WATER COMPANIES

# Finances



Nota nr. 2931121-02-07-0024
Wilt u bij correspondentie dit notanummer vermelden?
Datum 13 augustus 2002

Jaarafrekening

Voor inlichtingen
Haagregio 070 384 39 39
Tussen 08.00 en 17.00 uur

Meneer/Mevrouw/Firma
JQJC VERBEEK
Van Speijkstraat 98
2518 GE 'S-GRAVENHAGE

Duinwaterbedrijf Zuid-Holland
▸ Verkoopbedrijf

Leveringsadres
Van Speijkstraat 98
2518 GE 'S-GRAVENHAGE

| Meter | Verbruiksperiode van | tot en met | Meterstanden eind | begin | Verbruik in m3 | BTW % | Totaal verschuldigd |
|---|---|---|---|---|---|---|---|
| 211351 | 5-07-2001 | 2-07-2002 | 398 | 326 | 72 | | |
| Totaal verbruik | | | | | 72 | | |
| Verbruik 36 m3 x 1,36000 | | | | | | 6,00 | 48,96 |
| Verbruik 36 m3 x 1,32000 | | | | | | 6,00 | 47,52 |
| Vastrecht 1-08-2001 t/m 31-07-2002 | | | | | | 6,00 | 45,20 |
| Waterbelasting over 36 m3 | | | | | | 6,00 | 4,75 |
| Waterbelasting over 36 m3 | | | | | | 6,00 | 4,90 |
| Bijdrage precario | | | | | | 6,00 | 6,32 |
| Bijdrage precario | | | | | | 6,00 | 8,64 |
| Omzetbelasting (BTW) | | | | | | | 9,99 |
| | | | | | | | 176,28 |
| In rekening gebracht(e) voorschot(ten) | | | 159,74 | BTW | 9,58 | | 169,32 |
| | | | | | | | 6,96 |
| Eerste voorschot nieuwe verbruiksjaar | | | | | | | 46,64 |
| | | | | | | | 53,60 |

Gelieve het bedrag middels bijgaande acceptgiro over te maken. Zorgt u ervoor dat het bedrag uiterlijk 3-09-2002 op onze rekening is bijgeschreven.

Nieuw voorschot: 44,00 + 2,64 BTW = 46,64
Inning overige voorschotten vindt plaats in november februari mei

Wilt u uitleg over de jaarafrekening? Bezoekt u dan onze website WWW.DZH.NL onder klantenservice. Ook uw verhuizing kunt u hier opgeven of haal een gratis verhuisbericht op het postkantoor.

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15-07-1999 t/m 11-07-2000 64 m3

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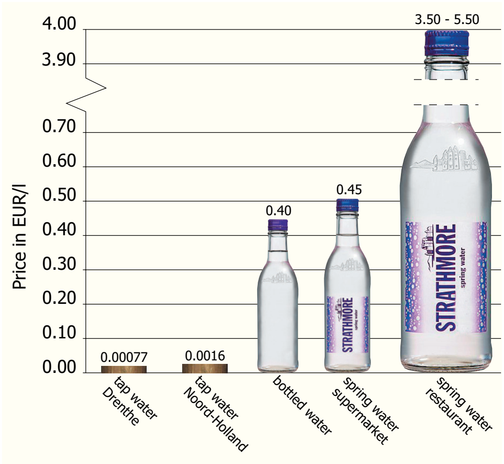

### *Framework*
This module is about the financial aspects of the public drinking water supply. On a company level, the balance sheet of a water and water tarifs are discussed. Specific details will be presented on the investment and operational costs, as well as cost comparisons for alternatives.

### *Introduction*
This module has the following contents:



### *Study goals*
After having studied this module, you will be able to:
- identify the terms balance sheet, profit and loss account, investment costs, capital costs, and operational costs
- calculate tariffs for a cost-covering drinking water supply
- prepare an estimate of the investment costs
- prepare an estimate of the operational costs
- prepare a cost comparison of alternatives

# 1. Introduction

A water company is not only a technical company, but also a concern. Therefore, many different facets play a part, for example, the social aspects (e.g., staff, clients) and the financial aspects (e.g., economy).

The financial aspects have a lot in common with the technical aspects. A water company invests in a new infrastructure (i.e., production plants and distribution network), spends money on its operation (staff, energy and chemicals), and has to make sure that the expenses are covered by its income (standing charges and consumption rates).

This module looks at the financial aspects of a water company.
First, the water company is presented as a concern. Specific attention is given to the fact that a water company is a legal monopoly. Therefore, the main objective of the concern is not making a profit, but covering costs.
The financial strength and conditions of a company become clearer after reading the (financial) annual report. Understanding the report will make rate fixing clearer and a comparison across different companies possible.
Investments and operational issues are important aspects within a water supply company. These aspects will, therefore, be specifically dealt with and elaborated upon. Finally, items playing a role in comparing the costs for various alternatives will be presented.

# 2. Water company as an enterprise

## 2.1 *Drinking water supply as a monopoly*

A water company looks like a typical enterprise. Enterprises typically operate in a free market, where other suppliers are active as well. The company exists as long as clients are willing to buy the product for a price at which the company can make a profit. In such a situation, the company is forced, by the market, to balance price and quality.
Competition makes sure that the company reaches a high level of efficiency, and the company will pursue maximum profits and, therefore, cost reductions.
The company is, in this way, controlled by the market. The government mainly oversees that the different suppliers in the market do not make inadmissible market deals, that the supplied products are acceptable with relation to health and safety, and that the production and transportation of used products take place in an environmentally and technically sound way.

**Monopoly**
Having described how typical private companies are run, it can now be shown how a water company actually differs greatly from this.
First of all, a water company is a monopoly within the distribution area assigned by the government. The most important arguments for an assigned monopoly are that

- the distribution of water determines the price to such an extent that it is never economically attractive to have more suppliers
- the quality and availability of drinking water is of such social importance that it should not be pressured by economic considerations of companies
- the drinking water supply does not qualify for operation by different companies, because this will make quality responsibilities and delivery guarantees very unclear. This is the reason why the government pursues the guarantee of quality (always clean and healthy) and quantity (always in the needed quantities under sufficient pressure) as an integral responsibility of one single company from source to tap


*Figure 1 - Money and water: aqueduct on €5 note*

### Government supervision

Because of a lack of control by the market, control of a water company by the government is necessary. This is included in the Water Supply Act, where several supervisors are assigned (responsibility/authority of the cabinet minister, quality control by the ministry, supervision by public boards (in municipalities and provinces).
Next to this, the water companies in the Netherlands have created extra possibilities for a public mutual comparison of companies (VEWIN benchmark).

The government's supervision of the water company is relatively simple, because all Dutch water companies are government-owned limited liability companies, or municipal services (Amsterdam).
In a government-owned limited liability company, the company's stocks are owned by the provinces and municipalities. The owners are the democratically chosen representatives of the consumers, in as far as the stocks are proportionally divided. With this, a balanced and controllable consideration is possible between quality, reliability, nature conservation, and costs. The stocks usually represent only a symbolic value; in which the owners have a minimal capital contribution (and, therefore, no expectations of capital return).

### Profit

A water company does not strive to make a profit, but looks after the public interest, at cost.
An important basic principle is that consumers pay for the actual costs, and not for future expenses. Moreover they might count on a high cost efficiency within the water company.

However, making a profit is allowed under the following circumstances:

- Profit can be obtained strategically, when it is used for building up company capital, thereby gaining a better position on the capital market, which can be of importance in securing loans at acceptable interest rates
- Profit can be obtained strategically to avoid sudden large increases in rates. For that reason, the decision can be made for gradual, step-by-step increases and, through this, a capital reserve is built up
- Profit (and also losses) can be obtained non-strategically, if the sales and the costs differ from what was estimated when the rates were being determined

A special form of company profit is the dividend paid to local authorities.
This could be a significant sum, as water rates sometimes included hidden municipal taxes. Nowadays this practice is forbidden by law.

## *2.2 Financial annual report*

Because of their social position water companies feel more or less obligated to maintain an open communication with their consumers.
An important instrument for this communication is the company's annual report (Figure 2). An annual report gives a clear summary of the financial management of a water company. In their annual report, most water companies give consumers information about their technical and organizational developments.

A financial annual report consists of a balance sheet (list of possessions and debts at the end of the financial year) and a profit and loss account (list of incomes and expenses in the financial year).

### Balance sheet

Table 1 shows an example of a water company's balance sheet.
This table shows that more than 95% of the possessions of this water company are tangible fixed assets (e.g., buildings, installations and pipes).


*Figure 2 - Front page of an annual report of a water company*

*Table 1 - Balance sheet of a water company (PWN 2001, 100% = €784.5 mln)*

| **Assets** | **(%)** | **Liabilities** | **(%)** |
|---|---|---|---|
| Tangible fixed assets: | | Equity capital: | |
| - Buildings and land | 20.0 | - Issued shares | 0.9 |
| - Machinery and installations | 16.3 | - Realized revaluation reserve | 16.6 |
| - Pipelines | 52.2 | - General reserves | 3.6 |
| - Other fixed company equipment | 2.4 | Contribution for new connections (egalization) | 8.0 |
| - Fixed capital assets under construction | 4.7 | Provisions | 4.3 |
| Financial fixed assets | 0.4 | Long-term debts | 53.0 |
| Inventories | 0.2 | Short-term debts: | |
| Receivables | | - Loans to be amortized next year | 5.6 |
| - Debtors | 3.0 | - Cash loans | 0.9 |
| - Other receivables | 0.1 | - Loans due banks | 0.1 |
| - Accrued income | 0.4 | - Advance payments for water | 1.3 |
| Liquid assets | 0.2 | - Taxes and pensions | 0.0 |
| | | - Debts due suppliers | 2.7 |
| | | - Accrued expenses | 3.0 |
| Total | 100.0 | | 100.0 |

The distribution network has the largest share of those fixed assets.
Part of the capital is fixed in installations which are not yet in active operation (under construction).
The amount of the tangible fixed assets is the sum of the book value of all company assets. The book value is the purchase value minus the accumulated depreciations.
Almost 60% of the liabilities are fixed in long-term loans (incl. loans to be amortised next year). These long-term loans consist of a very large number of loans with different terms and different interest rates. The average term of the loans in this company is about 10 years, with an average interest rate of 5.8% (range 3 - 10%). The broad range in interest rates is caused by large fluctuations in time and the continuing closure and pay-off of loans.

Due to their low investment risk, water companies can borrow money relatively inexpensively, through financial institutions for the government (e.g., Bank of Dutch Municipalities, Bank of Dutch Waterboards, etc.). An average term of 10 years means that every year 10% of the loans has to be paid off. Partially new loans will be taken for this, because the depreciation period of the company assets has an average of about 35 years, and, therefore, the loaned amount will be earned back over a longer period.

About 21% of the liabilities of this company are established in equity capital. This mainly involves the realized revaluation reserve. The revaluation reserve is built up by obtained profits because this company depreciates based on the present value, instead of the purchase value. The background for using present value is that investments they made in the past would have cost more money based on today's prices due to inflation. In this way, consumers pay in part, for future investments.
The book value of the active assets is, for this company, around 60% of the (historical) purchase value (almost 40% is depreciated). The present purchase value is its value if it were built today, which is also often used as the insurance value. The present purchase value of the company's assets is 1.58 times the historical purchase value. This valuing corresponds to an average inflation rate of 3% over 15 years ($1.03^{15}$).
The remainder of the equity capital consists of the accumulated profit (general reserve), and the paid-up capital of the issued shares.

About 8% of the liabilities are built up from the onetime paid charges for new or modified connection to the distribution network (new connection charge). These contributions are depreciated over the same period as the corresponding material fixed assets.

About 4% of the liabilities consist of provisions. These are mainly reserves for staff who resigned early and provisions for the planned development of the organization. Also, demolishing costs for the company facilities that will be taken out of service are part of these liabilities.

**Investments and depreciations**

Through depreciations a one-time expense for an asset is earned back from annual allowances. The time it takes to earn it back corresponds to the depreciation period.

The depreciation periods for water companies are relatively long. On one hand, the technical facilities last a long time (buildings and pipes); on the other hand, there is a great certainty that during the entire depreciation period, incomes from water sales will be realized.

The depreciation period preferably equals the expected actual technical lifetime of the asset. In this way, the consumers pay as evenly as possible for the investments from which they also receive "pleasure" (the consumer pays for its "own" facility).

Table 2 shows the depreciation periods maintained by the water company described above.

As in nearly all concerns, including water companies, the investment costs are straight-line depreciated. Therefore, the annual depreciation for a certain company resource is constant during the total depreciation period. However, with this method, the interest expenses of an asset are high in the beginning and decrease to zero at the end of the depreciation period. The capital expenses (interest and depreciation) for this asset are, therefore, not equal over the depreciation period.

*Table 2 - Depreciation periods of a water company's assets (PWN 2001)*

| Types of company assets | Depreciation period (years) |
|---|---|
| Water abstraction facilities | 25 |
| Buildings of treatment plants | 30 |
| Filter units | 25 |
| Machinery and installations | 10 |
| Distribution network | 40 |
| Water meters | 20 |
| Office buildings | 40 |
| Inventories | 5 |

Because a water company of considerable size has many assets that have to be expanded or replaced at different times, the capital expenses, therefore, seemingly level off.

For companies with only a limited number of expensive components that also have to be acquired simultaneously, another depreciation method could be used.

Such a situation occurs, for example, at a large-scale surface water treatment plant. For this plant an annuity depreciation can be applied (interest plus depreciation are equal during the depreciation period), or a unitary depreciation can be used (interest and depreciation are such that the water rate is stable over the depreciation period, taking into account the anticipated development of the sales).

For every asset it is precisely registered how large the original investment was and how much is depreciated (earned back). The paid interest for this asset will not be separately listed.

The loans for all assets together equal the total loan amount. Loans are not related to the original investment works. This is because of new loans are obtained for both new investments as for the repayment of old loans.

Because of inflation, investments made in the distant past are relatively inexpensive. Through depreciation the users pay with today's money for the less expensive investments of the past.

Table 3 shows an overview of the purchase value of the assets, compared to the book value, and compared to the investments and depreciations in the given financial year.

This table also shows the large share of the distribution network in the financial balance of a water company.

An investment level equal to the depreciation shows that it is mainly a matter of maintaining the infrastructure (renewal and replacement).

A total investment level of 4% of the total purchase value equals an average replacement period of 25 years. For the pipes (see Table 3) a replacement period of 30 years (54.8/1.8) is realistic.

*Table 3 - Investments and depreciation of a water company (PWN 2001, 100% = €1,183 mln)*

| Assets | Purchase value (%) | Book value (purchase) (%) | Investments (%) | Depreciation (purchase) (%) |
|---|---|---|---|---|
| Buildings and land | 17.9 | 13.2 | 0.2 | 0.5 |
| Machinery and installations | 24.1 | 10.8 | 1.4 | 1.3 |
| Pipelines | 54.8 | 34.6 | 1.8 | 1.3 |
| Other fixed assets | 3.2 | 1.6 | 0.7 | 1.1 |
| Total | 100.0 | 60.3 | 4.1 | 4.2 |

However, this includes extensions because of the construction needed for new pipes in new residential areas. The total sales and production of this company did not increase (population growth compensated by water savings), but the number of clients did (population growth and decrease in average household size).

**Profit and loss account**

Table 4 provides an example of a profit and loss account of a water company.

The incomes of this water company are represented by more than 90% from the sale of water, by levies for the standing charge, and by payment for the delivered amounts of water (consumer rate). A very small share of the water revenues consists of a standing charge for fire hydrants, paid for by local governments.

The revenues for nature conservation and recreation mainly originate from admissions to the nature reserves and visitors' centers, and from camp fees.
The revenues from capitalized production mainly concern staff costs that are attributed to the investment work and which reappear in the tangible fixed assets.

The remaining revenues are derived from the execution of activities for third parties (renovation of streets when constructing the pipes, laboratory research) and by the sales of company assets.

Capital expenses are the largest expenditure of a water company. Depreciations, additions to the revaluation reserve and interest costs are almost 45% of the total costs.

The total costs at this company include 36% for staff costs. These costs involve its own staff or hired staff for contracted work, and extraordinary costs for organizational development. The work which is contracted out mainly consists of activities in the distribution network by third parties.

Expenses for materials are non-capitalized materials. Other external costs are largely consumer goods like energy and chemicals.
This company also buys a considerable amount of drinking water from a neighboring water company.

The realized profit will be added to the general reserves of the company. The increase in the company's equity capital consists of both this profit and the addition of the revaluation reserve.

*Table 4 - Profit and loss account of a water company (PWN 2001, 100% = €188.8 mln)*

| Revenues | (%) | Expenses | (%) |
|---|---|---|---|
| Net sales water: | | Purchase of drinking water | 5.1 |
| - Small user (households) | 75.7 | Staff | 22.9 |
| - Mid user | 4.7 | Third-party work | 11.0 |
| - Large user | 10.1 | Extraordinary costs | 2.6 |
| - Standing charge fire hydrants | 0.3 | Material | 5.5 |
| Nature conservation and recreation | 2.8 | Other external costs | 8.7 |
| Capitalized production | 2.8 | Depreciation (excluding revaluation) | 25.8 |
| Other revenues | 3.7 | Revaluation reserves (addition) | 3.6 |
| | | Interest | 14.3 |
| | | Profit (result) | 0.6 |
| Total | 100.0 | | 100.0 |

Water companies are lawfully excused from the levies of corporate taxation.

## 2.3 *Rate determination*

In order to avoid profits or losses, it is necessary for a water supply company to charge a cost-covering rate. This rate is usually determined annually based on the budget for the coming fiscal year. In this budget, the expected expenses and incomes are noted.

For a reliable estimation of the capital costs for the coming year, it is necessary to formulate an investment budget for that year (new constructions and replacement investments), as well as an expectation of the assets which will be removed. These estimations should include assets like treatment plants and distribution network. Based on these estimations, the development of the balance sheet value over the year can be established and, with this, the capital needs (loans).
The interest costs can be reliably estimated because the largest share of the capital is loaned through long-term loans. For new loans an estimation of the interests from the coming year will have to be made.

All remaining expenses are generally reliable estimations based on the expenses of the last year. Apart from the purchase costs for (drinking) water and operational costs (energy and chemicals), these costs are hardly related to the true production and sales in the coming year.

The total expenses should be covered by the total incom. The non-water income can often be estimated from historical information. The remaining part has to come from water revenues. The water revenues depends on the estimated water use within the different consumption categories and the tarif policy of the company. The tarif policy includes:
- chosen ratio between fixed rate (standing charge) and the volume rate per consumption category (small use versus large use)
- chosen ratio of cost-covering by the different consumption categories

**Fixed rate versus volume rate**
The water company of Table 4 uses the following rates for small use (2003):
- fixed rate (standing charge)
  €43.00 per year (6% VAT incl.)
- volume rate
  €1.34 per $m^3$ ( 6% VAT incl.)

With an average consumption of 117 $m^3$ per year per household, the annual cost for drinking water per household is €199.78 per year (43.00 + 117 · 1.34).
This means that 21% of the revenues from households consist of fixed charges and 79% of volume charges.

These cost percentages differ greatly from the water company's expenses which are mainly fixed costs for capital and staff.
A rate ratio of 90% for fixed charges and 10% for volume charges would better correspond to the actual cost relationship. In principle such a rate ratio could be adopted. However, from a political point of view, this would be considered less advisable, because there is no stimulus for the

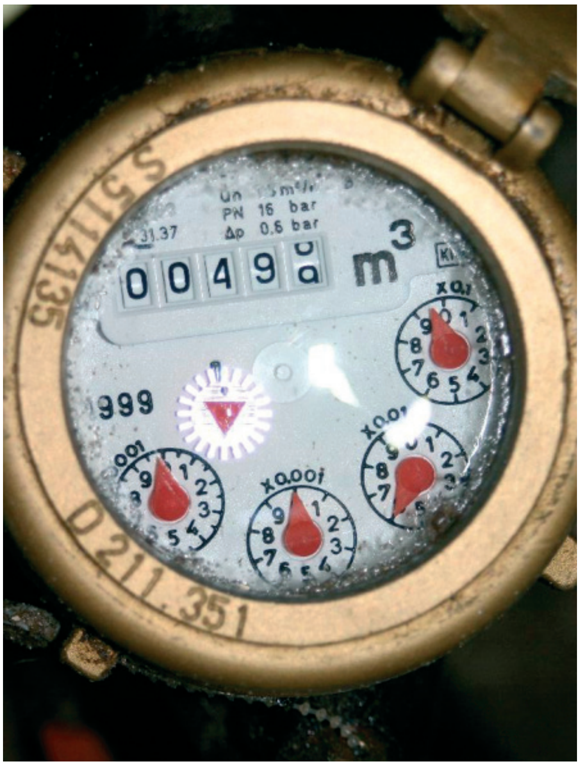


*Figure 3 - Water meter*

individual citizen to use drinking water economically. The ratio between the fixed and volume charges is based almost entirely on social and political arguments.

A result of the above-mentioned cost relationship is that less water consumption (due to water savings) results in an increase in the volume rate to avoid losses to the company.

The large share of fixed costs and relatively high costs to measure the delivered water (meters with an annual meter recording) are the reasons that, in some areas, an unmetered delivery is found.
The choice for metering or not is mainly a social consideration. However, from an economical point of view, the unmeasured delivery of drinking water is usually cheaper in total, as long as large spills are avoided.

The costs for delivery to and consumption by the consumer are calculated per calendar year. For large users consumption is based on the meter reading at the end of a calendar year. For small users the meters are recorded during the year (Figure 3) after which balancing takes place with the earlier estimated annual consumption (Figure 4).

**New connection charge**
The connections to houses are relatively expensive, when considered as part of the total costs of the drinking water supply because of the many small pipes. Therefore, one-time entry rates are usually charged when making or changing the connection.

The water company in the sample uses the following one-time entry rates for small-scale consumers (2003):
- direct definitive entry €360.52 (6% BTW incl.)
- entry with a preliminary construction connection €882.80 (6% BTW incl.).

The received entry charges are for administrative reasons not deducted from the investment costs for these connections. The received charges are listed on the balance sheet as capital reserve. To this reserve, depreciation will be applied.

**Volume rates for small and large use**
Usually large users pay less for drinking water than small users. This is motivated by the relatively high costs for the small pipes in the distribution network needed for small users. In other words, large users are connected to main pipes and, therefore, do not use these small pipes. Also, large users typically use water more equally, which means that for the same annual sales smaller pipes can be used.

Table 5 shows an example of the rates for small, mid- and large users.
In this example the average rate per m$^3$ for large users is around 75% of the average rate for small users. Moreover, the share of the fixed rate in the total costs is smaller for the large users (10% of the annual costs).

There are also companies in which there is no separate large user volume rate. This is motivated by a policy choice which states that it should be equally attractive for everyone to save water.
The relationship between the rates for large and small users is, in this way, more or less determined on political grounds. However, on technical grounds it is defensible to establish lower rates for large users.

## 2.4 *Benchmark comparison of water companies*

Because water companies are monopolies, there

*Table 5 - Example of rates for small and large water users for a water company (PWN 2003, excluded 6% VAT)*

| Annual use | Connection | | Rates | | Costs | |
|---|---|---|---|---|---|---|
| | Maximum consumption | Peak factor | Fixed | Volume | | |
| (m$^3$) | (m$^3$/h) | ( - ) | (€ / y) | (€ / m$^3$) | (€ / y) | (€ / m$^3$) |
| 117 | 1.5 | 110 | 40.57 | 1.26 | 187.99 | 1.61 |
| 5,000 | 6 | 10 | 575.00 | 1.24 | 6,775.00 | 1.36 |
| 200,000 | 70 | 3 | 24,250.00 | 1.07 | 238,500.00 | 1.19 |

**Nota nr.** 2931121-02-07-0024

*Wilt u bij correspondentie dit notanummer vermelden?*

**Datum** 13 augustus 2002

**Jaarafrekening**

**Voor inlichtingen**
Haagregio 070 384 39 39
Tussen 08.00 en 17.00 uur

Meneer/Mevrouw/Firma

JQJC VERBEEK

Van Speijkstraat 98
2518 GE 'S-GRAVENHAGE

**Duinwaterbedrijf Zuid-Holland**

▸ **Verkoopbedrijf**

Leveringsadres

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| Gelieve het bedrag middels bijgaande acceptgiro over te maken. Zorgt u ervoor dat het bedrag uiterlijk 3-09-2002 op onze rekening is bijgeschreven. | | | | | | | 53,60 |

Nieuw voorschot: 44,00 + 2,64 BTW = 46,64
Inning overige voorschotten vindt plaats in november februari mei

Wilt u uitleg over de jaarafrekening? Bezoekt u dan onze website WWW.DZH.NL onder klantenservice. Ook uw verhuizing kunt u hier opgeven of haal een gratis verhuisbericht op het postkantoor.

| | | |
|---|---|---|
| Historisch verbruik | 11-07-2000 t/m 5-07-2001 | 64 m3 |
| | 15-07-1999 t/m 11-07-2000 | 64 m3 |

betaald
8/9/02

*Correspondentieadres*

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**Vlietregio**
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2640 AA Pijnacker

Postbank 11600

*Ingeschreven in het Handelsregister onder nr. 27122974*

6039

*Figure 4 - Invoice for drinking water*

*Table 6 - Examples of statistical indicators for a water company (PWN 2001)*

| Quantity | Unit | Value |
|---|---|---|
| Sales in distribution area | mln $m^3$ / y | 104.2 |
| Number of connections | - | 692,340 |
| Sales in own distribution area | $m^3$ / y / connection | 150 |
| Percentage small users | $m^3$ / $m^3$<br>connection/connection | 77%<br>99.4% |
| Length of main distribution network | m / connection | 13.6 |
| Land | $m^2$ / connection | 103 |
| Staff | FTE/ 1000 connections | 1.14 |
| Equity capital | € / connection | 239 |
| Tangible fixed assets | € / connection | 1,088 |
| Revaluated purchase costs for active assets | € / connection | 2,711 |
| Net sales water | € / y / connection | 247 |

is no control by the market on the delivered product regarding quality, efficiency or costs. To overcome this lack of control, the Dutch water companies regularly conduct company comparisons voluntarily. This is called the VEWIN Benchmark. In this company comparison, the water quality of the delivered water, consumer satisfaction regarding the service, the environmental aspects, and the economic efficiency are all involved.

### Indicators for company comparison

Water companies in the Netherlands vary widely in size, technical infrastructures and financial positions. To compare water companies the information is usually expressed in amounts per connection. Within the number of connections, households are by far the largest group. Figures per connection, therefore, are characteristically for an average family.

Table 6 shows a couple of statistical indicators for the sample company. In this table both the technical and financial aspects are included. These are closely related because of the nature of water companies.

### Comparison of costs per household

Table 7 shows the annual costs for an average household for different distribution areas for some Dutch water companies.

From this table one sees that surface water companies are considerably more expensive than groundwater companies, mainly because more complex treatment at a greater distance from consumers means a more expensive infrastructure.
Furthermore, from the VEWIN Benchmark, it becomes clear that within the same company there are remarkable differences between various distribution areas. This is caused by political agreements made by management when companies merge.
The rate differences can be explained by differences in:
- age of the infrastructures (lower capital costs for older installations)
- its performance on the capital market (realized average interest)
- equity capital (capital needs by loans)
- the size of the supply area (population or consumption density)
- utilization of the infrastructure (capacity reserve)

*Table 7 - Yearly costs for an average family with a water consumption of 130 $m^3$/y (VEWIN 2000)*

| Company | Company – supply area | Yearly costs family (€ / y) |
|---|---|---|
| Surface water companies | | |
| - Most expensive supply area | PWN – Region Haarlem | 248 |
| - Cheapest supply area | Water supply company Amsterdam | 166 |
| Groundwater companies | | |
| - Most expensive supply area | Vitens – Friesland | 166 |
| - Cheapest supply area | Groningen – Province (excluded city) | 101 |

- productivity of the staff (company and outside employees, salary levels, social situation of former staff)
- rate policy (mutations in equity capital, rate differences between large and small use)

The differences in rates will get smaller in the coming years because of company mergers and because of the rate normalization within a company.

## 3. Investment costs

### *3.1 Definition of investment costs*

The investment costs represent the total costs of developing a project or plant. These costs are paid during the preparation and construction of the project through to the moment that the project (e.g., treatment plant) is taken into operation. From that moment on, the installation generates revenues and the costs afterwards are considered to be exploitation costs. Usually this timing corresponds to the date the completed construction is taken over by the principal (water company).

Investment costs can also appear during the operation period of the asset. Examples include expansion of the plant and replacement of major parts.

The investment costs, both of newly built constructions and the expansion and replacement of major parts, are the basis of the capital costs of an asset.
The preparation costs are also part of the investment costs of an asset. Especially in the initial stage of a project, it is not always clear which costs really have to be ascribed to the investment costs of a future asset or to the general operational costs of a (water) company. Two examples of this are the costs for the feasibility study and the preliminary technical study (pilot plant).
For a clear picture of the costs of a water company, it is important that costs are ascribed to the investment costs of the asset in an early stage, even if the final completion of the asset is uncertain. This is one way to avoid losing the initial costs to the general costs of a company. This will also make the investment loss clear when a new construction project is cancelled.

### *3.2 Uniform structure of investment costs*

To estimate, secure and justify investment costs, a uniform and unambiguous concept definition is necessary.
For construction in the Netherlands, presentation of the investment costs has to satisfy NEN 2631: “Investment costs of buildings - Terminology and classification.” This classification is depicted in Table 8.

The definitions, according to this norm, also play a part in establishing levies like building fees. Building fees usually amount to a percentage of the construction costs, according to NEN 2631.

**Land costs**
Acquisition costs represent the purchase sum of the site with all its additional costs.
The costs for infrastructural facilities include the costs of construction outside the site to make it suitable for use.

The site preparation costs include, among other things, the demolition of buildings, the removal of old pipes, as well as providing accessibility for construction traffic.

The land costs vary noticeably per project. When expanding an existing installation, the terrain might already be owned by the client. When building on new locations, there are often negotiations to be made regarding the price.
Acquisition costs are usually not depreciated, assuming that the land itself has a stable value.
The land costs for water treatment plants are usually only a small part of the total investment costs (less than 1 - 2%).

**Construction costs**
Water installations are not a part of the construction costs. According to the norm, these belong to the installation costs.

*Table 8 - Overview of investment costs (according to NEN 2631)*

| Part | | Sub part | |
|---|---|---|---|
| 1 | Land costst | 1 | Acquisition costs |
| | | 2 | Costs for infrastructural facilities |
| | | 3 | Site preparation costs |
| 2 | Construction costs | 1a | Buildings: Structural works |
| | | 1b | Buildings: Installations (mechanical and electrical) |
| | | 1c | Buildings: Fixed furnishing |
| | | 2a | Ground: Structural works |
| | | 2b | Ground: Installations (mechanical and electrical) |
| | | 2c | Ground: Fixed equipment |
| 3 | Equipment costs | 1a | Buildings: Water supply installations |
| | | 1b | Buildings: Loose installations |
| | | 1c | Buildings: Work for installations |
| | | 2a | Ground: Water supply installations |
| | | 2b | Ground: Loose installations |
| | | 2c | Ground: Work for installations |
| 4 | Additional costs | a | Preparation and supervision costs |
| | | b | Levies |
| | | c | Insurance |
| | | d | Start-up costs |
| | | e | Financing costs |
| | | f | Risk balancing |
| | | g | Unforeseen expenses |
| | | h | Maintenance costs of the acquired land |
| | | i | Sales tax |

A drinking water production plants consists, in large part, of a variety of installations. To these belong installations like filter units, clear water reservoirs, pumps and pipes, etc.
The advantage of this interpretation is that the construction fees for a new drinking water production plant will be limited. The levies are not charged on installation costs in compliance with the jurisprudence.

Included in the construction costs are, among other things, office facilities for the staff and sanitary facilities. Construction costs are separated into costs for buildings and costs for the ground.
The construction costs (in conformance with the above-mentioned interpretation) are usually a small part of the investment costs (less than 2 - 5%) in drinking water production plants.

**Installation costs**
The water treatment and supply installations are included in the installation costs according to NEN 2631 and are the most expensive part of constructing a drinking water production plant.

To make an initial estimation of the costs of the treatment and pumping units, cost-functions are often used, which are based on previously completed projects. In such functions, often the design capacity is typically included as a variable (shown below in paragraph 3.4).
Besides the above-mentioned costs of the water supply installations, the furnishing of staff facilities, workshop, laboratory, etc. is also part of the installation costs. These installation costs are usually a small part of the investment costs (less than 1 - 3%) for water supply production plants.

**Additional costs**
The preparation and supervision costs include the costs for the design, preparation of tender documents and building management. It include both the internal costs of the initiator and the external consultancy costs for all separate project stages (from preliminary research to completion). The preparation and supervision costs typically make up a substantial part of the investment costs (15 - 25%).
These costs are not always equally distinguishable. Some water companies consider the prepa-

ration costs as normal activities for the general management. In other cases the construction is put out to tender as a turnkey project, in which case a large part of the engineering costs is included in the contract sum. Also, in a different way of contracting, where the detailed engineering is carried out by the contractor, there is a shifting of this item to the contract sum. When comparing the different projects, this potential shift has to be taken into account.

The levies contain, among other things, the fees for the building permit. The amount of these fees differs per municipality. Generally, they amount to 0.5 - 1.5% of the overall construction cost (in conformance with the above-mentioned interpretation of NEN 2631), with the lower percentages applied to the higher construction costs.

The financing costs mainly represent interest during construction. Payments are made during the preparation and building stages until the moment of start up.

The building interest depends on the length of time between payments and the moment of start up, and on the interest rate. When the building period is 2 years, the interest is 10%, and the progress of building is more or less constant (constant monthly costs during the period of building), then the interest on the investment costs amounts to about 10%. The interest costs during construction for drinking water production plants will vary between 5 - 15% of the total investment costs.

Sales taxes include the V.A.T. on the investment costs.
Drinking water companies are exempt from V.A.T., which means that they do not have to pay V.A.T., when making investments. When working with depreciations, the investment costs excluding V.A.T. should, therefore, be taken into account.

Unexpected expenses should not be recorded as a separate entry in the cost presentation, but should be added to as many other expected expenses as possible. The background for this is that, with a seperate cost entry, the post-calculation of projects will be less transparent. The presentation of the cost estimations during the preparation and building stages should reflect estimations in every category of likely costs. Putting one large figure in the “unexpected costs” category gives rise to questions about the total cost estimations.
For drinking water production plants, the remaining additional costs (Section c, d, e, f, and h) are usually small (1 - 3% of the investment costs).

## *3.3 Index of investment costs*

When determining the investment costs for a specific project, often information from comparable projects with comparable process components is used. This applies especially to the beginning of the design process, when detailed design information for the concerned project is still missing.
When the information on the costs of an actual project is used, the following should be considered:

- are all cost components included in the investment costs?
- what was the moment of realization (price level)?
- what was the installed capacity (split treatment, reserve capacity)?

**Price level**

The cost of goods and services change, in time, which means that investment costs will change too. The basis for this can be either price increases or price decreases. Price increases can be the result of inflation, which means that the cost for loans and materials will rise. Price decreases can be the result of more efficient management, when production is less costly due, for example, to scaling-up, mass production, or automation.

Looking at the potential price difference, it is important to determine when the investment costs were calculated. This is indicated as the price level.

**Price-index figures**

The development of the price level is described using price-index figures.
Statistics Netherlands, CBS, publishes various price-index figures, like the consumers’ price-

index (CPI). The CPI shows the development of the price of goods and services that are purchased for consumption by the average household in the Netherlands in a base year (1995 or 2003). The CPI is an important standard for inflation and is often used by companies and government, for example, within the framework of loan negotiations, creating an index of rents and annuities, and when adjusting tax tables. Inflation is measured as the increase in the CPI over a certain period compared to the same period in the previous year.
In the period from 1996 to 2002 inflation in the Netherlands was an average of 3% per year.

CBS also publishes price-index figures for producers' prices, including those for industry in general and for the construction industry specifically.
For the building industry, the production price-index figures for buildings are published, for house building, for commercial buildings, and for governmental buildings, hospitals, etc.
For the building industry also a couple of price-index figures for land, water and road construction are published, like excavating work, road building and sewage systems.
The price-index for sewerage concerns sewerage within built-up areas for construction and renewal. The index contains, among other things, the demolishing and transporting of brick and asphalt paving, digging of trenches, buying of pipe material (concrete pipes), pipe laying, making house connections, back filling, and transporting excess earth.

In Figure 5 the progression of the price-index figures for sewage systems within built-up areas is

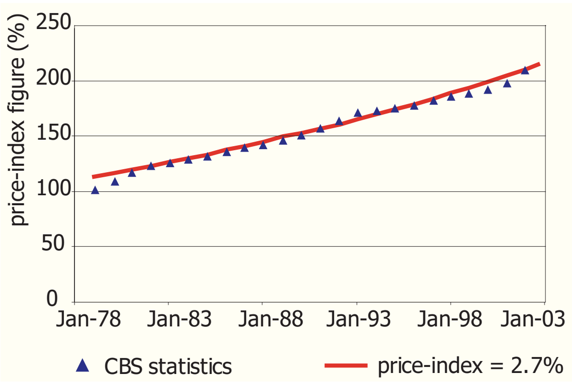


*Figure 5 - Price-index figures for sewage systems within built-up areas (CBS 2002)*

shown. It turns out that the prices have more than doubled in 23 years. Since 1982 the annual price increase has been nearly constant at a level of 2.7% per year (growth rate per year 1.027).

**Levelling the price level**

When recalculating the investment costs of actualized projects to a desirable price level, price-index figures are used.

The investment costs can be determined to a certain time using:

$$K_a = K_b \cdot \frac{\text{price-index figure time a}}{\text{price-index figure time b}}$$

in which:
$K_a$, $K_b$ = investment costs at time a and b

For a time in the future there is no price-index figure available. Therefore, an extrapolation of the future price-index figure has to be made.

Based on an expected price development with a fixed increase in the price per year, a future price $K_a$ can be determined from:

$$K_a = K_b \cdot (\text{growth rate per year})^n$$

in which:
n = number of years between time a and time b

**Price-index with compound cost components**

Drinking water production plants comprise different kinds of construction parts.
The most important of these are:
- civil structures (large-scale construction)
- mechanical installations
- electrical installations
- instrumentation and control installations

The development of the costs will not be the same for these parts. For the civil constructions, the gradual increase in wages will be influential, while for the instrumentation and control installations the relative price decrease of electronics plays an important part.
Therefore, for compound constructions, an index will be determined per kind of construction part to derive a reliable calculation to another price level.

*Table 9 - Price-indices of different parts of compound works*

| Part | Sub part | Characteristic index figure |
|---|---|---|
| Land costs | Acquisition | Consumers Price Index |
| | Infrastructure | Price Index Civil Engineering |
| | Site preparation | Price Index Civil Engineering |
| Construction and equipment costs | Civil engineering | Price Index Utility buildings |
| | Mechanical engineering | Price Index Machine Industry [(1)] |
| | Electrical engineering/instrumentation | Price Index Electrotechnical Industry |
| | Other | Consumer Price Index |
| Additional costs | Preparation and supervision | Index government wages |
| | Interest during construction | Discount rate for promissory notes +1% |
| | VAT | Ratio of actual value |
| | Other additional costs | Consumer Price Index |

[(1)] product price index of internal sales of the industry

The most important index figures for the realization of drinking water production plants are summarized in Table 9.

Suppose that for drinking water plants a compound index figure can be determined. For this example, a certain relationship is supposed for the costs of the different parts, illustrated in Table 9.
In practice the following division of the costs of a conventional water supply plant (with filters and reservoirs constructed in concrete) applies:

- civil structures 40 - 60%
- mechanical installations 20 - 30%
- electrical installations 10 - 20%
- instrumentation and control 5 - 15%

In the period between 1980 and 1995 an analysis was made of the compound index of the WRK surface water treatment plant in Andijk. A compound index showing a 3% rise in the costs per year was acquired. This is reasonably equal to the index figure of commercial buildings.
With an index of 3% per year, the index figure of the investment costs increases up to 1.35 ($1.03^{10}$) in a period of 10 years and up to 1.81 ($1.03^{20}$) in a period of 20 years.

## 3.4 *Investment costs and capacity*

To transfer the investment costs of a realized project to a future project, the following questions are important to consider:

- is the treatment scheme of the projects equal?
- is the capacity of the projects equal?
- is the complexity and/or “luxury level” of the projects equal?

To compare production plants with different treatment schemes, investment functions per treatment process can be formulated. By adding the costs of the different processes, the total investment costs can be determined.
The complexity may differ per project. Sometimes the building permit only allows a very restricted building area, which means that a complex piled up construction is needed. Therefore, the investment costs are higher.
Also, aspects like representative buildings, with facilities for excursions, influence construction costs.
Because of these variations, the investment costs differ, even when the treatment scheme and capacity are equal. Differences of ±30% are possible, which is a factor of 2 between the most expensive and the least expensive project design.

**Scale factor**

Of course, the capacity of the plant determines, to an important extent, its investment costs.
For the relation between capacity and investment costs, cost functions can be formulated.
The relation between capacity and investment costs are usually well described by the general formula:

$$K = a \cdot (\text{capacity})^b$$

in which:

| | | | |
|---|---|---|---|
| K | = | investment costs | (E) |
| a | = | costs factor | ( - ) |
| b | = | scale factor | ( - ) |

In Figure 6 this relationship is given graphically for various scale factors. In this relationship the scale factor is the most important part.

The cost ratio of two different capacities depends only on the scale factor:

$$\frac{K_1}{K_2} = \left(\frac{\text{capacity}_1}{\text{capacity}_2}\right)^b$$

A scale factor of 1.0 indicates that there is a linear relationship between capacity and investment costs. This usually occurs when more of the same elements are needed for a larger plant, like in membrane filtration in which more of the relatively expensive membrane elements are necessary.
A more or less linear relationship also occurs in very large installations when the process parts already have a maximum capacity and, even more units are required to increase it further. An example is rapid sand filters that, due to restrictions in backwash water facilities, are usually not larger than 30 - 50 $m^2$.

A scale factor of 0.6 - 0.7 occurs for process parts for which, at a larger capacity, the size of the elements increases. Reservoirs are a typical example.
When the water height of a reservoir is selected, then with a larger volume the surface of the floor and roof will change on a linear scale with the volume (scale factor 1.0). The surface of the walls will

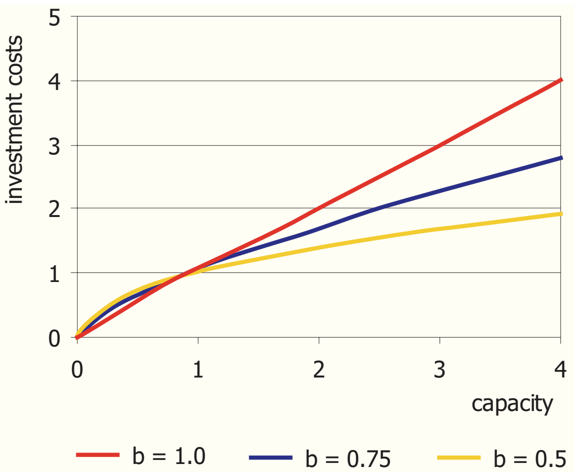


*Figure 6 - Relationship between capacity and investment costs for different scale factors*

change with the square root of the volume (scale factor 0.5).
In practice the scale factor for units of water production plants will be between 0.6 and 0.9, within the capacity range of factor 2 to 6.

**Functions for investment costs**
For all sorts of processes or installations, cost functions can be formulated to conform to the general formula for investment costs, based on (uniform) information from field practice.
When deriving these formulas, the range of the cost function is limited and that has to be taken into account. In very small installations, the costs of additional facilities will play a relatively important role; in very large installations, the scale effect will relatively decrease (more of the same elements).

Capacity in the cost function involves different quantities for different processes, like annual capacity, hour capacity, volume, surface area, etc.
The annual capacity is a suitable parameter for global initial cost estimations.
The maximum hour capacity of a process unit is a suitable parameter if the concerned process differs only slightly in design criterion, and, therefore, the size has a fixed relationship with the capacity.
The specific size of a process unit will always give the most reliable cost function. The cost function for rapid sand filters will use the filter surface area as the capacity parameter. A plant with a designed filtration velocity of 4 m/h will be more expensive than a plant with the same hydraulic capacity, but with a designed filtration velocity of 8 m/h. For flocculation, the total volume will be used as the capacity parameter, because large differences in residence time may occur, and different sizes can therefore have the same hydraulic capacity. Also, in reservoirs, volume will be the determining capacity parameter.

The capacity parameters for transport pipes are their length and diameter. For the length, a scale factor of 1.0 (costs are linear with the length) is applied; for the diameter, the same is true. The cost of pipe material and the excavation are more or less proportional to the diameter.

When the scale factor is 1.0 for the diameter, then the scale factor for the capacity of pipes is 0.5. This is because the design velocity is equal to the most economical velocity, which is for all capacities more or less constant.

**Investment functions for different design phases**

Cost functions used for the initial stage of a project will, in general, have large inaccuracies. One reason for this is that relatively little is known during the initial stage (treatment scheme, specific construction demands, etc.); another reason is that many things can and will change during subsequent designs.

Linear functions are often used for these cost functions (scale factor 1.0), in which the cost factor is chosen within an indicated range, based on the complexity and scale of the considered project.

Table 10 shows some examples of functions for investment costs for initial cost estimations.

The accuracy of these functions will be about ±50%.

*Table 10 - Examples of investment cost functions for initial cost estimations*

| Process / Process part | Cost factor (€ / $m^3$ yearly capacity) |
|---|---|
| Production from groundwater | 1.5 - 3.5 |
| Production from bank filtration | 2.0 - 4.0 |
| Production from surface water (direct) | 3.0 - 5.0 |
| Production from surface water (soil aquifer recharge) | 4.0 - 8.0 |
| Groundwater abstraction | 0.10 - 0.15 |
| Aeration | 0.10 - 0.15 |
| Degasifying | 0.20 - 0.30 |
| Rapid sand filtration | 0.30 - 0.55 |
| Filter backwash water treatment | 0.05 - 0.15 |
| Raw water pumping | 0.10 - 0.15 |
| Microstrainers | 0.05 - 0.15 |
| Flocculation | 0.10 - 0.25 |
| Floc removal (sedimentation/flotation) | 0.5 - 0.25 |
| Rapid sand filtration | 0.30 - 0.55 |
| Activated carbon filtration (GAC) | 0.50 - 0.90 |
| Softening | 0.35 - 0.60 |
| Disinfection | 0.05 - 0.20 |
| Membrane filtration | 1.00 - 2.00 |
| Slow sand filtration | 0.70 - 1.50 |
| Clear water pumping station | 0.40 - 0.70 |
| Clear water storage | 0.20 - 0.35 |

In a later stage of the project, like when formulating the draft design, more complex cost functions can be used. Preferably, a scale factor in the cost function will then be included.

The accuracy of certain cost functions per process unit are generally ±30%, assuming that the treatment scheme is known. A greater accuracy will typically not be possible, because, at this stage, it is not yet known what the construction will look like. With this level of accuracy, usually fairly good policy decisions can be made, such as decisions to choose a simpler or more staged plan, or an alternative treatment scheme.

The investment costs account for about 50% - 60% of the production of and/or transportation costs for drinking water. Operation costs (energy, chemicals and staff) are, in general, estimated with a higher degree of accuracy. This will level the inaccuracy in the estimation of the investment costs within the estimation of the production or transportion costs.

Table 11 shows some examples of functions for investment costs for Dutch designs.

During the preliminary and final designs, more and more accuracy in the design is established, and many more details are known. What has been determined is how many and which pumps will be installed, which buffer volume will be chosen, and which additional facilities (e.g., central control room, emergency power, laboratory, etc.) will be used.

The budget of the preliminary design can, therefore, be established with greater detail. Estimations are formulated per discipline (e.g., civil, mechanical or electrical engineering). The estimations will partly be based on more detailed cost functions and partly on figures based on designers' and suppliers' previous experiences.

*Table 11 - Examples of several functions of investment costs (equipment costs) in sketch design*

| Process units | Transport pipelines |
|---|---|
| Rapid sand filters: €0.15 million per $m^2$ filter area $^{0.61}$ | Normal route: €500 per meter diameter per meter length |
| Clear water storage: €0.003 million per $m^3$ storage volume $^{0.70}$ | Complex route: €1,000 per meter diameter per meter length |

**Estimating investment costs**

A surface water treatment plant of 20 million $m^3/y$ (design capacity 3,200 $m^3/h$) consists of several processes, like those below.

| **Process part** | | | | |
|---|---|---|---|---|
| Flocculation | Residence time | 20 min | Volume | 1,070 $m^3$ |
| Flotation | Surface load | 15 m / h | Surface | 215 $m^2$ |
| Filtration | Surface load | 7 m / h | Surface | 460 $m^2$ |
| Activated carbon filtration | Empty bed contact time | 15 min | Volume of carbon | 800 $m^3$ |
| Clear water storage | Volume | 20,000 $m^3$ | | |
| Clear water pumping station | Capacity | 5,760 $m^3$ / h | | |

Based on these process units, the investment costs (level of policy plan or sketch design) are estimated using the cost functions for the process units. The table below gives the result of the cost estimation.

| **Cost element** | **Costs (million € )** |
|---|---|
| Construction and equipment costs for process units: | |
| - Flocculation | 2.3 |
| - Flotation | 2.8 |
| - Filtration | 6.8 |
| - Activated carbon filtration | 6.7 |
| - Clean water storage | 3.7 |
| - Clean water pumping station | 7.3 |
| Subtotal process units | 29.6 |
| | |
| Other (non-process related) investment costs (41% of subtotal process units) | 12.1 |
| - Land costs (2% of subtotal process units) | |
| - Other construction costs (5% of subtotal process units) | |
| - Additional costs: | |
| - Preparation and supervision (20% of subtotal process units) | |
| - Financing costs (10% of subtotal process units) | |
| - Other additional costs (4% of subtotal process units) | |
| Total investment costs | 41.7 |

On the level of tender documents and specifications, the investment costs can be estimated based on estimations in detail (e.g., 300 filter nozzles per filter, 2,500 kg of concrete steel, 50 $m^2$ of front/façade element, etc.), in which a large degree of accuracy can be reached. All information used for the cost estimation can be taken from the “bill of quantities” and the lists of specifications.
Such a budget usually has the same accuracy as the budget from the contractor (±5 - 10%).

Based on post-calculations of a project, the investment costs can finally be determined.
The post-calculation can also be used to estimate cost functions for various other design phases.

# 4. Operational costs

## *4.1 Definition of operational costs*

The operational costs contain all (integral) costs which are made or will be made to use an object, construction or plant.
These costs are made during (parts of) the operation period of the installation or plant and after completion of the construction.

In water supply companies the operational costs can be presented for different configurations, such as:

- the complete company (conform annual report)

- all production plants together (integral production costs)
- a certain production plant (local production costs)
- the complete distribution network (integral distribution costs)
- a certain part of a distribution area (local distribution costs)
- the complete sales department (sales costs)

When estimating the operational costs of a part of the company, it is necessary that the boundaries of this part be clearly defined and that possible overhead costs be assigned in a reliable way.
The sum of the operational costs of all the different parts eventually has to be equal to the operational costs of the total company.

The operational costs are estimated to calculate the total cost price of the different parts of the company. This is important for the calculation of costs to the buyers, because there are different rates charged, such as to large consumers, for bulk delivery to other water supply companies, or for rate differences per part of the distribution area.

The operational costs will also be calculated when determining various alternatives during the preliminary studies. The operational costs will eventually be calculated back into consumers' rates.

## 4.2 *Uniform structure of operational costs*

A uniform and unambiguous concept definition is needed to explain and justify the operational costs.
Various systems are developed, sometimes from the formation of company administrations (annual accounts) but also for specific applications. For buildings in the Netherlands, the presentation of operational costs can be used according to NEN 2632: "Working costs of buildings - Terminology and classification."
The classification is given in Table 12. In the table a few typical cost items for drinking water supply are included.

Operational costs are represented annually and, because of the fiscal status of water supply companies, those costs are presented excluding VAT. The operational costs minus the fixed costs are also indicated as variable costs.

**Interest and replacement reserves (capital costs)**
The costs for interest and replacement reserves are indicated as capital costs. The costs for the interest are the actual paid interest costs for loans, but also the costs when using the equity capital.
The cost for replacement reserves is the depreciation based on the current rebuilding value. This way of depreciating is only used for projects within the company, if the company uses the same form of depreciation, to avoid discrepancies in the cost calculations.
The costs for the acquisition of land are often not depreciated, because land is not consumed and has a relatively fixed value. Sometimes, these acquisition costs are revalued based on current acquisition costs.

The depreciation periods are not equal for the various assets. Therefore, the costs for the replacement reserves are determined separately for similar assets (buildings, machines, distribution network, inventories, etc.)

To determine the capital costs, an economic depreciation period is assumed. The economic depreciation period does not necessarily have to be equal to the technical lifetime of an installation. It might be that the condition of an installation is still technically sufficient, but economical operation is no longer possible due to the superfluousness of the process unit or due to high maintenance costs.

To determine the capital costs, a straight-line depreciation, annuity depreciation, or unitary depreciation can be used. Straight-line depreciation is the most common in concerns; annuity and unitary depreciations are most often used in cost comparisons of alternatives.

*Table 12 - Definition of operational costs (according to NEN 2632)*

| Part | | Sub part | |
|---|---|---|---|
| 1 | Fixed costs | a1 | Interest |
| | | a2 | Replacement reserve (depreciation of actual building costs) |
| | | a3 | Ground rent |
| | | a4 | Owners part real estate tax |
| | | a5 | Assurance costs (fire, glass, etc.) |
| | | a6 | Governmental contribution (taxes, levies, etc.) |
| | | c1 | Rent |
| | | c2 | Loss of rent |
| | | c3 | Environmental tax |
| | | c4 | Users part real estate tax |
| 2 | Consumables | b1 | Energy costs (electricity and fuels) (maintain) |
| | | c5 | Energy costs (electricity and fuels) (use) |
| | | | Water |
| | | | Chemicals |
| | | | Other consumables (regeneration activated carbon, seeding material, etc.) |
| | | | Removal waste products |
| 3 | Maintenance costs | b2 | Technical maintenance (maintain) |
| | | b3 | Cleaning maintenance (maintain) |
| | | c6 | Technical maintenance (use) |
| | | c7 | Cleaning maintenance (use) |
| 4 | Administrative management costs | a7 | Accounting costs (property) |
| | | b4 | Accounting costs (maintain) |
| | | b5 | Rental costs |
| | | b6 | Administrative staff costs |
| | | c8 | Moving costs |
| | | c9 | Mediation costs |
| | | c10 | Accounting costs (use) |
| 5 | Specific operational costs | a8 | Surveillance costs (property) |
| | | b7 | Surveillance and security (maintain) |
| | | c11 | Surveillance and security (use) |
| | | | Operation installations |
| | | | Quality monitoring |

a – costs related to property ownership
b – costs related to ready-to-use maintenance
c – costs related to partial or complete use

**Straight-line depreciation**

In straight-line depreciation, the same depreciation is taken each year.

The annual depreciation, then, is constant over the depreciation period. Therefore, the remaining sum decreases in a line straight over the depreciation period and so does the interest that has to be paid annually.

The annual capital costs consist of depreciation plus interest.

In year t these amount to:

$$A_t = I \cdot \left( \frac{1}{n} + \frac{n + 1 - t}{n} r \right) = I \cdot a_t$$

in which:

| | | | |
|---|---|---|---|
| I | = | investment costs | ( € ) |
| R | = | interest | ( - ) |
| N | = | depreciation period | ( y ) |
| $A_t$ | = | capital costs in year t | ( € / y ) |
| T | = | year from beginning (t = 1….n) | ( y ) |
| $a_t$ | = | annuity in year t | ( $y^{-1}$ ) |

Figure 7 shows this development of the capital costs for a depreciation period of 10 years and an interest rate of 7%. The total paid interest amounts to 39% of the loaned sum (a bit more than 10 times half the interest for the first year).

When the depreciation period is 40 years, then the total paid interest is 144% of the loaned sum (a bit more than 40 times half the interest of the first year).

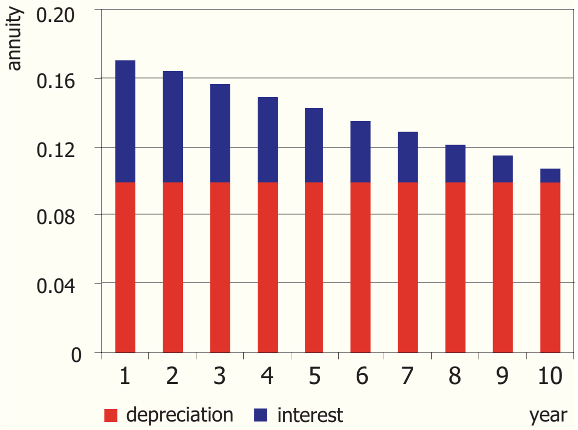


*Figure 7 - Development of depreciation and interest (annuity) with straight-line depreciation (10-year, 7%)*

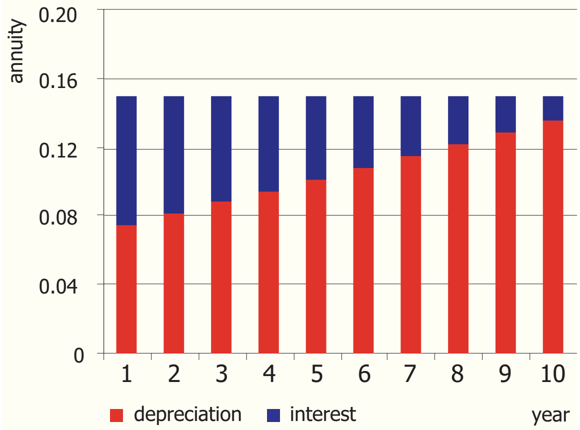


*Figure 8 - Development of depreciation and interest (annuity) with annuity depreciation (10-year, 7%)*

When the depreciation period is longer, the interest rate has a larger influence on the capital costs. When the depreciation is straight-line, the interest costs are linearly dependent on the interest.

**Annuity depreciation**

In annuity depreciation the annual capital costs (sum of interest and depreciation) are constant over the depreciation period. This means that in the first few years, the interest share is large and the depreciation share is small.

The depreciation period and the interest rate determine the extent of the annual capital costs, according to the annuity formula:

$$A_t = I \cdot \frac{r \cdot (1+r)^n}{(1+r)^n - 1} = I \cdot a_t$$

Figure 8 shows the development of the capital costs for a depreciation period of 10 years and an interest rate of 7%. The total paid interest amounts to 42% of the loaned sum, which is 3% more than with the straight-line depreciation.
When the depreciation period is 40 years, then the total paid interest is 200% of the loaned sum, which is 56% more than with a straight-line depreciation.
When the depreciation period is longer, the interest has a bigger influence on the capital costs.
When the depreciation period is 40 years and the interest rate is 3.5%, then the total paid interest would be 87% of the loaned sum.

**Unitary depreciation**

Unitary depreciation targets a constant cost price of the product over the total depreciation period. Therefore, the expected development in the sales of the product is taken into account.

The development of the capital costs is also dependent on the sales forecast.
When a growth in sales is expected, capital costs over the depreciation period will increase.
Due to delayed repayment, the interest costs will be higher for unitary costs than for annuity depreciation.

**Interest**

The interest rate is interest paid at the end of each year for the previous year. The discount rate is interest which is paid each year in advance.

To calculate the capital costs, a water company usually works with the average interest of the loan portfolio of the company.

At higher interest rates, investments get more expensive, which makes deliberation of alternatives with relatively lower investment costs more attractive.
Inflation has the opposite effect on this deliberation. Old investments become relatively less expensive because they are repaid when money typically has decreased in value and, therefore, will create a smaller burden.

This combined effect can be taken into account by calculating the investment costs using the net interest rate instead of the raw rate. This is the interest rate (market rate, or average company rate) minus the inflation. When the interest rate is 7% and the inflation rate is 3%, then the net interest rate is 4%.
The net interest rate has been fairly constant the past few years, varying between 2 and 4%, because the interest rate fluctuates with the inflation rate, and the net interest rate actually indicates the real costs of loans or money.

**Levies**
To the operational costs of a water supply company also belong the various government payments like taxes and levies.
In 2002 the total direct and indirect levies on drinking water in the Netherlands amounted to €0.32 per $m^3$ (VEWIN- Waterleidingstatistiek). The direct levies (cost price increasing) amounted to €0.14 per $m^3$ and contained groundwater tax, provincial groundwater levy, and pipeline and concession compensations (precario). The indirect levies amounted to €0.18 per $m^3$ and contained the tax on tap water and the sales tax (VAT).

An important part of these levies originates from Dutch environmental laws.
Groundwater taxes amount to €0.178 per $m^3$ of abstracted groundwater and the tax on tap water is €0.136 per $m^3$ of delivered water, for the first 500 $m^3$ per connection.

As a result of precario rights, provinces and municipalities are allowed to raise taxes on use by a third party of the space above, on or under the ground (or water) which is reserved for 'public service' (a kind of rent). Only a limited number of provinces and municipalities are using this right and, if they do so, large fluctuations in rates (rate for pipes €0.01 - 3.00 per m per year) can exist. For example, the water supply company PWN in Zaanstad has to pay €1.5 million annually to the municipality for the precario tax on their pipes. Of course, these taxes are charged directly to the consumers in this municipality, at €40 per household per year.

In the Netherlands in total, the total precario rights are about €0.01 per $m^3$ of delivered water.

The provincial groundwater levies are raised for groundwater conservation management. The rates differ per province. In the Netherlands the total provincial groundwater levies are about €0.01 per $m^3$ of delivered water.

In water companies, received sales taxes (VAT) are deducted from the investments and purchases, and the net amount is remitted to the government.
Private consumers of drinking water pay 6% sales tax as a net expense.

Water companies in the Netherlands are excluded from profit taxes.

**Consumables**
Consumables are goods which are specifically consumed by the different processes. Also, the replacement of process parts (e.g., UV-lamps, sieves) can be ascribed to this.
The consumables can be divided into the following categories:
- energy (electricity, fuels)
- water
- chemicals (acids, bases, flocculants)
- other consumables (seeding material for pellet reactors, regeneration activated carbon, UV-lamps)
- disposal of waste (sludge, backwash water, pellets)

Consumables do not include general maintenance materials (paint, lubricating oil, tools, etc.). These are included in the maintenance costs.

**Energy**
The energy costs can be divided into two parts:
- headloss (pressure loss) over the process units (or pressure increase with pumps)
- other energy consumption, specifically for a process unit (UV lamps, saturation in flotation, ozone)

*Table 13 - Specific energy consumption of different treatment processes*

| Process component | Headloss (Wh / m³) | Other specific energy consumption (Wh/m³) |
|---|---|---|
| Flocculation | 4 | 20 (mixers) |
| Flotation | - | 50 (saturation) |
| Degasifying tower | 40 | 40 (RQ = 50) |
| Filtration | 12 | - |
| Softening | 20 | - |
| UV disinfection | 12 | 50 |
| Membrane filtration | 1,000 | - |

In Table 13 the energy consumption for a few process units is shown conforming to this division.

### Chemicals

The cost of chemicals can be globally calculated based on the dosage (mg/l or mmol/l) and the chemical bulk price (cost price equals 100% product per kg or mmol).
The prices for consumables can be very dependent on local circumstances. Of importance, for example, is the size and usage of the goods (bulk transport, quantum discount) and the distance to the production locations (transport costs).

In Table 14 the approximate costs for some frequently used chemicals are shown per unit of dosage.

### Other consumables

In a couple of processes it is a question of frequent replacement of process parts to maintain the working of the machine or process. The cost of these consumable goods can be significant. Some typically used consumables for drinking water production are shown below.

*Table 14 - Specific chemical costs*

| Chemical | Dose (unit) | Costs (€ / m³ per unit dose) |
|---|---|---|
| Sulfuric acid | 1 mmol / l | 0.015 |
| Hydrochloric acid | 1 mmol / l | 0.015 |
| Caustic soda | 1 mmol / l | 0.015 |
| Lime | 1 mmol / l | 0.010 |
| $CaCO_3$ | 1 mmol / l | 0.015 |
| Ferric chloride | 1 mg / Fe | 0.001 |
| Ferric chloride sulfate | 1 mg / Fe | 0.0005 |
| PAC | 1 mg / l Al | 0.001 |
| $Cl_2$ | 1 mg / l | 0.001 |
| NaOCl | 1 mg / l | 0.002 |

Activated carbon has to be regenerated regularly. The annual regeneration volume depends on the load on the carbon, which is expressed in bed volumes (BV). This is the relationship between the treated volume of water ($m^3$) and the volume of carbon ($m^3$).
The total cost for this regeneration amounts to approximately €500 per $m^3$ carbon, which includes emptying, filling, and transport as well as replacement of lost carbon during regeneration.
The cost for new activated carbon is about €800 per $m^3$ carbon.

In pellet reactors used for softening, seeding material is used, usually about 5% of the total weight of the formed $CaCO_3$.
The cost for this seeding material varies between €150 per ton (sand) and €400 per ton (garnet sand).

The replacement costs for UV-lamps depend on the type of lamp and its lifetime. For high pressure lamps, the replacement cost is about €350 per year per lamp; for low pressure lamps, about €200 per year per lamp.

### Maintenance costs

The maintenance costs contain all costs for maintenance, including the repair and replacement of parts of installations within the depreciation period, as far as these are not included in the consumables.

A longer depreciation period often results in the replacement of more parts of the installation within this period and, thus, higher maintenance costs.

The maintenance costs per year are often estimated as a percentage of the construction costs. The civil, mechanical and electrical parts require maintenance to different degrees, therefore, different percentages are used. For the specific parts the percentage has to be estimated as accurately as possible together with the depreciation period.
Generally, the following average percentages for structures and installation costs are used to deter-

**Estimating operational costs**

A surface water treatment plant of 20 million $m^3$/y (design capacity 3,200 $m^3$/h) exists for several processes, like in the previous example.
The operational parameters are given below.

| Process unit | | | | |
|---|---|---|---|---|
| Flocculation | Energy | 24 Wh / $m^3$ | Dosing Fe | 5 mg / l |
| Flotation | Energy | 50 Wh / $m^3$ | Suspended solids (sludge) | 20 mg / l |
| Filtration | Energy | 12 Wh / $m^3$ | Suspended solids (sludge) | 5 mg / l |
| Activated carbon filtration | Energy | 8 Wh / $m^3$ | Regeneration | 15,000 BV |
| Clear water storage | | | | |
| Clear water pumping station | Energy | 200 Wh / $m^3$ | | |

Based on this, operational costs (sketch design phase) can be estimated as given below.

| **Process unit** | **Total (€ / m³)** | **Fixed costs (€ / m³)** | **Consumables (€ / m³)** | **Maintenance (€ / m³)** | **Specific operational costs (€ / m³)** | **Administrative costs (€ / m³)** |
|---|---|---|---|---|---|---|
| Flocculation | 0.047 | 0.017 | 0.017 | 0.002 | 0.006 | 0.005 |
| Flotation | 0.053 | 0.022 | 0.017 | 0.002 | 0.008 | 0.005 |
| Filtration | 0.088 | 0.046 | 0.004 | 0.006 | 0.018 | 0.009 |
| Activated carbon filtration | 0.116 | 0.051 | 0.030 | 0.005 | 0.018 | 0.010 |
| Clear water storage | 0.039 | 0.025 | 0.000 | 0.001 | 0.010 | 0.003 |
| Clear water pumping station | 0.108 | 0.058 | 0.012 | 0.007 | 0.020 | 0.010 |
| Total | 0.446 | 0.220 | 0.081 | 0.024 | 0.081 | 0.042 |

mine the annual maintenance costs for the total treatment plant:

- civil structures 0.5%
- mechanical installations 2%
- electrical installations 4%
- furnishings 10%

**Administrative management costs**

The administrative management costs refer exclusively to those costs for the administration (i.e., management) of the installation.
Administrative management costs include:

- costs for the administrative staff
- accounting
- costs for the main office (as far it can be charged to the concerned plant)

Administrative management costs depend on the organization of the company. For estimations, usually 10 - 15% of the remaining operational costs can be used.

**Specific operational costs**

The specific operational costs in the operation of a treatment plant consist of:

- operating costs:
  - staff costs
  - other costs (including facilities for staff);
- quality monitoring costs:
  - laboratory costs
  - optimization research

Specific operational costs are related to staff size and specific analysis costs.
For an estimate it can be assumed that the percentage of the investment costs (land acquisition costs excluded) is 2% for operation and 2% for quality monitoring.

## 5. Cost comparison of alternatives

When a production plant is designed, in most cases, choices have to be made between various alternatives.

The alternatives can differ from each other in the process units, the chemical and energy consumption, maintenance, etc.
Often, alternative choices occur when the investments aren't completely handled at the beginning of the project, but are spread over time (building in stages).
To compare the alternatives unambiguously with each other, it is necessary to have a comparison standard.
In principle two approaches are available:
- comparison of the net present value of investments and operational costs
- comparison of the integral cost price

By using these methods, the alternative investments, together with the accompanying annual operational costs, can be financially and correctly compared with each other.

**Net present value**
The net present value is the sum that should be paid at the beginning of the project (or operation time) when all costs would have to be paid all at once.
Money that hasn't been spent will bring in interest.

The net present value (at point of time t = 0) of an investment I, at time t can be calculated with:

$$NPV = \frac{I}{(1 + r)^t}$$

in which:

| | | | |
|---|---|---|---|
| NPV | = | net present value | ( € ) |
| t | = | time between moment of investment and moment of comparison | ( y ) |

For a plant to be built in the future, it must be remembered that the proposed investment increases in price, because of general money devaluation (inflation).
Taking this into account, the net present value can be calculated with:

$$NPV = I \cdot \frac{(1 + i)^t}{(1 + r)^t}$$

in which:
i = inflation correction ( - )

The formula mentioned above can be approximately rewritten into:

$$NPV = \frac{1}{(1 + (r - i))^t}$$

in which:
r – i = real interest rate ( - )

**Integral cost price**
In the integral cost price calculation, the costs per product are used for deliberation.
In principle, the same rules apply as discussed under the net present value, such as interest costs, inflation, etc. Only now, the comparison does not aim at an imaginary quantity (NPV), but at the cost to the consumer, which is a more appealing quantity.

In this method (theoretically) the development of the incomes (sales) also has to be taken into account. Often, calculation of the cost price in the first year is sufficient. The operational costs of the first year are divided by the sales of the first year.
For more or less constant sales, such a simplification is accurate enough to be used for the comparison of alternatives.

Figure 9 gives an example of the eloquence of the concept "integral cost price."

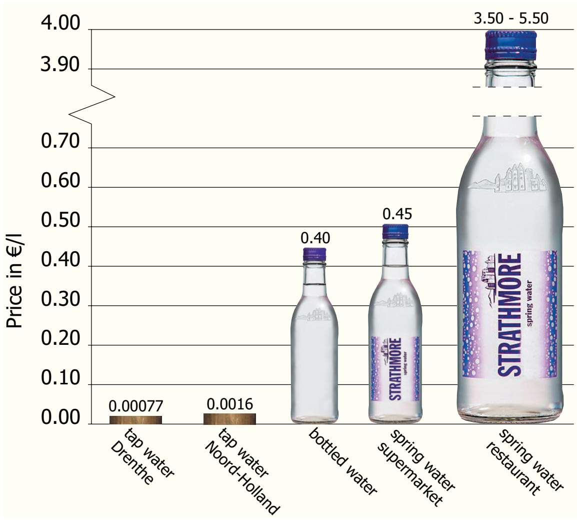


*Figure 9 - Integral costs of different types of drinking water*

**Project horizon and depreciation period**

When determining the investments, attention should also be given to the horizon of the project (the time period which is considered in the comparison, typically 30 - 40 years) in relation to the depreciation period (or technical lifetime) of process parts.

When the considered horizon is 30 years and a project is evaluated in which the depreciation period for the buildings is 30 years and the machines are depreciated (replaced) in 10 years, then, for the net present value determination, a reinvestment of the machines after 10 years and after 20 years should be taken into account.

### 5.1 Comparison of investment costs with phased building

With an increasing demand for water, the capacity of a new production plant could also be realized in stages.

As an example of this, two alternative investment possibilities for the same project are considered. In alternative 1 an investment of I takes place at t=0. In alternative 2 an investment of I1 takes place at t=0 and an investment of I2 after t years.

A postponed investment is of interest if, based on the net present value, an advantage is achieved:

$$I_1 + I_2 \cdot \frac{(1+i)^t}{(1+r)^t} < I$$

Assume that a onetime investment of €100 million can be replaced for an initial investment of €60 million, followed by an investment of €50 million after 7 years, in which the operational costs for both alternatives are presumed equal. Both investments together are €110 million, which is 10% more than the onetime investment.

The net present value of the second investment after 7 years is €36 million with an interest rate of 8%, the total net present value of both investments amounts to (60 + 36 =) €96 million.

This is less than the onetime investment of €100 million, so this makes building in stages financially attractive.

With a postponed investment, there is a better connection with the treatment vision at that moment. An extra advantage could be seen if the drinking water consumption does not increase as much as expected, which might extend the period beyond 7 years.

Likewise, there are, of course, all sorts of considerations against investing in stages, like an extra disturbance of the operation, an extra building stage with related attention, etc.

### 5.2 Comparison of investment and operational costs

Besides estimating the net present value of the investment costs, operational costs should also be taken into account.

How to include this is illustrated below using an example with two alternatives.

Alternative 1 is a project with low investment costs (€60 million) and high operational costs (€7.55 million per year).

Alternative 2 is a project with high investment costs (€100 million) and low operational costs (€4.00 million per year).

Furthermore, it is assumed that the operational costs of both projects are constant during their technical lifetime.

With an annuity of 0.089 (interest rate at 8%, depreciation period 30 years), the yearly capital costs of the projects are €5.34 million and €8.89 million, respectively. This makes the total annual costs for both alternatives (capital and operational) equal (7.55 + 5.34 = 4.00 + 8.89).

Based on this relationship, the conclusion could be drawn that the alternatives are comparable on a financial basis. However, this is not the case, since the above-mentioned comparison is, in fact, one formulated for the first year of operation (t=1). In time, the variable costs will increase, more or less correlated to inflation. This means that, in time, the variable costs will have a more important share in the total annual costs. This can be taken into account now by correcting the variable costs with the inflation percentage and by making all amounts constant to t=0.

Using a formula, the annual variable costs can be made constant as follows:

$$NPV_{Et} = E_{t=0} \cdot \frac{(1+i)^t}{(1+r)^t} = E_{t=0} \cdot \frac{1}{(1+r-i)^t}$$

in which:

$NPV_{Et}$ = net present value of the variable costs in year t

$E_{t=0}$ = variable costs in year t=0

After summing all variable costs over the lifetime of the project, the total net present value is as follows:

$$NPV_E = \sum_{t=0}^{t=n} \left( E_t \cdot \frac{(1+i)^t}{(1+r)^t} \right)$$

in which:

$NPV_E$ = net present value of all variable costs over the lifetime of the project

With a 30-year project lifetime, and a real interest rate of 5% (interest 8% and inflation 3%), the total net present value of alternative 1 is €175 million and of alternative 2 is €160 million.
In general, this means that with a conventional comparison of alternatives, the influence of the variable costs is underestimated. From this example, it is clear that the alternative with the higher investment costs is eventually the most economical solution.

When comparing alternatives, inflation should always be taken into account.
This can usually be achieved simply by calculating with real interest figures instead of the interest on the capital market or the average interest of the company loans.

## *Literature and websites*


**Financial information on water companies**

- Waterleidingstatistiek (VEWIN, annual report)
- Annual reports water companies
- www.vewin.nl

**Financial concepts and information**

- Kapitaalslasten en inflatie, J.W.H. de Mol van Otterloo, $H_2O$ (10) 1977, no. 2, p. 45-53
- Handbuch der Wasserversorgungstechnik, Grombach/Haberer/Trueb, R. Oldenbourg Verlag München/Wien (1985)
- Kostenaspecten in planningsmodellen voor de drinkwatervoorziening, Koster, RIVM, $H_2O$ (18), 1985, no. 15
- Investeringskosten van gebouwen, begripsomschrijvingen en indeling, NEN 2631, 1st edition (March 1979)
- Exploitatiekosten van gebouwen, NEN 2632, 1st edition (September 1980)
- Standaardisatie van kosten, DHV Water (1998)

## Questions and applications

### *Water company as an enterprise*

1. What is the content of a financial annual report?

2. Indicate which of the following items belong to the assets and which to the liabilities of a balance sheet.
   a - Contributions for new connections
   b - Realized revaluation reserve
   c - Liquid assets
   d - Loans due banks
   e - Debtors
   f - Provisions
   g - Advance payments for water
   h - Long-term debts
   i - Buildings and land
   j - Provisions
   k - Fixed company assets under construction
   l - Accrued expenses
   m - Issued shares

3. What effects arise for the interest costs and the capital costs if the investment costs are straight-line depreciated?

4. For the items below on a profit and loss account indicate if they belong to the revenues or expenses of a water company:
   a - Standing charge fire hydrants
   b - Materials
   c - Purchase of drinking water
   d - Sales to small users
   e - Third party work
   f - Staff
   g - Capitalized production
   h - Interest
   i - Depreciations

### *Investment costs*

1. To which four groups can the investment costs be divided according to NEN 2631?

2. What can be done to compare production plants with different treatment schemes? How can investment costs be determined?

3. For the capacity in the costs function for different purposes also different quantities can be used. What are these? Explain them.

### *Operational costs*

1. For water companies, the operational costs can be represented for different company parts. Which?

2. Indicate in which 5 groups the operational costs are divided according to NEN 2632.

3. Explain the difference between straight-line depreciation and annuity depreciation.

4. What is meant by consumables? Give some examples.

5. Out of which parts consist the specific operational costs in the operation of a treatment plant.

### *Cost comparison of alternatives*

1. When developing a production plant - in most cases - choices have to be made. The alternatives can differ from each other in the process units, the chemical and energy consumption, the maintenance, etc. Also, alternatives come up in which the investments are not completely made in the beginning of the project, but spread over time (phased building). How can you compare these alternatives in an unambiguous way?

2. Explain the term “net present value.”

### *Applications*

1. A water company is a monopoly within the distribution area assigned by the government. Give a couple of arguments for an assigned monopoly.

2. Surface water companies are considerably more expensive than groundwater companies, caused by the more expensive infrastructure required (more complex production and at a greater distance from the consumers). Explain what else can cause the rate differences.

## Answers

### *Water company as an enterprise*

1. A financial annual report consists of a balance sheet (list of possessions and debts at the end of the financial year) and a profit and loss account (list of revenues and expenses during the financial year).

2. Assets: c, e, f, I, k
   Liabilities: a, b, d, g, h, j, l, m.

3. The interest costs of a company are high in the beginning and will decrease to zero at the end of the depreciation period. The capital costs (interest and depreciation) for such a company are, therefore, not even over the depreciation period.

4. Revenues: a, d, g
   Expenses: b, c, e, f, h, i

### *Investment costs*

1. - land costs
   - construction costs
   - equipment costs
   - additional costs

2. To compare production plants with different treatment schemes, investment functions per treatment process can be formulated. By adding the costs of the different processes, the investment costs can be determined.

3. The annual capacity is a suitable parameter for initial cost estimations. The maximum hour capacity of a process part is suitable if the concerned process part has hardly any differences in design load, and, therefore, the size has a fixed relation with the capacity.
   The specific size of a process part will give the most reliable cost function.
   The cost function for rapid sand filters will have the filter surface as its capacity parameter.
   For flocculation the total volume will be used as the capacity parameter.

### *Operational costs*

1. For water companies, the operational costs for the different company parts can be indicated, such as:
   - complete company (annual report)
   - all production plants together (integral production costs)
   - a certain production plant (local production costs)
   - the complete distribution network (integral distribution costs)
   - a certain part of a distribution area (local distribution costs)
   - the complete sales department (sales costs)

2. - fixed costs
   - consumables
   - maintenance costs
   - administrative management costs
   - specific operational costs

3. Straight-line depreciation:
   In straight-line depreciation, every year the same depreciation takes place. Because of this, a linear decrease in the remaining amount takes place over the depreciation period and so does the interest that has to be paid annually.

   Annuity depreciation:
   In annuity depreciation the annual capital costs (sum of interest and depreciation) are constant over the depreciation period. This means that in the early years the interest share is large and the depreciation share is small.

4. Consumables are the costs for consumer goods like energy and chemicals. The replacements of process parts (for example, UV-lamps, sieves) can also be included here.

The consumables costs can be divided into:
- energy (electricity, fuels)
- water
- chemicals (acids, bases, flocculants)
- other consumables (seeding material for pellet reactors, regeneration and supplementation activated carbon, UV-lamps)
- disposal of waste (sludge, backwash water, pellets)

Consumables do not include general maintenance materials (paint, lubricating oil, tools, etc.). These are included in the maintenance costs.

5. The specific operational costs in the operation of a treatment plant consist of:
   - operating costs:
     - staff costs
     - other costs (among other things, facilities for staff)
   - quality monitoring costs:
     - laboratory costs
     - optimization research

### *Cost comparison of alternatives*

1. To compare these alternatives, two methods of approach can be used:
   - comparison of the net present value of investments and operational costs
   - comparison of the integral cost price

2. The net present value is the sum that should be paid at the beginning of the project (or operation time) when all costs would have to be paid all at once. It takes into account the fact that money that hasn't been spent will bring in interest. For a future construction, it has to be taken into account that the required investment in the future will be higher because of the general money devaluation (inflation).

### *Applications*

1. Arguments for an assigned monopoly are:
   - distribution of water determines the price to such an extent that it is never economically attractive to have more suppliers
   - the quality and availability of drinking water is of such social importance that it should not be under pressure by companies' economic considerations
   - drinking water supply does not qualify for operation by different companies, because this will make quality responsibilities and delivery guarantees very unclear. This is the reason why the government's pursuits of a quality guarantee (always safe and healthy) and a quantity assurance (always in the demanded quantities under sufficient pressure) is, best served by one single company from the source to the tap

2. Rate differences can be explained by differences in:
   - age of the infrastructure (capital costs)
   - performance on the capital market
   - equity capital
   - size of the distribution area
   - utilization of infrastructure
   - staff productivity
   - rate policy