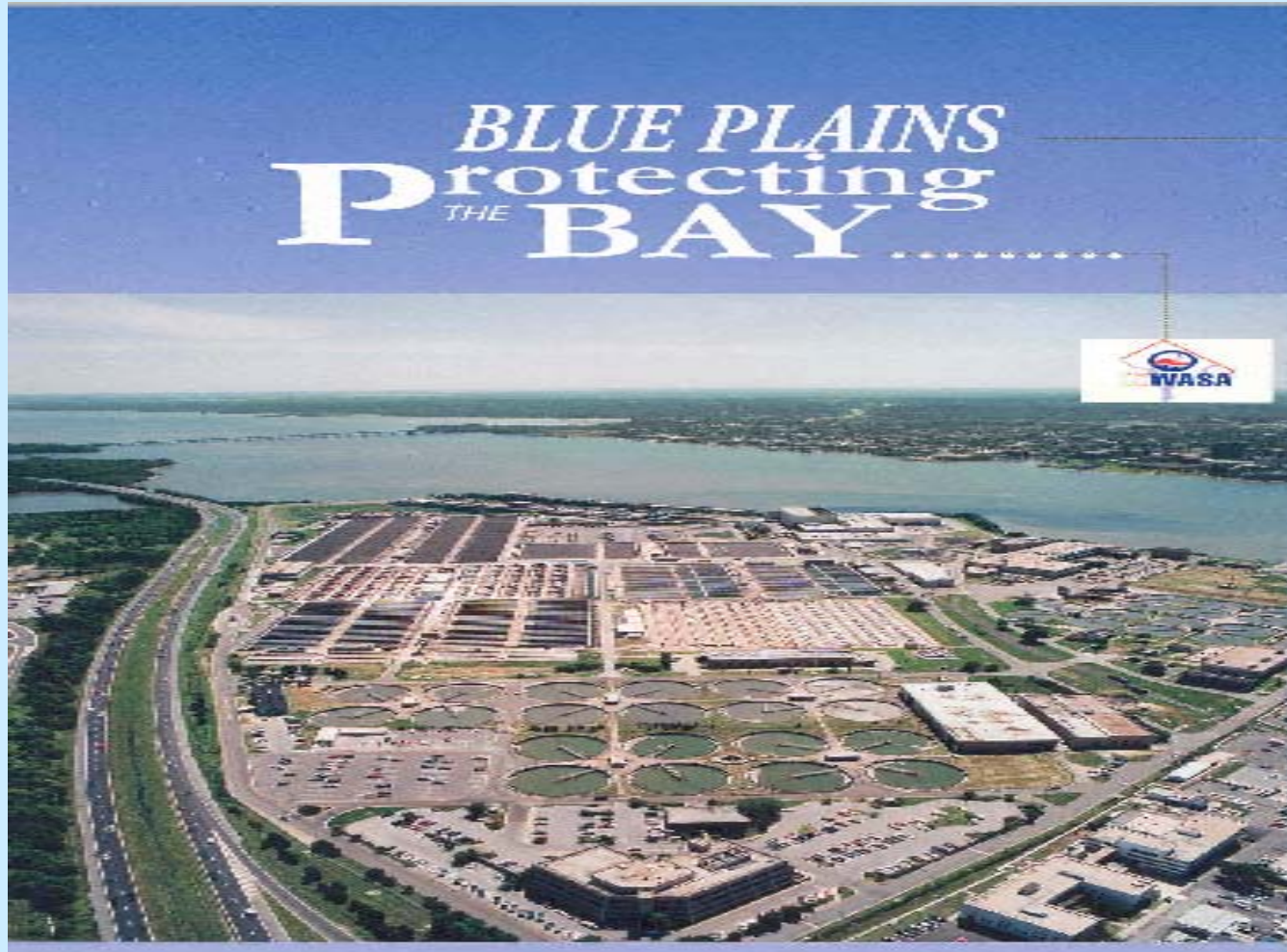


# Decision for DCWASA

“SELECT CHEMICALS TO IMPROVE WASTEWATER TREATMENT PROCESS”



# Overview

- DCWASA, District of Columbia Water and Sewer Authority, is the largest wastewater treatment plant in the world.
- Wastewater is treated from MD, VA, and DC.
- DCWASA serves more than two million people and the average flow to the plant is 370 million gallons per day.

# Overview

- Nitrification and Denitrification process
  - These processes reduce the amount of nitrogen in wastewater, which will be discharged to Potomac river.



*Denitrification demonstration reactors and sedimentation basins at the Blue Plains Facility are outlined in orange. The control basin is outlined in blue.*

# Overview

- Nitrification and Denitrification process
  - However, the nitrification and denitrification processes change the wastewater alkalinity.
  - To maintain a target residual alkalinity of 80 mg/l as CaCO<sub>3</sub>, supplemental alkalinity addition to the nitrification process is required
  - From 1981-2001, additional alkalinity for the process at DCWASA was provided by lime.

# Overview

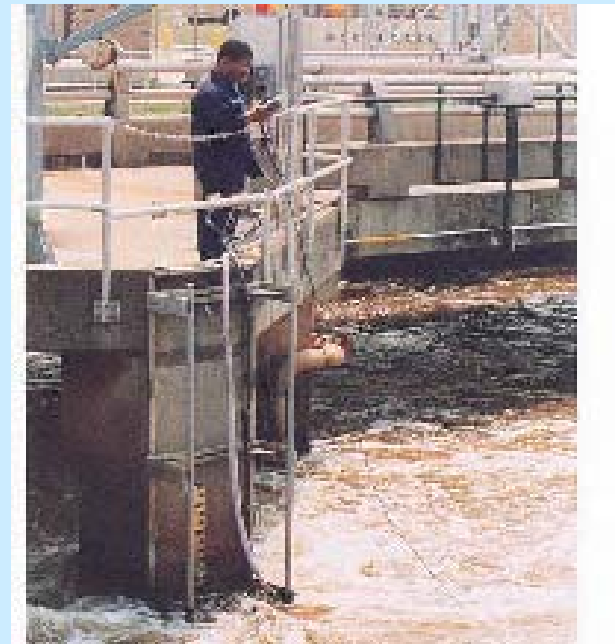
- For years, the lime storage and feed facilities have experienced **repeated failures** and require nearly **continual maintenance**
- In addition, the lime facilities created additional plant maintenance issues according to migration of lime **dust**.
- As the result, DCWASA decided to construct the temporary **Sodium Hydroxide Facilities** in 2000.

# Overview

- This facility satisfies the alkalinity needs of the nitrification process.
- However, **costs for sodium hydroxide are high**, especially compared to lime, and are wide variation because sodium hydroxide is produced as a byproduct of production of chlorine based compounds.
- Also, sodium hydroxide is a **very hazardous chemical** which can effect to those who work in facility and around facility.

# Objective

- Select 1) the chemical and 2) the alternative for the nitrification and denitrification process according to
  - 1.safety
  - 2.cost
  - 3.store and maintenance
  - 4.effect to process



# Select chemicals

Given DCWASA's past history with lime and sodium hydroxide, as part of the preliminary design of the nitrification facilities, these chemicals were evaluated for use in providing supplemental alkalinity.

1. Lime (CAO)
2. Sodium hydroxide (NaOH, Caustic soda)
3. Potassium hydroxide (KOH)
4. Magnesium hydroxide (Mg(OH)<sub>2</sub>)
5. Sodium carbonate (Soda ash)



# Select chemicals

## **Subjective rating chemicals**

From the given information, we ask the administrator and his team to order this chemicals based on these aspects

- 1.safety
- 2.cost
- 3.store and maintenance
- 4.effect to process

# Select chemicals

	1. Magnesium hydroxide	2. Potasium hydroxide	3.Soda ash	4.Hydrated lime	5.NaOH
<b>safety</b>	much less harzard to handle when compared with NaOH and KOH	hazard as NaOH			require a lot of safety measures for safe handling and storage more harzardous than lime
<b>cost</b>	comparatively high required the installation of an entirely new chemical feed facility	weight 40% greater than NaOH so 40% more KOH is required to provide the same alkalinity adjustment same price as NaOH	2 times as much as lime to change the same alkalinity high chemical cost compared to lime	less expensive than other chemicals considered	more expensive than lime cost is variable
<b>store and maintenance</b>	easy to ship and store but can form deposite in pipelines and valves, increasing maintenance requirments and costs,	can be store and fed from the existing NaOH facilities	installation of a new chemical storage and feed system would be required must be stored and pumped at temperature greater than 100 F have potential of foaming due to generation of carbon dioxide	difficult and maintenance-intensive to handle	easier to maintain than lime facilities
<b>effect to process</b>				provide a divalent cation may be beneficial in terms of sludge settleability and dewatering	<b>MAY</b> negatively impact sludge settleability and dewatering
<b>PH</b>	maximum ph 9.5	strong base ph.>13.5	the range of 11	range 12.0	>=13.5

# Select chemicals

chemical substance	safety	cost	store and maintenance	effect to process
<b>1. Magnesium hydroxide</b>	3	3	2	1
<b>2. Potasium hydroxide</b>	1	1	5	1
<b>3.Soda ash</b>	4	3	2	2
<b>4.Hydrated lime</b>	4	5	1	5
<b>5.NaOH</b>	1	2	5	3

# Select chemicals

However, to make this rate more meaningful, the administrator and their experienced team have to rate the different levels in the scale, indicating how much each level is worth relative to other levels.

weight for each attribute	0.2	0.3	0.3	0.2
chemical substance	safety	cost	store and maintenance	effect to process
<b>1. Magnesium hydroxide</b>	50	60	20	0
<b>2. Potassium hydroxide</b>	0	0	100	0
<b>3. Soda ash</b>	70	60	20	30
<b>4. Hydrated lime</b>	70	100	0	100
<b>5. NaOH</b>	0	30	100	50

# Select chemicals

Over all Score for each chemical	
1. Magnesium hydroxide	34
2. Potassium hydroxide	30
3. Soda ash	44
4. Hydrated lime	64
5. NaOH	49

# Find alternatives

1. Operate only the existing NaOH facility
2. Construct the smaller Lime facility and continually operate NaOH facility,  
“Combined facilities”

# Find alternatives

- For the **two chemicals we selected, Lime and NaOH, a more detailed evaluation was performed.**
- We evaluate in terms of the capital, operating, and maintenance costs on the twenty years life cycle basis
- Since **the existing sodium hydroxide facilities** are new (2001), in good operational order, and have sufficient volume to store sodium hydroxide more than 10 days of average, facilities **will not require any capital improvement**

# Find alternatives

- Compared to **Lime facility**, the current condition of facilities is **out of date**, we need to pay substantial capital for a new facility. Also, using lime facilities to satisfy the alkalinity demand will require a large lime facility, which would be used **infrequently**.
- Therefore, using only lime to satisfy the alkalinity demand will **not be financially advantage**.

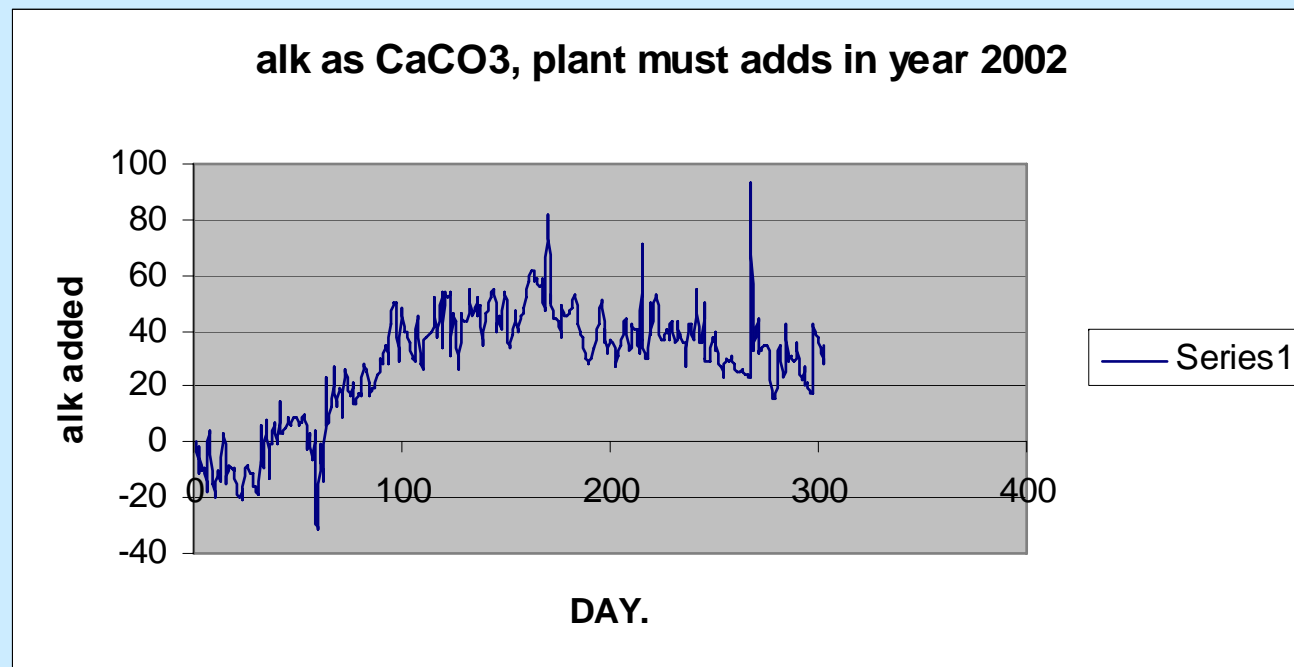


# Find alternatives

- Another alternative will be considered. **The lime facilities will be sized** to handle the alkalinity demand that the plant need during a year and **the existing sodium hydroxide facilities will be used** to satisfy additional demand
- Therefore, we have two alternatives for making decision
  1. Operate only NaOH facility
  2. Construct smaller Lime facility and continue using NaOH facility. We will call “Combined facility”

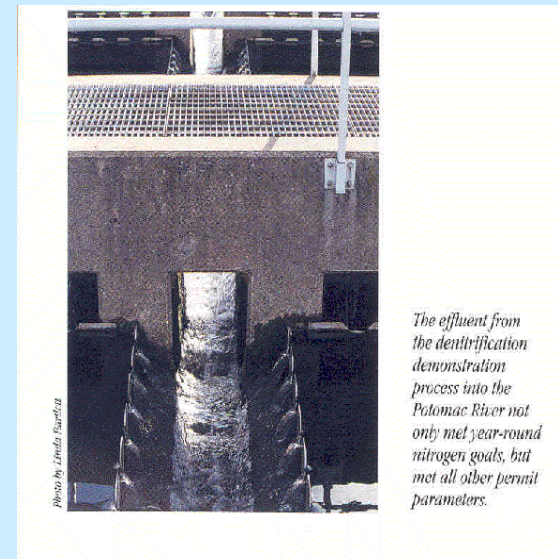
# Additional alkalinity year 2002

From the history data, Jan-Oct year 2002, the alkalinity as  $\text{CaCO}_3$  we need to add to wastewater to maintain the standard alkalinity in wastewater, **80 mg/l** is shown below



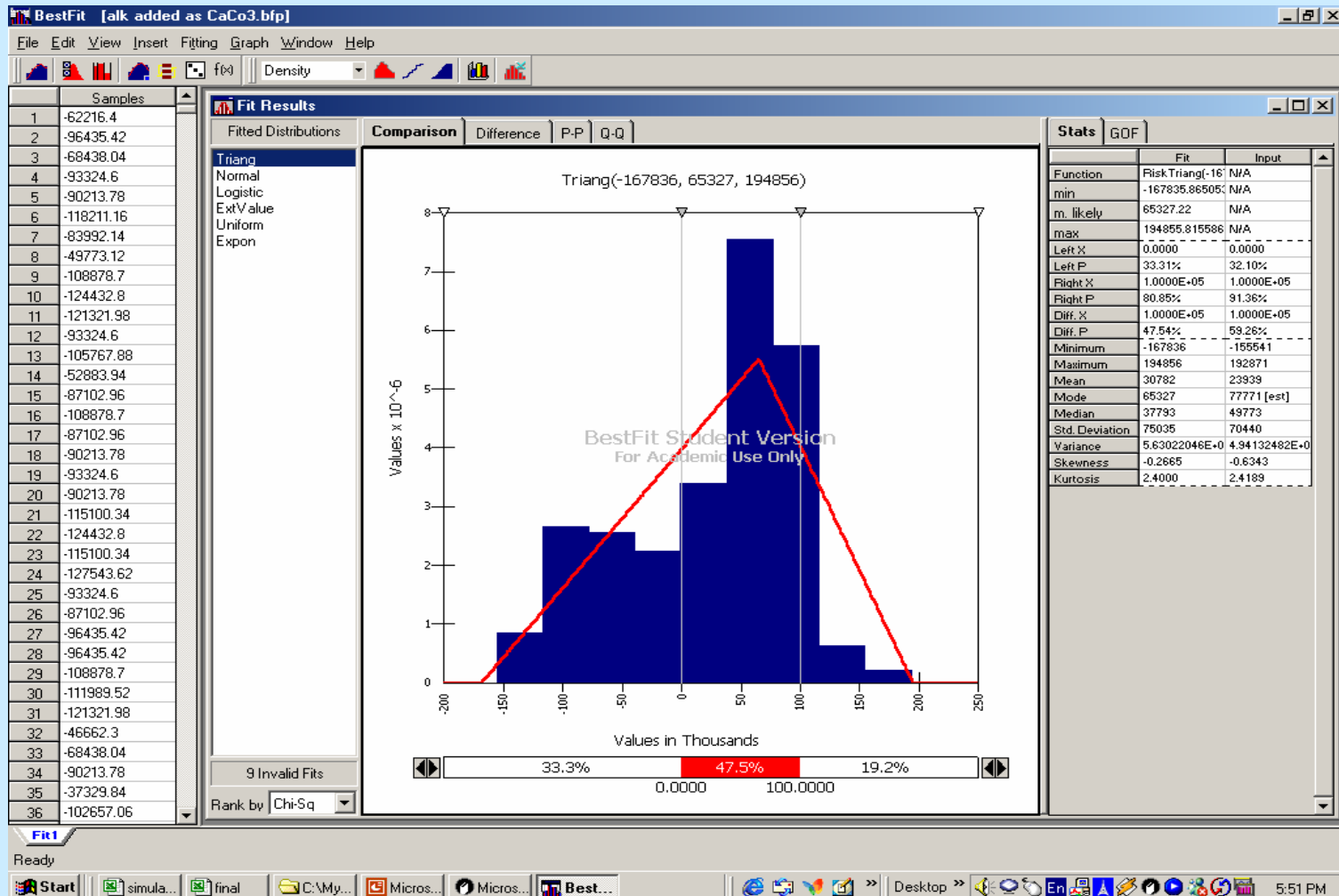
# Additional alkalinity year 2002

- lbs/day as  $\text{CaCO}_3$  = MGD X 8.34 X mg/l  $\text{CaCO}_3$
- Avg. plant influent = 373 million gallon per day

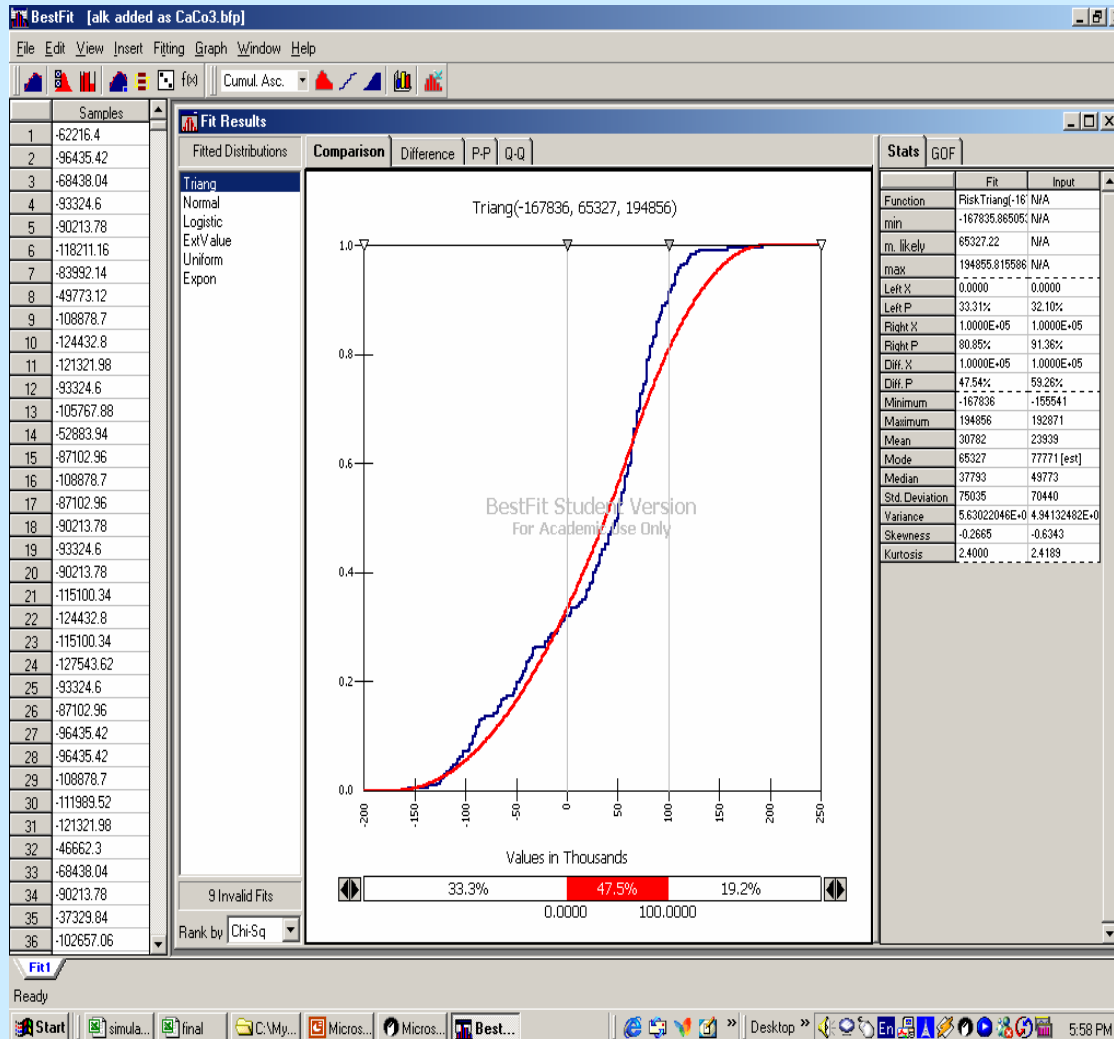


# Additional alkalinity year 2002

From Bestfit, the distribution of additional alkalinity is in the form of triangular distribution.



# Additional alkalinity year 2002

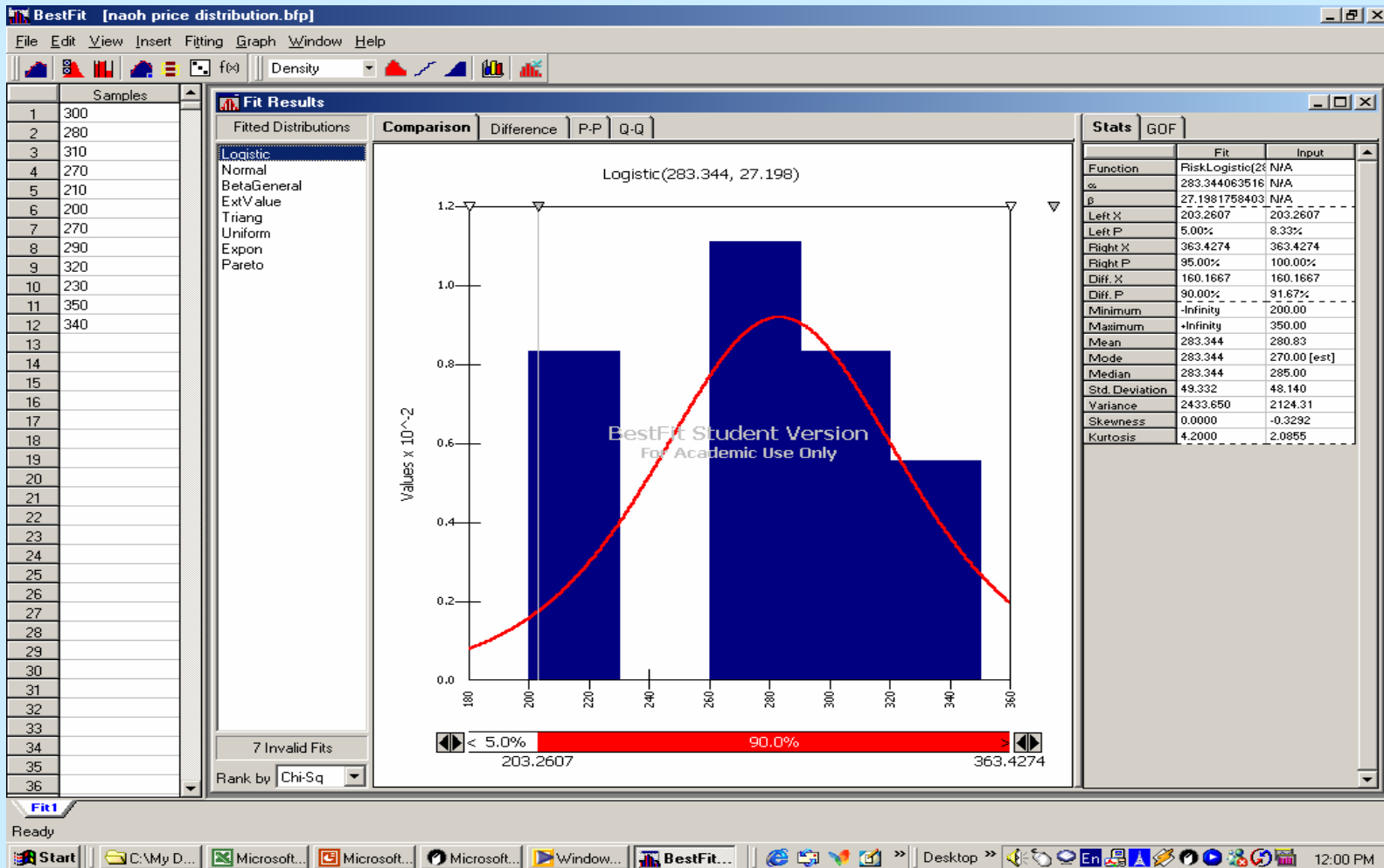


- From cdf, 33% of the year we don't need to add alkalinity
- 66.67% of the year we need to add from
- 0-192871 lbs/day as CaCO<sub>3</sub>.

# Cost of chemical

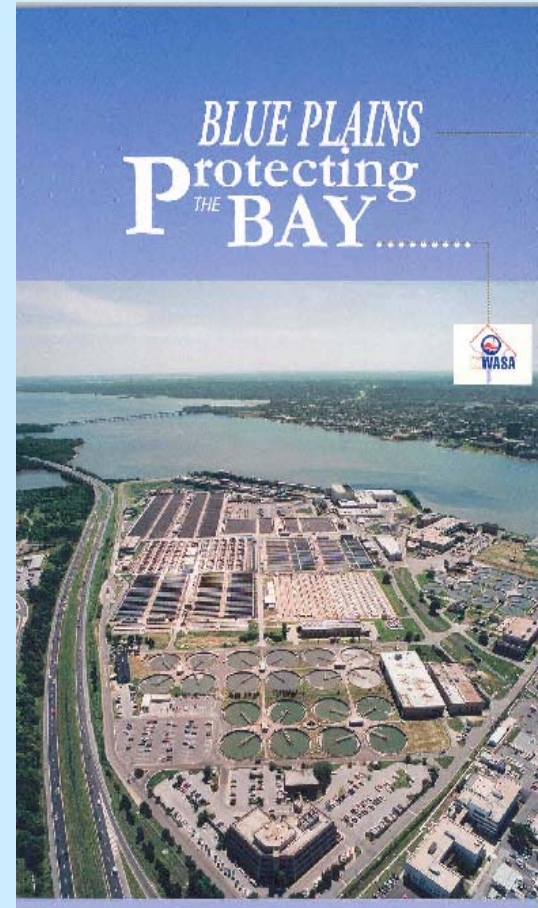
- Lime cost is around \$70-\$72/ ton, which does not fluctuate much compared to NaOH.
- NaOH price is varied from \$0.20-\$0.35/kg, based on the historical data we do contract with contractor.

# Cost of chemical



# Find overall cost

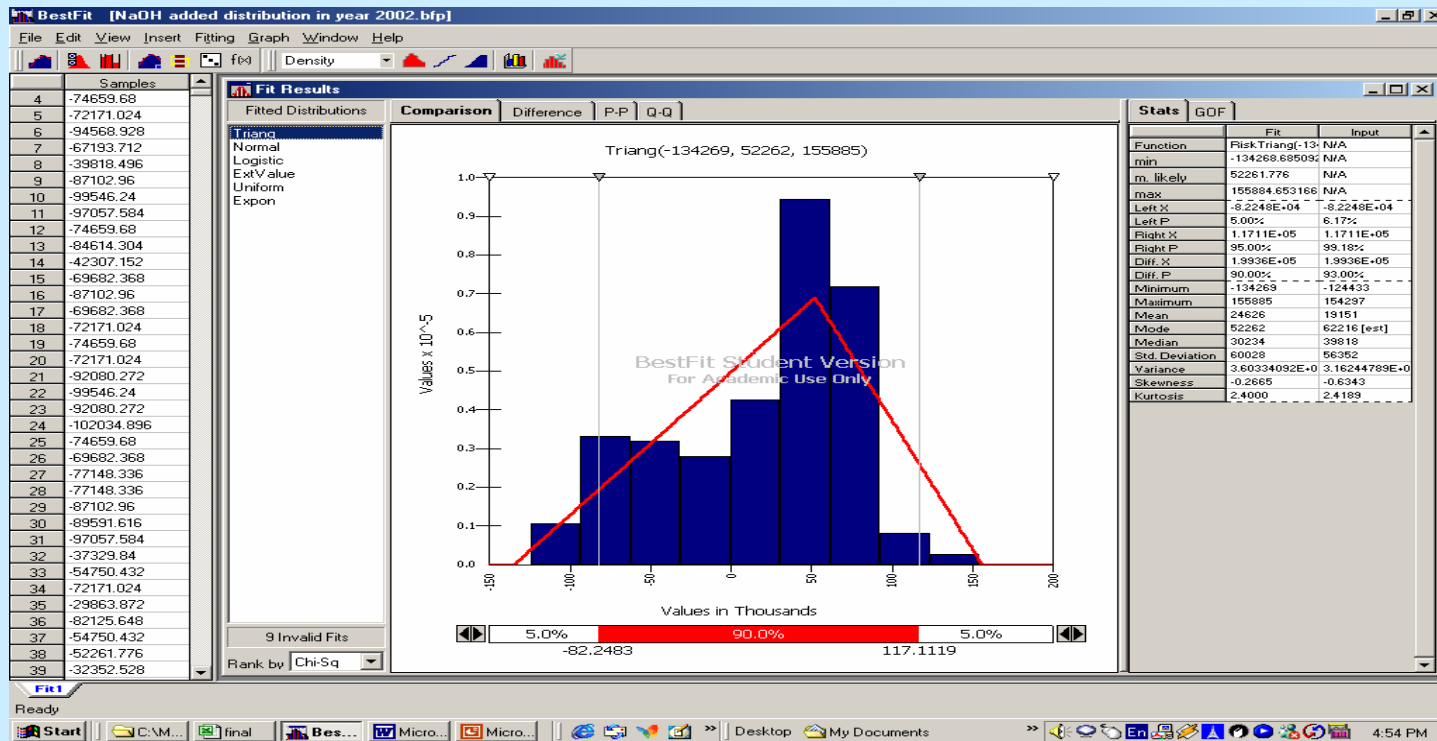
- NaOH only alternative
- Combined facility alternative





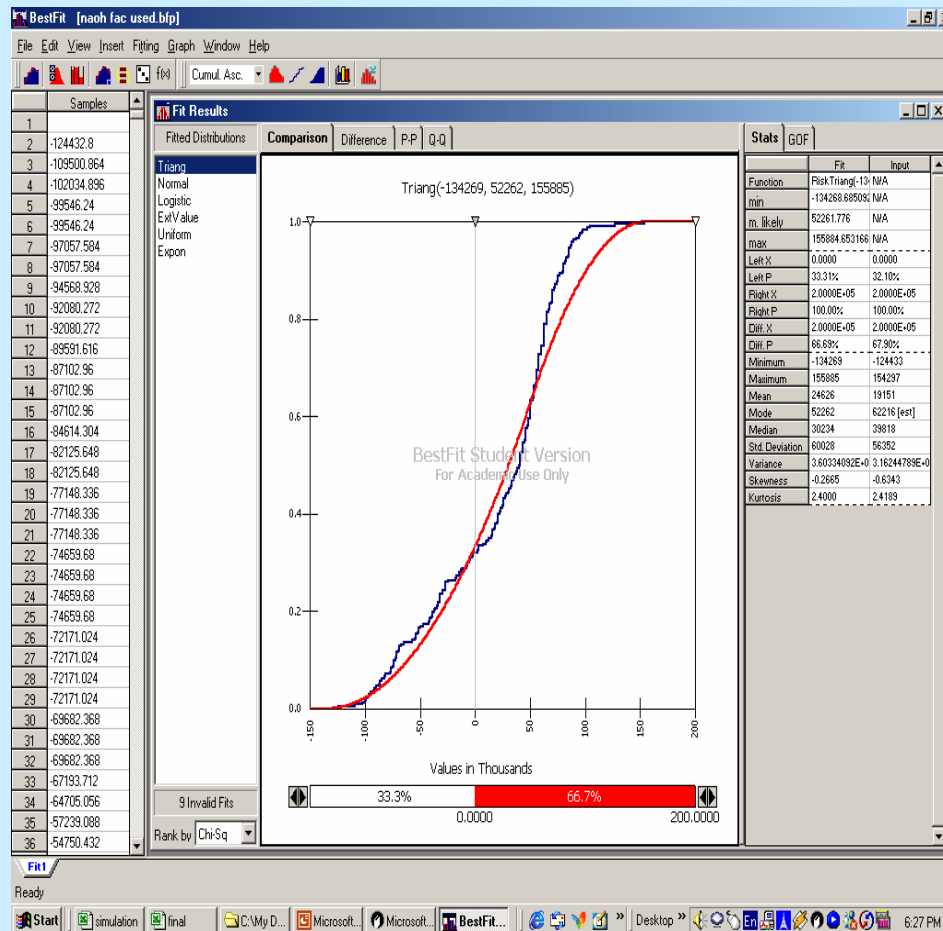
# NaOH only facility

- The amount of NaOH used in this facility can calculate by lbs/day as  $\text{NaOH} = \text{lbs/day as CaCO}_3 \times \text{eq.wt. NaOH} (40)/\text{eq.wt. CaCO}_3(50)$



# NaOH only facility

- We add NaOH 66.67% of year

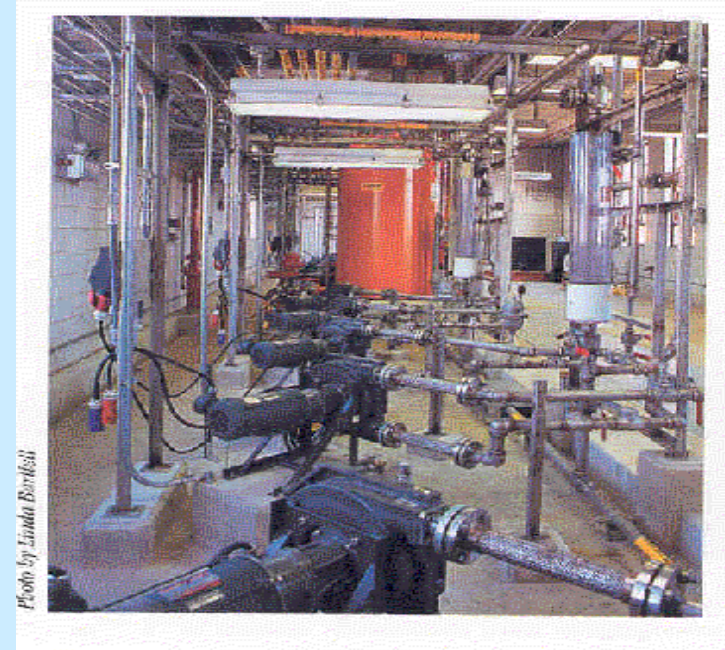


# NaOH only facility

Amount of NaOH used per day						
	lbs/day	ton/day				
most likely	19151	8.675403				
max	154297	69.896541				
min	0	0				
naoh used(lbs/day)	naoh used(t0n)	%naoh used	naoh price(ton)	naoh cost		
19151	8.675403	0.6667	320	675558.5		
<b>1.cost of continued use of the NaOH facility</b>						
cost component	type of cost	cost	present worth 3%*20years		max	min
capital cost	single	-	-			
amount of NaOH used(ton/day)		8.67			69.89	0
price of NaOH(Price/dry ton)		320.00			320	256
annual operation cost for NaOH facilities	annuity	23,432.00	348,609.00	fixed cost	383,469.90	313,748.10
annual maintenance cost for NaOH facilities	annuity	13,320.00	198,168.00	fixed cost	217,984.80	178,351.20
cost of NaOH facility for 20 years	14,049,532.10					

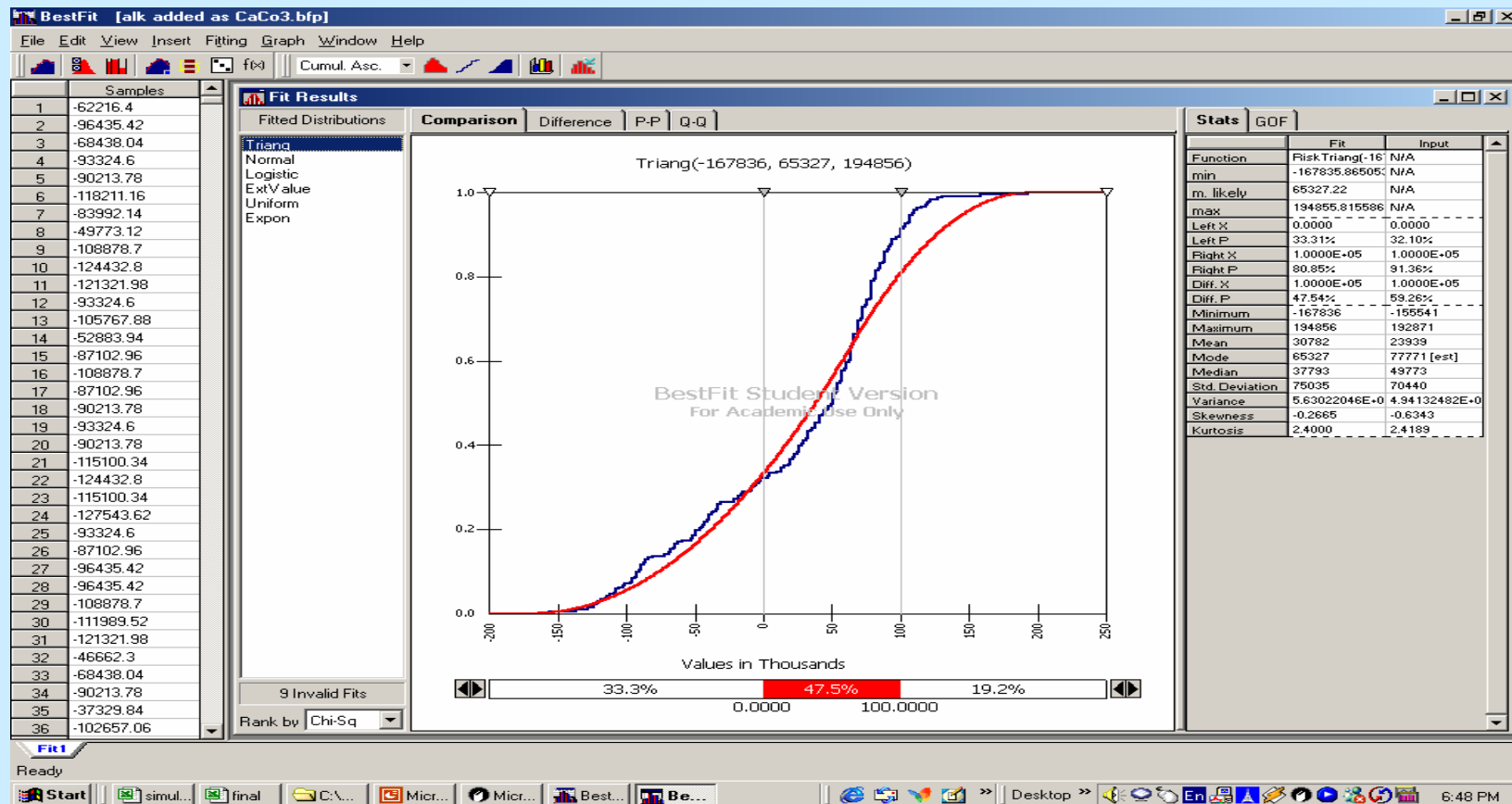
# NaOH only facility

- We estimate the cost of operating NaOH facility equaled to \$14000000



# Combined facility

Construct small lime facility and continue using the existing NaOH facilities



# Combined facility

## Construct small lime facility and continue using the existing NaOH facilities

From the cdf graph of alk added as CaCO<sub>3</sub> year 2002 we can see that

- 1).33.3% of year we don't need to add any alkalinity
- 2).47.5% of year we added alkalinity as CaCO<sub>3</sub> from 0-100,000 lbs/day
- 3).19.2% of year we added alkalinity as CaCO<sub>3</sub> from 100000-194856 lbs/day

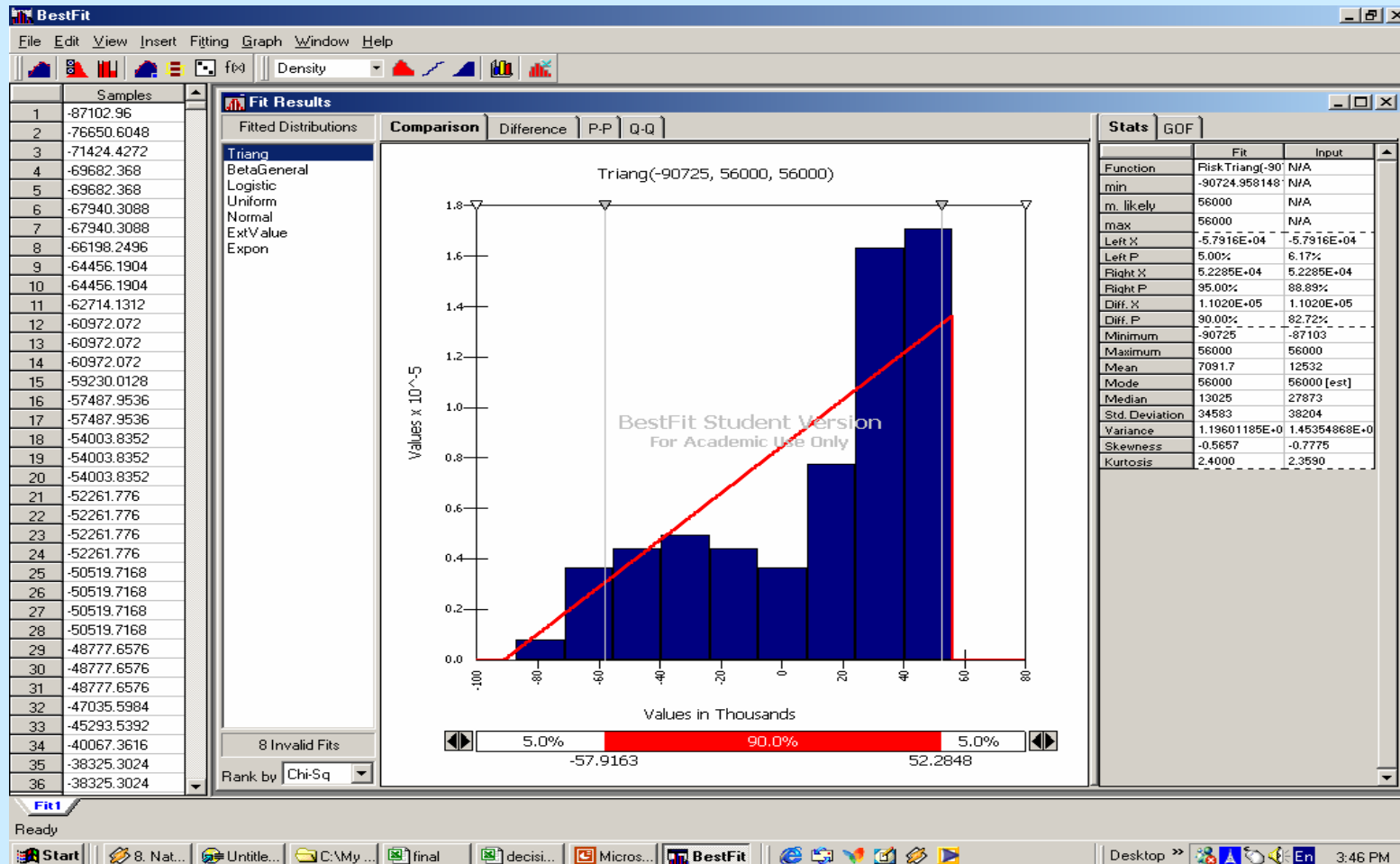
Therefore we decide another alternative for this problem, That is we creat a smaller lime facility by sizing the new lime facility that meets

- the 66.67%(47.5%+19.2%) alkalinity as CaCO<sub>3</sub> requirement(0-100000lbs/day) and then use the existing NaOH facility when the alkalinity requirment is over the capacity of this lime facility. That is 19.2% of year.(100000-194856lbs/day)

We call this alternative "combined facility"

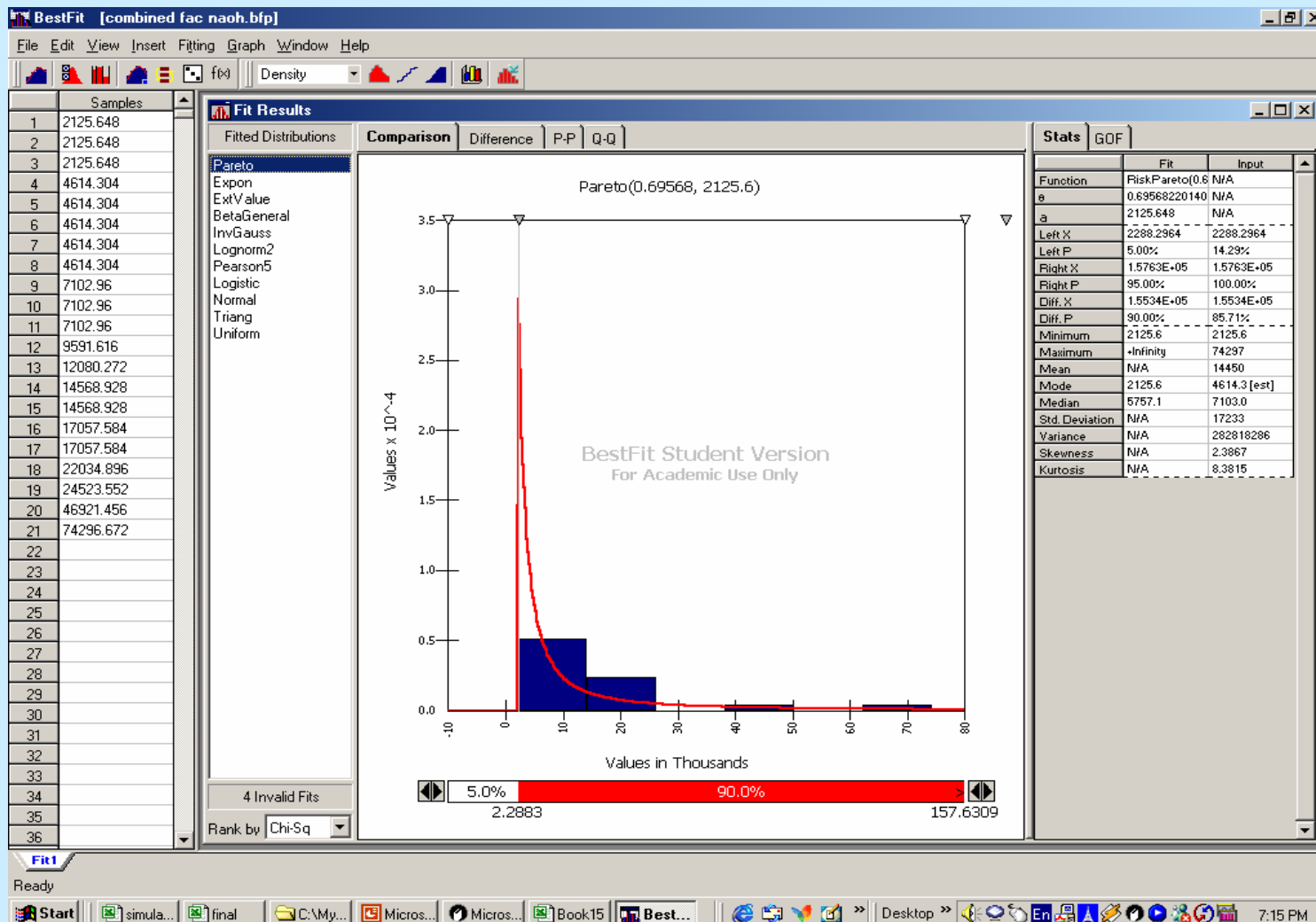
# Combined facility

Lime added for alkalinity as CaCO<sub>3</sub> requirement(range 0-100000lbs/day)



# Combined facility

NaOH added for alkalinity as CaCO<sub>3</sub> requirement (range > 100000 lbs/day)







# Combined facility

lime used(lbs/day)	lime used(t0n)	%lime used	lime price(ton)	lime cost				
12532	5.676996	0.6667	72	99465.94297				
naoh used	naoh used(t0n)	%naoh used	naoh price	naoh cost				
14450	6.54585	0.192	320	146794.6138				
combined cost								
246260.5567								
<b>sensitivity analysis for combined facility</b>								
cost component			type of cost	cost	present worth 3%		max	min
demolition costs			single	1220000	1220000	fixed cost	-	-
capital cost for construction of new package			single	394000	394000	fixed cost	401880	394000
amount of lime(ton/day)				5.67			25.368	0
price of lime (cost per ton)				70			72	70
annual operation cost for lime facilities			annuity	17453	259654	fixed cost	285619.4	233688.6
annual maintenance cost for lime facilities			annuity	22503	334786	fixed cost	368264.6	301307.4
annual cleaning grid removal cost			annuity	66150	984145	fixed cost	-	-
amount of NaOH				6.54			33.66	0.96
price of NaOH				320			320	256
annual operation cost for NaOH facilities			annuity	17107	254507	fixed cost	279957.7	229056.3
annual maintenance cost for NaOH facilities			annuity	23304	346705	fixed cost	381375.5	312034.5
slaker overhaul( after 10 years )			single	40000	40000	fixed cost	-	-
Manufacturing cost in 20 years				8698742.059				

# Combined facility

- We estimate the cost of operating Combined facility that equals to \$8.6million



# Sensitivity analysis

NaOH facility

Sensitivity analysis NaOH facility					
1.cost of continued use of the NaOH facility					
cost component		cost	max	min	
amount of NaOH used(ton/day)		8.67	69.89	0	
price of NaOH(Price/dry ton)		320	350	200	
annual operation cost for NaOH facilities		348609	383469.4	313747.7	
annual maintenance cost for NaOH facilities		198168	217984.3	178350.8	

# Sensitivity analysis

NaOH facility

**TopRank**

File Edit Settings Variables Execute Results Window Help

Open Save Settings +Output List Step WhatIf Results Graph Multi Hide Wizard

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**Results**

Outputs

Cell	Name	Current
C15	total cost / cost	14049532.1

Most Significant Inputs for total cost / cost in C15

Rank	Cell	Name	Output Max	When Input Value=	Output Min	When Input Value=
#1	C8	amount of NaOH used(ton/day) / cost	+678.633%	69.89	-96.108%	0
#2	C9	price of NaOH(Price/dry ton) / cost	+9.01%	350	-36.041%	200
#3	C10	annual operation cost for NaOH facilities / cost	+248%	383469	-.248%	313747
#4	C11	annual maintenance cost for NaOH facilities / cost	+141%	217984	-.141%	178350

Summary Detail Percent% Actuals Change Sort

---

**Detail By Input**

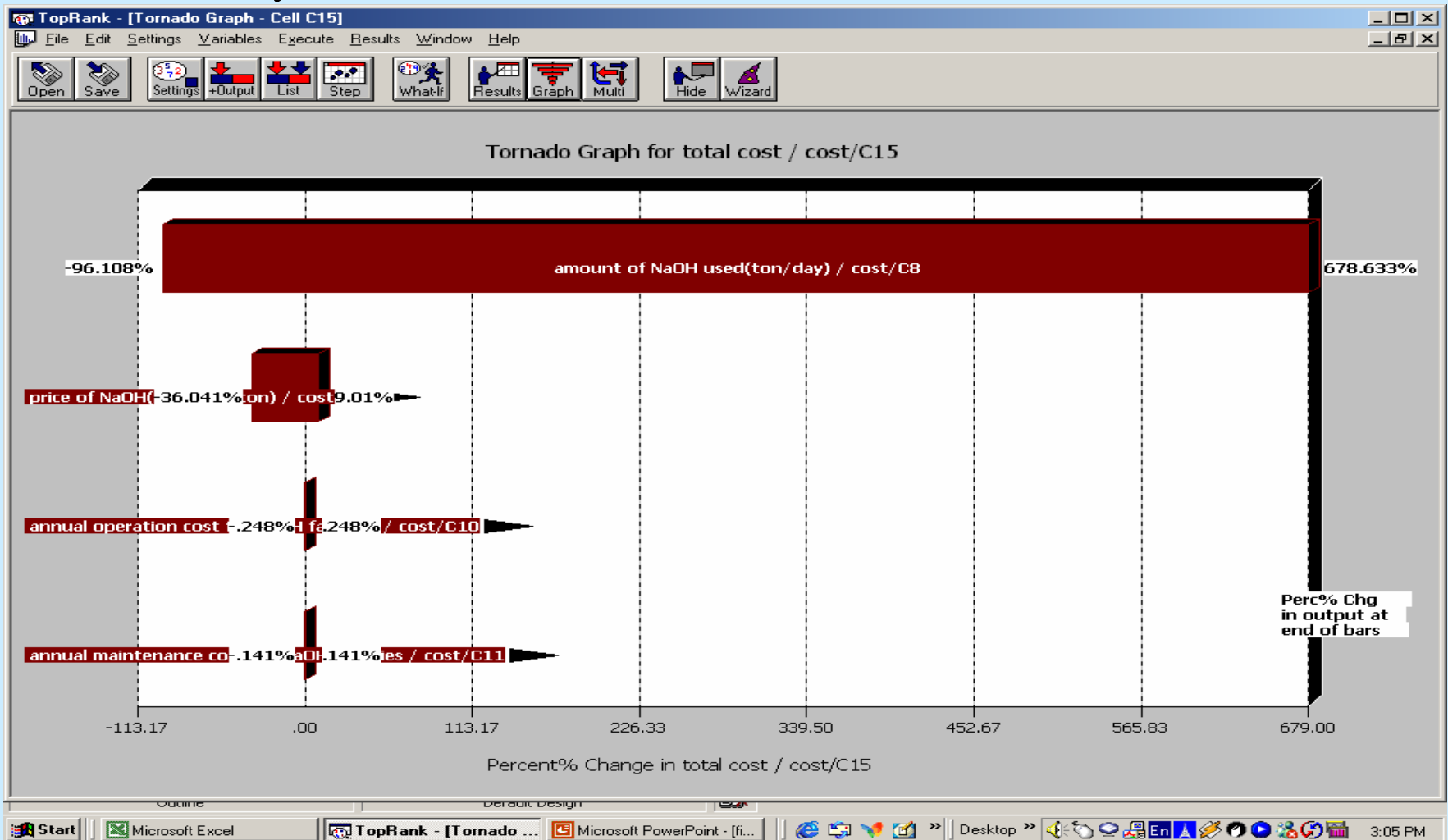
Input Values Used:		Output %Change from Base:	
Cell	Input Name	Value Used	%Chg
			total cost / cost
			C15
C8	amount of NaOH used(ton/day) / cost	0	-100%
C8	amount of NaOH used(ton/day) / cost	23.29667	+168.704% +162.139%
C8	amount of NaOH used(ton/day) / cost	46.59333	+437.409% +420.386%
C8	amount of NaOH used(ton/day) / cost	69.89	+706.113% +678.633%
C9	price of NaOH(Price/dry ton) / cost	200	-37.5%
C9	price of NaOH(Price/dry ton) / cost	250	-21.875%
C9	price of NaOH(Price/dry ton) / cost	300	-6.25%
C9	price of NaOH(Price/dry ton) / cost	350	+9.375%
C10	annual operation cost for NaOH facilities / cost	313747	-10.%

Current Variables: 1 output, 4 inputs Defaults: Auto ID on, vary inputs -10% to 10%, default distribution= Uniform, default steps= 4

Start Microsoft Excel TopRank Microsoft PowerPoint - [fi... Desktop 3:04 PM

# Sensitivity analysis

## NaOH facility



# Sensitivity analysis

Combined facility

sensitivity analysis for combined facility					
cost component	cost	present worth 3%	max	min	
demolition costs	1220000	1220000	-	-	
capital cost for construction of new package	394000	394000	401880	394000	
amount of lime(ton/day)	5.67		25.368	0	
price of lime (cost per ton)	70		72	70	
annual operation cost for lime facilities	17453	259654	285619.4	233688.6	
annual maintenance cost for lime facilities	22503	334786	368264.6	301307.4	
annual cleaning grid removal cost	66150	984145		-	
amount of NaOH	6.54		33.66	0.96	
price of NaOH	320		320	256	
annual operation cost for NaOH facilities	17107	254507	279957.7	229056.3	
annual maintenance cost for NaOH facilities	23304	346705	381375.5	312034.5	
slaker overhaul( after 10 years )	40000	40000	-	-	

# Sensitivity analysis

## Combined facility

**TopRank**

File Edit Settings Variables Execute Results Window Help

Open Save Settings +Output List Step What-If Results Graph Multi Hide Wizard

**Results**

Outputs

Most Significant Inputs for Manufacturing cost in 20 years / single in D18

Rank	Cell	Name	Output Max	When Input Value=	Output Min	When Input Value=
#1	D11	amount of NaOH / cost	+139.832%	33.66	-28.771%	0.96
#2	D6	amount of lime(ton/day) / cost	+77.147%	25.368	-22.206%	0
#3	D12	price of NaOH / cost	+0.000%	320	-6.744%	256
#4	E14	annual maintenance cost for NaOH facilities / present worth 3%	+3.99%	381375	-.399%	312034
#5	E9	annual maintenance cost for lime facilities / present worth 3%	+3.85%	368264	-.385%	301307
#6	D7	price of lime (cost per ton) / cost	+6.34%	72	0.000%	70
#7	E8	annual operation cost for lime facilities / present worth 3%	+2.98%	285619.4	-.298%	233688.6
#8	E13	annual operation cost for NaOH facilities / present worth 3%	+2.93%	279957	-.293%	229056
#9	E5	capital cost for construction of new package / present worth 3%	+0.9059%	401880	0.000%	394000

Summary Detail Percent% Actuals Change Sort

**Detail By Input**

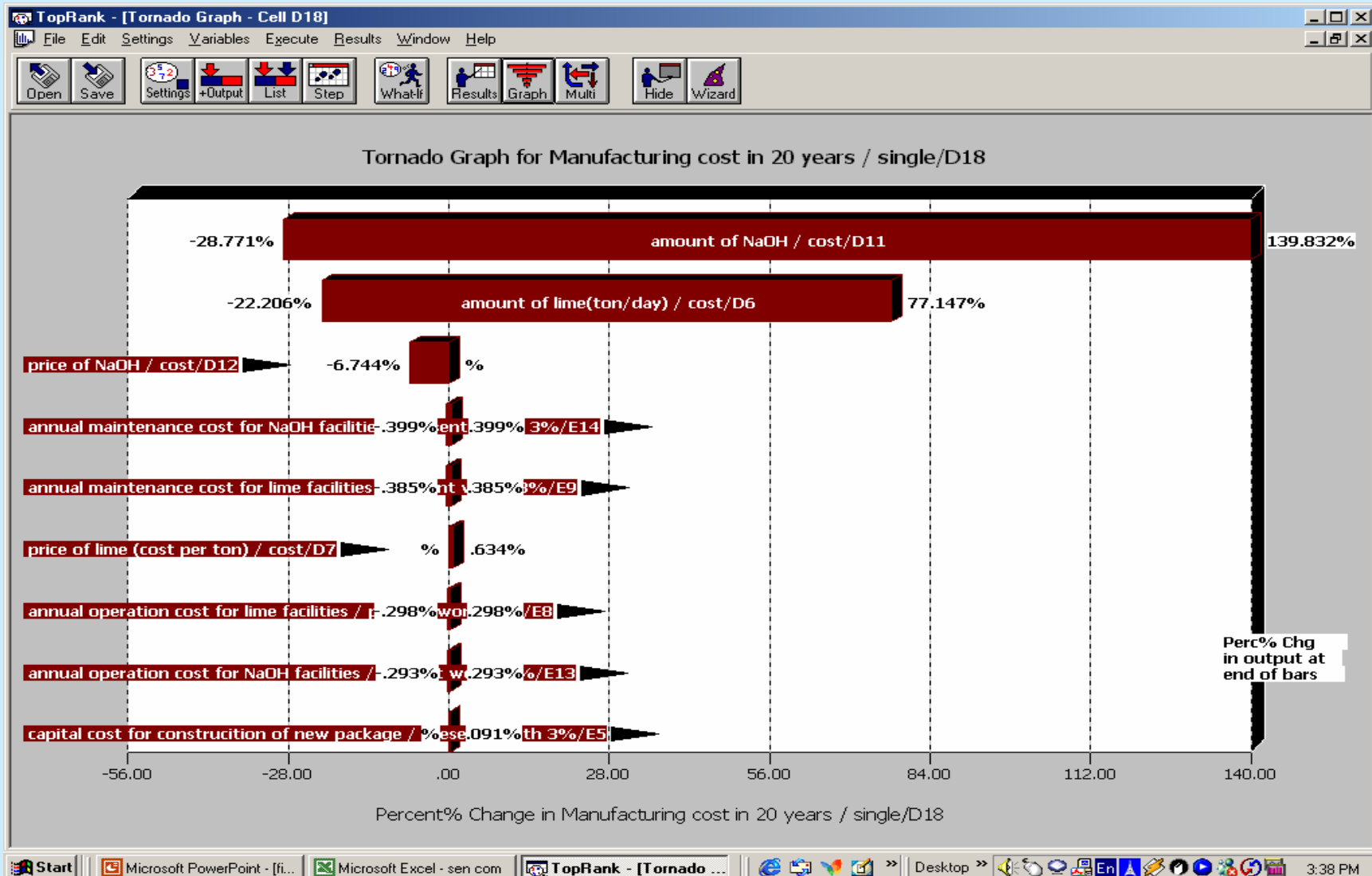
Cell	Input Name	Value Used	%Chg	Output %Change from Base: D18
D11	amount of NaOH / cost	0.96	-85.321%	-28.771%
D11	amount of NaOH / cost	11.86	+81.346%	+27.43%
D11	amount of NaOH / cost	22.76	+248.012%	+83.631%
D11	amount of NaOH / cost	33.66	+414.679%	+139.832%
D12	price of NaOH / cost	256	-20%	-6.744%
D12	price of NaOH / cost	277.3333	-13.333%	-4.496%
D12	price of NaOH / cost	298.6667	-6.667%	-2.248%
D12	price of NaOH / cost	320	0%	0.000%
E13	annual operation cost for NaOH facilities / present worth 3%	229056	-10.0%	-.293%
E13	annual operation cost for NaOH facilities / present worth 3%	246023	-3.334%	-.09753%
E13	annual operation cost for NaOH facilities / present worth 3%	262990	+3.333%	+.09752%
E13	annual operation cost for NaOH facilities / present worth 3%	279957	+10.0%	+.293%

Current Variables: 1 output,9 inputs Defaults: Auto ID on, vary inputs -10% to 10%, default distribution= Uniform, default steps= 4

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# Sensitivity analysis



# Sensitivity analysis(summary)

- NaOH facility
- Most significant input
  - 1.amount of NaOH when input maximum, 69.89 tons
  - 2.price NaOH when input maximum
  - 3.annual operation cost
  - 4.annual maintenance cost

# Sensitivity analysis(summary)

- Combined facility
- Most significant input
  - 1.amount of NaOH when input 33.66 tons(maximum)
  - 2.amount of Lime (maximum)
  - 3.price NaOH
  - 4.annual maintenance cost NaOH
  - 5.annual maintenance cost Lime
  - 6.price of lime

# Simulation

## Simulation NaOH facility

input amount NaOH added-triangular

-max 69.89, min 0, most likely 8.67

input price of NaOH-logistic

-alpha 283.34, beta 27.198

input operation cost-uniform

-max 383469, min 313747

input maintenance cost-uniform

-max 217984, min 178350

# Simulation

Simulation NaOH facility(amount NaOH=tri, price=logistic)

The screenshot displays the @RISK - Results window. The left sidebar shows a tree view with 'Outputs' (C14 - naohcost) and 'Inputs' (C7- amount of NaOH used(ton/yr), C8- price of NaOH(Price/dry ton), C9- annual operation cost for NaOH, C10- annual maintenance cost for NaOH). The main area shows a 'Summary Statistics' table with the following data:

	Name	Cell	Minimum	Mean	Maximum	x1	p1	x2	p2	x2-x1	p2-p1
Output 1	naohcost	C14	3789061	3.667007E+07	1.168884E+08	8277350	5%	7.420362E+07	95%	6.592628E+07	90%
Input 1	amount of NaOH used(ton/yr)	C7	1.54152	26.1487	64.8727	5.462293	5%	54.32742	95%	48.86513	90%
Input 2	price of NaOH(Price/dry ton)	C8	150.3735	283.7438	432.2253	201.8951	5%	362.6919	95%	160.7968	90%
Input 3	annual operation cost for NaOH	C9	313873.8	348575.9	383012.4	316914.7	5%	379442.1	95%	62527.41	90%
Input 4	annual maintenance cost for NaOH	C10	178622.7	198182.3	217843.7	180183.9	5%	215725.6	95%	35541.75	90%

The bottom status bar shows 'Ready', 'Sim# 1 of 1', 'Iter# 100 of 100', 'Runtime 00:00:00', and 'Sec/Iter 0'. The Windows taskbar at the bottom shows the Start button, several open applications (simula..., C:\My..., final, Micros..., C:\My..., Micros..., @RI...), and the system clock at 3:20 PM.

# Simulation

## Simulation NaOH facility(amount and price NaOH=normal)

@RISK - Results - [Summary Statistics]

File Edit View Insert Simulation Results Graph Window Help

Outputs

- Sheet2!D19 - combined fac cost
- Sheet1!C14 - naohcost

Inputs

- Sheet2!E6- capital cost for const
- Sheet2!D7- amount of lime(ton/c
- Sheet2!D8- price of lime (cost pe
- Sheet2!E9- annual operation cos
- Sheet2!E10- annual maintenanc
- Sheet2!D12- amount of NaOH /
- Sheet2!D13- price of NaOH / co
- Sheet2!D14- annual operation c
- Sheet2!D15- annual maintenanc
- Sheet1!C7- amount of NaOH use
- Sheet1!C8- price of NaOH(Price
- Sheet1!C9- annual operation cos
- Sheet1!C10- annual maintenanc

	Name	Worksheet	Cell	Minimum	Mean	Maximum	x1	p1	x2	p2	x2-x1
Output 1	combined fac cost	Sheet2	D19	5266291	9748086	2.037549E+07	5940024	5%	1.406597E+07	95%	8125942
Output 2	naohcost	Sheet1	C14	7.998211E+09	2.544289E+10	4.672726E+10	1.030935E+10	5%	3.925479E+10	95%	2.894544
Input 1	capital cost for construction o	Sheet2	E6	394024.4	397585.5	401701.6	394204.4	5%	401271.1	95%	7066.625
Input 2	amount of lime(ton/day) / cost	Sheet2	D7	1.385257	9.837104	21.31527	2.789531	5%	18.63352	95%	15.84399
Input 3	price of lime (cost per ton) / cc	Sheet2	D8	70.02737	71.02232	71.96542	70.11518	5%	71.87304	95%	1.757858
Input 4	annual operation cost for lime	Sheet2	E9	234275.7	258539.6	284893.5	235916.3	5%	281927	95%	46010.67
Input 5	annual maintenance cost for li	Sheet2	E10	304778	337706.6	367555.3	306068.5	5%	365274.4	95%	59205.91
Input 6	amount of NaOH / cost	Sheet2	D12	1.039758	6.482465	23.70564	1.135802	5%	14.73035	95%	13.59455
Input 7	price of NaOH / cost	Sheet2	D13	202.1964	280.1169	346.3143	208.6097	5%	338.9034	95%	130.2937
Input 8	annual operation cost for NaO	Sheet2	D14	229395.4	253696.3	279599.2	231398.5	5%	277796.6	95%	46398.06
Input 9	annual maintenance cost for N	Sheet2	D15	312254	348883.3	380455.3	316268.8	5%	377800.4	95%	61531.56
Input 10	amount of NaOH used(ton/da	Sheet1	C7	7751.56	19016.98	35496.9	10272.46	5%	28367.99	95%	18095.53
Input 11	price of NaOH(Price/dry ton) /	Sheet1	C8	142.1405	272.9084	390.0318	191.1672	5%	352.0019	95%	160.8346
Input 12	annual operation cost for NaO	Sheet1	C9	313796.2	350673.8	383276.1	315356.4	5%	381376.9	95%	66020.5
Input 13	annual maintenance cost for N	Sheet1	C10	178799.7	197081.7	217801	179032.2	5%	215330.6	95%	36298.41

Tab 1 Tab 2 Tab 3 Tab 4 Tab 5 Tab 6 Tab 7 Tab 8

Ready

Sim# 1 of 1 Iter# 100 of 100 Runtime 00:00:00 Sec/Iter 0

Start Mic... Win... Book1 simul... C:\... Best... Best... @... Desktop 4:13 PM

# Simulation

## Simulation Combined facility

The screenshot displays the @RISK - Results window, which provides a detailed summary of simulation statistics. The interface includes a menu bar (File, Edit, View, Insert, Simulation, Results, Graph, Window, Help), a toolbar with various icons, and a tree view on the left showing the simulation structure with 'Outputs' and 'Inputs' sections. The main area is dominated by the 'Summary Statistics' table, which lists 10 simulation components (Output 1 to Input 9) with their respective statistical data. The status bar at the bottom indicates the simulation is ready, with 100 iterations completed in 00:00:00 runtime.

	Name	Cell	Minimum	Mean	Maximum	s1	p1	s2	p2	s2-s1	p2-p1
Output 1	combined fac cost	D19	4845241	9982860	2.399951E+07	5905638	5%	1.465979E+07	95%	8754152	90%
Input 1	capital cost for construction o	E6	394059.7	397941.3	401860.1	394315.5	5%	401454.6	95%	7139.125	90%
Input 2	amount of lime(ton/day) / cost	D7	0.2573767	10.33254	23.24848	2.563816	5%	20.30206	95%	17.73824	90%
Input 3	price of lime (cost per ton) / co	D8	70.01199	71.00166	71.99149	70.08067	5%	71.88659	95%	1.805916	90%
Input 4	annual operation cost for lime	E9	233934.7	259653.8	285456.3	236017.5	5%	282837.2	95%	46819.75	90%
Input 5	annual maintenance cost for li	E10	301466.9	334785.6	368069.8	304307.6	5%	364542	95%	60234.41	90%
Input 6	amount of NaOH / cost	D12	0.9945989	6.461738	29.51982	1.212967	5%	17.36744	95%	16.15447	90%
Input 7	price of NaOH / cost	D13	200.3447	280.3575	349.8268	219.6082	5%	335.6001	95%	115.9919	90%
Input 8	annual operation cost for NaO	D14	229110.9	254530.8	279570.2	231155.9	5%	277116.9	95%	45961.06	90%
Input 9	annual maintenance cost for N	D15	312131.3	346714.2	381366.8	315436.7	5%	377447.9	95%	62011.25	90%

# Simulation

## Simulation Combined facility

@RISK - Results - [Summary Statistics]

File Edit View Insert Simulation Results Graph Window Help

	Name	Worksheet	Cell	Minimum	Mean	Maximum	x1	p1	x2	p2	x2-x1	p2-p1
Output 1	combined fac cost	Sheet2	D19	5704667	9850986	1.589666E+07	6114530	5%	1.382431E+07	95%	7709783	90%
Output 2	naohcost	Sheet1	C14	5303254	3.771695E+07	1.088158E+08	9772934	5%	7.993962E+07	95%	7.016669E+07	90%
Input 1	capital cost for construction o	Sheet2	E6	394059.4	398062.7	401816.4	394679.3	5%	401653.2	95%	6973.906	90%
Input 2	amount of lime(ton/day) / cost	Sheet2	D7	3.026812	10.87426	24.64968	3.81323	5%	19.76338	95%	15.95015	90%
Input 3	price of lime (cost per ton) / cc	Sheet2	D8	70.00431	71.0278	71.97704	70.02419	5%	71.86671	95%	1.842522	90%
Input 4	annual operation cost for lime	Sheet2	E9	235713.5	263890.8	285593.5	236867	5%	284704.5	95%	47837.47	90%
Input 5	annual maintenance cost for li	Sheet2	E10	301572.1	336288.5	368112.6	305261.8	5%	366511.4	95%	61249.69	90%
Input 6	amount of NaOH / cost	Sheet2	D12	0.96672	5.758353	21.43416	1.125033	5%	15.62404	95%	14.499	90%
Input 7	price of NaOH / cost	Sheet2	D13	210.2153	278.5442	344.437	224.6456	5%	331.6539	95%	107.0083	90%
Input 8	annual operation cost for NaO	Sheet2	D14	229268.4	253503.5	279491.8	231880.8	5%	277472.5	95%	45591.67	90%
Input 9	annual maintenance cost for N	Sheet2	D15	312665.1	343524.3	381296.3	313419.2	5%	378996.1	95%	65576.94	90%
Input 10	amount of NaOH used(ton/da	Sheet1	C7	5.036067	27.29482	65.52349	6.95714	5%	56.90235	95%	49.94521	90%
Input 11	price of NaOH(Price/dry ton) /	Sheet1	C8	156.2205	279.2614	436.9416	193.6117	5%	369.3955	95%	175.7839	90%
Input 12	annual operation cost for NaO	Sheet1	C9	313924	349830.8	383365.1	317824.8	5%	377467.7	95%	59642.94	90%
Input 13	annual maintenance cost for N	Sheet1	C10	178635.5	198957.4	217956.3	180544.4	5%	216287.8	95%	35743.42	90%

Ready  
Ready

Tab 1 Tab 2 Tab 3 Tab 4 Tab 5 Tab 6 Tab 7 Tab 8

Sim# 1 of 1 Iter# 100 of 100 Runtime 00:00:01 Sec/Iter .01

Start sim... C:\... final Mi... C:\... Mi... @... Be... Desktop 4:05 PM

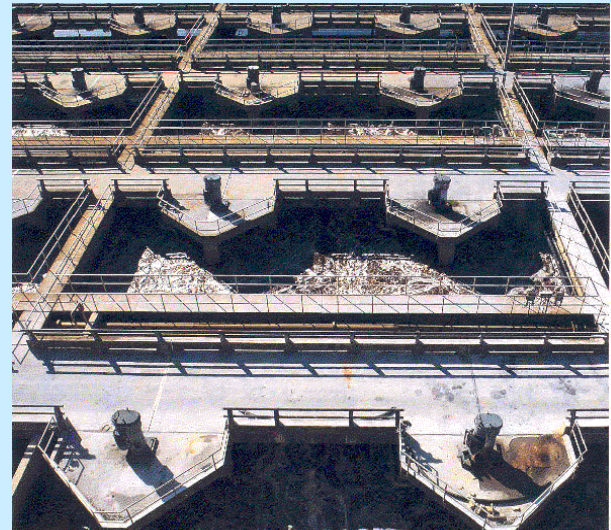


# Simulation summary

		mean	max	95%
<b>NaOH facility</b>	amount NaOH=triangular price=logistic	35	98	73
	amount NaOH=normal price=normal	12	21	18
	amount NaOH=normal price=logistic	12	26	18
	amount NaOH=triangular price=normal	36	102	77
<b>Combined facility</b>	amount of lime=tri amount NaOH=exponential price=logistic	9.9	23	14
	amount of lime=normal amount NaOH=exponential price=logistic	8.4	28	18
	amount of lime=normal amount NaOH=exponential	8.4	24	19

# Simulation summary

- By changing different distributions to the significant inputs, the result shows that operating the second alternative, “combined facility”, is more beneficial than operating only NaOH facility.



# Project summary

- We choose the alternative two, “combined facility”. Even though we have to pay a capital for building a new lime facility, we can get more benefit from this alternative when we consider about long-run profit(20 years).
- However, running these facilities we have to focus on amount of NaOH, amount of Lime, and price of NaOH respectively, according to sensitivity analysis.

# Future work

- Knowing the price of NaOH in the past 3 years, we can find the forecasting method and forecast for the budget plan in the future.
- We haven't included the safety issue in this problem and it may effect the decision even the operator in these facility are about 20 persons.

# Future work

- We can search for the possibility that these operators may be sick, quit for their job according to the health problem, and cost of training new operator.
- However, right now DCWASA already decide to construct a new lime facility according to the cost benefit and there is some belief that the lime also improve the settling of wastewater.