Universidad
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Zacatecas

# EVALUATION OF SURFACE WATER SOURCES FOR DOMESTIC SUPPLY IN THE FRESNILLO - GUADALUPE INDUSTRIAL COMPLEX.

RiverWare User Group Meeting

Dr. Ángel Alfonso Villalobos de Alba[1], Dra. Alba Nélida García Beltrán[1], M.I. Hansell Omar López Cazares[2]

1 Profesor Investigador, Universidad Autónoma de Zacatecas
2. Egresado, Universidad Autónoma de Zacatecas

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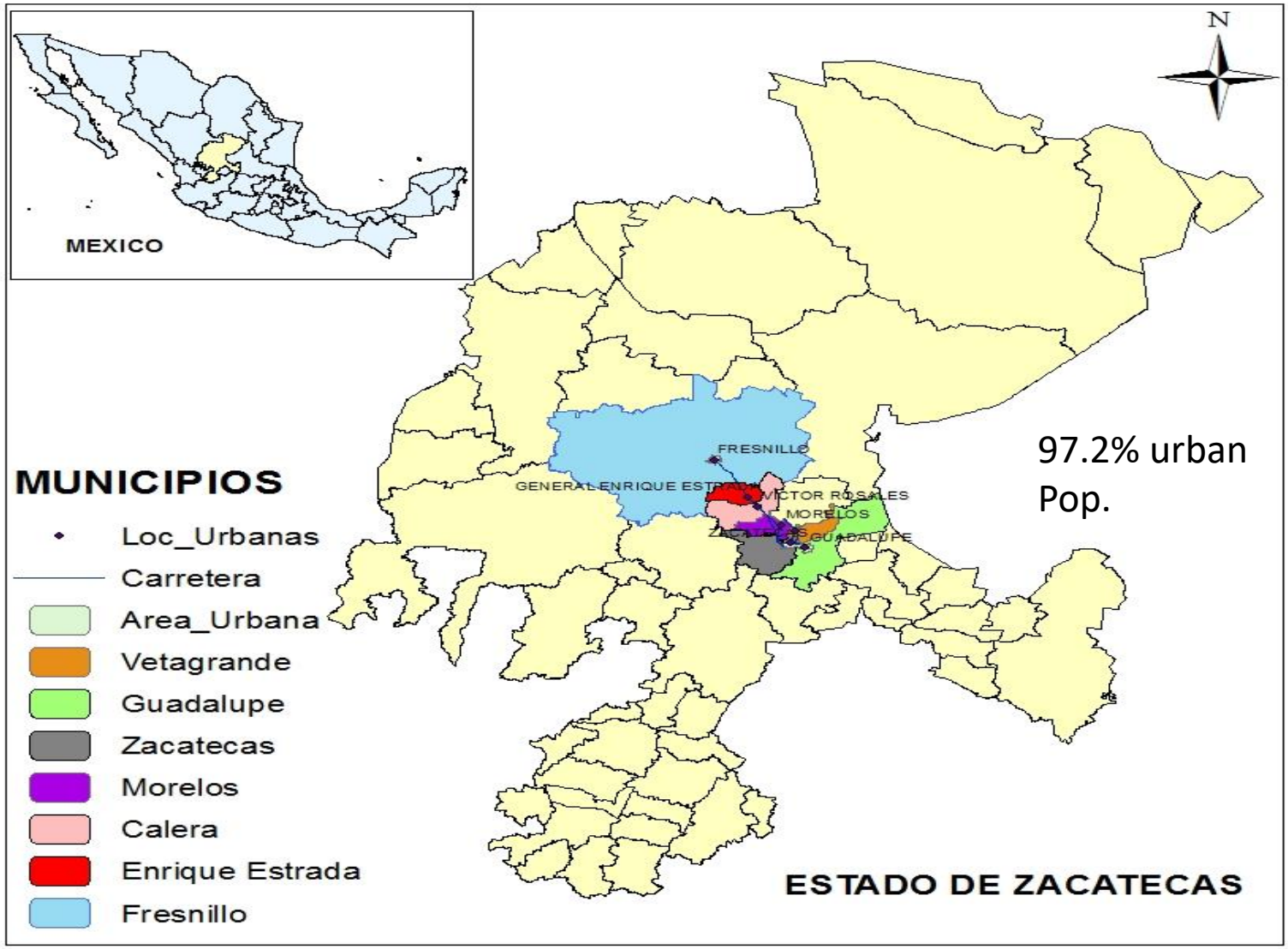
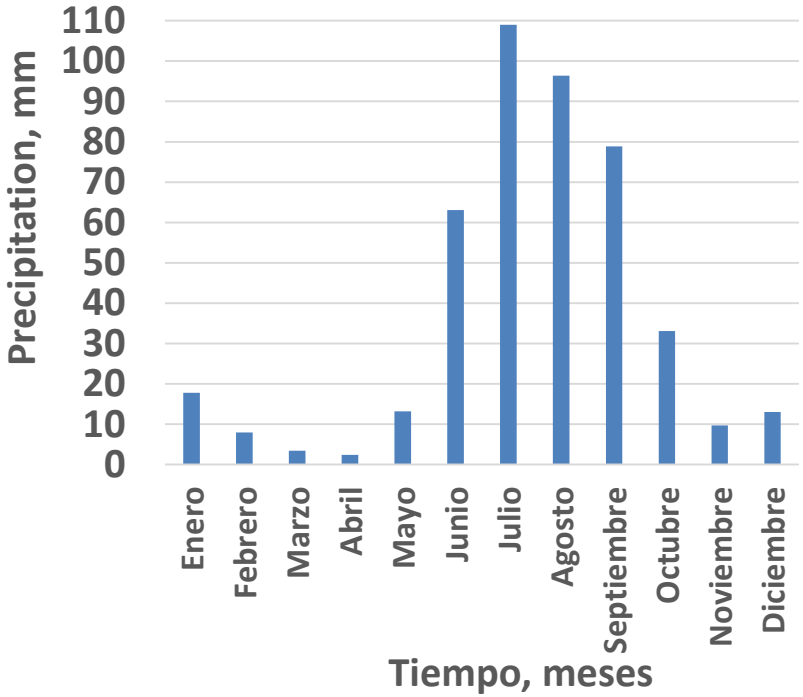
# Introduction

**Zacatecas city and its surrounding urban areas have serious problems** with its **drinking water supply**. The main source of supply is with groundwater. Currently, the water supply agency has to **pumped from more than 100 m deep** in part of the aquifer, which has caused **some wells to not meet the quality parameters to be potable**.

# Introduction: Target population



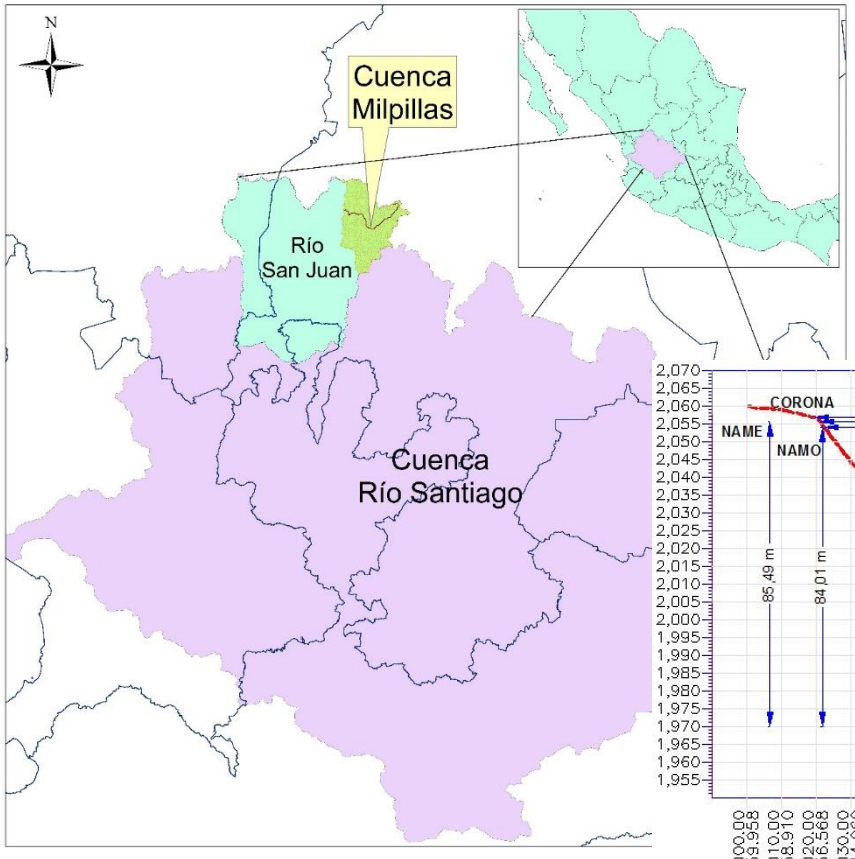
# STUDY AREA

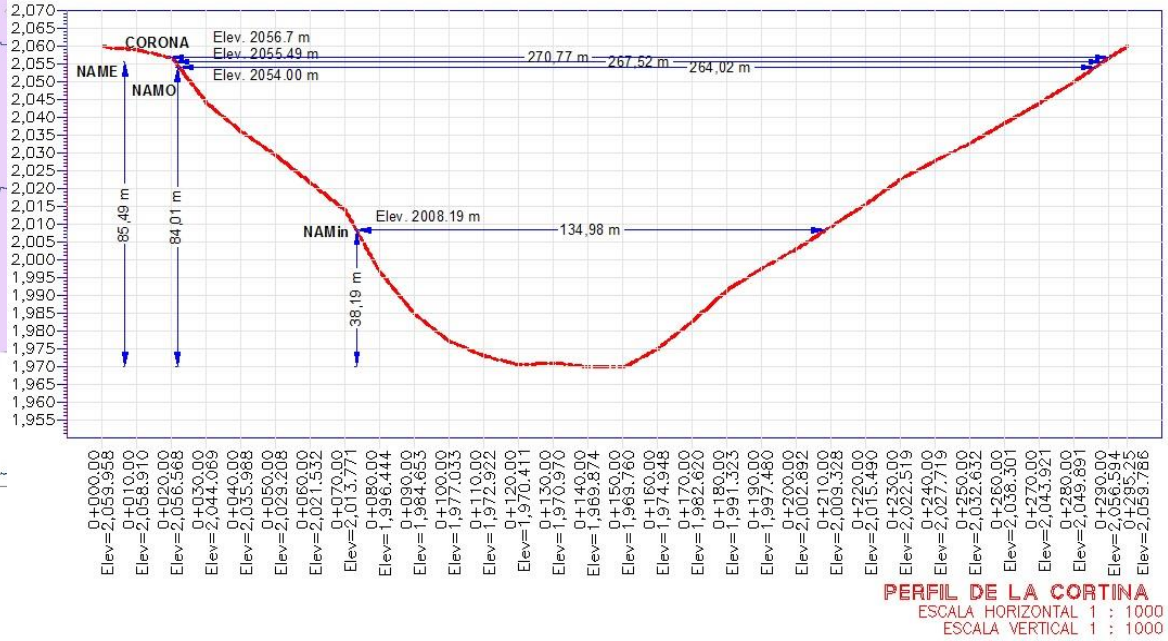

The study area is located in the western part of Zacatecas state, it includes the municipalities of Chalchihuites, Jiménez de Teul, Sombrerete and Valparaíso.

# Milpillas Dam

As a result of the studies of feasibility : there is an alternative that involve Milpillas Dam and an acueduct of 180 km length to supply a demand of 1.3 m3/s.



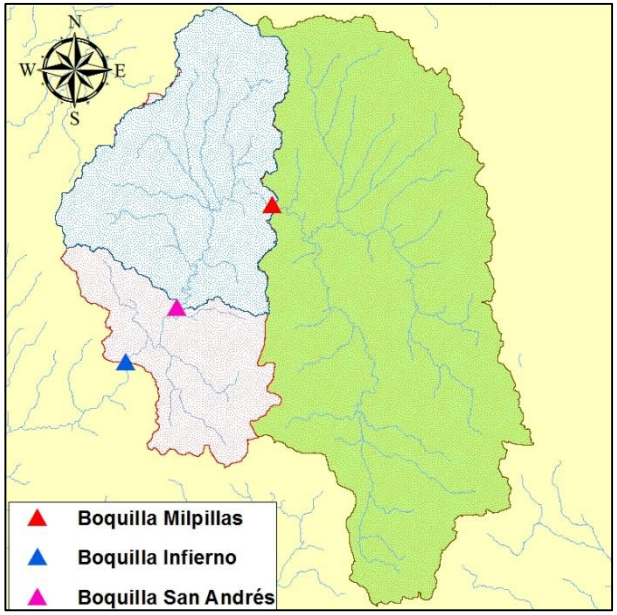




# Study cases:

- Milpillas Dam simulation
- San Andrés- Milpillas system: Determine the transfer flow from San Andrés to Milpillas
- Relocate Milpillas Dam to “El Infierno” site.

# AVERAGE ANNUAL RUNOFF




San Andrés and El Infierno subbasins are not gauged, so the runoffs were estimated.

| BASIN | ANNUAL AVERAGE RUNOFF($Hm^3$) | MONTHLY AVERAGE RUNOFF ($Hm^3$) |
|---|---|---|
| Milpillas | 62.30 | 5.19 |
| San Andrés Cuenca Propia | 28.91 | 2.41 |
| EL Infierno Cuenca Propia | 41.60 | 3.47 |
| San Andrés Completa | 91.21 | 7.60 |
| El Infierno Completa | 103.89 | 8.66 |

# Information used for reservoir simulation

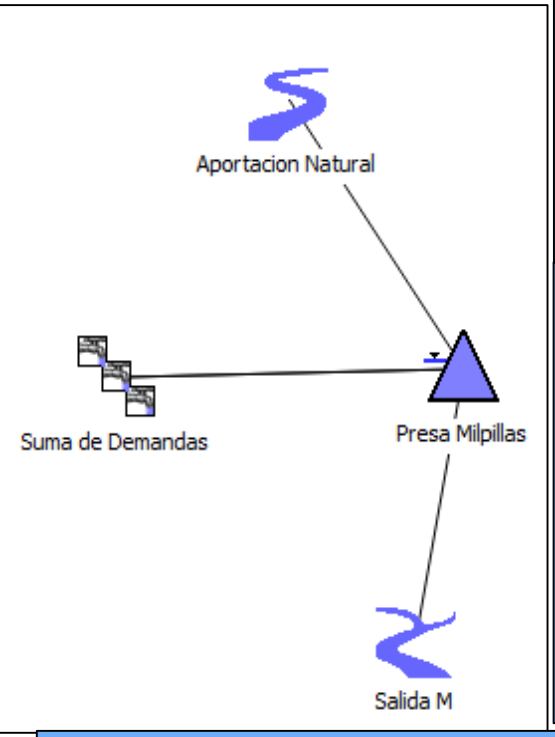
- Inflows for each sub-basin
- Evaporation coefficients of the study area
- Volume-Elevation-Area Tables (E-V-A)
- Demands for supply drinking water
- Minimum ecological flow in each reservoir

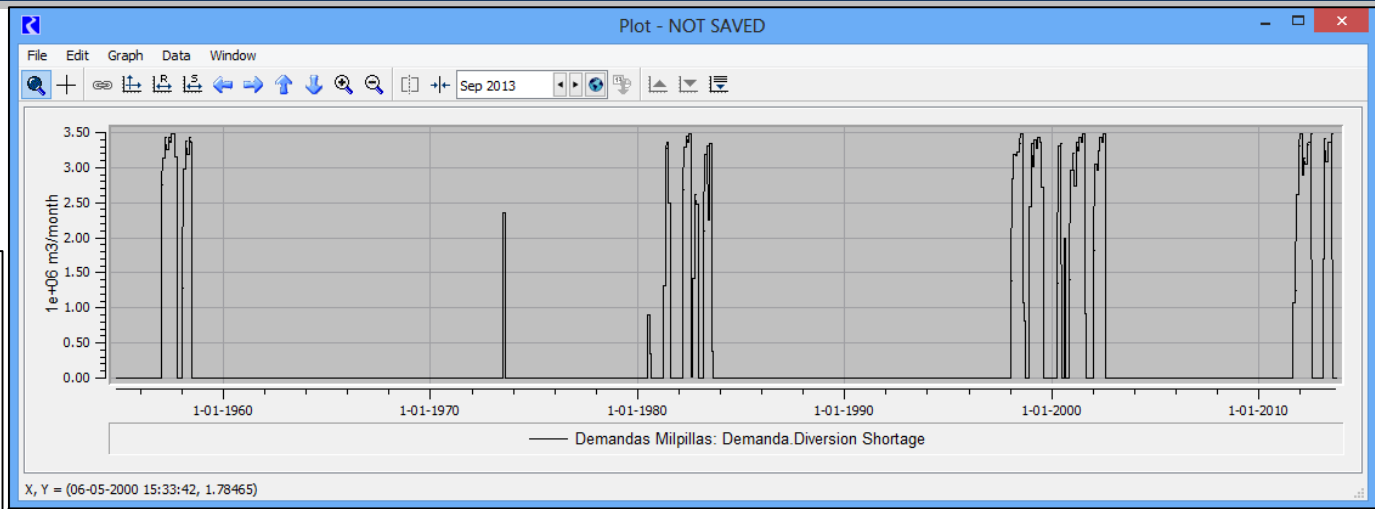
The inflows series for the simulation have a period of 59 years. This information will be necessary to carry out the simulations in RiverWare.

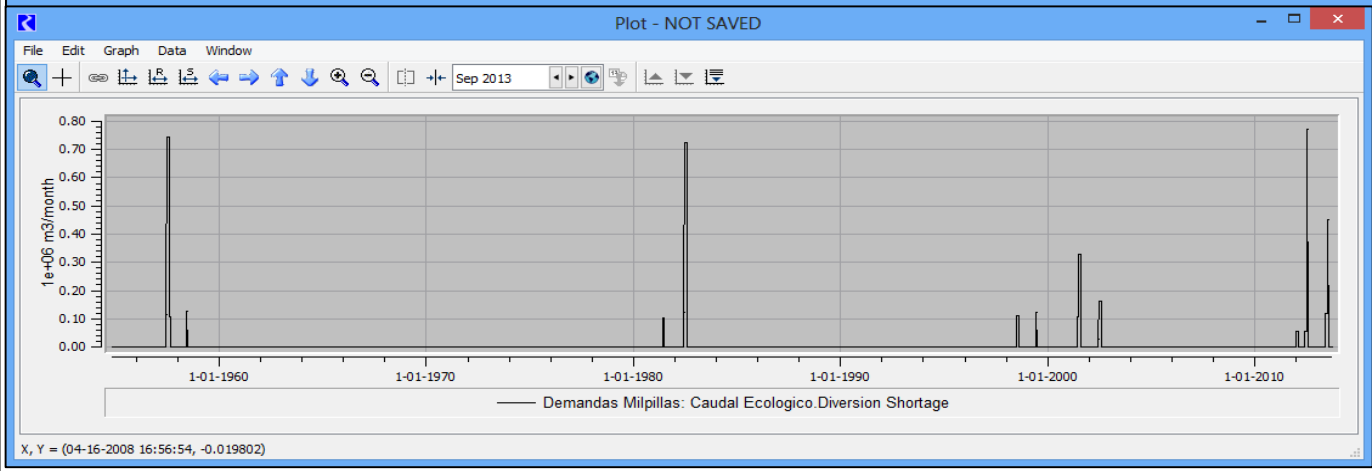
- The simulation begins in September 1954,
- There is a monthly time step model for each case, 708 months to evaluate.

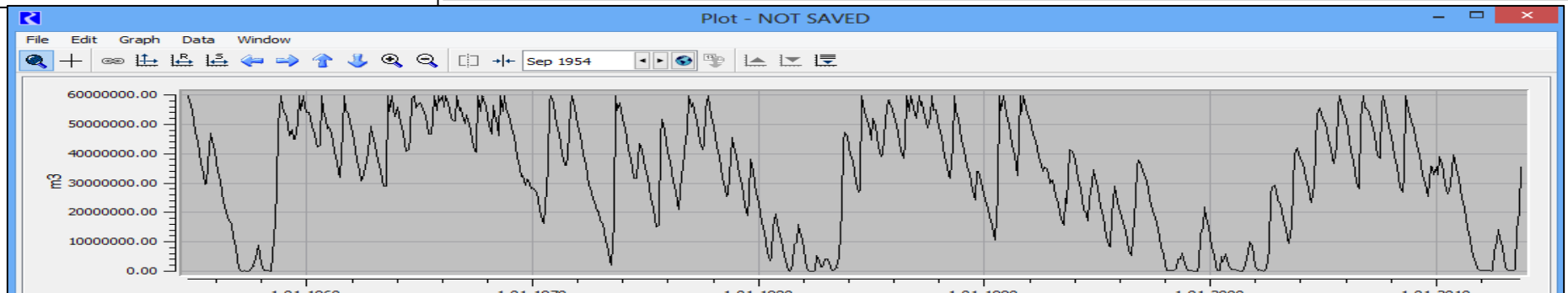
A rule-based simulation was used.

# Case 1: MILPILLAS reservoir



# Results: Case 1

Simulation start at full capacity: 59.604 $Hm^3$.

| Milpillas demand ($m^3/s$) | Inflow ($Hm^3$) | Demands ($Mm^3$) | | Outflows ($Mm^3$) | | | | Shortage% | | System efficiency% | Supply garanty . (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ecological flow | Drinking water | Ecol Flow | Drinking Water | Spill | Evaporation | Ecol flow% | Drinking water % | | Ecological flow | Drinking water | Total |
| 1.2 | 3,676.57 | 367.54 | 2,232.75 | 363.45 | 2,055.87 | 1,199.81 | 81.11 | 1.11 | 7.92 | 65.38 | 98.89 | 92.08 | 93.04 |
| **1.3** | **3,676.57** | **367.54** | **2,418.81** | **363.18** | **2,163.84** | **1,098.89** | **74.87** | **1.19** | **10.54** | **68.28** | **98.81** | **89.46** | **90.69** |
| 1.4 | 3,676.57 | 367.54 | 2,604.87 | 360.75 | 2,269.21 | 1,001.57 | 69.78 | 1.85 | 12.89 | 71.05 | 98.15 | 87.11 | 88.48 |
| 1.5 | 3,676.57 | 367.54 | 2,790.94 | 359.8 | 2,368.14 | 908.69 | 65.2 | 2.11 | 15.15 | 73.69 | 97.89 | 84.85 | 86.37 |
| 1.6 | 3,676.57 | 367.54 | 2,977.00 | 359.28 | 2,454.42 | 827.03 | 61.63 | 2.25 | 17.55 | 76 | 97.75 | 82.45 | 84.13 |

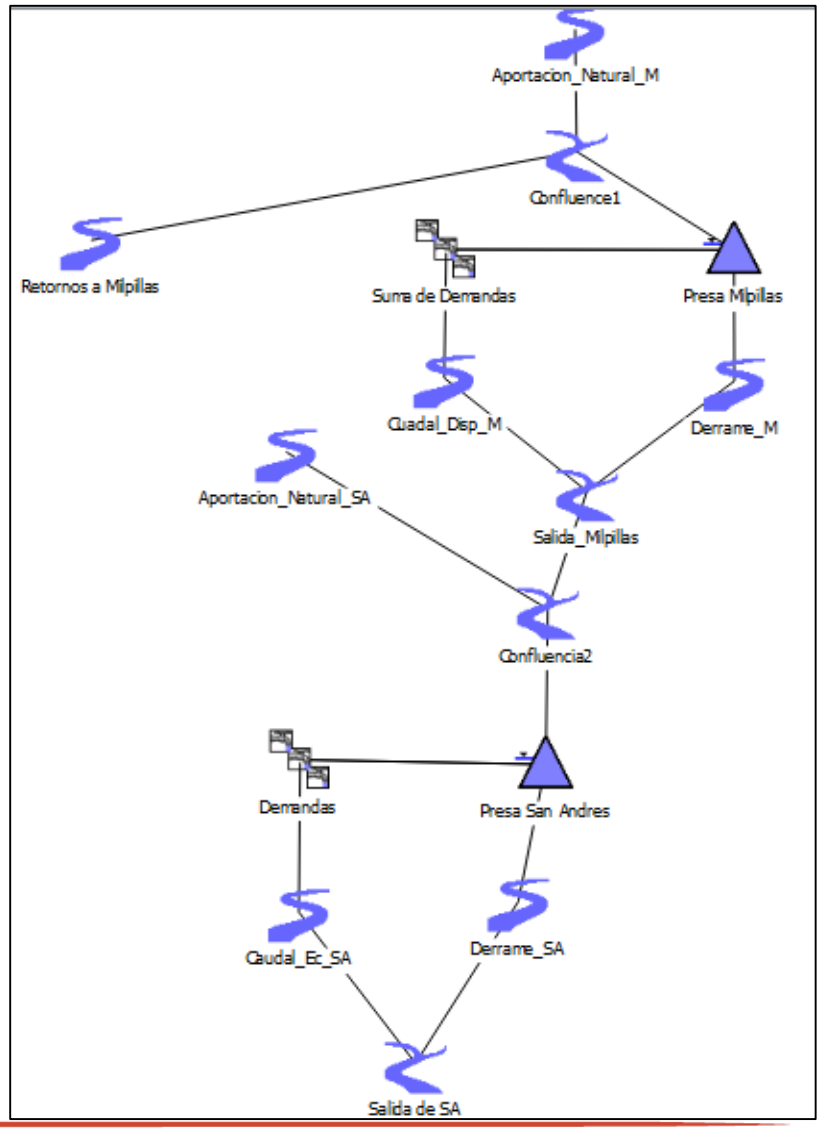
# Case 2: Milpillas - San Andrés system

Since Milpillas can not guarantee the demand throughout the period, it seeks to complete the supply with San Andrés.

Some analyzes are carried out to determine the volume of water that the San Ándres dam can provide.

2a. Constant transfer flow

2b. Transfer flow f(Milpillas Empty space)



# Case 2a. (Constant) Transfer flow from San Andrés to Milpillas

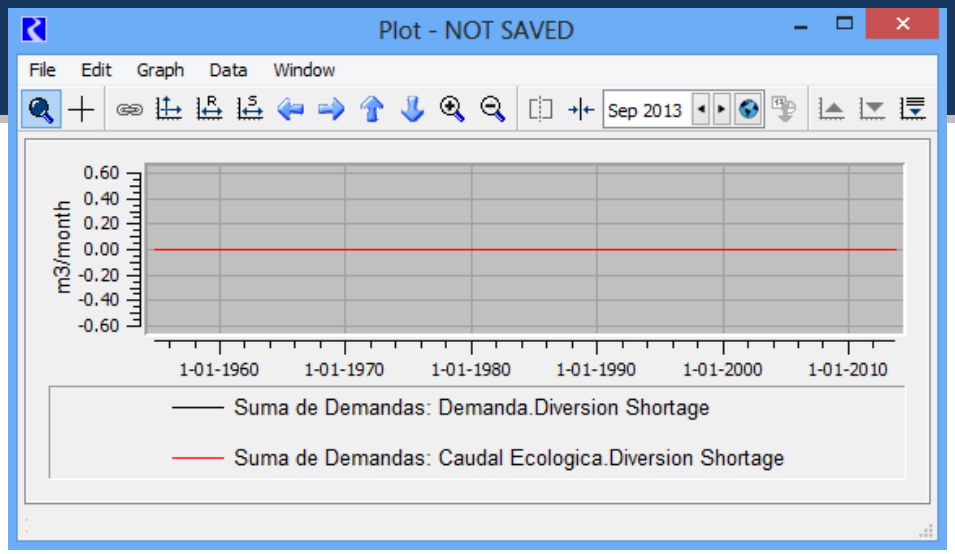
Milpillas demand of 1.3 $m^3/s$, both reservoirs starts at full capacity

| | Capacidad Útil ($m^3$) | Elevación máxima (m) | Altura de la cortina (m) |
|---|---|---|---|
| **Milpillas** | 59,604,109.63 | 2,053.605 | 83.6 |
| **San Andrés** | 92,091,582.91 | 1,882 | 110 |

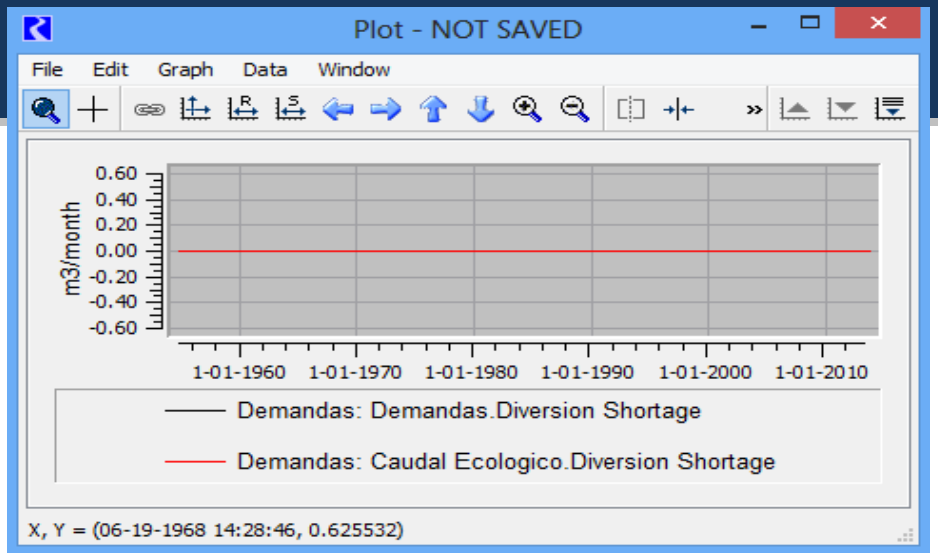
Different simulations were carried out varying the constant monthly demand of San Andrés, from 0.4 $m^3$ / s to 0.7 $m^3$ / s

| San Andrés demand ($m^3/s$) | Total Inflow ($Mm^3$) | Available water ($Mm^3$) | Total demand ($Mm^3$) | | Outputs ($Mm^3$) | | | | Shortage % | | System efficiency % | Supply garanty . (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Ecologigal Flow SA | Drinking water | Ecological SA | Drinking W Milpillas | Spill SA | Evaporated | Ecologycal SA % | Drinking Water Milpillas % | | Ecologycal | Drinking water | Total |
| 0.2 | 5,383.04 | 5,405.48 | 170.59 | 2,418.81 | 170.59 | 2,299.42 | 2,707.30 | 228.17 | 0 | 4.94 | 45.69 | 100 | 95.06 | 95.39 |
| 0.25 | 5,383.04 | 5,405.31 | 170.59 | 2,418.81 | 170.59 | 2,326.19 | 2,678.97 | 229.56 | 0 | 3.83 | 46.19 | 100 | 96.17 | 96.42 |
| 0.3 | 5,383.04 | 5,405.34 | 170.59 | 2,418.81 | 170.59 | 2,358.74 | 2,643.33 | 232.68 | 0 | 2.48 | 46.79 | 100 | 97.52 | 97.68 |
| 0.35 | 5,383.04 | 5,404.88 | 170.59 | 2,418.81 | 170.59 | 2,378.62 | 2,622.16 | 233.51 | 0 | 1.66 | 47.17 | 100 | 98.34 | 98.45 |
| 0.4 | 5,383.04 | 5,402.19 | 170.59 | 2,418.81 | 170.59 | 2,395.08 | 2,601.37 | 235.15 | 0 | 0.98 | 47.49 | 100 | 99.02 | 99.08 |
| 0.45 | 5,383.04 | 5,397.77 | 170.59 | 2,418.81 | 170.59 | 2,407.36 | 2,583.45 | 236.36 | 0 | 0.47 | 47.76 | 100 | 99.53 | 99.56 |
| 0.5 | 5,383.04 | 5,397.70 | 170.59 | 2,418.81 | 170.59 | 2,415.59 | 2,575.00 | 236.52 | 0 | 0.13 | 47.91 | 100 | 99.87 | 99.88 |
| **0.6** | **5,383.04** | **5,401.72** | **170.59** | **2,418.81** | **170.59** | **2,418.81** | **2,575.55** | **236.77** | **0** | **0** | **47.94** | **100** | **100** | **100** |
| 0.7 | 5,383.04 | 5,402.41 | 170.59 | 2,418.81 | 170.59 | 2,418.81 | 2,575.97 | 237.04 | 0 | 0 | 47.93 | 100 | 100 | 100 |

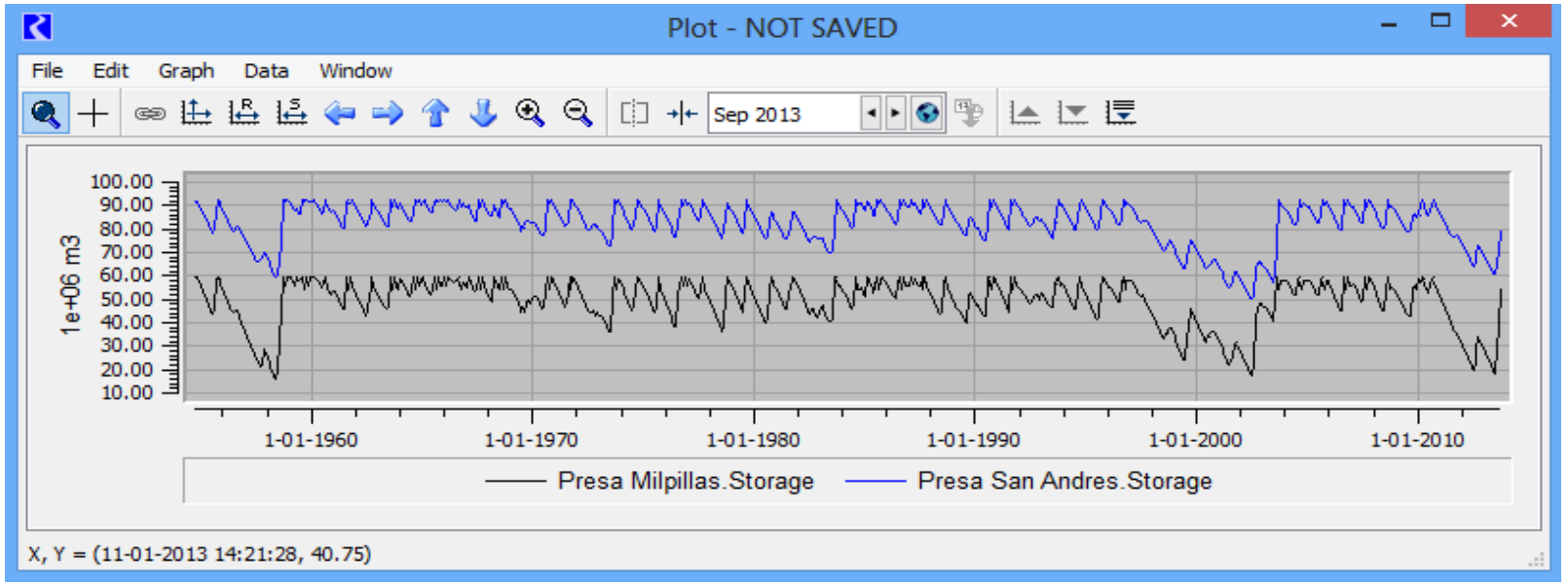
System efficiency < 50 %




**Deficit in drinking and ecological demands, Milpillas, E2a.**




**Deficit in drinking and ecological demands, San Andrés, E2a.**




**Milpillas and San Andrés storages variation, E2a.**

# Case 2b.

The aim was to find the necessary factors to obtain a minimum deficit and an optimal storage for both reservoirs.

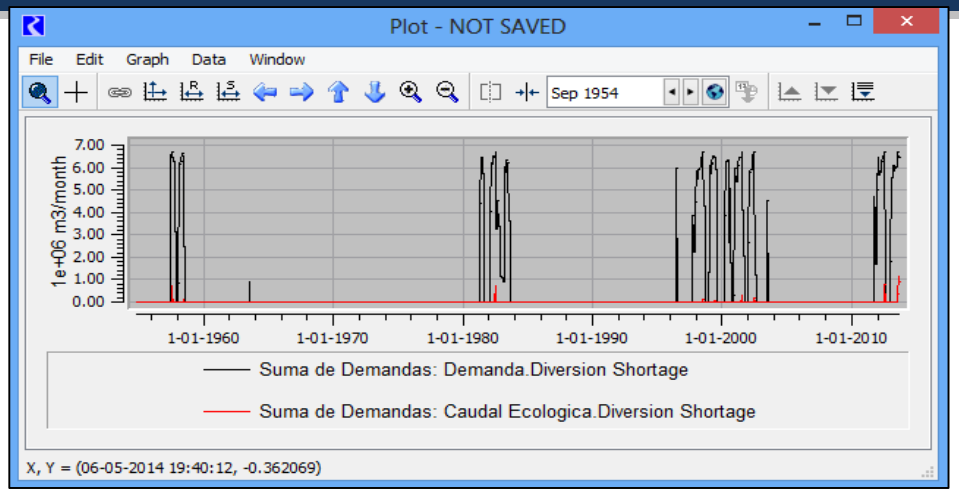
Milpillas demand from 1.3 $m^3/s$ hasta 2.7 $m^3/s$

Reserve volumen (number of months).

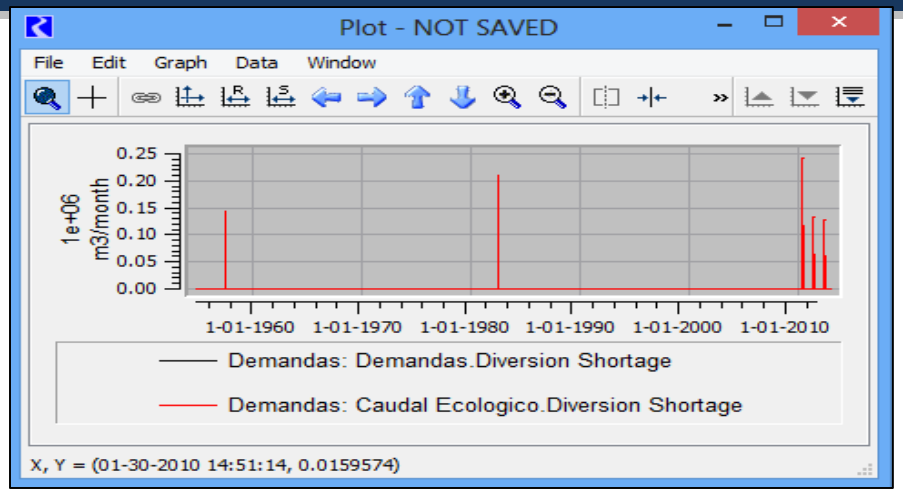
System efficiency: 79.1 %

| San Andrés Max demand ($m^3/s$) | Inflows system ($Hm^3$) | Available Water ($Hm^3$) | Demands in simulated period($Hm^3$) | | | Outflows($Hm^3$) | | | | Shortages % | | % Efficiency | Supply garanty . (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Ecologycal Flow SA | Drinking Water | Total | Ecologycal Flow | Drinking Water Milpillas | Spill SA | Evaporated Volume | Ecologycal Flow% | Drinking water % | | Ecologycal Flow | Drinking wáter % | Total |
| 2.564 | 5,383.04 | 5,481.99 | 170.59 | 4,651.56 | 4,822.15 | 170.56 | 3,932.66 | 1,232.65 | 146.12 | 0.02 | 15.46 | 74.85 | 99.98 | 84.54 | 85.09 |
| 2.862 | 5,312.25 | 5,445.96 | 167.99 | 4,579.42 | 4,747.41 | 167.46 | 4,109.52 | 1,033.64 | 135.34 | 0.32 | 10.26 | 78.53 | 99.68 | 89.74 | 90.09 |
| 3.084 | 5,312.25 | 5,444.16 | 167.99 | 4,579.42 | 4,747.41 | 167.46 | 4,130.91 | 1,033.64 | 144.62 | 0.32 | 9.79 | 78.95 | 99.68 | 90.21 | 90.54 |
| 3.283 | 5,312.25 | 5,445.96 | 167.99 | 4,579.42 | 4,747.41 | 167.51 | 4,134.28 | 1,002.07 | 142.10 | 0.29 | 9.72 | 78.99 | 99.71 | 90.28 | 90.61 |
| 4.682 | 5,312.25 | 5,445.96 | 167.99 | 4,579.42 | 4,747.41 | 167.51 | 4,134.60 | 999.08 | 144.77 | 0.29 | 9.71 | 79.00 | 99.71 | 90.29 | 90.62 |
| 4.673 | 5,312.25 | 5,445.96 | 167.99 | 4,579.42 | 4,747.41 | 167.36 | 4,140.27 | 990.45 | 147.88 | 0.38 | 9.59 | 79.10 | 99.62 | 90.41 | 90.74 |
| 7.842 | 5,312.25 | 5,445.96 | 167.99 | 4,579.42 | 4,747.41 | 167.38 | 4,137.35 | 991.71 | 149.52 | 0.37 | 9.65 | 79.04 | 99.63 | 90.35 | 90.68 |
| 11.731 | 5,312.25 | 5,445.96 | 167.99 | 4,579.42 | 4,747.41 | 167.38 | 4,130.73 | 999.63 | 148.21 | 0.37 | 9.80 | 78.92 | 99.63 | 90.20 | 90.54 |

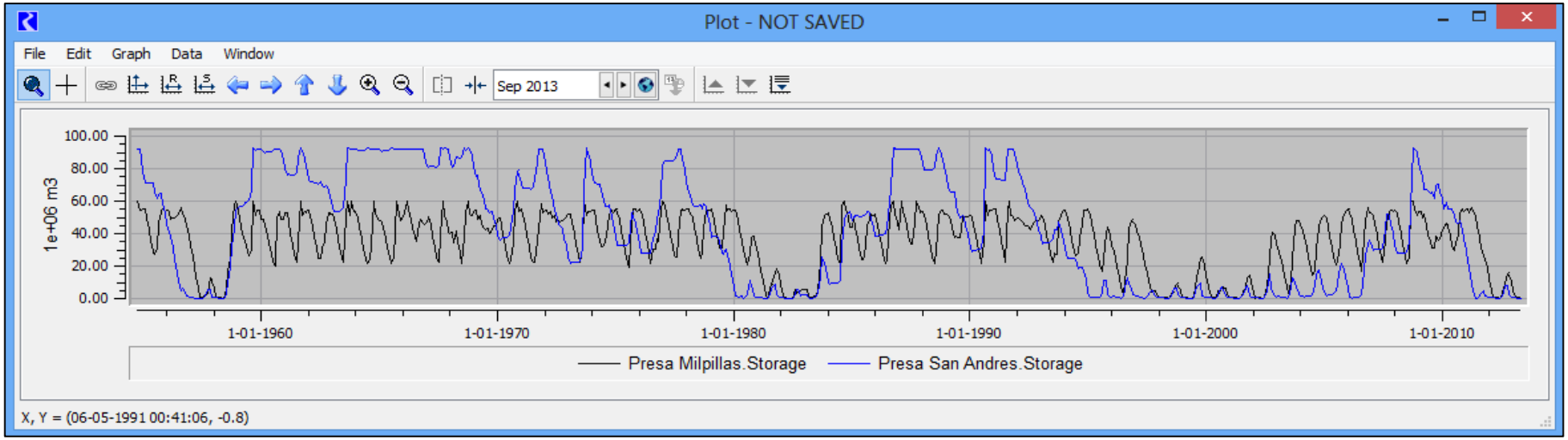
These results show the maximum demand requested in San Andrés, so Milpillas can supply 2.7 $m^3$ / s




**Shortages in Milpillas, 2b.**

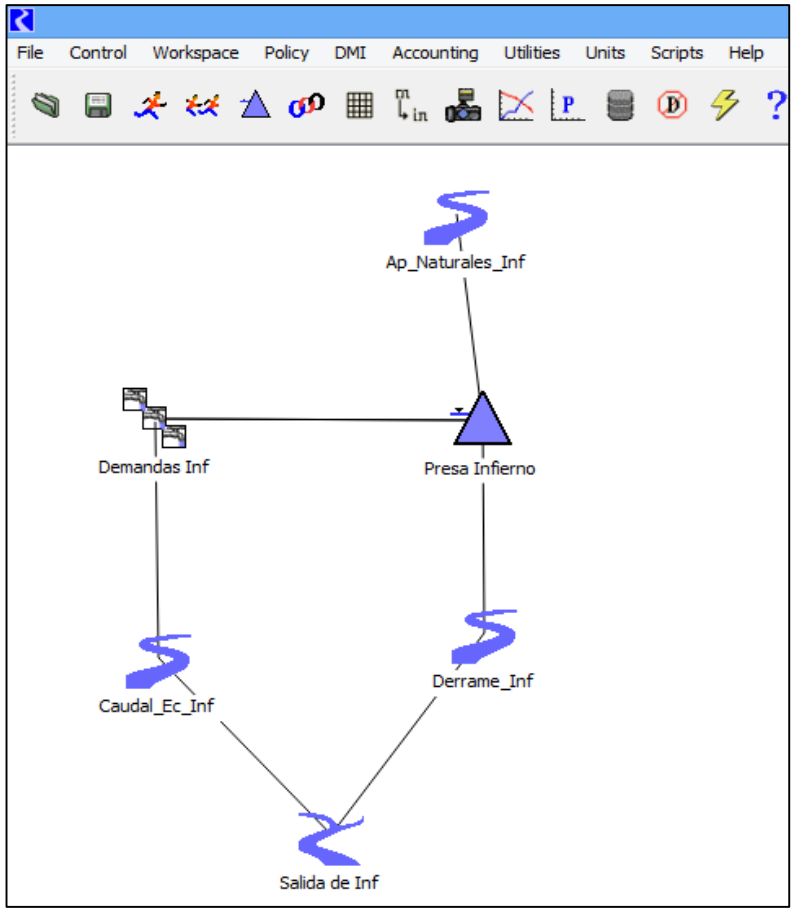



**Shortages in San Andrés, 2b**




**Milpillas and San Andrés storages, 2b.**

# **Case 3. El** Infierno site Simulation



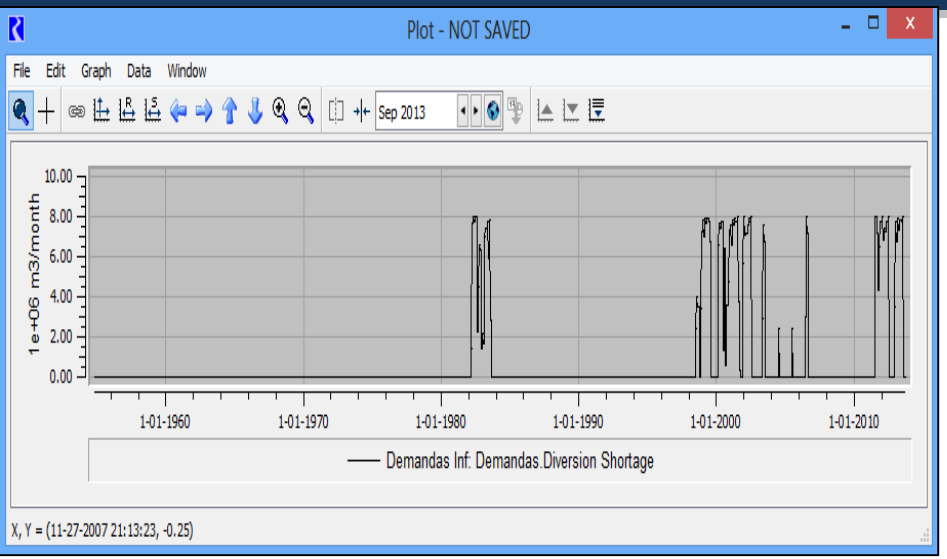

| Dam | Storage capacity($m^3$) | Pool elevation (m) | hight dam (m) |
|---|---|---|---|
| **Infierno** | 326,360,700 | 1,830.00 | 139 |

# Case 3. Results

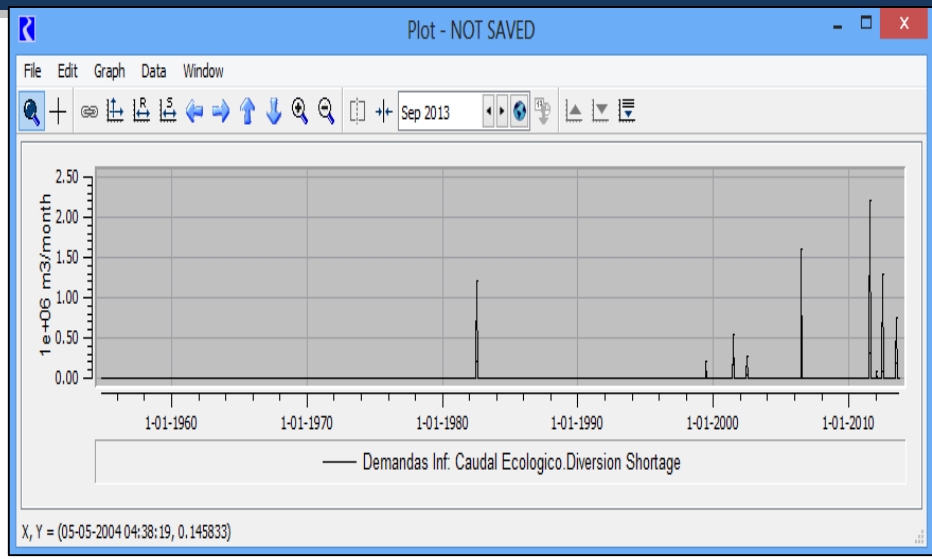
Water Volume requested to el Infierno from 1.3 $m^3/s$ to 3.0 $m^3/s$,

| Infierno Demand ($m^3/s$) | Available Water ($Mm^3$) | Demands ($Mm^3$) | | Outputs ($Mm^3$) | | | | Shortages % | | Efficiency system % | Garanty. (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ecologycal flow | Drinking Water | Ecologycal flow | Drinking Water | Spill | Evaporated | Ecologycal flow | Drinking Water | | Ecologycal flow | Drinking Water | Total |
| 2.6 | 6,401.31 | 612.98 | 4,837.62 | 609.59 | 4,651.44 | 891.87 | 248.41 | 0.55 | 3.85 | 82.19 | 99.45 | 96.15 | 96.52 |
| 2.8 | 6,402.37 | 612.98 | 5,209.75 | 609.33 | 4,881.05 | 683.23 | 228.75 | 0.6 | 6.31 | 85.76 | 99.4 | 93.69 | 94.29 |
| **3** | **6,403.42** | **612.98** | **5,581.87** | **603.81** | **5,042.11** | **550.11** | **207.39** | **1.5** | **9.67** | **88.17** | **98.5** | **90.33** | **91.14** |
| 3.17 | 6,404.32 | 612.98 | 5,898.18 | 602.33 | 5,171.90 | 441.51 | 188.58 | 1.74 | 12.31 | 90.16 | 98.26 | 87.69 | 88.68 |

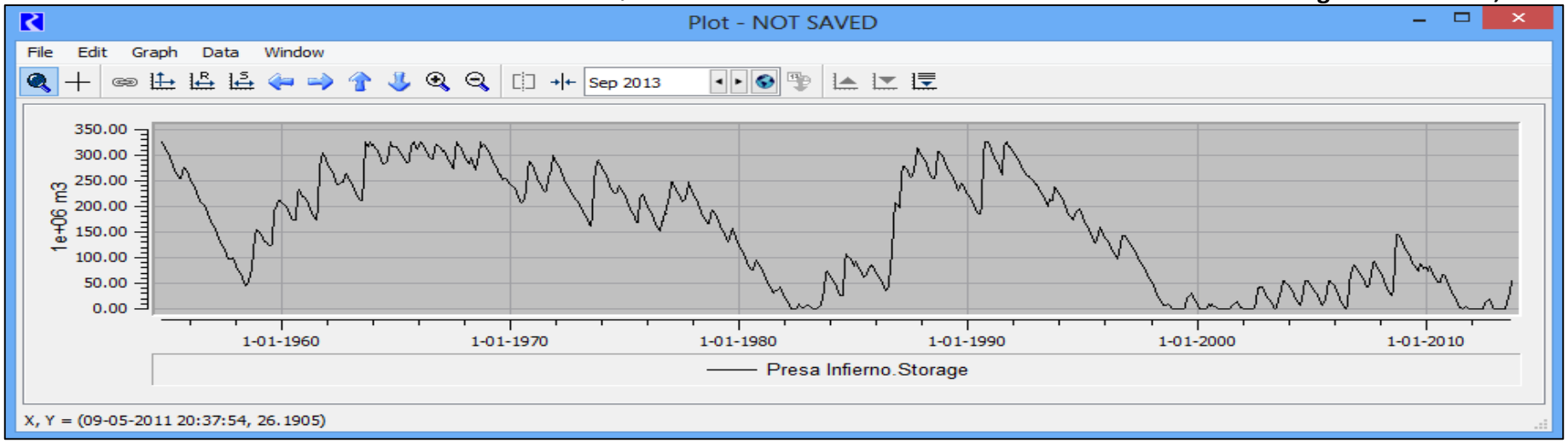
For demand = 3$m^3/s$, system efficiency =88.17 %




**Déficit en la demanda de usuario en Infierno, E3.**




**Déficit en la demanda de caudal ecológico en Infierno, E3.**




**Variación del embalse del Infierno, E3.**

# Summary of Results

| Case | Elevation Dam (m) | Storage capacity ($Hm^3$) | Demand Max San Andres ($m^3/s$) | Demand Max Infierno ($m^3/s$) | Reserve volume Milpillas | Milpillas Demand ($m^3/s$) | Inflow volume | Available water Hm3 | Demands ($Hm^3$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Ecologycal flow | Drinking water | Total |
| **1** | 2052 | 59.60 | **n/a** | n/a | n/a | **1.30** | 3,676.570 | 3736.1695 | 367.54 | 2,418.81 | 2,2786.35 |
| **2a** | 2052-1879 | 151.70 | **0.60** | n/a | n/a | **1.30** | 5,383.041 | **5,401.72** | 170.59 | 2,418.81 | 2,589.41 |
| **2b** | 2052-1880 | 151.70 | **4.67** | n/a | **6** | **2.50** | 5,312.255 | **5,445.96** | 167.99 | 4,579.42 | 4,747.41 |
| **3** | 2052-1830 | 151.70 | **5.61** | n/a | n/a | **2.50** | 5,383.041 | **5,479.88** | 170.59 | 4,651.56 | 4,822.15 |

| Outflows ($Hm^3$) | | | | Shortages | | %Efficiency | Garanty (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| Ecologycal flow | Drinking water | Spill | Evaporado sistema | Ecologycal flow | Drinking water | | Ecologyc al flow | Drinking water | Total |
| 363.45 | 2,163.87 | 1,098.89 | 74.87 | 1.19 | 10.64 | 68.28 | 98.81 | 89.46 | 90.69 |
| 170.59 | 2,418.81 | 2,575.55 | 236.77 | 0.00 | 0.00 | 47.94 | 100.00 | 100.00 | 100.00 |
| 167.36 | 4,140.27 | 990.45 | 147.88 | 0.38 | 9.59 | 79.10 | 99.62 | 90.41 | 90.74 |
| 169.14 | 4,232.01 | 980.81 | 158.59 | 0.85 | 9.02 | 88.17 | 98.5 | 90.33 | 91.14 |

# Conclusions

The objective of the project is to stop using the underground water to recover the piezometric levels and the aquifer´s water quality.

Milpillas capacity can not be increase due to topographical conditions.

Case 1: Release 1.3, system efficiency 68.28%

Case 2a: Release 1.3, system efficiency 47.94%

Case 2b: Release 2.7, system efficiency 79.1%

Case 3: Release 3.0, system efficiency 88.14%

The best option is “El Infierno” site since more water can be extracted for the Fresnillo-Guadalupe industrial complex and the price of cubic meter of water is reduced around 20%. This option also presents deficits, but they can be mitigated by making joint use of surface and underground water.