Application of GIS-based SWAT framework for water management of irrigation project under rotational water supply

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- Importance of Irrigation Water Management in Water Scarce Regions
- Development of framework using SWAT for irrigation water management of command area
- Case study
- Application

- Irrigation agriculture is a primary user of diverted water
- Irrigated agriculture is caught between two perceptions that are contradictory
  - ❖ agriculture is highly insufficient by growing 'water-guzzling crops'
  - ❖ irrigation is essential for production of sufficient food in the future, given the anticipated increases in food demand due to world population growth and changes in diets
- Globally, food production from irrigation represents more than 40% of the total and uses only about 17% of the land area devoted to food production
- Irrigated agriculture practiced with complete disregard to resource conservation and sustainability
- Most efficient irrigation water management
- Water saving and maximizing its productivity

- Failure in water saving strategy
  - insufficient water supply for irrigation will be the norm
  - irrigation management will shift towards maximizing the production per unit water consumed, the water productivity.
- Deficit irrigation strategy - application of water below full crop-water requirements
- Deficit irrigation can lead to greater economic gain in case of drought and water scarce condition

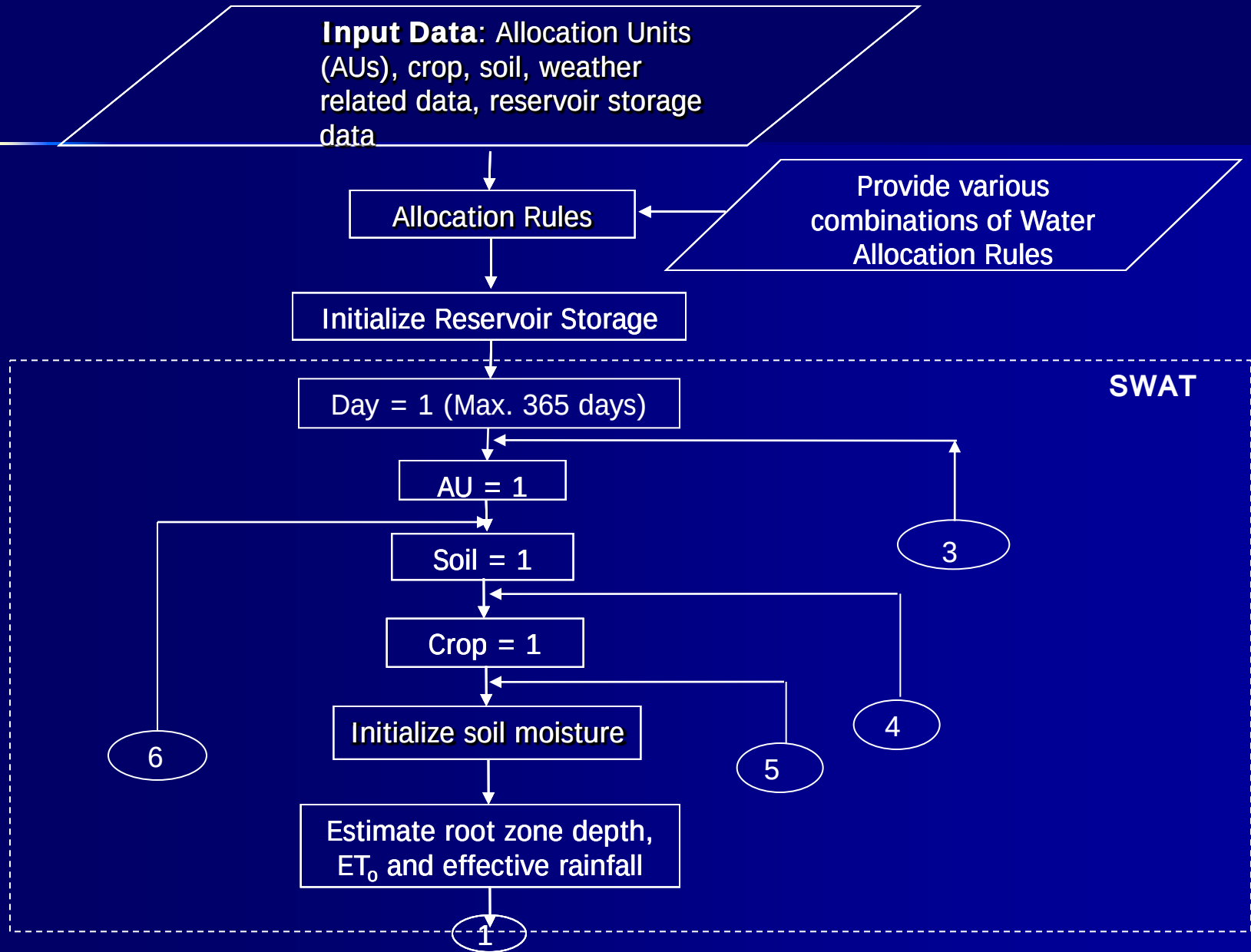
Objective

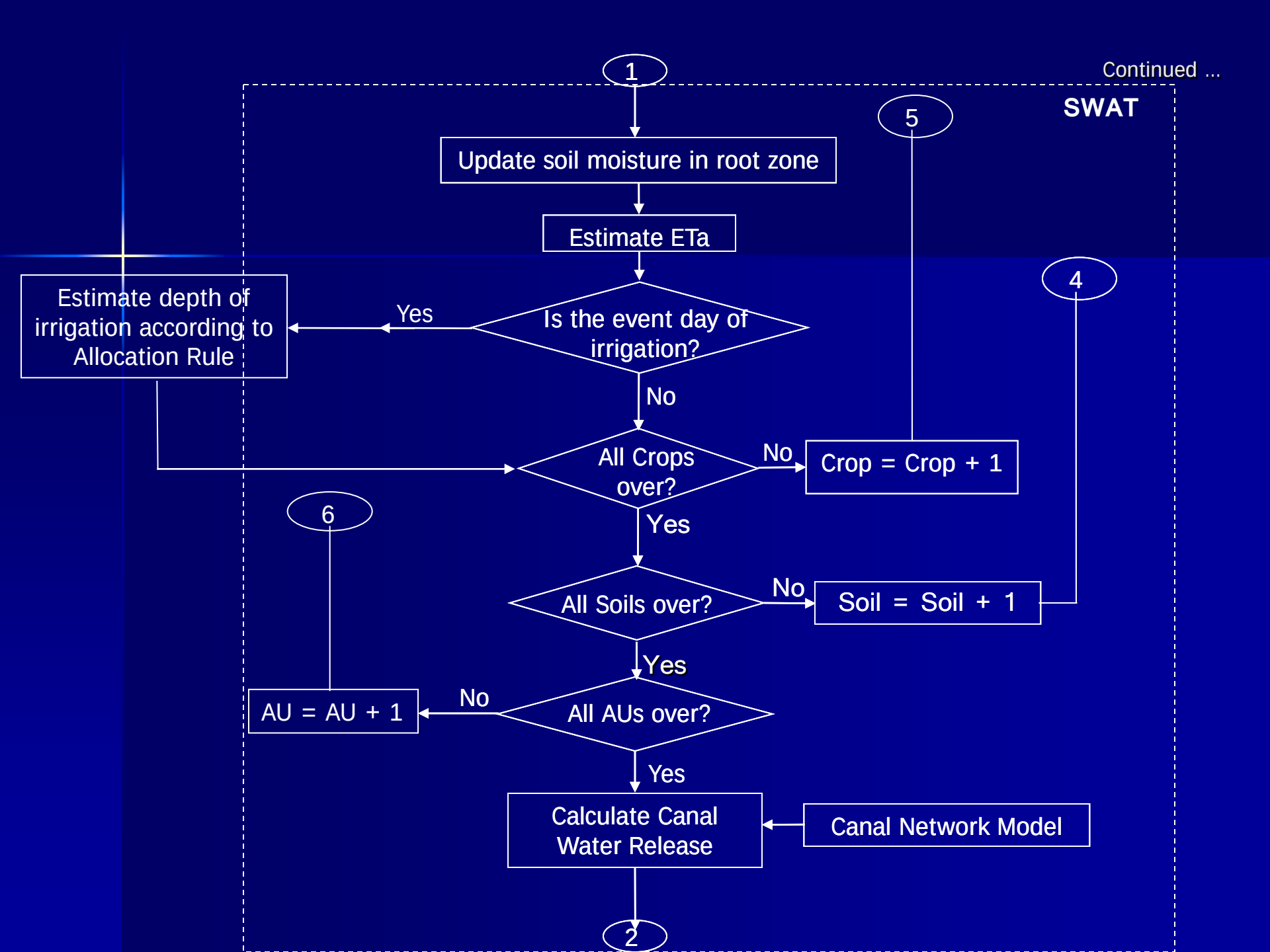
- To evaluate the crop yield for deficit irrigation, and to select the most suitable and sustainable irrigation planning strategy under rotational irrigation system in the irrigation command

Components of Framework

- Watershed- Total command area, Subbasin- Outlet command area; Stream-Canal, HRU- Allocation unit
- Tool framework mainly comprises three modules:
  - Allocation rules module
  - SWAT modules
  - economic module
- Framework also has a facility to use crop growth module externally
- Water allocation rules can be given as input according to water availability in reservoir
- Soil water balance is done through SWAT module
- External crop growth model uses output of ETp and ETa from SWAT
- Economic module computes cost of cultivation of crops, gross and net benefits of individual crop as well as project net benefit for respective allocation rule
- Tool framework is able to estimate daily updates of reservoir storage

Development of Conceptual Framework

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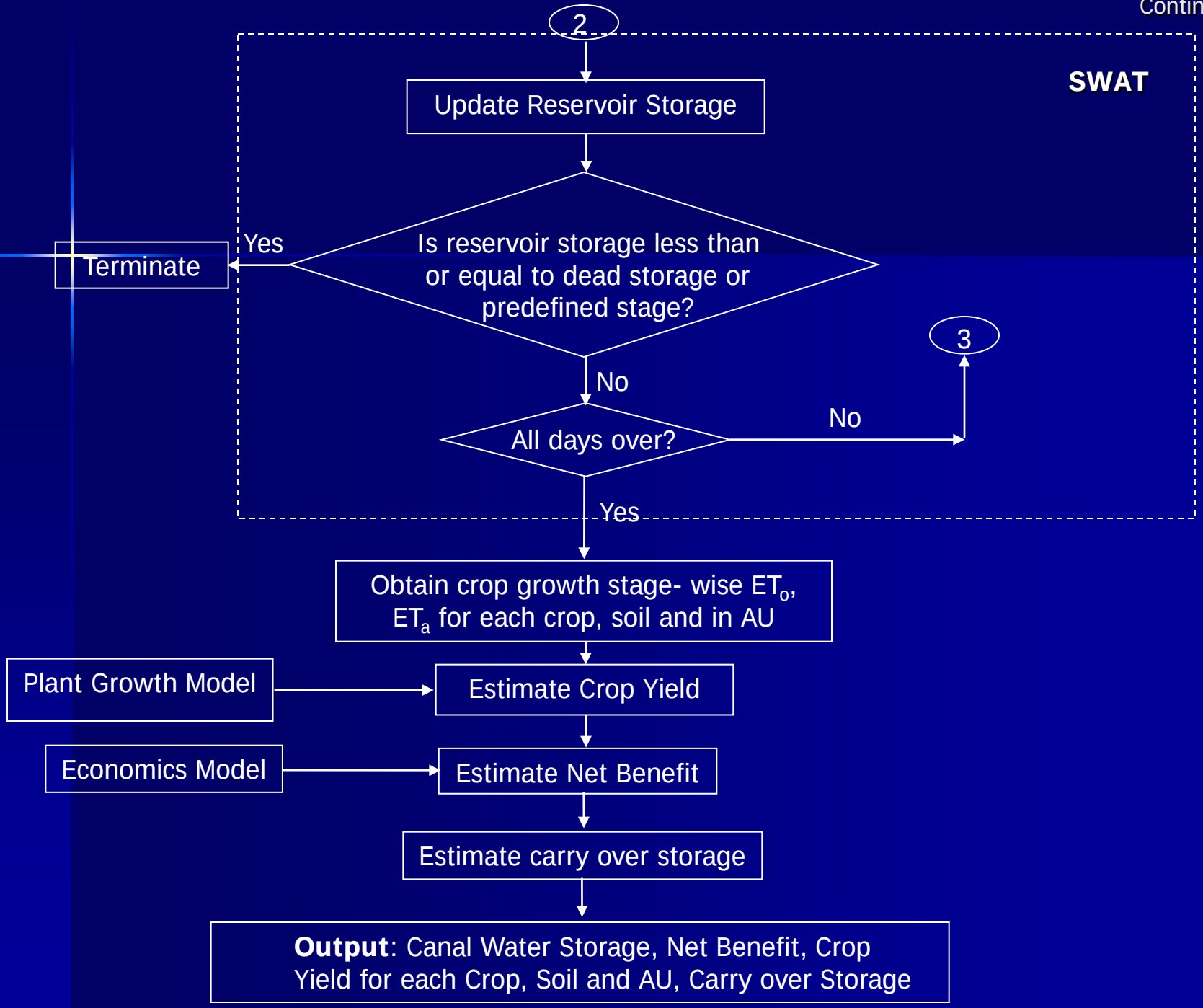
SWAT
1
Update soil moisture in root zone
Estimate ETa
Is the event day of irrigation?
Yes
Estimate depth of irrigation according to Allocation Rule
No
All Crops over?
No
Crop = Crop + 1
5
4
Yes
All Soils over?
No
Soil = Soil + 1
6
Yes
All AUs over?
No
AU = AU + 1
Yes
Calculate Canal Water Release
Canal Network Model
2

Continued ...

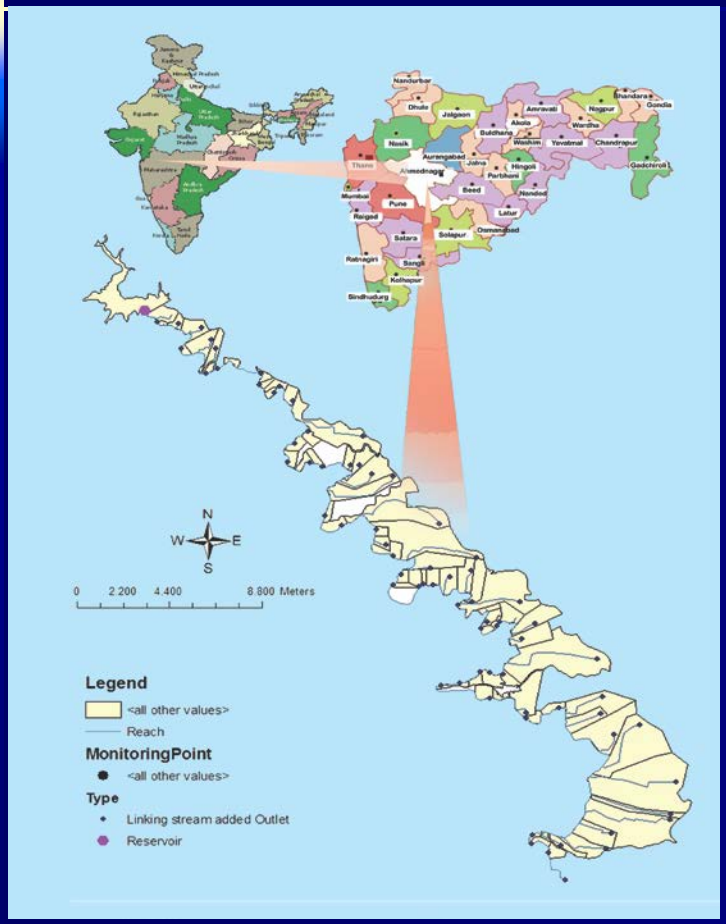

2
SWAT
Update Reservoir Storage
Is reservoir storage less than or equal to dead storage or predefined stage?
Yes
Terminate
No
3
All days over?
No
Yes
Obtain crop growth stage- wise ET_o, ET_a for each crop, soil and in AU
Plant Growth Model
Estimate Crop Yield
Economics Model
Estimate Net Benefit
Estimate carry over storage
Output: Canal Water Storage, Net Benefit, Crop Yield for each Crop, Soil and AU, Carry over Storage

External Crop Growth Model

- Stewart water production function (or any other suitable model)

$$\frac{Y_a}{Y_m} = 1 - \sum_{s=1}^{ns} K_{y_s} \left(\frac{ET_{o_s} - ET_{a_s}}{ET_{o_s}} \right)$$

Location of Study Area



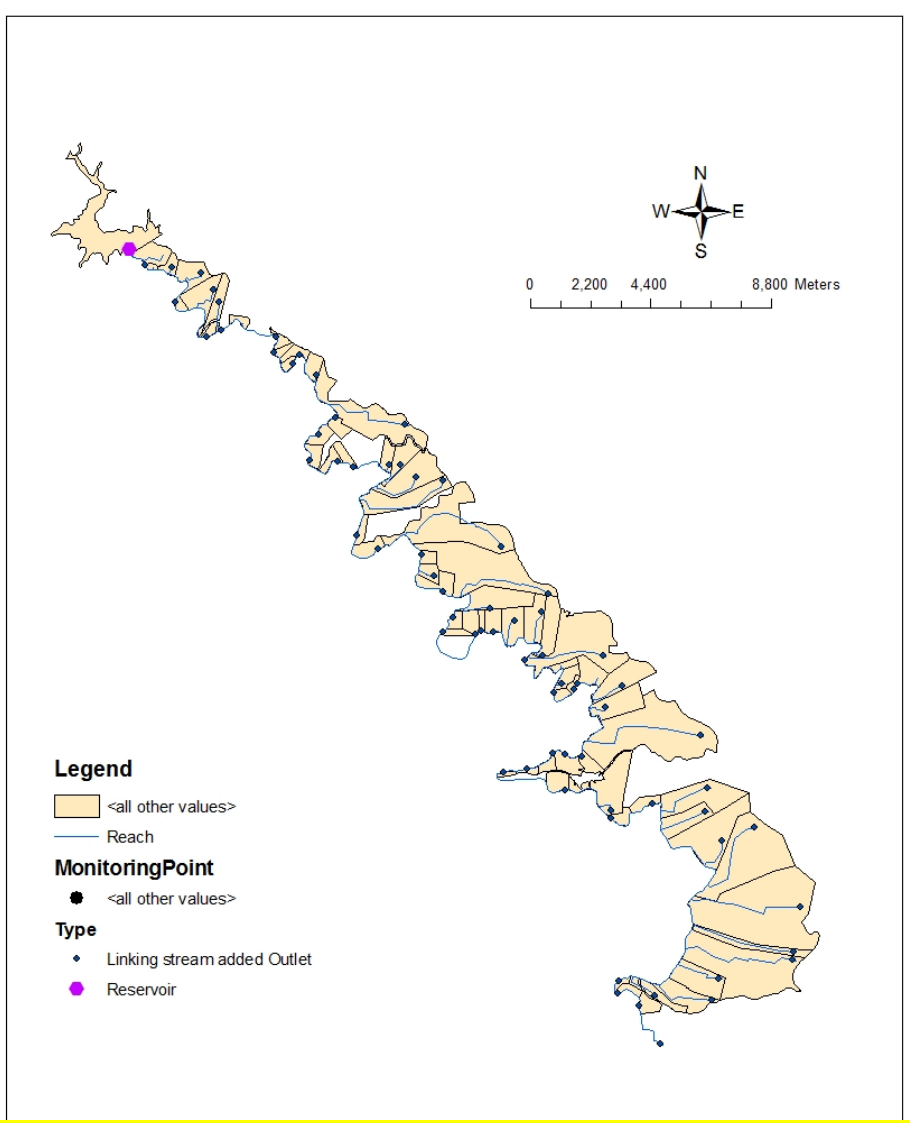
Location of Sina Irrigation Project

- **Sina Medium Irrigation Project**
- Tributary of river Bhima in Krishna basin
- Location: Nimgaon Gangarda village, Tal. Karjat, Dist. Ahmednagar
- Location: Latitude 18o49'0"N Longitude 74o57'0"E
- Topo-sheets No.: 47 J/13, 47 J/14, 47 N/1 and 47 N/2

Features of Study Area

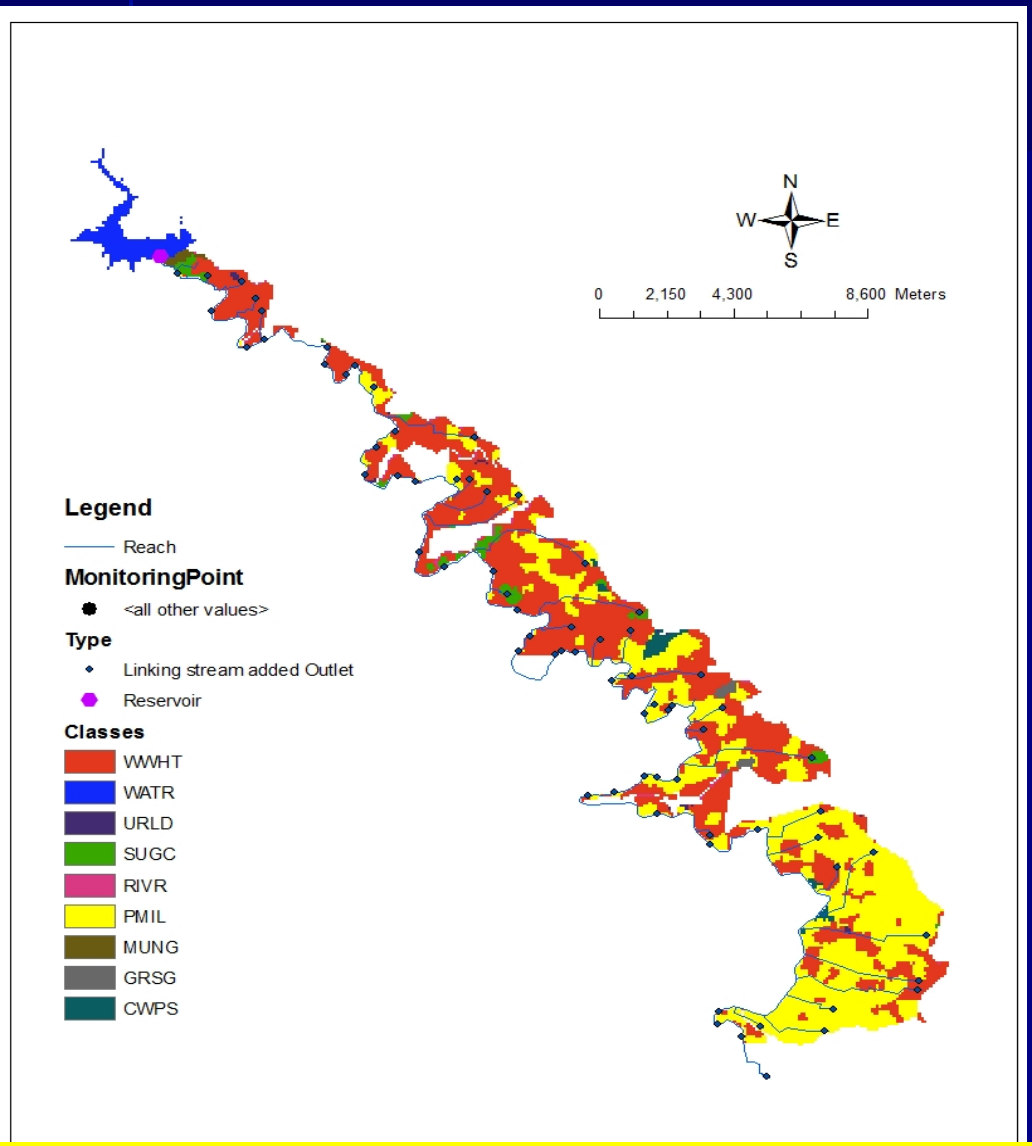
- Annual rainfall: 503.80 mm
- Reservoir gross capacity: 67.98 M cum
- Live storage: 52.33 M cum
- Dead storage: 15.65 M cum
- Observed percentage of live storage in reservoir over a period of 25 years is **69.92** (36.57 M m^3)
- Culturable Command Area (CCA): 9677 ha
- Irrigable Command Area (ICA): 8445 ha
- ICA under Right Bank Canal: 7655 ha

Stream network and area commanded by different units



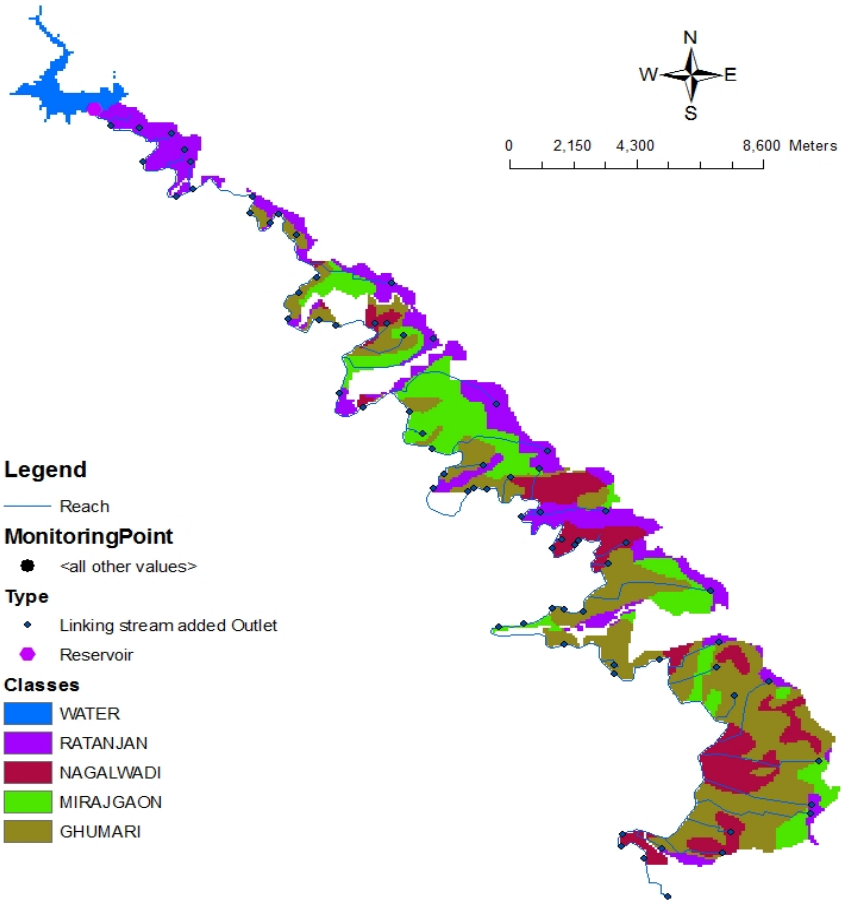
- RBC length: 73 km
- Total 71 units (RBC):
  36 Direct Outlets,
  31 Minors and
  4 Distributaries

Cropping pattern in study area



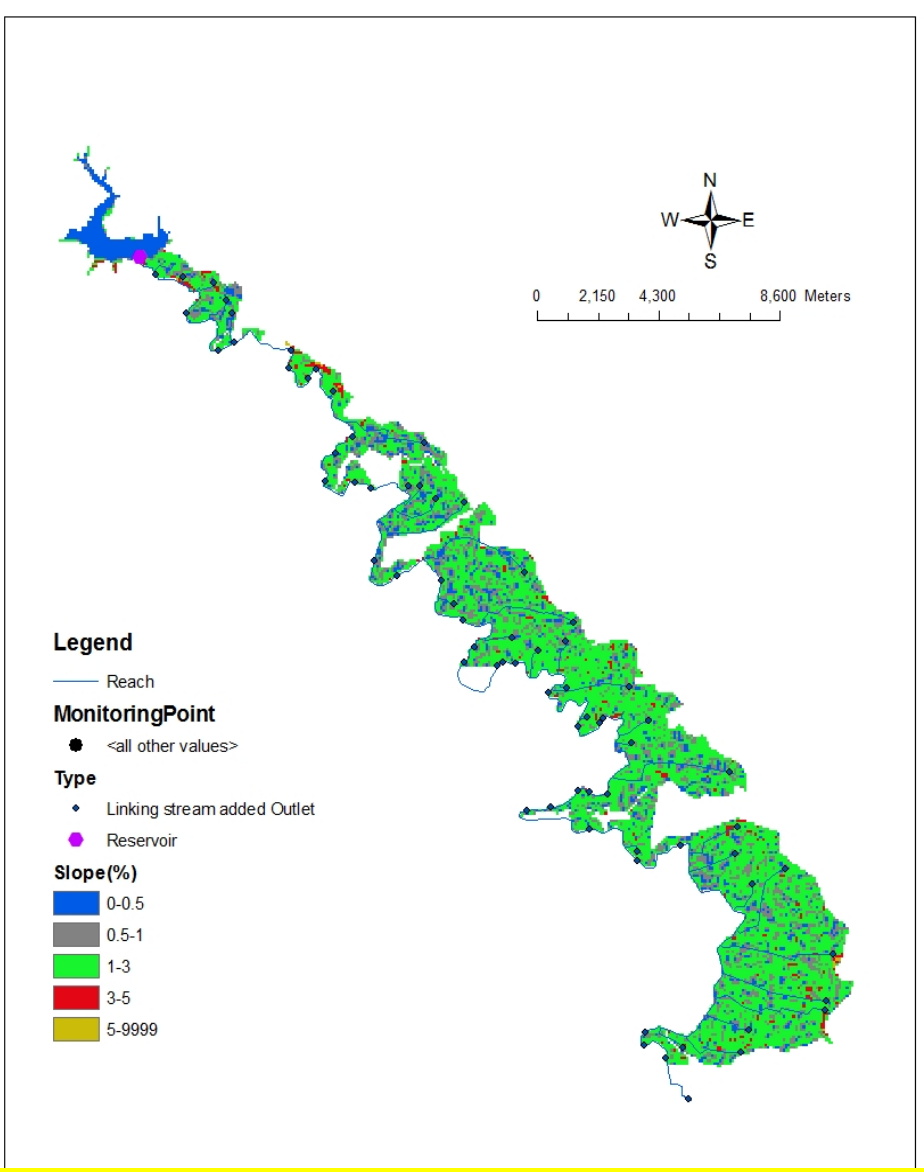
- *Kharif* season (June to October) crops:
  - Sunflower (4154 ha)
  - Pearl millet (3320 ha)
  - Mung bean (89 ha)
  - *Kharif* sorghum (14 ha)
- *Rabi* Season (November to March) crops:
  - Wheat (4154 ha)
  - Groundnut (3320 ha)
  - *Rabi* sorghum (89 ha)
  - Onion (14 ha)
- Annual crops:
  - Sugarcane (78 ha)

Soils of study area



- Mirajgaon series (Clay): 1566 ha
- Ratanjan series (Silt clay): 1820 ha
- Ghumari series (clay loam): 3084 ha
- Nagalwadi series (Silt loam): 1185 ha

Soil Slope in study area



- 0-0.5% slope: 75 ha
- 0.5-1% slope: 1276 ha
- 1-3% slope: 6265 ha
- 3-5% slope: 38 ha
- Above 5% slope: 2 ha

Water Allocation Rules

- Percentage of area to be irrigated
  - 100% ICA
  - 80% ICA
  - 60% ICA
  - 40% ICA
  - 20% ICA
- Release rate from reservoir
  - 5 m^3/sec
  - 4 m^3/sec
  - 3 m^3/sec
  - 2 m^3/sec
  - 1.5 m^3/sec
- Irrigation depth
  - 90 mm
  - 70 mm
  - 50 mm

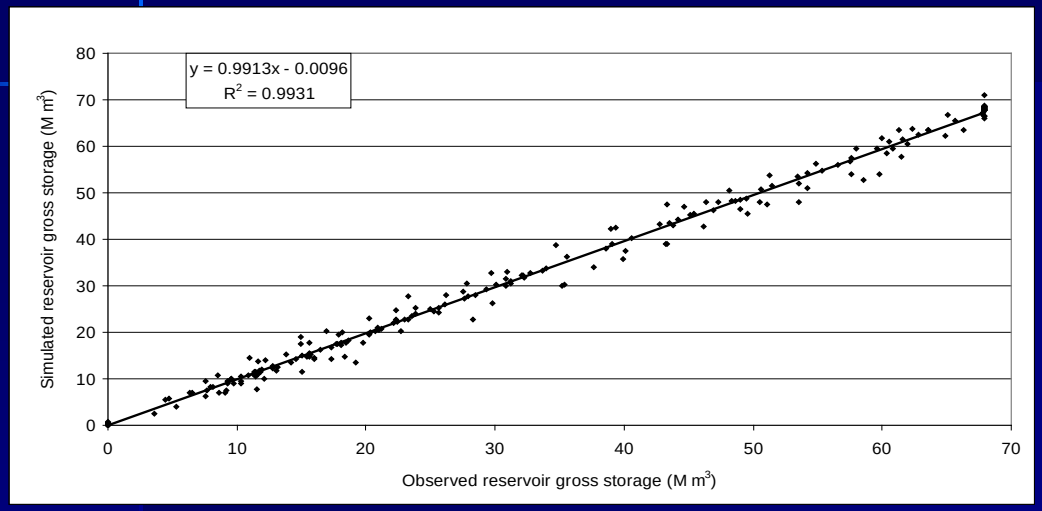
Irrigation Rotation

- Kharif season (June to October): 28 days
- Rabi season (November to February): 21 days
- Summer season (March to May): 14 days

Parameters for SWAT Calibration

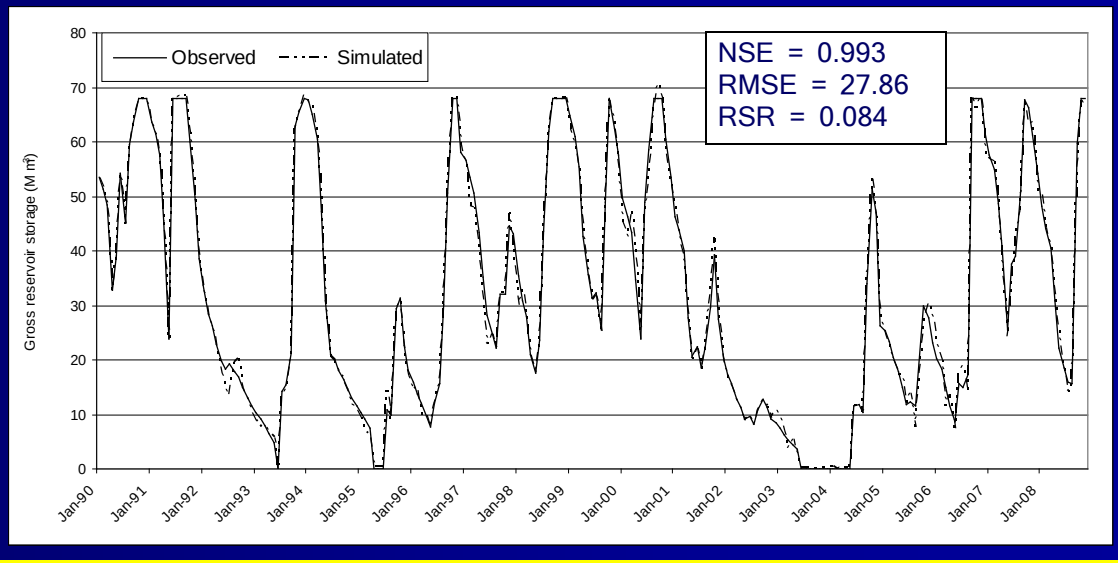
- For reservoir storage, calibration parameter was considered as saturated hydraulic conductivity of reservoir bed, which was varied from 0.2 mm/hr to 2.0 mm/hr
- NSE approaching to 1, lowest RMSE and RSR approaching to 0 was found at saturated hydraulic conductivity of 0.54 mm/hr
- For canal conveyance efficiency, saturated hydraulic conductivity of canal material, which was varied from 0.3 to 3.5 mm/hr and Manning's coefficient (n) varied from 0.025 to 0.060, were considered as calibration parameters
- NSE approaching to 1, lowest RMSE and RSR approaching to zero was found at saturated hydraulic conductivity of canal as 0.68 mm/hr and Manning's coefficient as 0.037.

Calibration of SWAT for Reservoir Storage

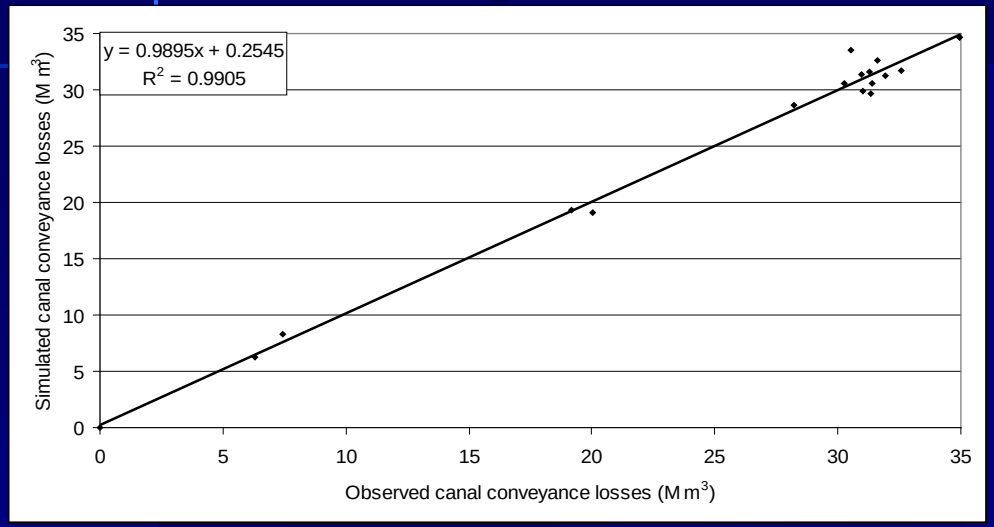


Reservoir gross storage calibration using slope and y-intercept method

Reservoir gross storage calibration using quantitative statistical methods

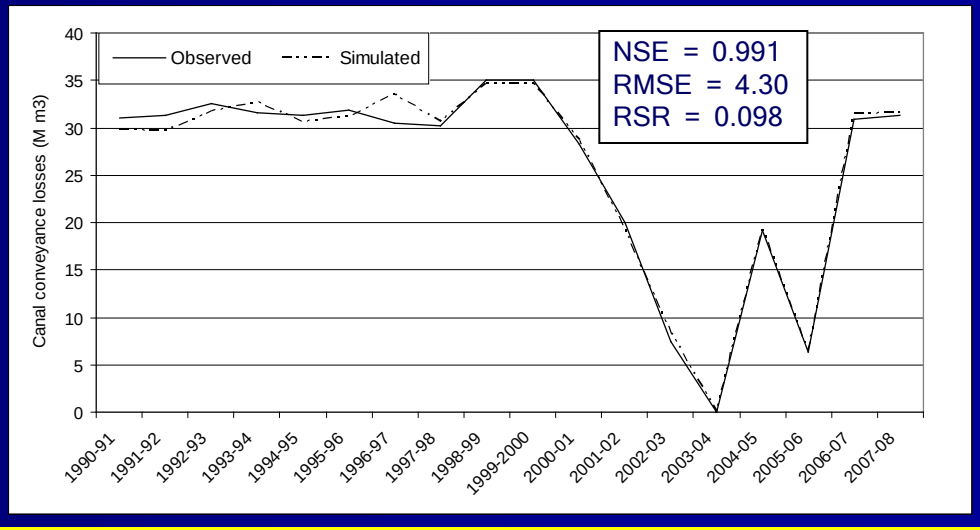


Calibration of SWAT for Canal Conveyance Losses



Conveyance losses from canal network calibration using slope and y-intercept method

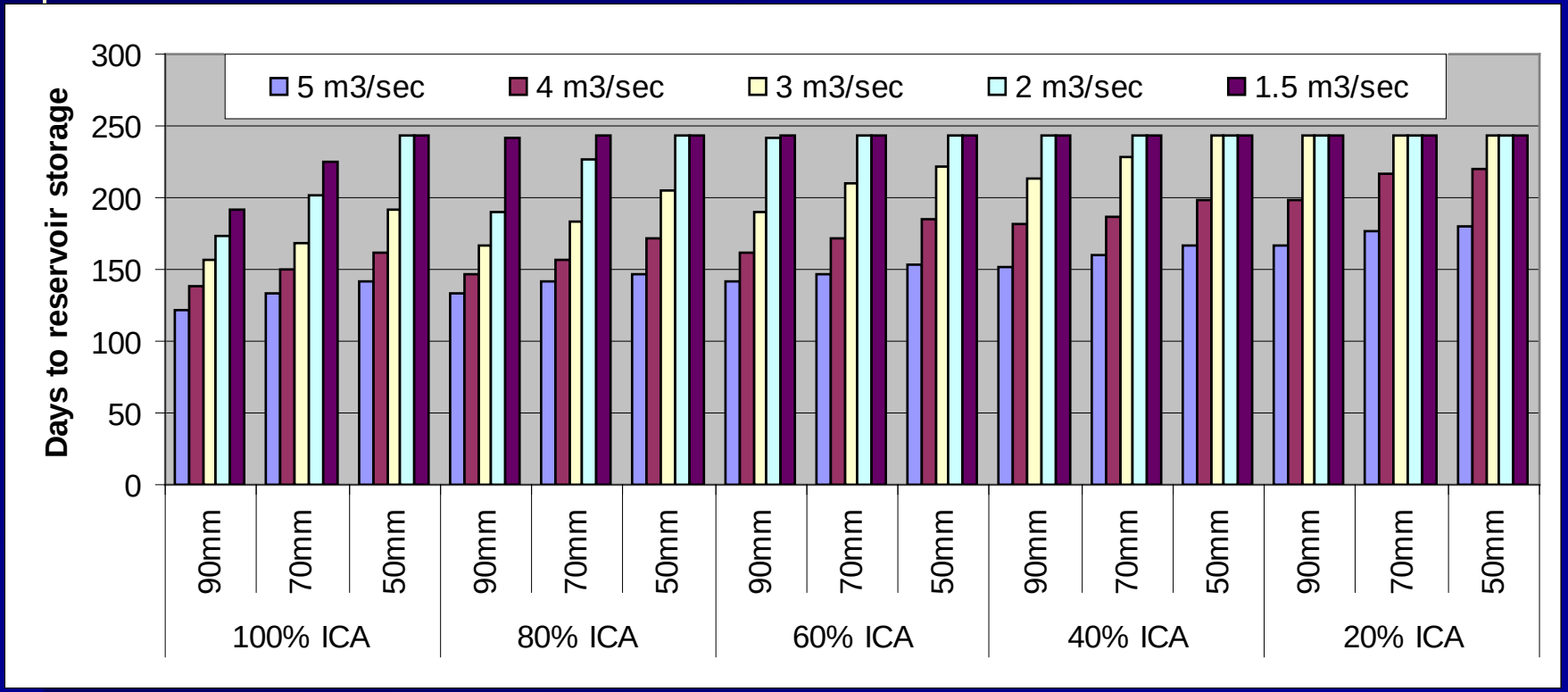
Conveyance losses from canal network calibration using quantitative statistical methods



Assessment of Operational Rules

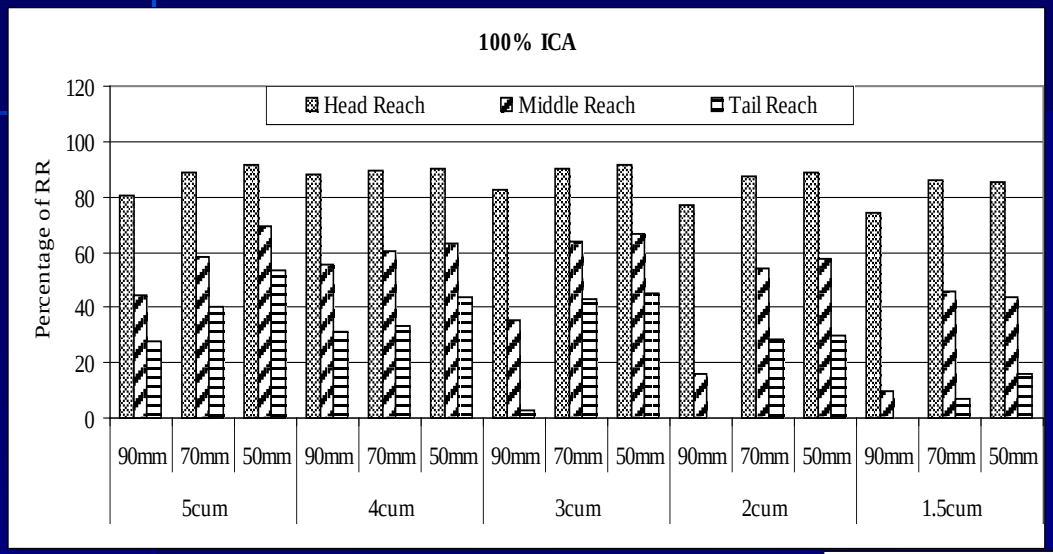
- Scenario was developed for the year 1998 and 1999
- Assessment was done for
  - Longevity of Live storage in reservoir
  - Water distribution uniformity in irrigated area
  - Conveyance efficiency in canal network
  - Project net benefit

Longevity of Live Storage in Reservoir



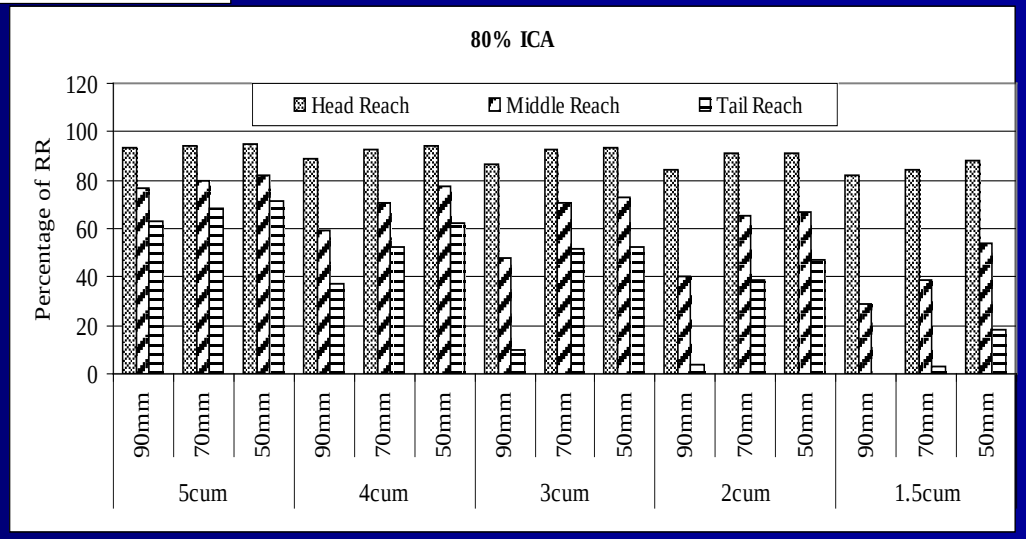
Longevity (days) of reservoir live storage from 1st October for different allocation rules (max days-243)

Water Distribution Uniformity

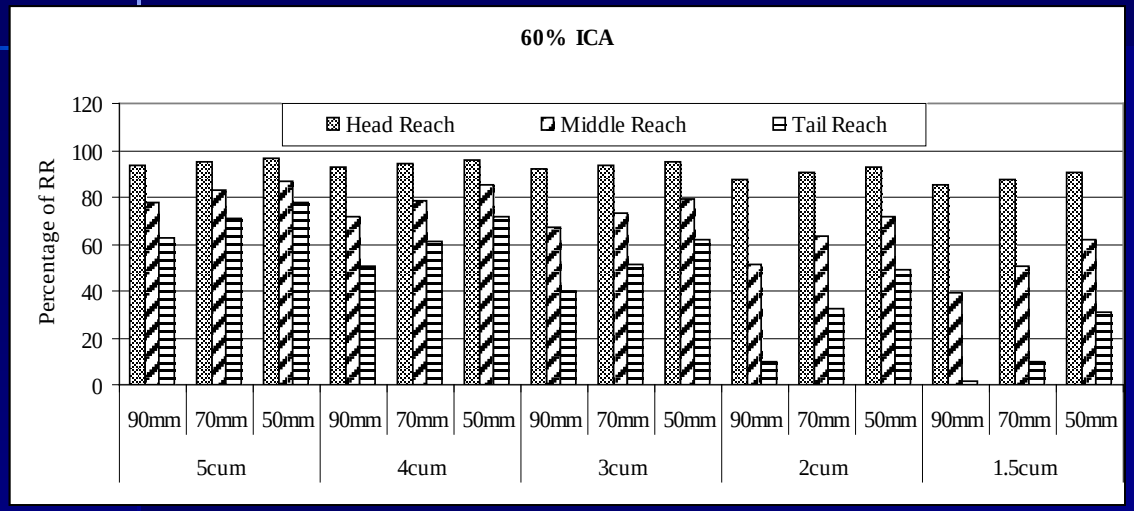


Water distribution for area to be irrigated 100% ICA (7656 ha)

Water distribution for area to be irrigated 80% ICA (6195 ha)

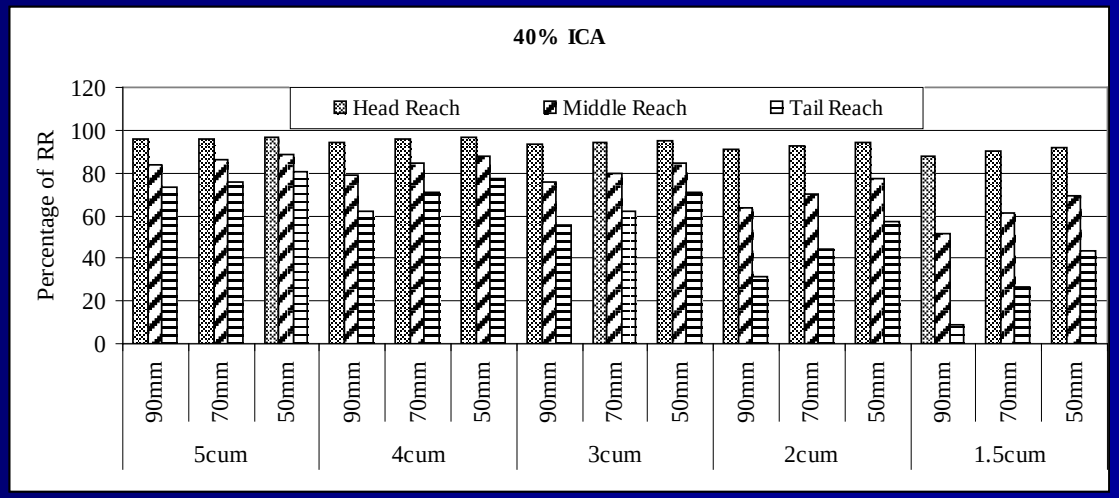


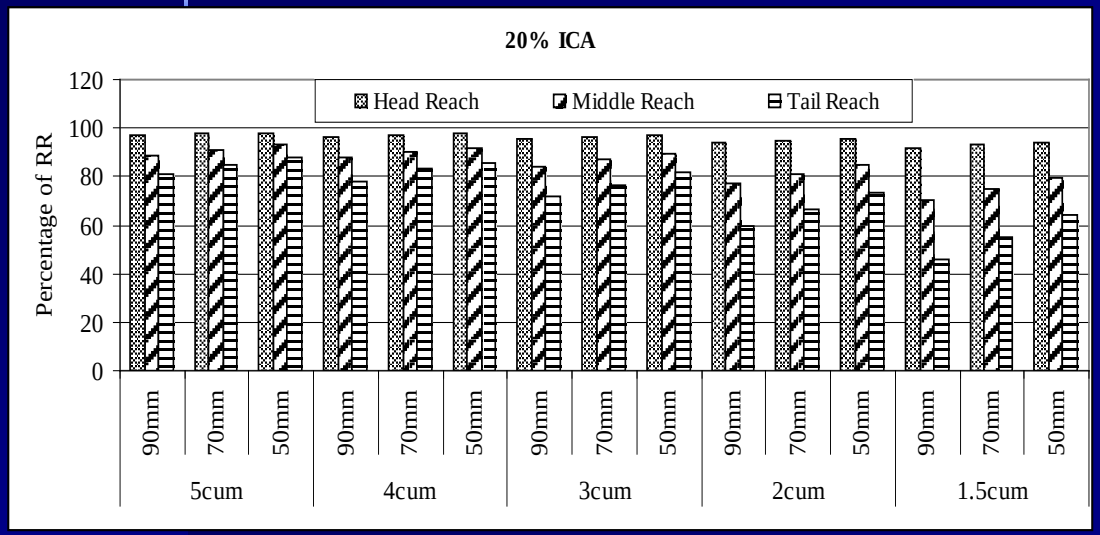
Water Distribution Uniformity



Water distribution for area to be irrigated 60% ICA (4621 ha)

Water distribution for area to be irrigated 40% ICA (3011 ha)

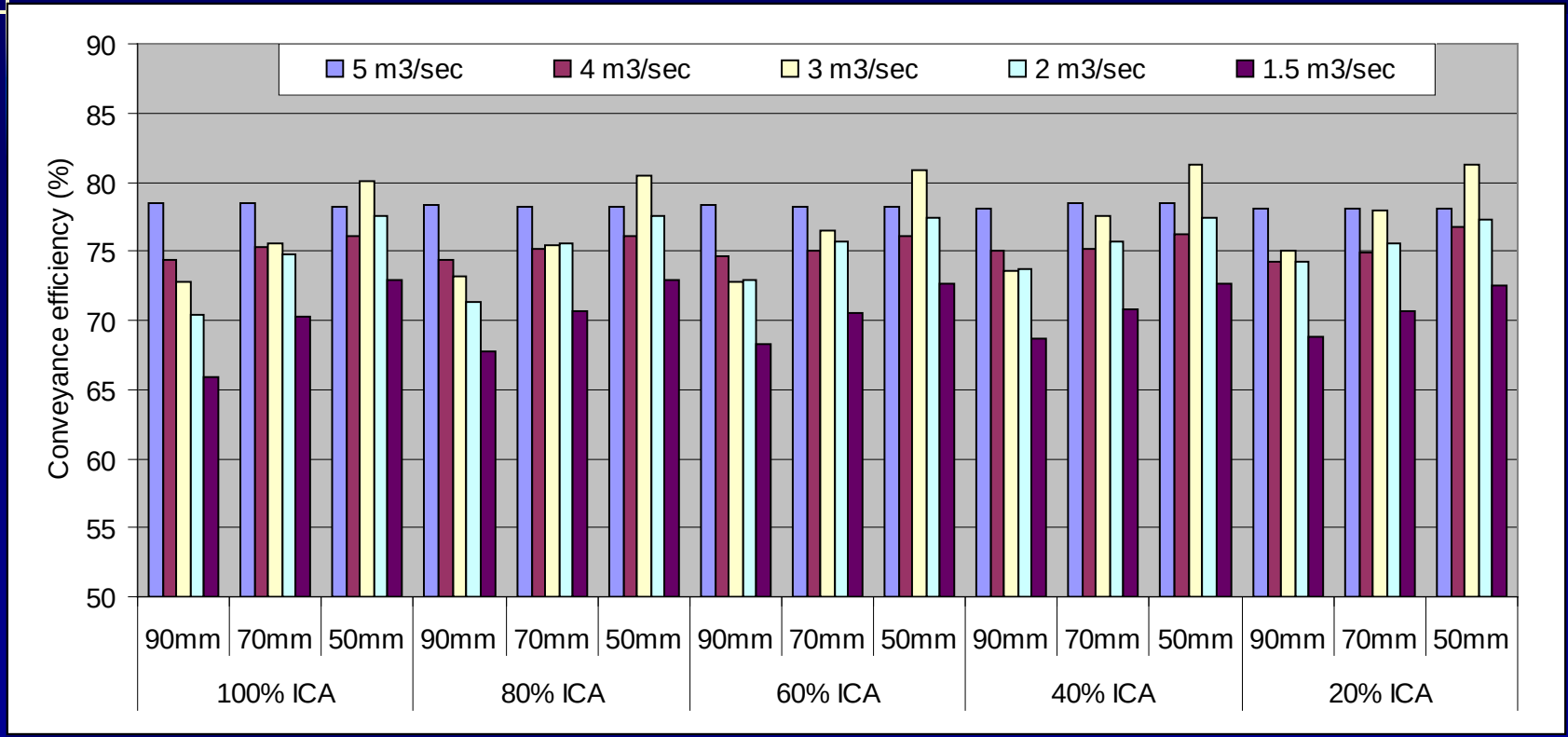




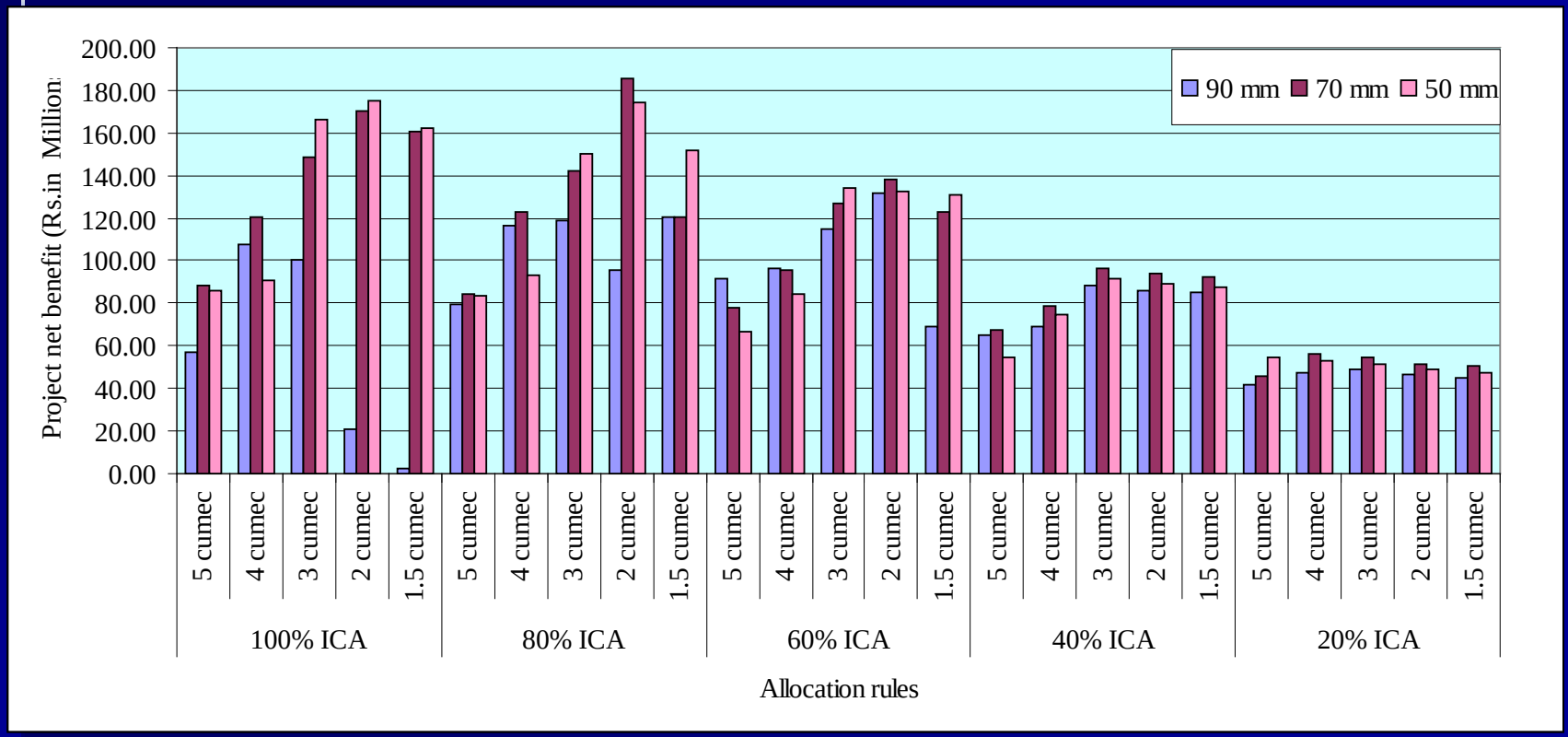
Water distribution for area to be irrigated 20% ICA (1511 ha)

- For areas to be irrigated more than 60% ICA and irrigation depth as 90mm, release rates reduced to zero in the tail reach
- Higher uniformity in all reaches due to reduced irrigation depths
- Higher uniformity with decrease in irrigated areas
- Operation rule with irrigation depth of 50 to 70mm and release rate below $3 m^3/sec$ achieved better uniformity in all reaches

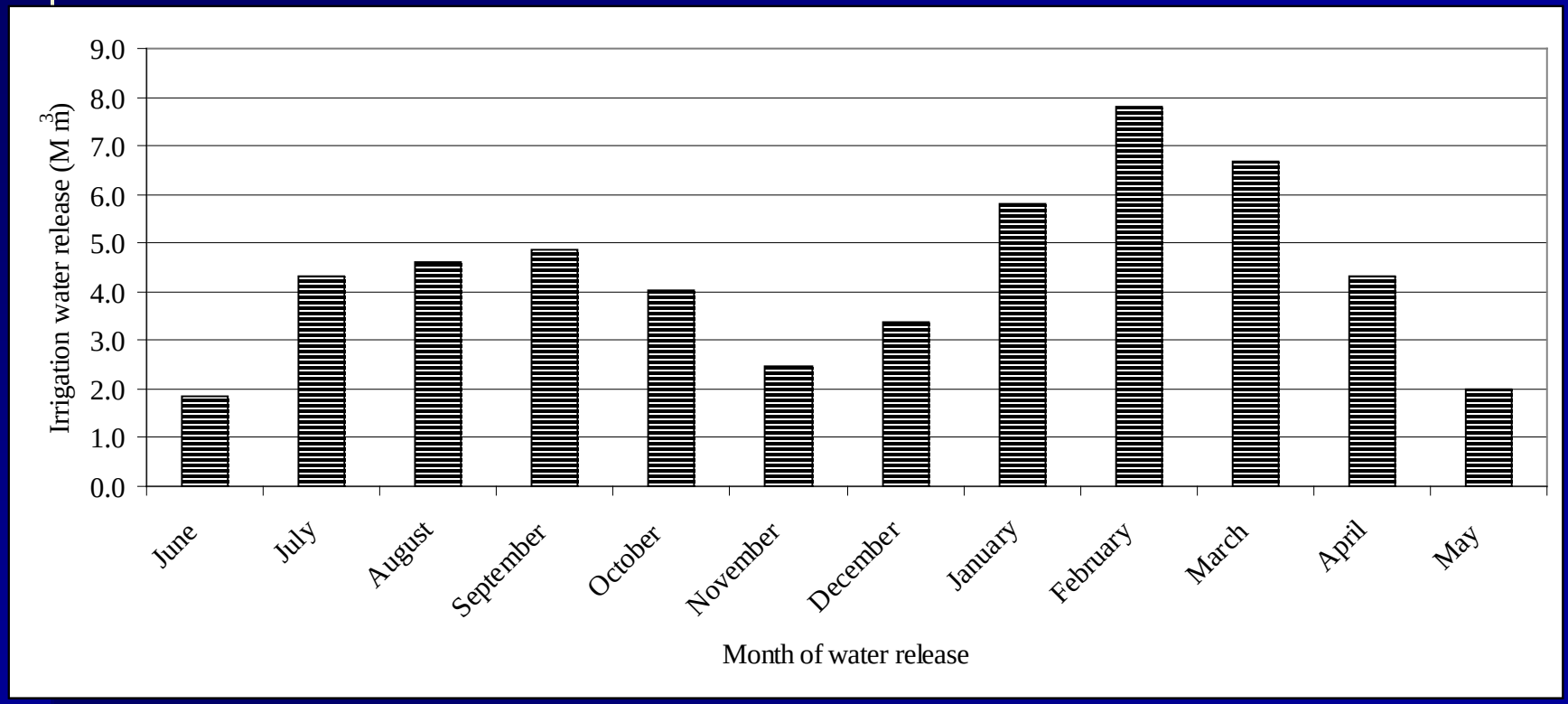
Conveyance Efficiency in Canal Network



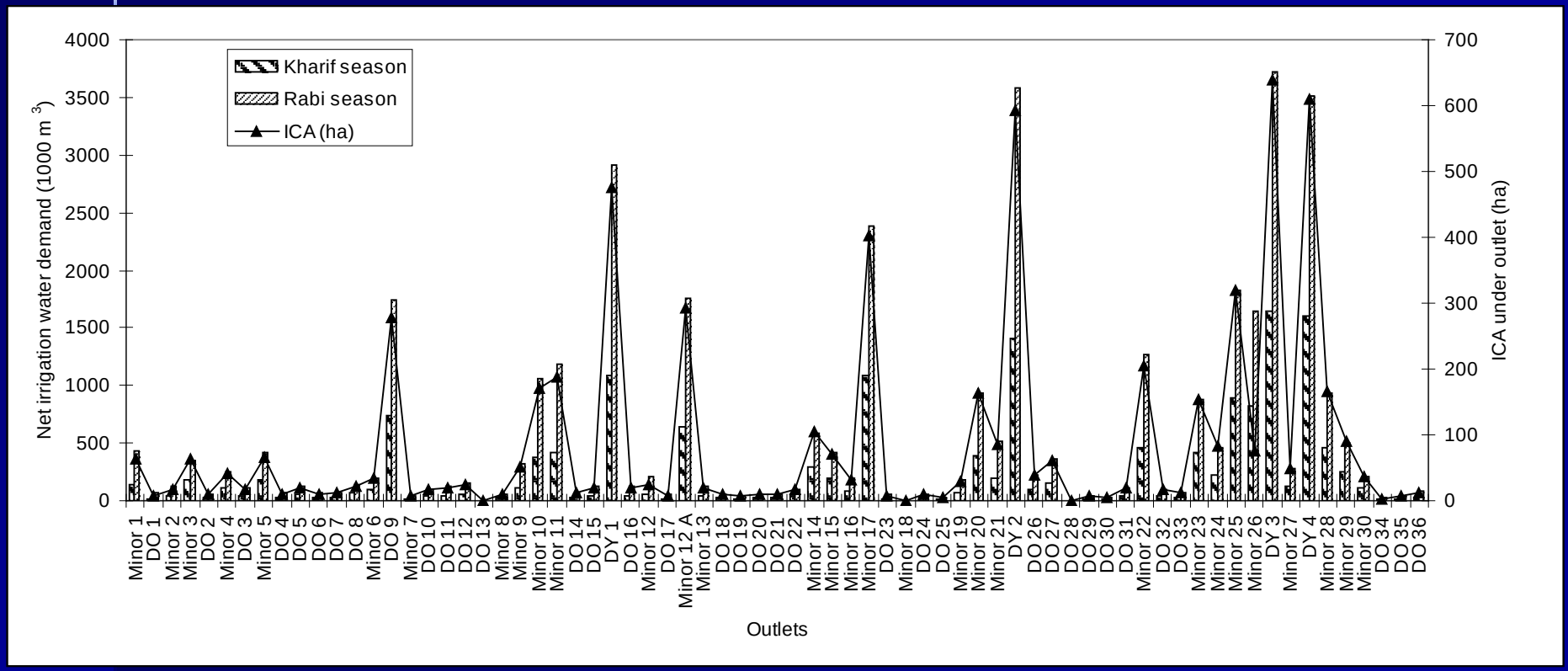
Project Net Benefit



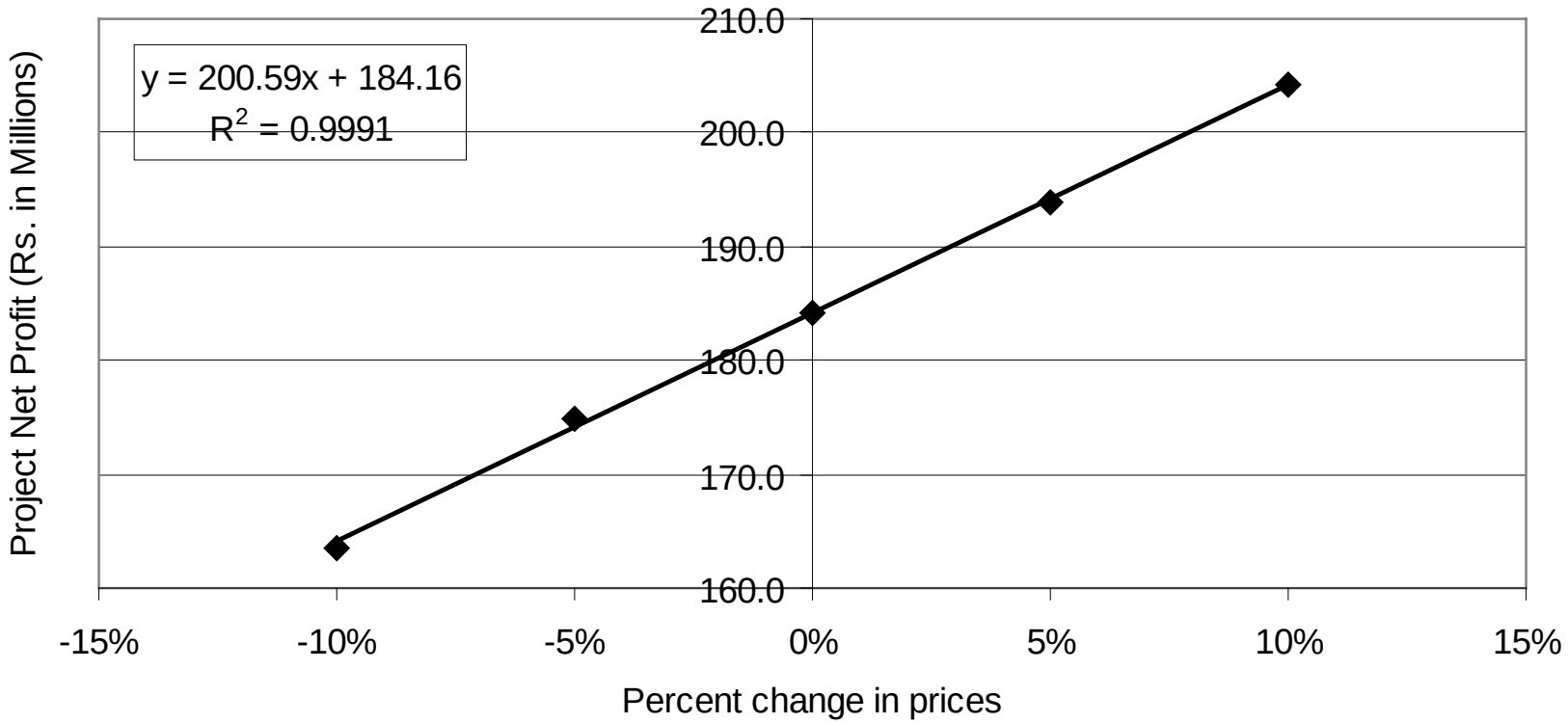
Required Monthly net irrigation water release from reservoir for highest benefited allocation rule



Net irrigation water demand for outlets for highest benefited allocation rule

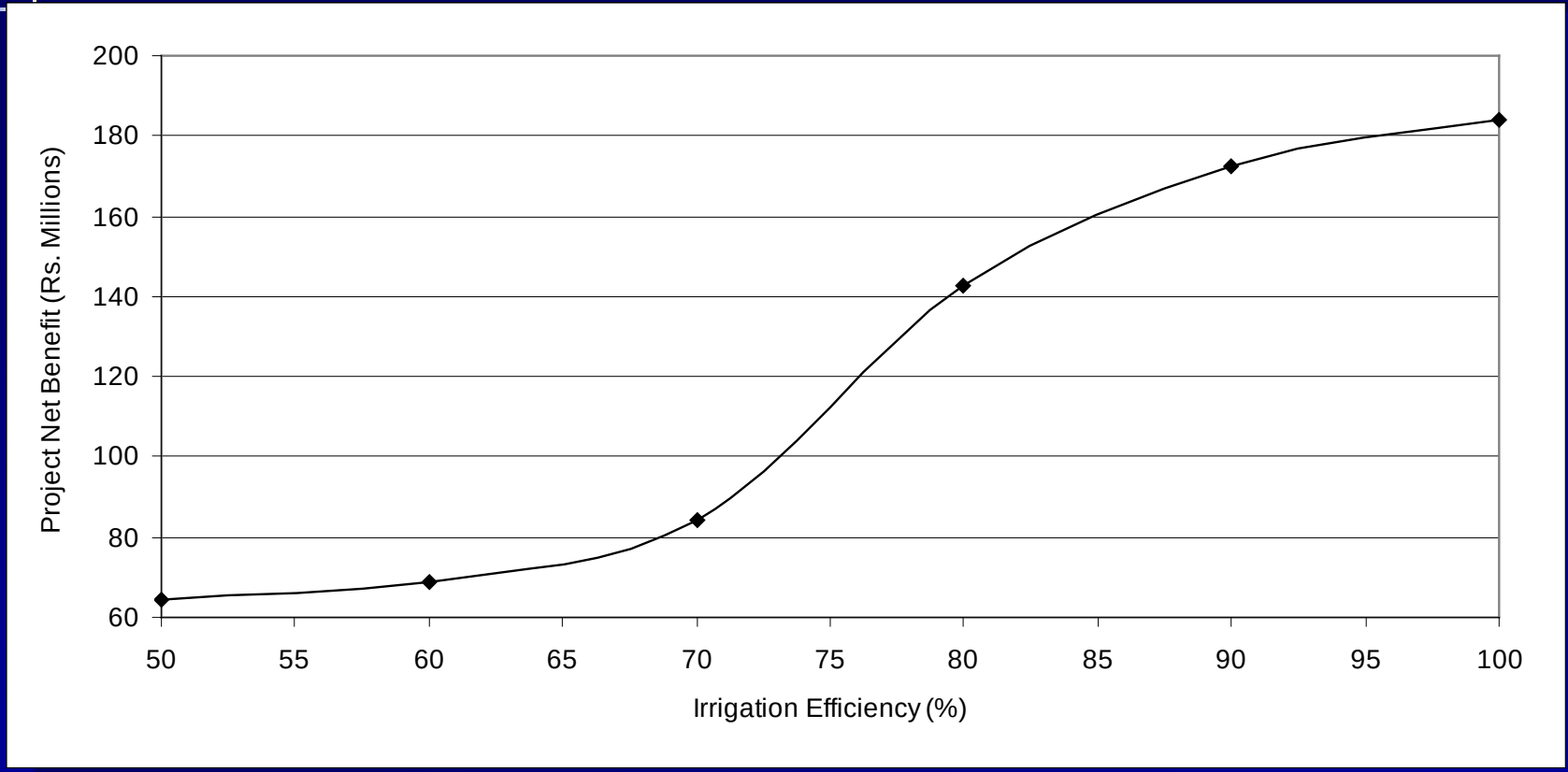


Sensitivity Analysis for external parameter



Sensitivity of project net benefit for external parameter (change in prices)

Sensitivity Analysis for internal parameter



Sensitivity analysis of project net benefit with internal parameter (irrigation efficiency)

Thank you !