 984	S4
C33	3 127	per brew	100 064	C28 + C31
C34	187	per brew	5 984	C33

⊕ Sources, other than streams, are presented at the end of each chapter.

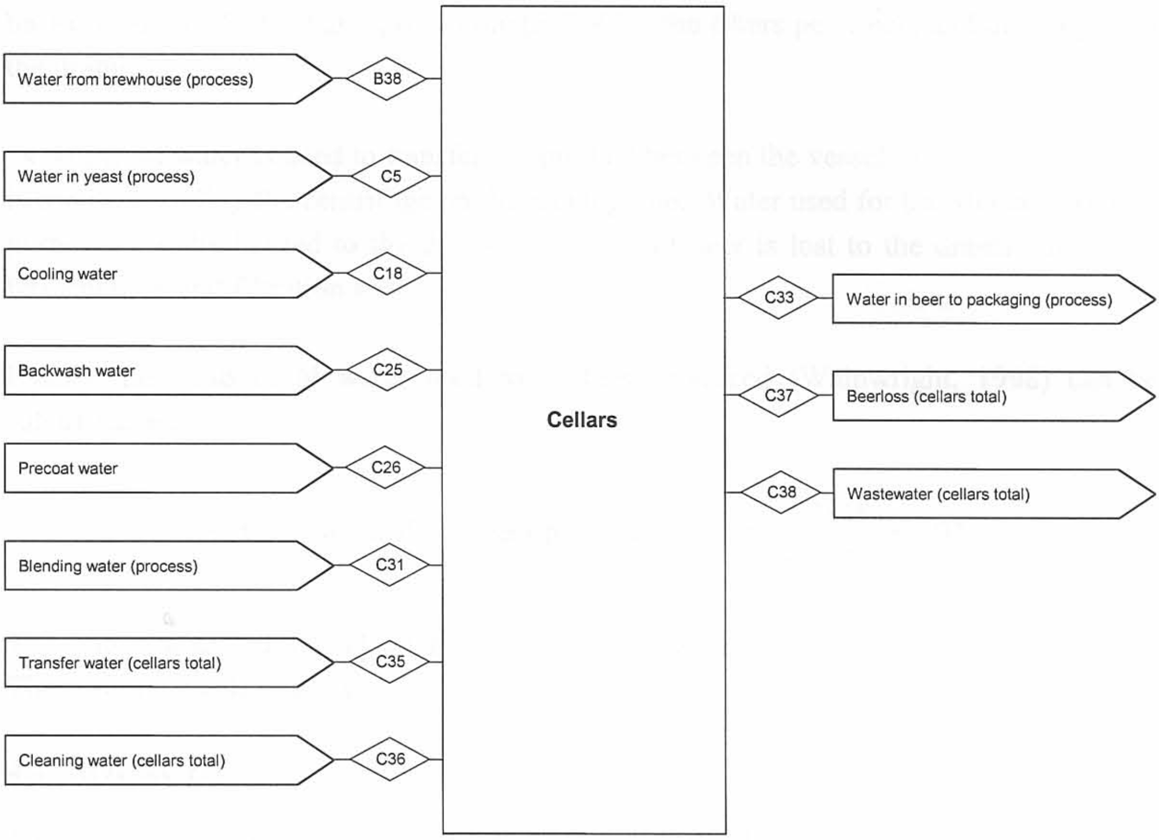
Figure 4.9 The water balance for blending and bright beer tank cleaning.

4.3 OVERALL MASS BALANCE OF THE CELLARS SECTION

The overall water balance over the cellars is shown in Figure 4.10.

A total of 92 848 hl water per week is introduced into the cellars section to produce 100 064 hl of normal gravity beer. This includes, *inter alia*, 32 672 hl per week of process water which is made up of:

- water in yeast (480 hl), and
- blending water (32 192 hl).



Stream	Volume per week (hl/week)	Source
B38	70 560	Section 4.2.1
C5	480	Section 4.2.2
C18	240	Section 4.2.4
C25	3 500	Section 4.2.6
C26	3 514	Section 4.2.6
C31	32 192	Section 4.2.7
C33	100 064	Section 4.2.7
C35	14 912	C1 + C6 + C11 + C12 + C21
C36	38 010	C2 + C7 + C8 + C13 + C14 + C22 + C27 + C32
C37	3 168	C16 + C29
C38	60 176	C4 + C10 + C17 + C20 + C24 + C30 + C34

Figure 4.10 The overall water balance for the entire cellars section.

38 010 hl of water is used for cleaning of vessels and lines and forms part of the wastewater discharged to the drains. During filtration, 7 014 hl of water is used for

backwashing (3 500 hl) and precoating (3 514 hl) the filters per week, and discharged to the drains.

14 912 hl of water is used to transfer the product between the vessels and 240 hl of water is used for cooling the centrifuge on the racking line. Water used for transfer and cooling purposes are discharged to the drains. 3 168 hl of beer is lost to the drains during the fermentation and filtration stages.

Finally, the ratio of hl water used to hl beer produced (Wainwright, 1998) can be calculated as:

$$(\text{Ratio of water used : beer produced})_{\text{cellars}} = \frac{92848}{100064} = 0{,}93$$

The water balance in this chapter does not include water for washdown and other losses. These streams will be considered in Chapter 6.

4.4 SOURCES

The sources used within this chapter for calculating the different water balances over the cellars are presented below.

Source	Reference
S6	Bradfield, P. (2001) "Operation in the SAB Rosslyn Cellars Section", Personal communication, Rosslyn plant, Pretoria.
S7	Naik, T. (2000) "Raw Materials used at the Rosslyn Plant", Personal communication, Rosslyn Brewery, Pretoria.
S8	Appelgrein, J. (2000) "Cooling of the Centrifuge on the Racking Line", Personal communication, Rosslyn plant, Pretoria.
S9	Roseveare, J. (2001) "Solids Content in the Beer at Different Stages of Production", Personal communication, Rosslyn plant, Pretoria.