pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION
Bureau of Point and Non-Point Source Management

Applicant Guidance for Wastewater Facility Cost-Effectiveness Analysis

Monetary costs shall be presented as present worth values for all capital and operation and maintenance (O&M) costs over the typical 20 year project planning period. Population growth beyond the 20 year planning period should not be considered. However, at times engineering consultants may find it more appropriate to perform the alternatives comparison over a longer time period. In this instance, the alternatives analysis can be adjusted to the 20 year project planning period with appropriate salvage value.

The cost-effectiveness analysis is not affected by the source of funds, but compares costs uniformly for each alternative. The analysis includes non-monetary factors like environmental effects, implementation capability, operability, performance reliability and flexibility. Some factors, such as the use and recovery of energy and scarce resources and the recycling of nutrients should be included in both the monetary and non-monetary cost analyses. The most cost-effective alternative is the alternative that has the lowest present worth value unless non-monetary costs are overriding. This alternative must meet the minimum requirements of applicable effluent limitations, groundwater protection, and other applicable standards. The following cost factors are associated with monetary evaluation:

1. Sunk Costs

Sunk costs are any investments or financial commitments made before or during facilities planning. These are not to be included in the cost-effectiveness analysis since they are incurred regardless of the alternative selected. Sunk costs include the cost of existing facilities and associated land, outstanding bond indebtedness and the cost of preparing the wastewater facilities plan.

2. Present Worth

Present worth, or net present value, is the sum of money that, if invested now at a given interest (discount) rate, would provide exactly the funds required to pay all present and future costs of the project over the planning period. It considers initial capital cost, O&M costs and salvage value at the end of the planning period. The recommended discount rate to be used in computing present worth is established by the U. S. Water Resources Council for each fiscal year (October 1 – September 30) and is communicated by EPA to DEP on an annual basis. Contact your DEP regional representative for the latest discount rate.

Capital construction costs used in a cost-effectiveness analysis shall include all construction costs including overhead and profit, land, relocation, rights-of-way, easement acquisitions, design engineering, field exploration, engineering services during construction, administrative and legal services including costs of bond sales, startup costs such as operator training and interest during construction. Capital costs shall also include contingency allowances depending on the cost estimate's level of detail.

The cost-effectiveness analysis includes the present worth of the annual O&M costs including routine replacement of equipment parts. These costs shall be adequate to ensure effective and dependable operation during the project planning period. Annual O&M costs shall be divided between fixed annual costs and variable costs.

3. Useful Life

The useful life of various project components to be used in a cost-effectiveness analysis should fall within the following ranges:

- Land - permanent.
- Piping - 50 years.
- Other Structures (plant buildings, tanks, basins, pumping, etc.) - 30 to 50 years.
- Process Equipment - 15 to 20 years.
- Auxiliary Equipment - 10 to 15 years.

Major components with a useful life of less than the planning period should show the present value of the replacement cost.

4. Salvage Value

Portions of the project's structures and equipment may have monetary value beyond the planning period and should be reflected in salvage value. If the structures and equipment have reached the end of their useful life during the planning period, the salvage value may be scrap value.

5. Interest During Construction

If interest during construction is anticipated to vary significantly from alternative to alternative, it may be included in the cost-effectiveness analysis using one of the following methods:

- If expenditures are uniform and the construction period is less than 4 years, interest is calculated as the product of the construction period (in years), the total capital expenditures (in dollars), and the discount rate.

- Where expenditures will not be uniform, or where the construction period will be greater than 4 years, interest during construction shall be calculated on a year-by-year basis.

6. Construction Staging

Applicants may wish to stage construction to make projects more affordable or to provide flexibility for uncertain growth. As a guideline, the staging period should be based on the following (where Q_f is the flow at the end of the 20-year planning period and Q_i is the flow at the initiation operation):

Q_f/Q_i Ratio	Staging Period (years)
Less than 1.3	20
1.3 to 1.8	15
greater than 1.8	10

7. Green Technologies

"Green" technologies which save energy or water or satisfy other relevant criteria are considered by design engineers at all decision-making levels including system, unit process and component levels. Such technologies should receive careful consideration and should be proposed if they are cost-effective. Applicants should be prepared to discuss their thought process on green technologies with their DEP project manager.

Applicants who select green technologies may be asked to describe the basis for the decision in a brief "business case" report. The documentation of green technology use will display the environmental awareness of the applicant as well as increase the likelihood of project funding.

8. Cost Estimation

Construction cost estimates reflect standard engineering practice as used for preliminary planning. Estimates of cost for nutrient credits are based on recent experience as documented on the PENNVEST website. To see the results from previous auctions go to pennvest.state.pa.us, click on the Nutrient Credit Trading box, then the "market" link.

9. Examples

Example 1 shows how to calculate present worth and equivalent annual cost for one wastewater treatment facility option. The analysis should be performed on all options being considered before selecting the most cost-effective alternative that also meets any necessary non-monetary factors such as environmental effects, implementation capability, operability, performance reliability and flexibility. Example 2 shows how to determine the break-even point between a capital project and a nutrient credit purchase.

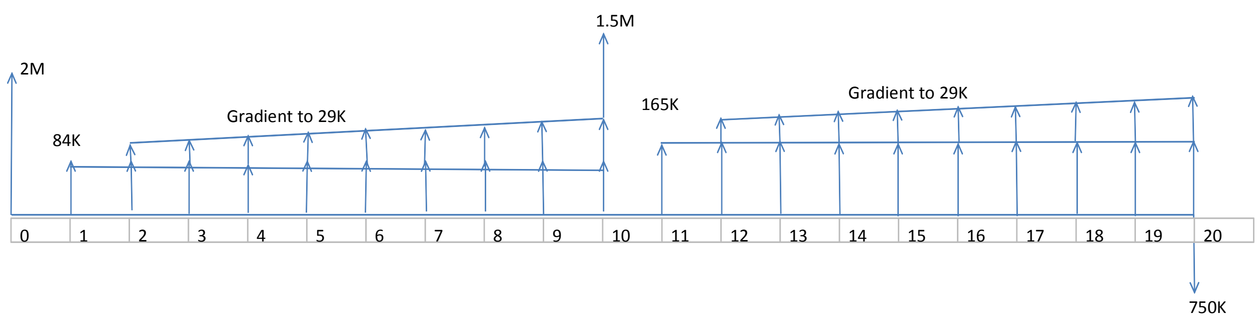
Example 1: A new wastewater treatment facility is needed. One alternative is to stage the construction. The facility will have a capacity of 5 MGD for years 1 through 10 of its life and 10 MGD for years 10 through 20.

Determine: Present Worth and Equivalent Annual Cost of this plant over the 20-year life.

Given:

- The estimated salvage value at the end of 20 years is $750,000.
- The estimated cost for constructing the 5 MGD plant is $2,000,000 and the estimated cost of the expansion to 10 MGD in year 11 (i.e. at the end of year 10) is $1,500,000.
- The estimated annual fixed O&M costs for years 1 through 10 are $84,000/year.
- The estimated annual fixed O&M costs for years 11 through 20 are $165,000/year.
- The estimated variable O&M costs for years 1 through 10 are $0 in year 1 to $29,000 in year 10, increasing linearly.
- The estimated variable O&M costs for years 11 through 20 are $0 in year 11 to $29,000 in year 20, increasing linearly.
- The Discount Rate is 7.625 percent.

Cash Flow Diagram – Costs at the end of each year over the 20 year planning period



Method: Present Worth considers the initial capital cost, operation and maintenance costs (years 1-10), expansion costs, O&M costs for years 11 through 20 and salvage value. Equivalent Annual Cost equals the present worth multiplied by the appropriate capital recovery factor.

Step 1:

Initial Capital Cost $ 2,000,000

Step 2:

Present Worth Of Constant Operating and Maintenance Costs

A. Present Worth of constant annual cost for years 1 through 10 equals given cost multiplied by the uniform series present worth factor for 7.625 percent for 10 years (6.825). Therefore,

   $84,000 (6.825) = $ 573,300

B. Present Worth of constant annual cost for years 11 through 20 equals given cost multiplied by the uniform series present worth factor for 7.625 percent for 10 years (6.825). However, this yields the present worth for year 10, which must be converted to the present worth for year 0. This is accomplished by multiplying the present worth for year 10 by a single payment present worth factor at 7.625 percent for 10 years. Therefore,

   $165,000 (6.825) (0.4796) = $ 540,100

Step 3:

Present Worth Of Variable Operating and Maintenance Costs

A. Present Worth of the variable O&M costs for years 1 through 10 is calculated using a gradient series where the gradient or slope is $29,000 / (10-1 years). The gradient factor is multiplied by the present worth factor for a gradient series for 7.625 percent and 10 years. Thus,

   ($29000 / 9) (26.612) = $ 85,700

B. Present Worth of variable annual cost for years 11 through 20 equals gradient cost multiplied by the gradient series present worth factor for 7.675 percent for 10 years (26.612). However, this yields the present worth for year 10, which must be converted to the present worth for year 0. This is accomplished by multiplying the present worth for year 10 by a single payment present worth factor at 7.625 percent for 10 years. Therefore,

   ($29,000 / 9) (26.612) (0.4796) = $ 41,100

Step 4:

Present Worth of the expansion cost that occurs at year 10 must be multiplied by the single payment present worth factor for 7.625 percent for 10 years to calculate present worth of the expansion at year zero (0). Thus,

Present Worth of expansion ($1,500,000) (0.4796) = $ 719,400

Step 5:

Present Worth of the salvage value at the end of 20 years equals the salvage value multiplied by the single payment present worth factor for 7.625 percent and 20 years (0.230). Therefore,

$750,000 (0.230) = $ 172,500

Step 6:

The sum of the values obtained in steps 1 through 4 minus the value obtained in step 5 is equal to the present worth of the plant. Thus,

Initial Capital Cost	$	2,000,000
Present Worth of constant O&M years 1 - 10:	$	573,300
Present Worth of constant O&M years 11 - 20:	$	540,100
Present Worth of variable O&M years 1 - 10:	$	85,700
Present Worth of variable O&M years 1: - 20:	$	41,100
Present Worth of expansion at year 10:	$	719,400
Subtotal	$	3,959,600
Minus present worth of salvage value:	$	172,500
Present Worth of Plant	$	3,787,100

Step 7:

Multiply present worth of plant from Step 6 by the capital recovery factor for 7.625 percent and 20 years (0.099) to get:

Equivalent Uniform Annual Cost = $3,787,100 (0.099) = $ 375,000

Example 2: Some wastewater treatment facility owners are required to remove nitrogen from their effluent. In some cases their existing treatment plants are otherwise fully functional but lack the ability to remove nitrogen. Decisions need to be made to either upgrade existing plants or replace them with new BNR technology. Facility owners in the Chesapeake Bay drainage area also have a third option, which is to purchase nitrogen credits instead of constructing nitrogen-removing capability at their facility. The reasoning is that if you pay someone else to remove the nitrogen elsewhere it has the same effect on the waterbody as removing it at your facility. The advantage of such an option is that it provides flexibility for owners and their consultants to choose alternatives that are cost-effective given the variables that exist in any wastewater system. Options can be priced which use credits for any portion of the planning period (e.g. 1 year, 20 years or anywhere in between).

This example is simplified so that it demonstrates the above principle in as brief a form as possible. New effluent limitations other than nitrogen may be factors, variations in O&M costs, the condition of the existing facility and other site-specific issues will all be relevant. The important concept to recognize is that a substantial sum of money can potentially be saved by continuing to use an otherwise good facility while postponing the capital expense of the new facility through credit purchases.

There are numerous ways to acquire credits. Credits can be generated at other treatment facilities owned by the applicant. They can be purchased directly from neighboring treatment facility owners. Treatment facility owners can pay local farmers to generate credits which can be used for treatment facility obligations. Credits can also be purchased through a state auction process. Engineers should creatively consider this basket of options and determine what makes sense for their client.

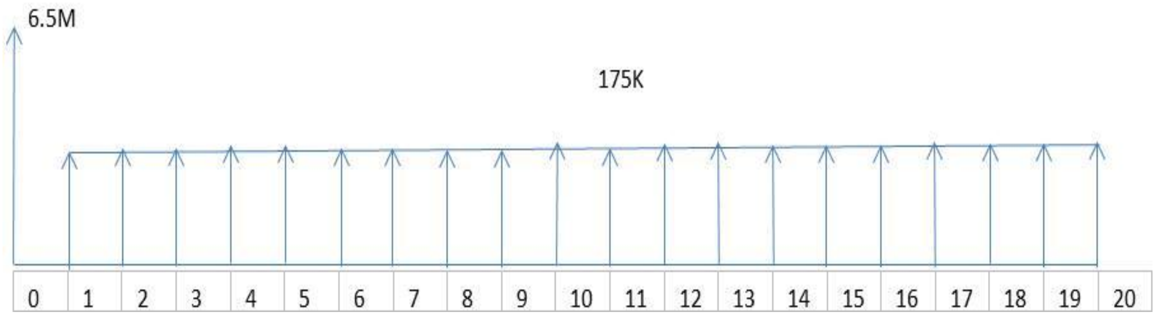
The goal of the approach in this example is to encourage cost-effective choices. It may be that current costs warrant the use of credits for a few years, but if an engineer is tasked to immediately make a conservative 20-year recommendation the outcome is likely to involve immediate construction. The approach used in this example encourages annual analysis to determine whether credit purchasing is or remains the most cost effective approach. Similarly, the analysis may be performed over a longer period of time if credits can be purchased under a longer term contract. This example assumes in both scenarios – one year and multiple year credit contracts, the engineer has evaluated capital construction options and has selected the most cost-effective alternative to compare to the use of credits.

> Determine: Break-even price for nitrogen credits - Short-Term Nutrient Control with Credits vs. Immediate BNR Facility
>
> Method: Set the equivalent uniform annual cost of each alternative equal to each other and solve for cost per credit.

Alternative #1: Construct the most cost-effective BNR plant now

Given:
- 1 MGD
- $6.5M capital cost
- $175,000 annual O&M cost
- $0 salvage value for new plant
- Discount rate 4.125%

Cash Flow Diagram – Costs at the end of each year over the 20 year planning period



Uniform series present worth 4.125% @ 20 years = 13.44
Single payment present worth 4.125% @ 20 years = 0.4455
Capital recovery factor 4.125% @ 20 years = 0.0744

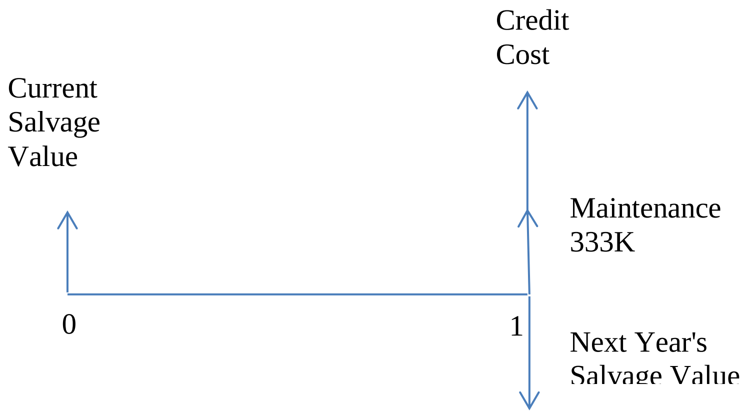
Present Worth = Capital cost + (Annual O&M x Uniform series present worth factor) – (salvage value x Single payment present worth factor)
= $6.5M + ($175,000 x 13.44) – ($0 x 0.4455)
= $8.852M

Equivalent Uniform Annual Cost = Present Worth x Capital Recovery Factor
= $8.852M x 0.0744
= $658,588

Alternative #2: Keep the old plant for one more year and buy credits

Given:
- The new plant is required to reduce the nitrogen concentration from 30 mg/l to 6 mg/l
- Old plant maintenance cost next year = $333,000 / year
- The old plant has been paid off
- Current salvage value = $0
- Next year salvage value = $0

Cash Flow Diagram: Costs at the end of each year



Note that this methodology follows the convention of keeping all costs and benefits related to the existing facility with the existing facility. As such, the current salvage value hinders the existing facility's cash flow and is in fact an opportunity cost; the cost associated with keeping the plant for another year instead of selling it or scrapping it.

Calculation of credits needed:

1 MGD x (30-6 mg/l) x 8.34 x 365 days/year = 73,058 pounds of nitrogen/year.

Present Worth Calculation:

Present Worth = Current Salvage Value + [Credit Cost + Maintenance Cost – Next Year's Salvage Value] x Single Payment Present Worth Factor

Where Single Payment Present Worth Factor 4.125% @ 1 year = 0.9604

Present Worth = 0 + [Credit Cost + $333,000 – 0] x 0.9604

Present Worth = 0.9604 x Credit Cost + $319,808

Equivalent Uniform Annual Cost Calculation:

Equivalent Uniform Annual Cost = Present Worth x Capital Recovery Factor

Where Capital Recovery Factor 4.125% @ 1 year = 1.04125

Equivalent Uniform Annual Cost = [$319,808 + .9604 x Credit Cost] x 1.04125

Equivalent Uniform Annual Cost = $333,000 + Credit Cost

Set Alternatives 1 and 2 Equivalent Uniform Annual Costs equal to each other and solve for Credit Cost:

$333,000 + Credit Cost = $658,588

Credit Cost = $325,588

However, Credit Cost = (Cost/Credit x Number of Credits Required)

Solving for the breakeven Cost/Credit:

Cost/Credit = $325,588/73,058 pounds = $4.46 per pound of nitrogen

Conclusion: If you can buy nitrogen credits for less than $4.46 per pound then buy them and postpone construction of the new facility until conditions change.

As an aside, if this facility had to purchase both nitrogen and phosphorus credits the same breakeven point exists. One would merely have to confirm that the combined credit purchases are below $325,588 for this option to remain attractive over immediate construction.