# A sequential Simulation-Optimization Model for Water Allocation from the multi-Reservoir System in the Karkheh River Basin System, Iran

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# Outline

Preface

Literature review

MODSIM decision support system

The extended MODSIM model

Reliability- Based simulation

Results and discussions

# Hydropower potential gross hypothetical capacity

# Importance of water resources in Iran

Low level of average precipitation (250 mm /year)

Consume more than 80% of water use in agriculture

Evaporation over 70% of annual rainfall

# Literature Review:

**Roman and Allan (1994)**

A complete hydrothermal system is simulated. The merit order among all the reservoirs to supply the demand is determined as a function of their reserve level. Simulated natural hydro inflows and transmission network are considered. The goal is to determine the service reliability in thermal, hydro or hydrothermal systems.

**Van Hecke et al. (1998) and Sankarakrishnana and Billinton (1995)**

The electric systems simulated do not consider the hydro topology. This simulation model takes a time step of one hour, and considers the electric network, whose node demand is defined as a function of the expected user type (industrial, residential, commercial, etc.). Variance reduction techniques are applied and the results are reliability measures. In [Sankarakrishnan 1995] sequential simulation is compared with non-chronological methods based on the load-duration curve.

**Afzali and Mousavi (2008)**

They developed and applied a reliability-based simulation- optimization model for a multi-reservoir hydropower system in the Khersan Hydropower system, Iran and showed that, unlike many single reservoir systems, integrated systems are able to produce stable excess electric energy.

# The MODSIM decision support system

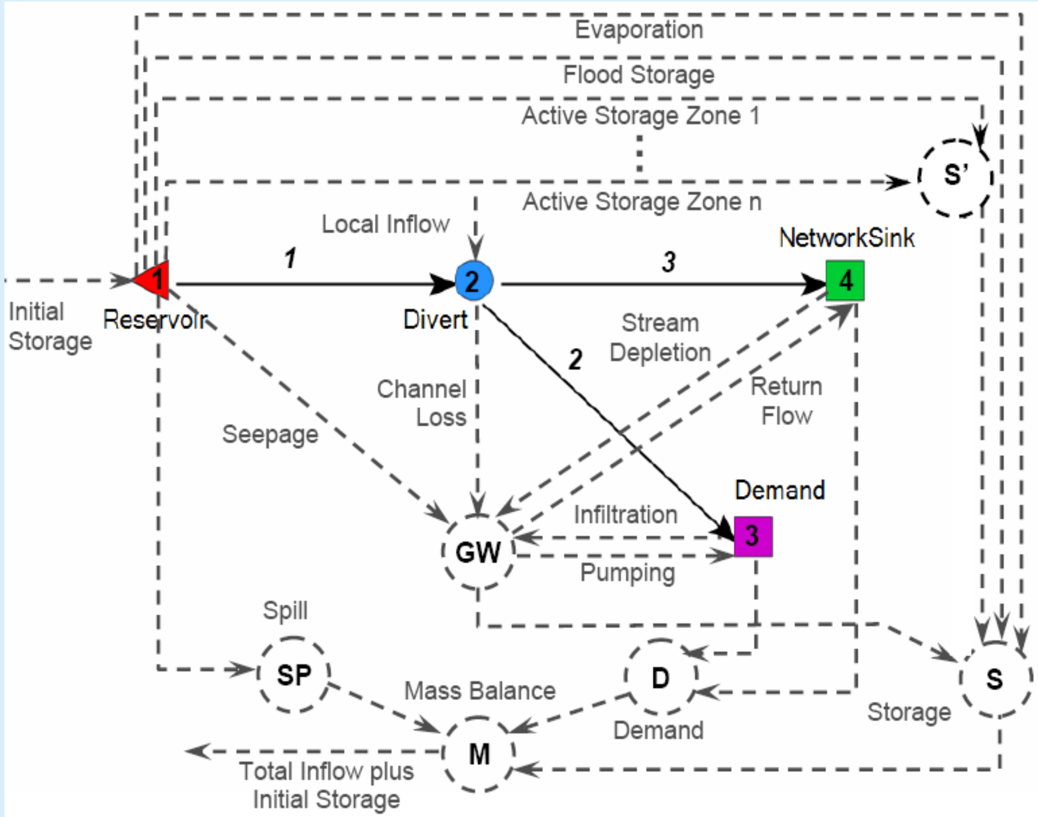
Network Flow Optimization(NFO)

$$C = -[50000 - priority \times 10]$$

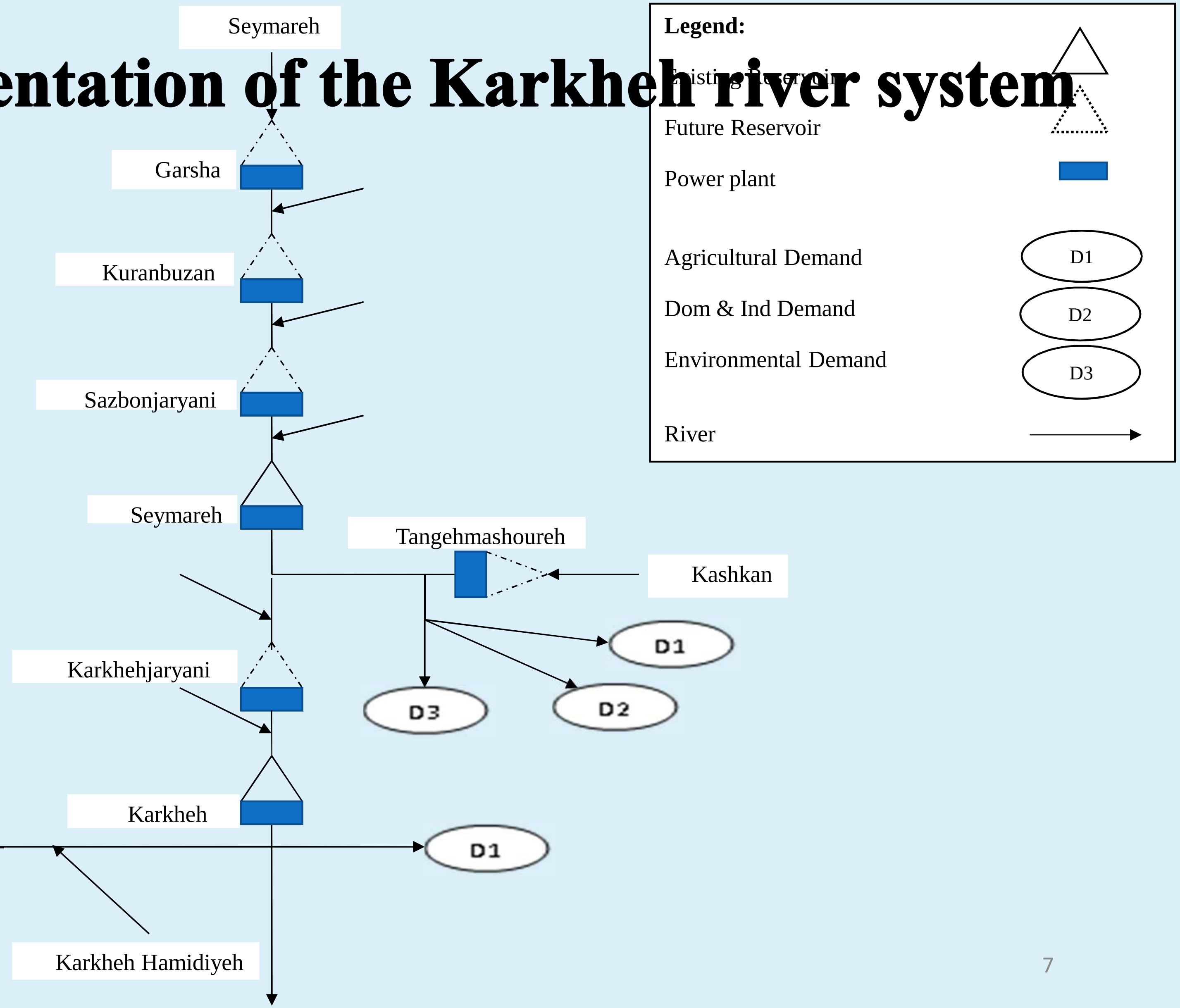
$$Minimize \sum_{l \epsilon A} C_l q_l$$

$$\sum_{j \epsilon O_i} q_j - \sum_{k \epsilon I_i} q_k = 0\ ; \quad for\ all\ i\ \epsilon\ N$$

$$l_l \leq q_l \leq u_l \quad for\ all\ l\ \epsilon\ A$$



# schematic representation of the Karkheh river system

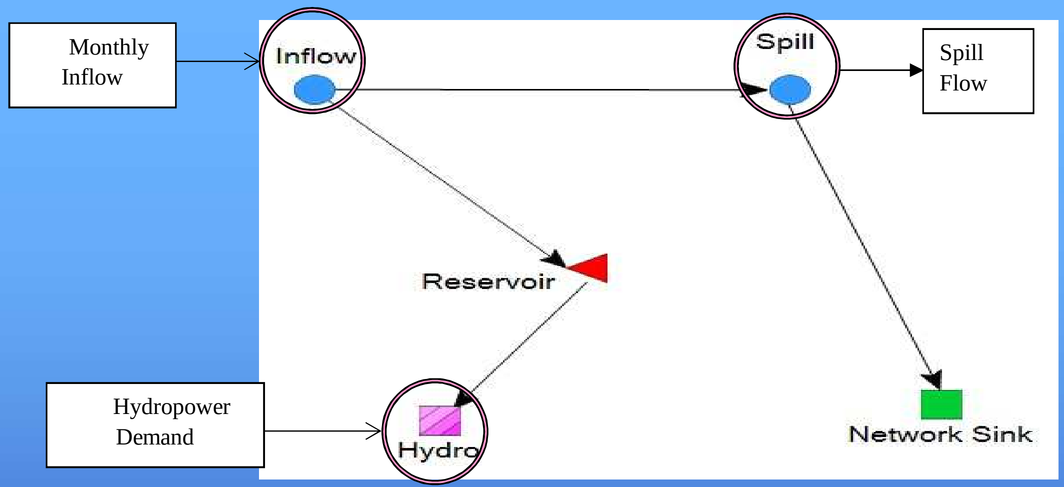
Hydropower Standard Operation Policy (HSOP)

What is the problem?

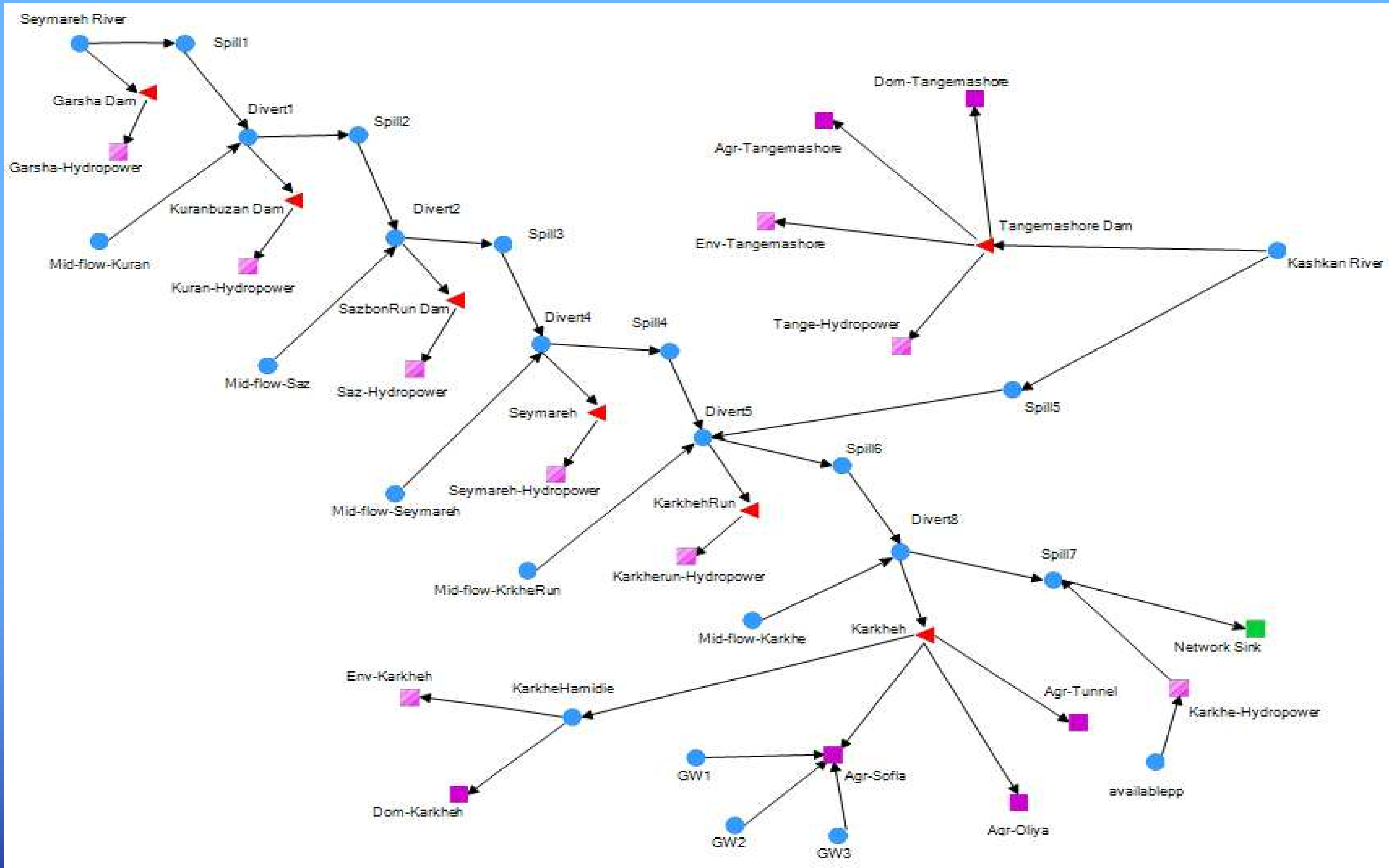
↓

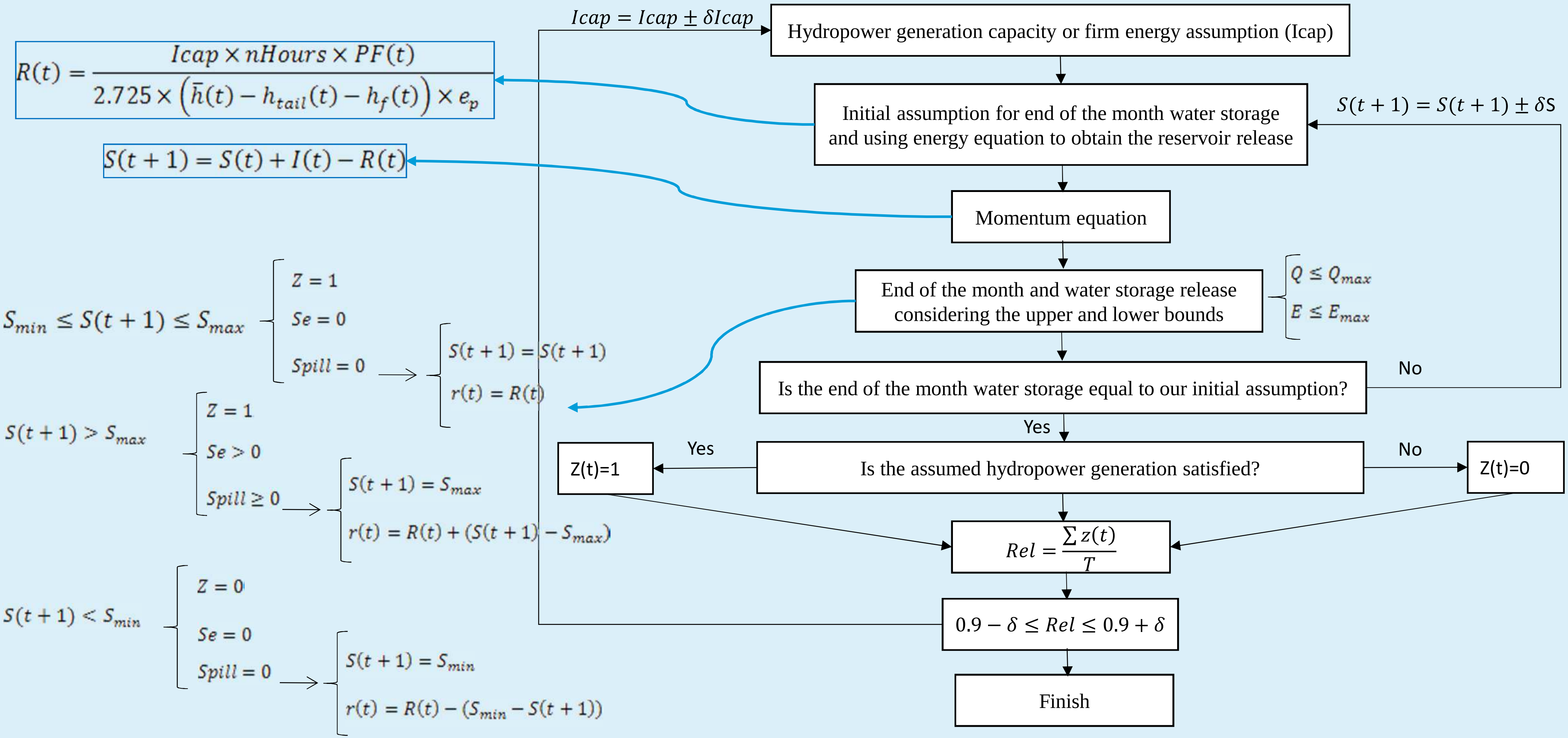
Extended MODSIM using Custom Coding

# Implementation of RBS in the Extended MODSIM model (RBSM)



| | | |
|---|---|---|
| | Firm Energy | Pf = 4 Hrs / 24 Hrs |
| Plant Factor = $E/Emax$ | Secondary Energy | 4 Hrs / 24 Hrs < Pf < 24 Hrs /24 Hrs |
| | Spill water | Pf > 24 Hrs / 24 Hrs |


Seymareh River
Spill1
Garsha Dam
Divert1
Spill2
Garsha-Hydropower
Kuranbuzan Dam
Divert2
Mid-flow-Kuran
Spill3
Kuran-Hydropower
SazbonRun Dam
Divert4
Spill4
Mid-flow-Saz
Saz-Hydropower
Seymareh
Divert5
Seymareh-Hydropower
Mid-flow-Seymareh
KarkhehRun
Spill6
Divert8
Karkherun-Hydropower
Mid-flow-KrkheRun
Spill7
Mid-flow-Karkhe
Karkheh
Network Sink
Env-Karkheh
KarkheHamidie
Agr-Tunnel
Karkhe-Hydropower
GW1
Agr-Sofla
Dom-Karkheh
availablepp
GW2
GW3
Agr-Oliya
Dom-Tangemashore
Agr-Tangemashore
Tangemashore Dam
Env-Tangemashore
Kashkan River
Tange-Hydropower
Spill5


Icap = Icap ± δIcap
Hydropower generation capacity or firm energy assumption (Icap)
R(t) = Icap × nHours × PF(t) / 2.725 × (h̄(t) − h_tail(t) − h_f(t)) × e_p
Initial assumption for end of the month water storage and using energy equation to obtain the reservoir release
S(t + 1) = S(t + 1) ± δS
S(t + 1) = S(t) + I(t) − R(t)
Momentum equation
End of the month and water storage release considering the upper and lower bounds
Q ≤ Q_max
E ≤ E_max
S_min ≤ S(t + 1) ≤ S_max
Z = 1
Se = 0
Spill = 0
S(t + 1) = S(t + 1)
r(t) = R(t)
Is the end of the month water storage equal to our initial assumption?
No
Yes
S(t + 1) > S_max
Z = 1
Se > 0
Spill ≥ 0
S(t + 1) = S_max
r(t) = R(t) + (S(t + 1) − S_max)
Z(t)=1
Yes
Is the assumed hydropower generation satisfied?
No
Z(t)=0
Rel = ∑z(t) / T
S(t + 1) < S_min
Z = 0
Se = 0
Spill = 0
S(t + 1) = S_min
r(t) = R(t) − (S_min − S(t + 1))
0.9 − δ ≤ Rel ≤ 0.9 + δ
Finish

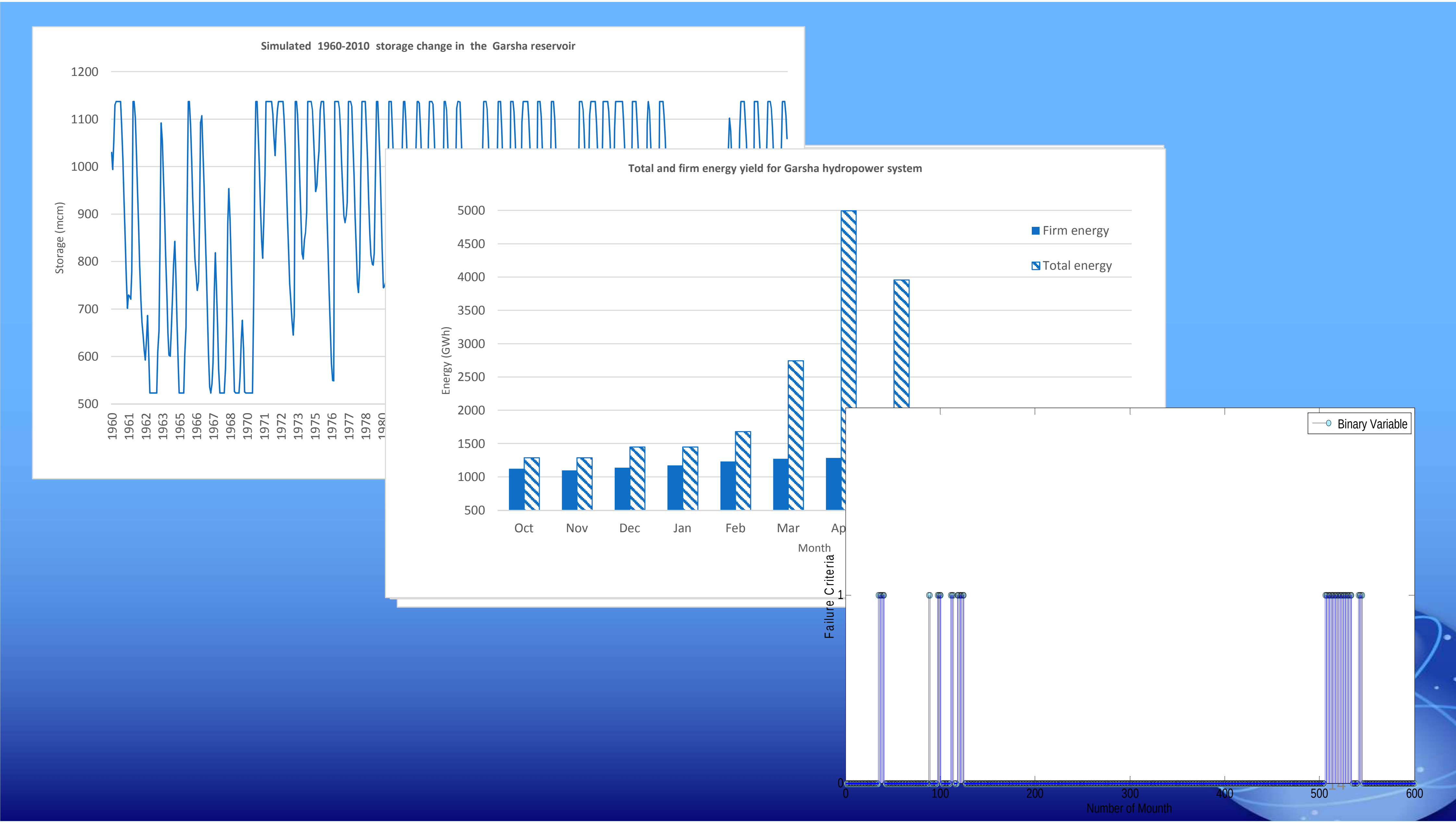
Total water demand

Vulnerability parameter

$$Vul = \sum_{t=1}^{T} D(t) - W(t) \Big/ \sum_{t=1}^{T} D(t)$$

Water supply

With adaptation of the agricultural areas under irrigation



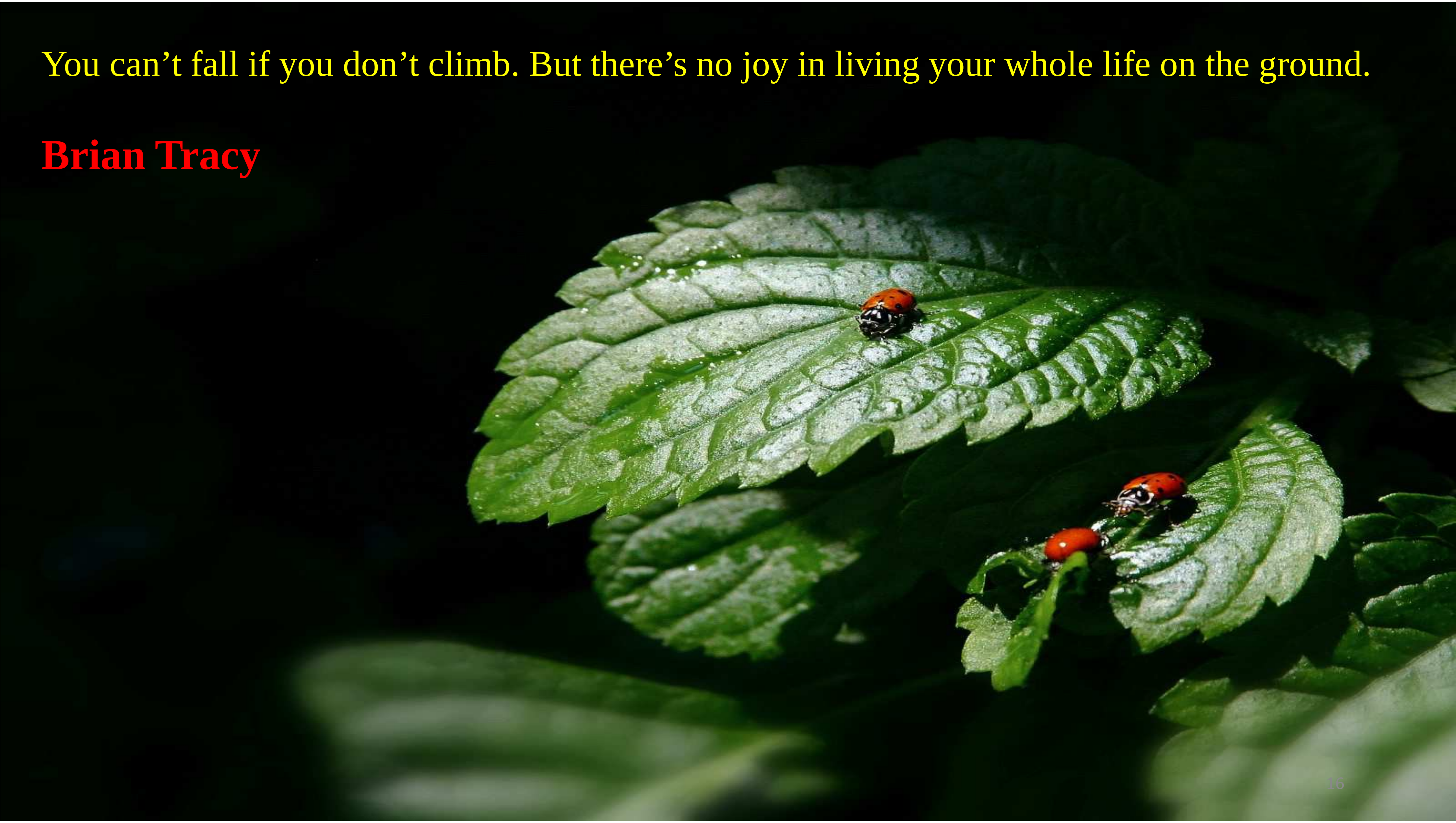
Simulated 1960-2010 storage change in the Garsha reservoir
Storage (mcm)
1200
1100
1000
900
800
700
600
500
1960
1961
1962
1963
1965
1966
1967
1968
1970
1971
1972
1973
1975
1976
1977
1978
1980
Total and firm energy yield for Garsha hydropower system
Energy (GWh)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
Firm energy
Total energy
Oct
Nov
Dec
Jan
Feb
Mar
Ap
Month
Binary Variable
Failure Criteria
1
0
0
100
200
300
400
500
600
Number of Mounth

MODSIM simulates the large- scale problems so fast (because of NFP)

Using extended-MODSIM for hydropower systems

Expand the extended MODSIM to multi-purpose systems

Systemic approach in multi-reservoirs systems


You can’t fall if you don’t climb. But there’s no joy in living your whole life on the ground.
Brian Tracy