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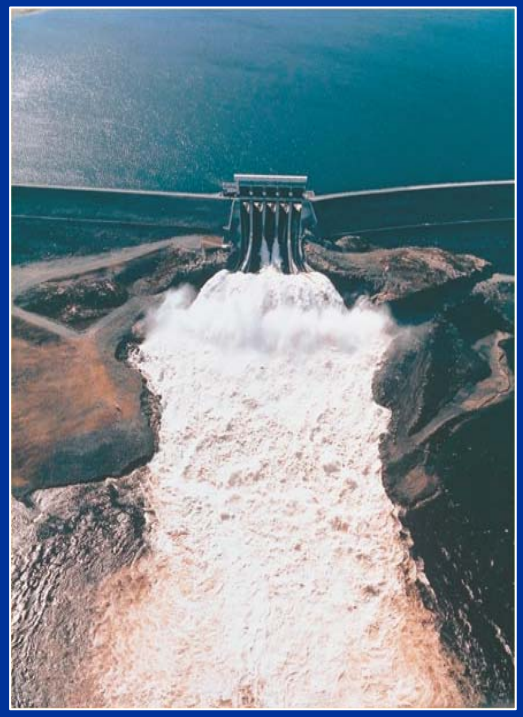
Water Management Decision-Support Software

November 17-18, 2005

Hydro Modeling and Optimization Tools for Power System Operation and Flood Management



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SNC◆Lavalin

- **SNC◆Lavalin**
  - **One of the world's leading groups of engineering companies**
- **Several specialized divisions**
  - **Two of them are particularly involved in power systems modeling and optimization as well as water management**
- **SNC◆Lavalin** Energy Control Systems (ECS)
  - **Deployment of control systems (SCADA/DMS/EMS) for the real-time operation of power networks**
- **Energy Division**
  - **Design of power systems and power plants, development of tools from the hydrologic side to optimize long term production and short term dispatch**
- **Both divisions work together on different projects**

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Hydro Management

- **Complexity of hydro management**
  - Variability of hydrology, energy (demand and/or price), …
  - Type and number of constraints for the operation
- **Impact of decisions about system operation**
  - Long term vs short term vs real time
  - Risk analysis

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Decision Support Software

- **Solutions for multiple water management players:**
  - **Applications for Generation Dispatch Control Centers**
    - → Hydro-generation scheduling and control applications of G E N ④™, the SCADA/EMS of SNC◆Lavalin ECS.
  - **Decision support applications for GenCos, Flood Control and Reservoir Management authorities**
    - → PROSPER™ for Optimal Generation
    - → Flood forecasting and reservoir management systems
- **One can supply inputs to the other**

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Energy Control Systems for Generation Dispatch

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GEN 4

Energy Control Systems (ECS)

Real-Time/Studies
Distributed Architecture
High Availability

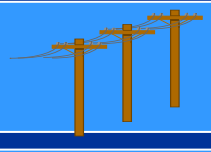
Operations Planning & Scheduling

Network Analysis & Security

Generation Management

EMS GEN 4

Distribution



DMS GEN 4

Outage / Switching Management
Service Call Centers

GEN 4

Acquisition – Control
Alarms
Historical Data Collection

SCADA GEN 4

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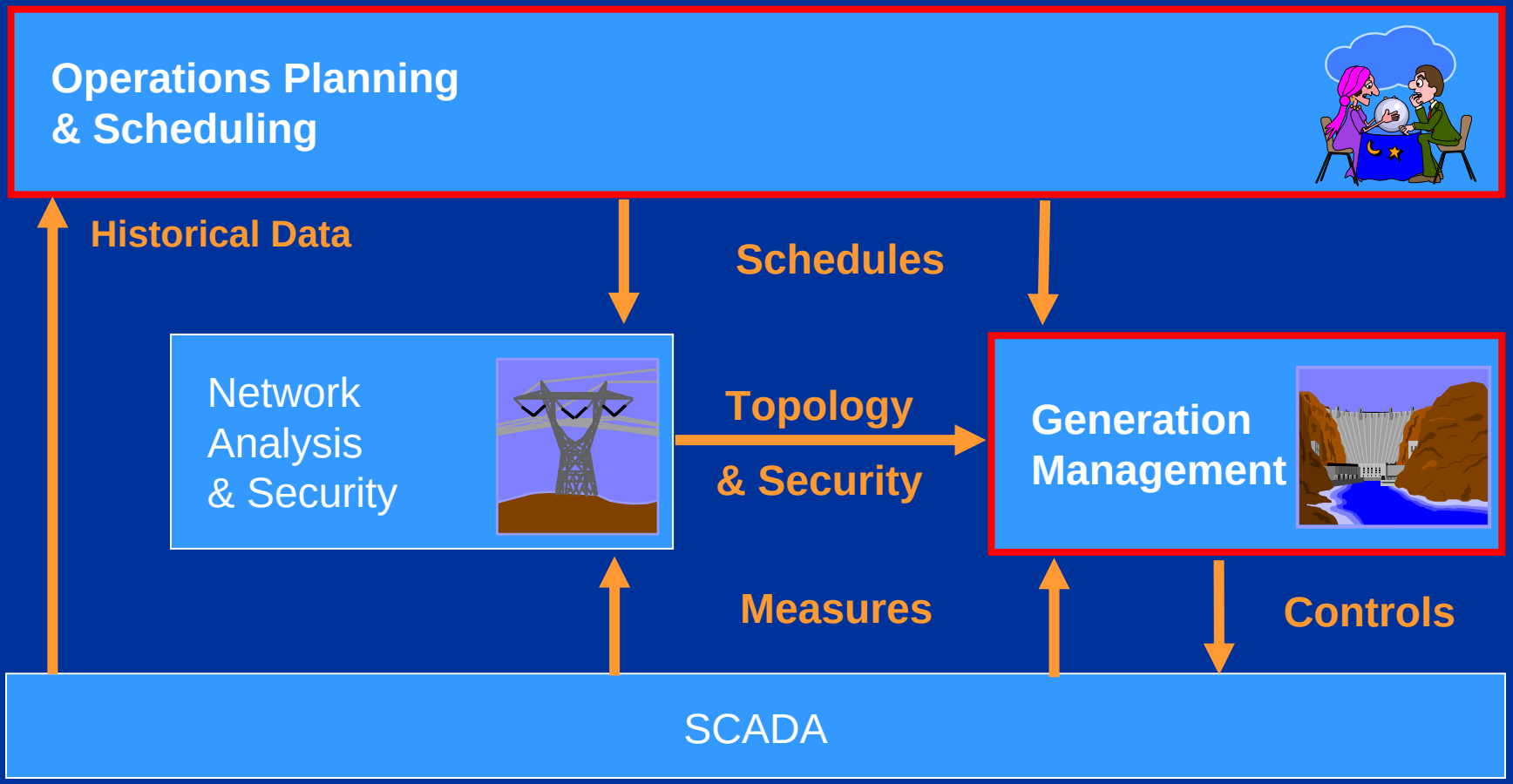
GEN 4

Energy Management System (EMS)



Generation Management

Generation Control

- Automatic Generation Control
- Economic Dispatch
- Reserve / Cost / Performance Monitoring

Voltage Regulation

- Automatic Voltage Control

Spillage

- Spillway Gate Control

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Economic Dispatch

- Based on "Equal Incremental Cost Criterion"
  - Optionally account for transmission losses
  - Optionally accounts for line constraints (Security Constrained Economic Dispatch)

- Calculates Base Point and Participation Factors for
  - dispatchable units (closed-loop)
  - all on-line units (open-loop)
- Source of Base Point and/or Participation Factors
  - Manually entered
  - Average of upper and lower regulating limits
  - Scheduled
  - Calculated (economic)
  - Power market (telemetered from another source)
- Avoids rough zones (cavitation, vibration…)

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Economic Dispatch

AGC Balanced Dispatch Summary (Real Time)

File View Edit

Operating Area: OP_AREA

Load Factor

Closed Loop	0.78196
Open Loop	0.77674

Control Information

Open-Loop Dispatch	Enabled
Avoid Prohibited Regions	Disabled

Economic Range

Closed Loop	1532.6
Open Loop	1642.6

Dispatch Information

CL Dispatchable MW	2516.4	CL High Disp Limit	2820.0
OL Dispatchable MW	2673.9	OL High Disp Limit	3010.0

Unit Information

Power Station	Unit ID	AGC Control Mode	Filtered MW Output	AGC Setpoint	ED Basepoint Closed-Lp	ED Basepoint Open-Lp	Economic Limits Max	Economic Limits Min	Participation Factors Closed-Lp	Participation Factors Open-Lp	Load Factor Closed-Lp	Load Factor Open-Lp	Economic Range
ABELS	GEN-1	Off-Line	0.0	0.0	0.0	0.0	20.0	16.0	0.0	0.0	0.0	0.0	300.0
ABELS	GEN-2	Control	17.3	17.1	19.1	19.1	20.0	16.0	0.0	0.0	0.8	0.8	4.0
ABELS	GEN-3	Control	59.9	59.9	59.1	58.8	70.0	20.0	0.0	0.0	0.8	0.8	50.0
ABELS	GEN-4	Control	59.8	59.9	59.1	58.8	70.0	20.0	0.0	0.0	0.8	0.8	50.0
ADAMS	GEN-5	Control	17.3	17.1	19.1	19.1	20.0	16.0	0.0	0.0	0.8	0.8	4.0
ADAMS	GEN-6	Control	17.4	17.1	19.1	19.1	20.0	16.0	0.0	0.0	0.8	0.8	4.0
ADAMS	GEN-7	Control	59.9	59.9	59.1	58.8	70.0	20.0	0.0	0.0	0.8	0.8	50.0
ADAMS	GEN-8	Control	59.8	59.9	59.1	58.8	70.0	20.0	0.0	0.0	0.8	0.8	50.0
ALDER	GEN-10	Control	78.3	78.6	80.8	80.5	95.0	30.0	0.0	0.0	0.8	0.8	65.0
ALDER	GEN-11	Control	78.4	78.7	80.8	80.5	95.0	30.0	0.0	0.0	0.8	0.8	65.0
ALDER	GEN-9	Control	78.4	78.6	80.8	80.5	95.0	30.0	0.0	0.0	0.8	0.8	65.0
ARNES	GEN-12	Control	157.4	157.7	166.0	165.4	190.0	80.0	0.1	0.1	0.8	0.8	110.0
ARNES	GEN-13	Control	157.3	157.6	166.0	165.4	190.0	80.0	0.1	0.1	0.8	0.8	110.0
ARNES	GEN-14	Base	157.5	157.7	0.0	165.4	190.0	80.0	0.0	0.1	0.0	0.8	110.0
ARTHU	GEN-15	Control	9.3	9.4	8.9	8.9	10.0	5.0	0.0	0.0	0.8	0.8	5.0
ARTHU	GEN-16	Control	9.3	9.3	8.9	8.9	10.0	5.0	0.0	0.0	0.8	0.8	5.0
ARTHU	GEN-17	Control	9.4	9.4	8.9	8.9	10.0	5.0	0.0	0.0	0.8	0.8	5.0
ARTHU	GEN-18	Control	9.4	9.4	8.9	8.9	10.0	5.0	0.0	0.0	0.8	0.8	5.0

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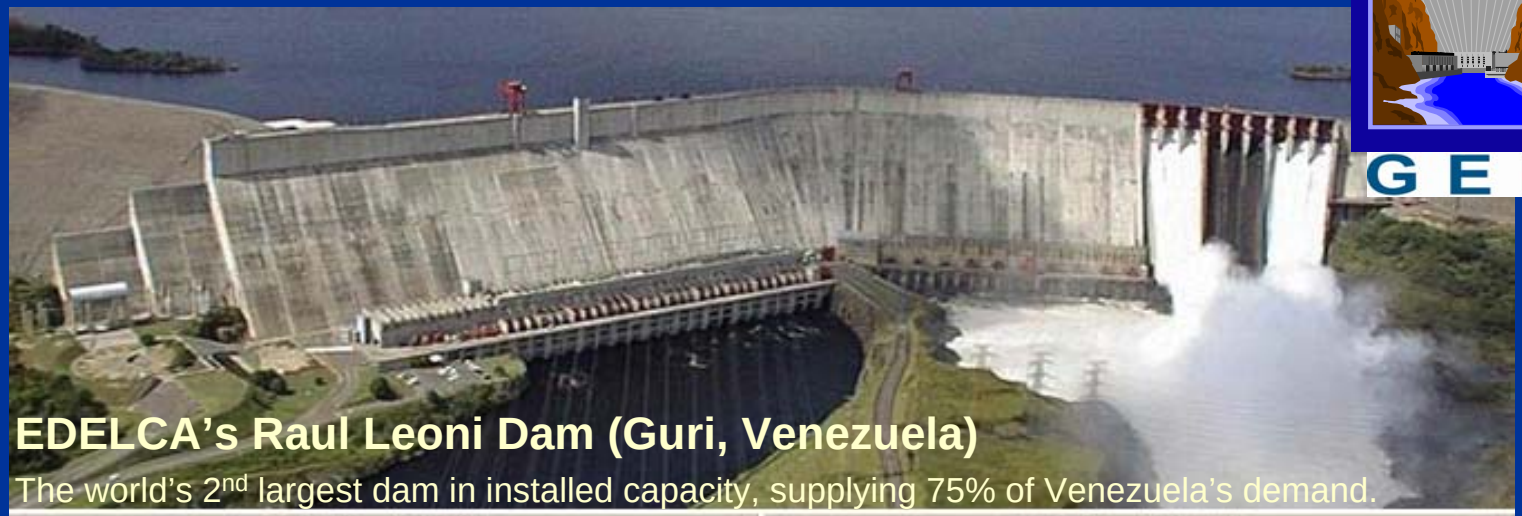
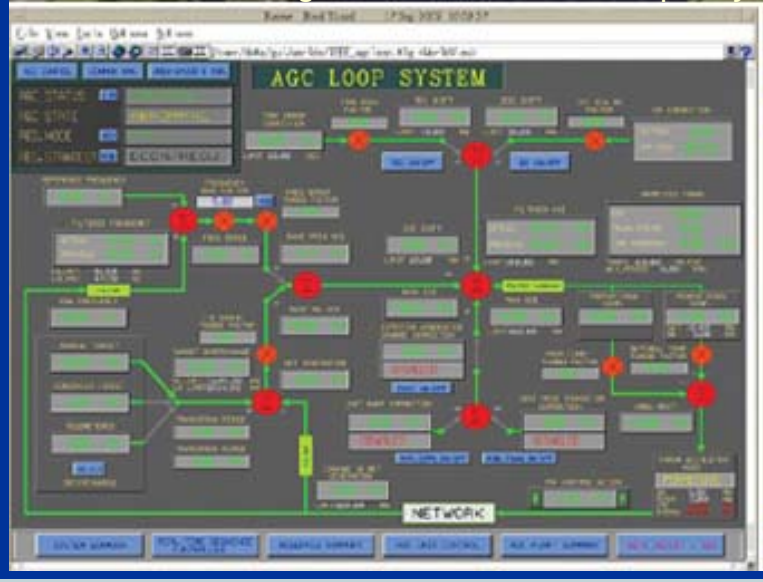
Economic Dispatch

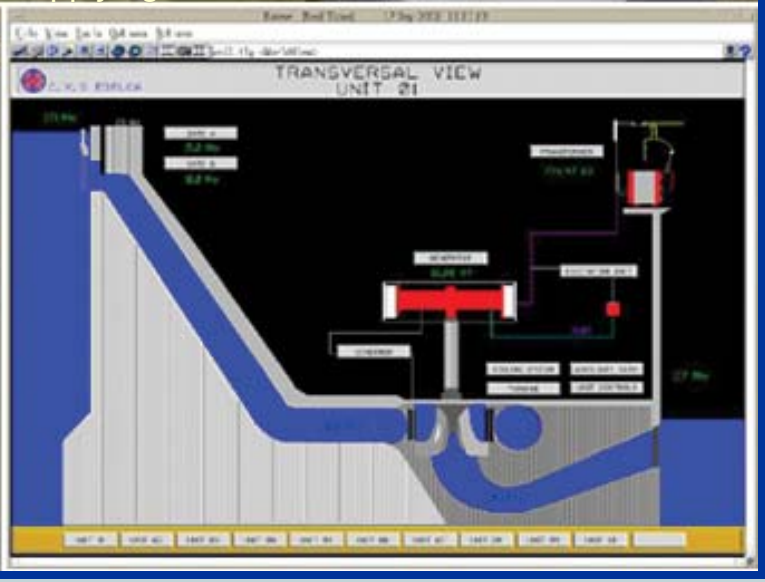
GEN 4



EDELCA's Raul Leoni Dam (Guri, Venezuela)

The world's 2nd largest dam in installed capacity, supplying 75% of Venezuela's demand.





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Economic Dispatch Plug-In

Hydro-Québec's SuperChop Example

- Hydro-Québec developed its own Economic Dispatch function called "SuperChop" to be used throughout the utility's control systems
- SuperChop successfully plugged into the G E N ④™ EMS systems being deployed within the upgrade of Hydro-Québec TransÉnergie's Regional Control Centers
- G E N ④™ EMS designed to host other Economic Dispatch plug-ins

Operations Planning & Scheduling

Forecasting & Operations Scheduling

- Load Forecasting
- Equipment Outage Scheduling
- Interchange Transactions Scheduling
- **Network Operations Scheduling** (Contingency Analysis over Time)

Generation Scheduling

- Hydro Flow Simulation
- Hydro Generation Scheduling / Hydro-Thermal Coordination
- Hydro Unit Commitment / Thermal Unit Commitment
- Security Constrained Unit Commitment

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Hydro Flow Simulation

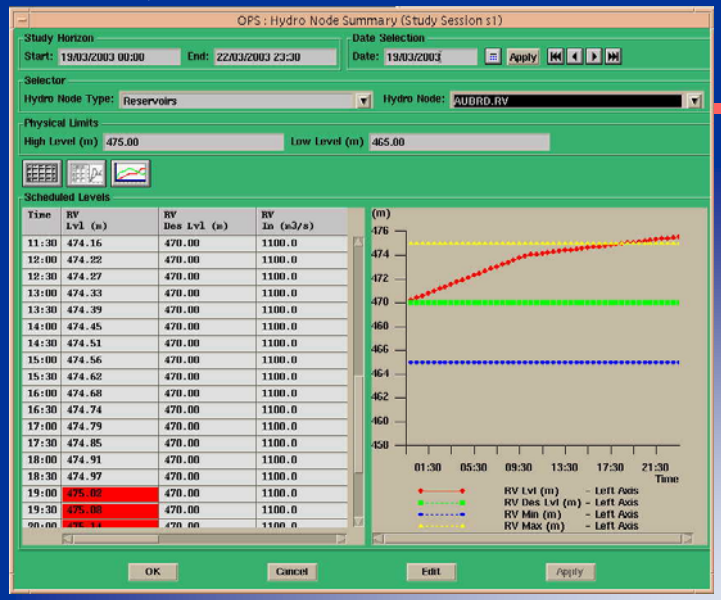
Full Node-Branch Hydro Model with automatic with automatic calculation of all water flows and levels.

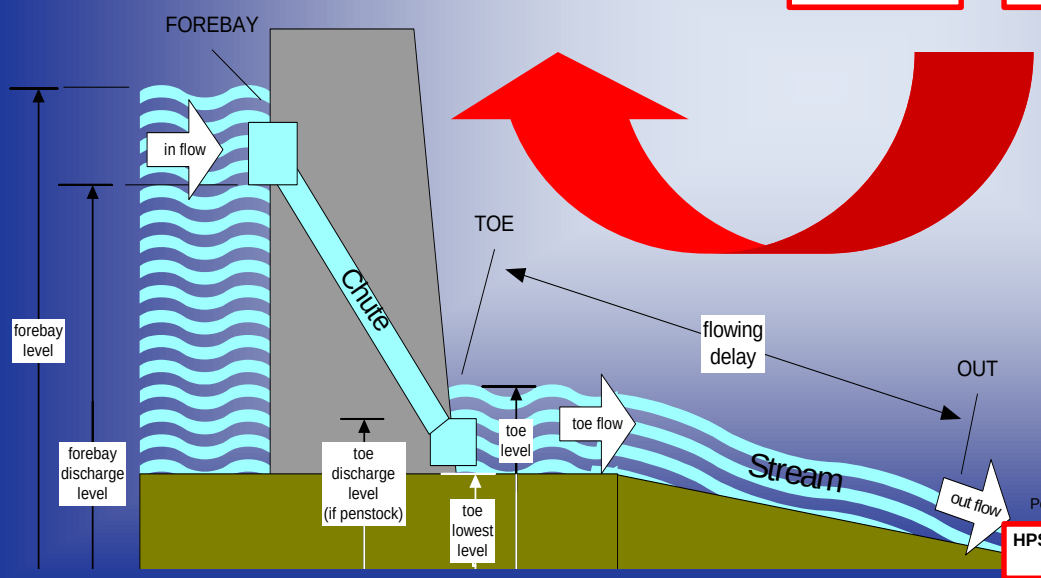
- **Cascading Dams / Tandem Reservoirs**
- **Adjustable Flowing Delays**
- **Piecewise Linear Discharge Rate Curve Sets**
- **Combined Tailraces / Head Loss Functions**
- **Open-air Outlets (e.g., spillways) & Sluices**
- **Sand Flow / Accumulation**

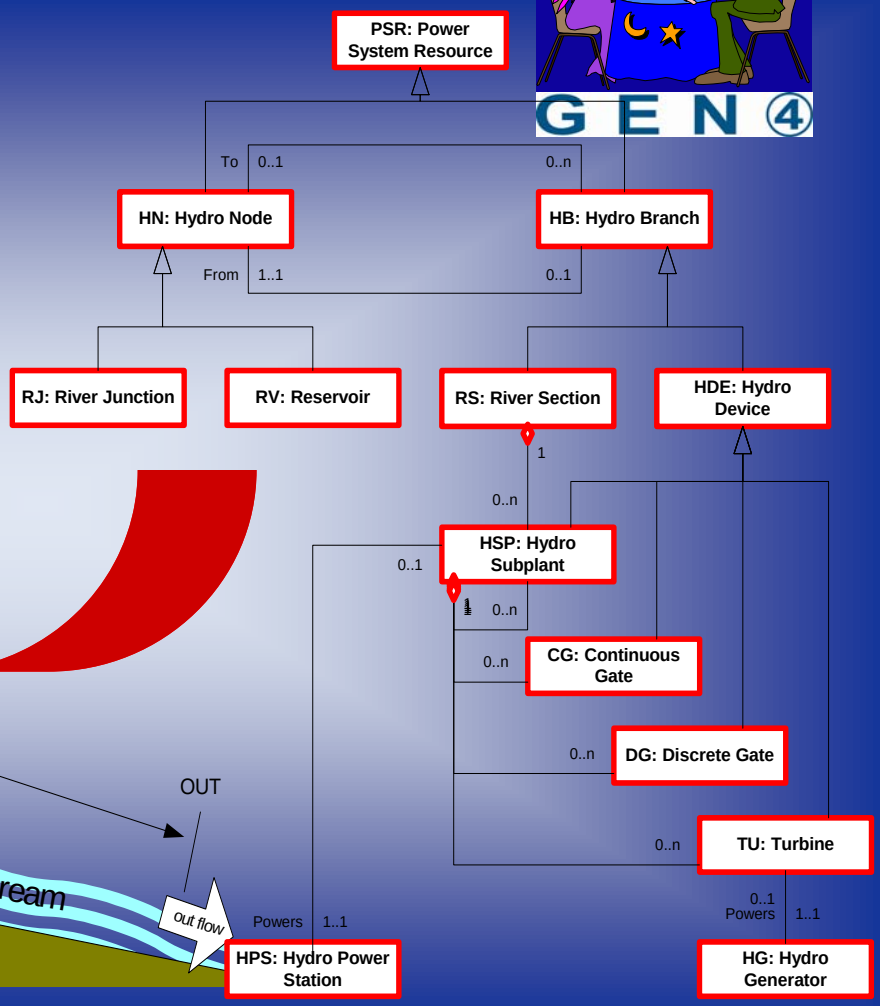
All input schedules (e.g., Inflow Forecasts / Reservoir Objectives) can be imported from/exported to external packages such as PROSPER™.

Typical Scheduling Horizon ranging from a few days to several weeks by 15-min to 3-hour steps.

Hydro Flow Simulation







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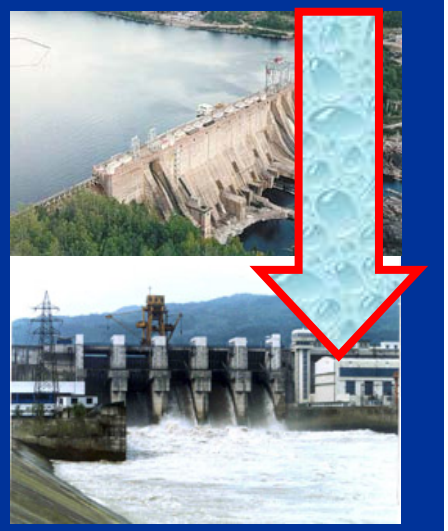
Hydro Generation Scheduling
& Hydro-Thermal Coordination

Main Features

- Thermal / Hydro Dispatch
- Generation Cost / Water Release Minimization
- Reservoir Level & Reserve Objectives
- Reservoir/Flow/Solution Smoothing Constraints
- Release/Sand Flushing Coordination
- Based on Linear Programming / MILP



Example

- Shawan Cascade Control Center (Sichuan, P. R. of China)

A cascading scheme with major flood control and sand silting issues.

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Hydro Generation Scheduling

& Hydro-Thermal Coordination

OPS : Hydro-Thermal Coordination Problem Parameter View (Study Session s1)

Weights and Penalties

Name	Weight	S1	L1	S2	L2	S3
Reservoir Volume	0.0	0.0	0.0	0.0	0.0	0.0
Node Out Flow	0.0	0.0	0.0	0.0	0.0	0.0
Node Inflow	0.0					
Desired Reservoir Volume	2.0					
Branch Inflow	0.0					
Branch Out Flow	0.0					
Turbinated Flow	0.0					
Non-Turbinate Release	0.0					
Generation	0.0					
Desired Generation	20.0					
Turbinated Flow Smoothing	2.0					
Reservoir Volume Smoothing	0.5					
Reservoir Release Coordination	0.0					
Branch Release Smoothing	0.0					
Desired Branch Release						

OK

OPS : Turbine Scheduling Summary (Study Session s1)

Study Horizon — Start: 19/03/2003 00:00 End: 22/03/2003 23:30

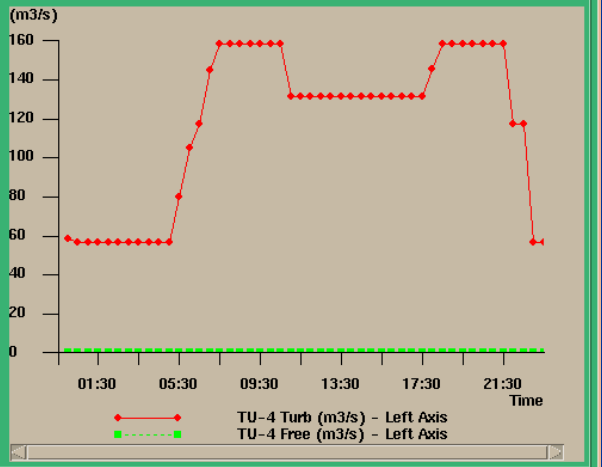
Date Selection — Date: 19/03/2003 Apply

Selector — Turbine: AUBRE.TU-4

Generator — Generator AUBRE.GEN-29

Inflow ans Limits

Time	GEN-29 Gen (MW)	GEN-29 Status	GEN-29 Avail.	GEN-29 Sched	TU-4 Toe (m)	TU-4 Head (m	TU-4 Turb (
	10	ON	YES	UC	471.89	53.09	56.8
	10	ON	YES	UC	471.90	53.08	56.8
3:30	10	ON	YES	UC	471.90	53.08	56.8
04:00	10	ON	YES	UC	471.90	53.07	56.8
04:30	10	ON	YES	UC	471.90	53.07	56.8
05:00	10	ON	YES	UC	471.90	53.06	56.8
05:30	20	ON	YES	UC	471.90	53.06	80.1
06:00	30	ON	YES	UC	471.90	53.06	105.2
06:30	35	ON	YES	UC	471.90	53.06	117.5
07:00	45	ON	YES	UC	471.90	53.06	145.2
07:30	50	ON	YES	UC	471.90	53.06	158.7
08:00	50	ON	YES	UC	471.89	53.06	158.7
08:30	50	ON	YES	UC	471.89	53.06	158.7
09:00	50	ON	YES	UC	471.89	53.05	158.7
09:30	50	ON	YES	UC	471.89	53.05	158.7
10:00	50	ON	YES	UC	471.89	53.05	158.7



OK Cancel Edit Apply

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Hydro Unit Commitment
& Thermal Unit Commitment

Main Features

- Optimal Unit Commitment & Loading
- Unit Start/Stop Costs & Constraints
- Release (hydro) / Fuel Costs (thermal) Minimization
- Hydraulic and Generation Constraints
- Maintenance Costs Minimization
- Based on Forward Dynamic Programming

Hydro Unit Commitment

& Thermal Unit Commitment

OPS : UC Summary (Study Session s1)

Study Horizon
Start: 0/12/2003 00:00 End: 7/12/2003 23:30

Date Selection
Date: 10/12/2003 Apply

Selector
Power Station MAIN.AUBRE

Time	GEN-26 status	GEN-27 status
06:00	OFF	OFF
06:30	OFF	OFF
07:00	OFF	OFF
07:30	OFF	OFF
08:00	OFF	OFF
08:30	OFF	OFF
09:00	OFF	OFF
09:30	OFF	OFF
10:00	OFF	OFF
10:30	OFF	OFF
11:00	OFF	OFF
11:30	OFF	OFF

OPS : System Schedules Summary (Study Session s1)

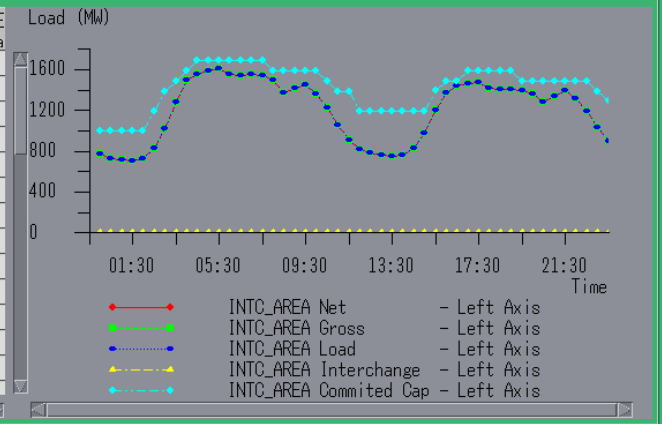
Study Horizon
Start: 0/03/2003 00:00 End: 2/03/2003 23:30

Date Selection
Date: 19/03/2003 Apply

Controls
Losses Accounted Losses Included in LF

MW Levels

Time	INTC_AREA Net	INTC_AREA Gross	INTC_AREA Load	INTC_ARE Intercha
00:00	771	771	771	0
00:30	731	731	731	0
01:00	715	715	715	0
01:30	707	707	707	0
02:00	725	725	725	0
02:30	828	828	828	0
03:00	1029	1029	1029	0
03:30	1283	1283	1283	0
04:00	1496	1496	1496	0
04:30	1557	1557	1557	0
05:00	1595	1595	1595	0
05:30	1616	1616	1616	0
06:00	1553	1553	1553	0
06:30	1540	1540	1540	0



Close

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Security Constrained Unit Commitment

- Unit Commitment combined with AC Power Flow for transmission security constraints enforcement.
- For integrated/de-regulated utilities as well as ISOs.
- Under development.

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Recent G E N ④™ Deployments

SNC·LAVALIN

GEN④

- Hydro-Québec — EMS (6+1+1)
- Toronto Hydro — DMS
- Enersource — DMS

- Northwest Electric — EMS
- Province of Gansu — EMS
- Province of Hebei — EMS
- Province of Ningxia — EMS
- Province of Sichuan — EMS
- Shawan Cascade — EMS

- Elektro Maribor — DMS
- Elektro Gorenjska — DMS
- Elektro Slovenija — DMS

- Taiwan Power Corporation — DMS

- Provincial Electricity Authority — EMS/DMS (5+1)

- Electricidad de Caracas — EMS
- EdelCa (Guri) — EMS

- NSTAR — EMS/DMS
- PSE&G — EMS
- Hawaiian Elec. — DMS

- Alexandria Elec. — DMS
- Canal Zone — DMS (6)

- E. ON, Finland — DMS

- EdeSur — EMS

- Reykjavik Elec. — DMS

- Powerlink Qsld — EMS
- Energex — DMS
- AGL — DMS

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Optimal generation models

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PROSPER™

- Package of water management models developed for hydroelectric systems

- Optimization and simulation models
  - Long term, mid term and short term
  - Study and planning
  - Utilization of the same database

- Can be used for the operation of complex hydroelectric systems including thermal unit

SNC·LAVALIN

PROSPER™

DDDP

Mid-term and long-term optimization model

EDM

Short term optimization model

PROSPER

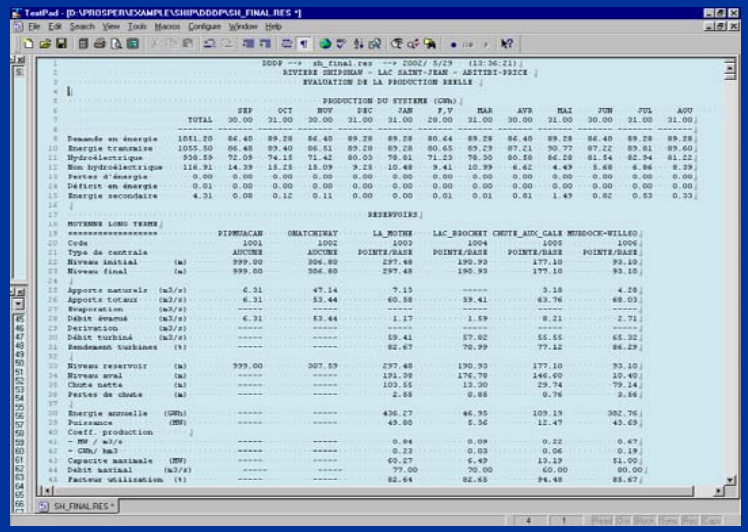
ESOLIN

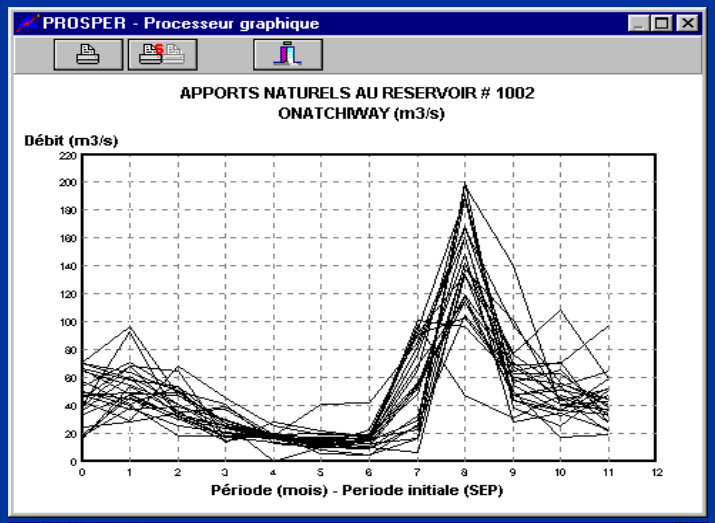
Mid-term and long-term simulation model

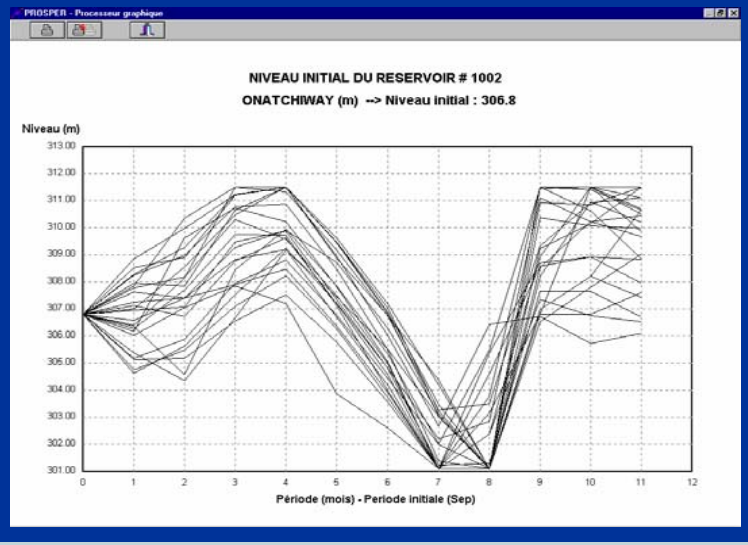
INSTANT

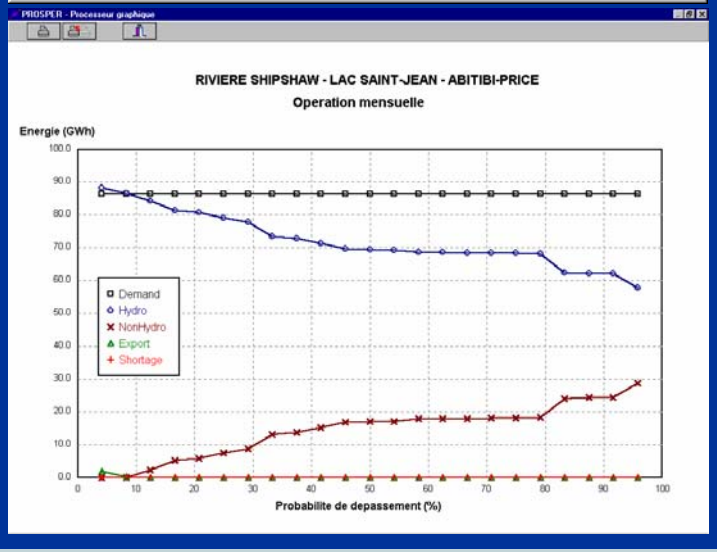
Unit dispatching optimization model

DDDP - Planning of hydroelectric resources









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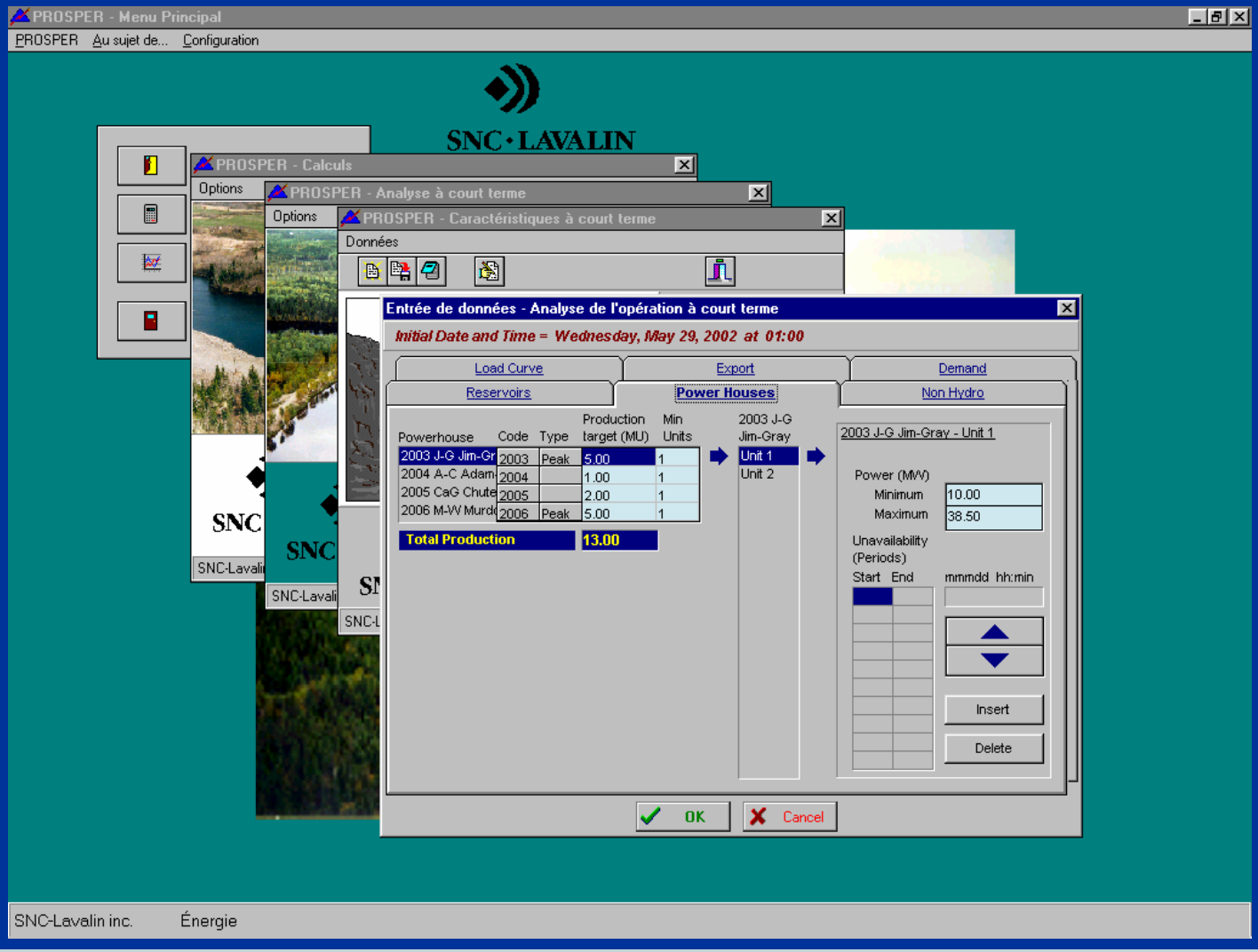
EDM - Short-term optimization



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Instant – Unit dispatching

INSTANT - Optimization of turbines operation

System Print

2005 N'SAGAR

Last Update : 04 June 2002 11:14:20

Optimization
- Flow
- Power

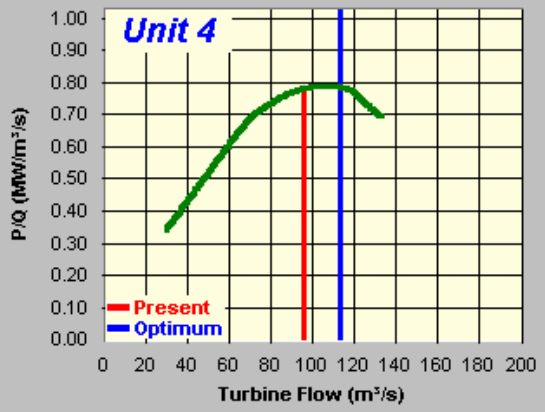
Reservoir Level 170.00 m

Tailwater Level 78.00 m

N'SAGAR

	Pmax (MW)		Present P (MW)	Present Q (m³/s)	Optimum P (MW)	Optimum Q (m³/s)
Unit 1	110.00	☑	75.00	95.34	93.60	119.28
Unit 2	100.00	☑	75.00	95.96	89.10	113.54
Unit 3	100.00	☐	0.00	0.00	0.00	0.00
Unit 4	100.00	☑	75.00	95.96	89.10	113.54
Unit 5	100.00	☑	75.00	95.96	89.10	113.54
Unit 6	100.00	☑	75.00	95.96	89.10	113.54
Unit 7	100.00	☑	75.00	95.96	0.00	0.00
Unit 8	100.00	☑	0.00	0.00	0.00	0.00
Total	710.00		450.00	575.15	450.00	573.45

Difference
-1.70
-0.30 %



Optimize Powerhouse | Print Powerhouse | Optimize System | Print System

SNC-Lavalin

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Flood forecasting and Reservoir management systems

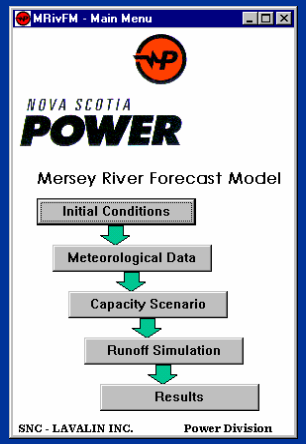
SNC·LAVALIN

Flood forecasting and reservoir management

- **Flood**
  - One of the most severe natural disasters
  - One of the most important risk in reservoir operation
- **Flood forecasting - Basic information required**
  - Observed rainfall conditions on drainage area
  - Meteorological forecast
  - Observed conditions in rivers and reservoirs
- **Action Required**
  - Evaluation of natural inflows in the system
  - Optimization of reservoir operation
  - Evaluation of flood impacts
  - Transmission of information

Flood forecasting and reservoir management

Systems developed by SNC-Lavalin

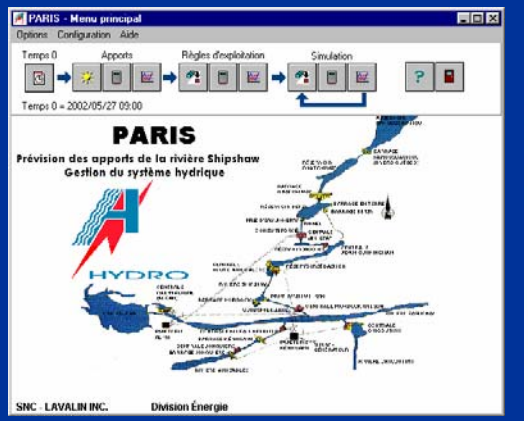


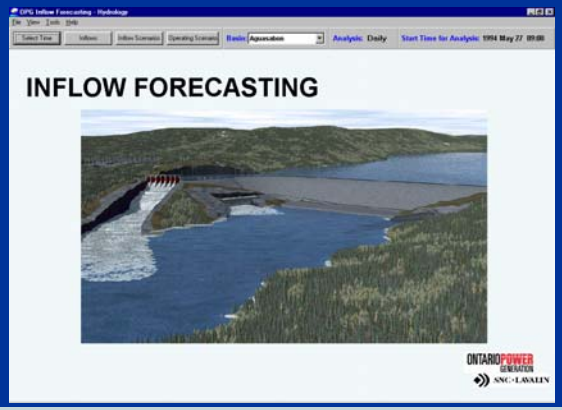
MRivFM

Nova Scotia Power Inc.
Mersey River
Nova Scotia
Installation in 1996

Paris

Abitibi-Consolidated Inc.
Rivière Shipshaw
Québec
Installation in 1997





OPGIF

Ontario Power Generation Inc.
Aguasabon River
Ontario
Installation in 2001

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Flood forecasting and reservoir management

Most recent developments

BLFMS
EGAT
Pattani River
Thailand
Installation in 2002

AWARE-FMS
RID
Lam Pao River
Thailand
Installation in 2006

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Aware - Objectives

- Forecast of flood discharge for the next 10 days
- Evaluation of river levels and inundation zones
- Optimization of reservoir management
- Transmission of information via internet

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AWARE - Components

Integration of three main modules

- **Remote Monitoring system - RMS**
- **Water Management System - WMS**
- **Information Display System - IDS**

AWARE - Components

Data collection

Field Data Collection

Telemetry Station 1

Telemetry Station 2

.....

Telemetry Station n

Rainfall Forecast

Forecast Agency

Data Interface (RMS)

- Data entry and validation
- Local database management
- Communication with Water Management Centre

Water Management (WMS)

- Computation of natural flow
- Optimization of reservoir operation
- Evaluation of river levels and inundation zones
- Transmission of results to IDS

Information Display (IDS)

- Presentation of forecast inundation zones, recommended reservoir operation
- Presentation and management of data
- Wide access (internet, intranet, security, …)

Users

Reservoir Operators

System Administrators

Governement Services

Public user 1

ublic user n

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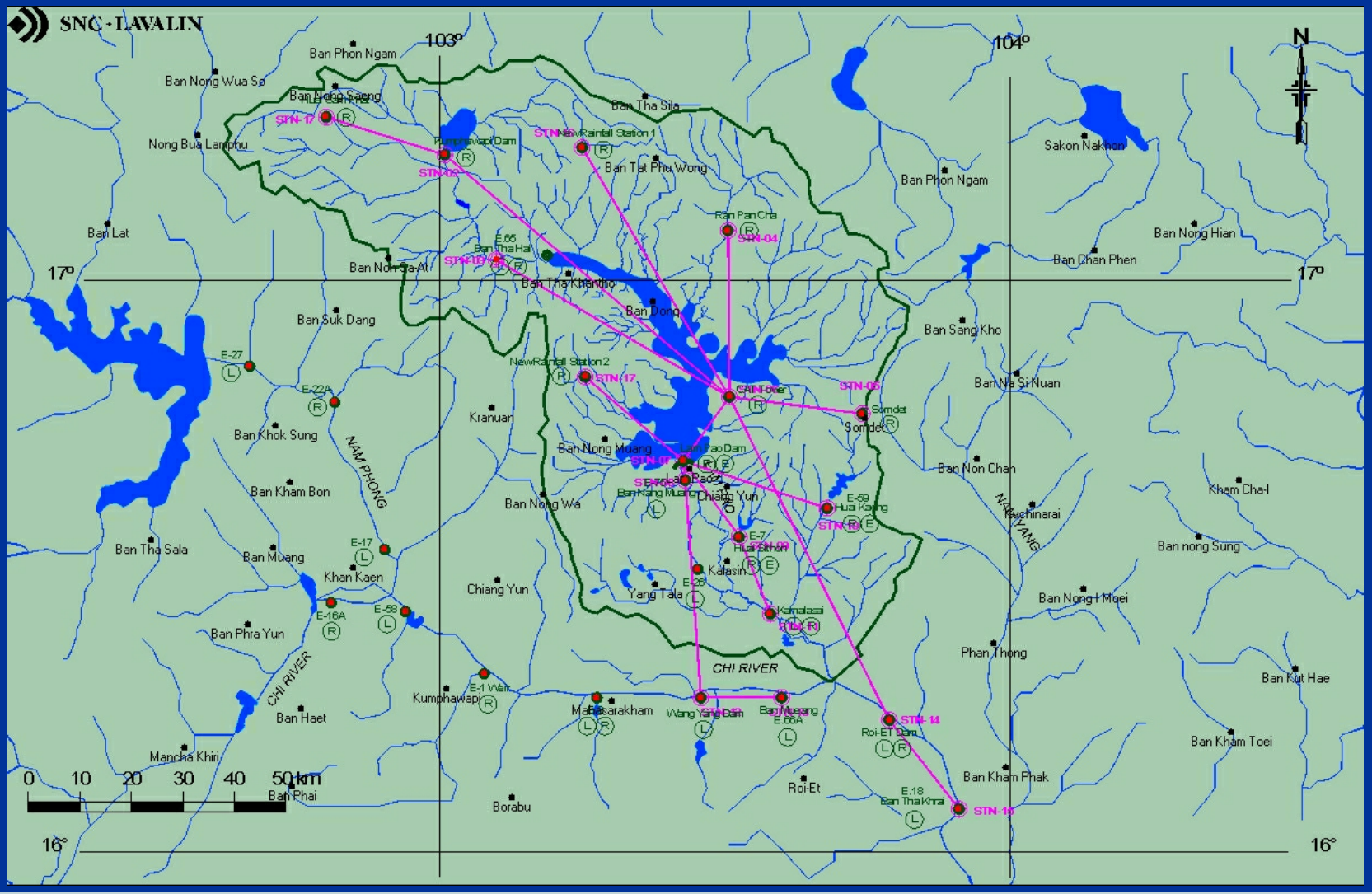
Telemetry System (RMS)



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Hydraulic Analysis (WMS)

Integration of three models

- **Rainfall-runoff model**
- **Reservoir management model**
- **River hydrodynamic model**

Data provided by RMS system

Results are sent to IDS system

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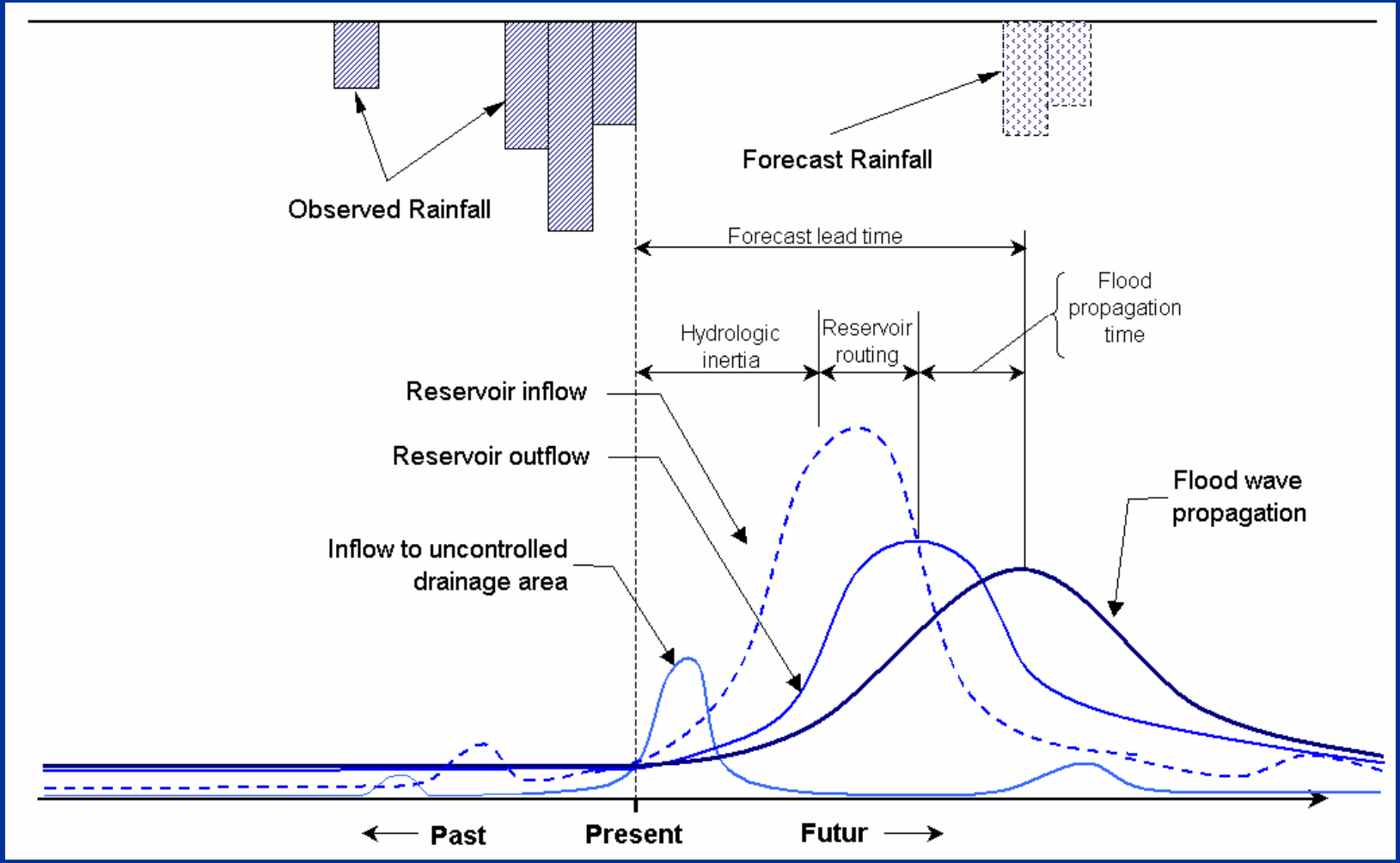
Rainfall-runoff Model

- External model controlled by WMS
- SSARR model was used for Lam Pao Project
- Any rainfall-runoff model can be used
  - Transfer of results in the main database of AWARE
- Results
  - Forecast of natural inflow for the next days

Forecasting Flood Conditions



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Reservoir Management Model

- Optimization of the reservoir operations
  - Minimize flood damages
  - Maximize water available for irrigation
- Based on optimization model Prosper
  - Adapted for this project
- Can take into account powerplant operation
- Results
  - Evaluate consequences of initial reservoir operation rules
  - Optimize operation to minimize flood consequences

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Hydrodynamic Model

- **External model controlled by WMS**
- **UNET model (USACE) was used for Lam Pao River**
  - **Other models were considered such as :**
    - → Mike 11 (Danemark)
    - → One-D (Canada)
    - → Mascaret (France)
- **Results**
  - **Evaluate the flood propagation along the river**
  - **Evaluate the inundation extents**
  - **Evaluate the consequences of levees breach**

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Information Display System (IDS)

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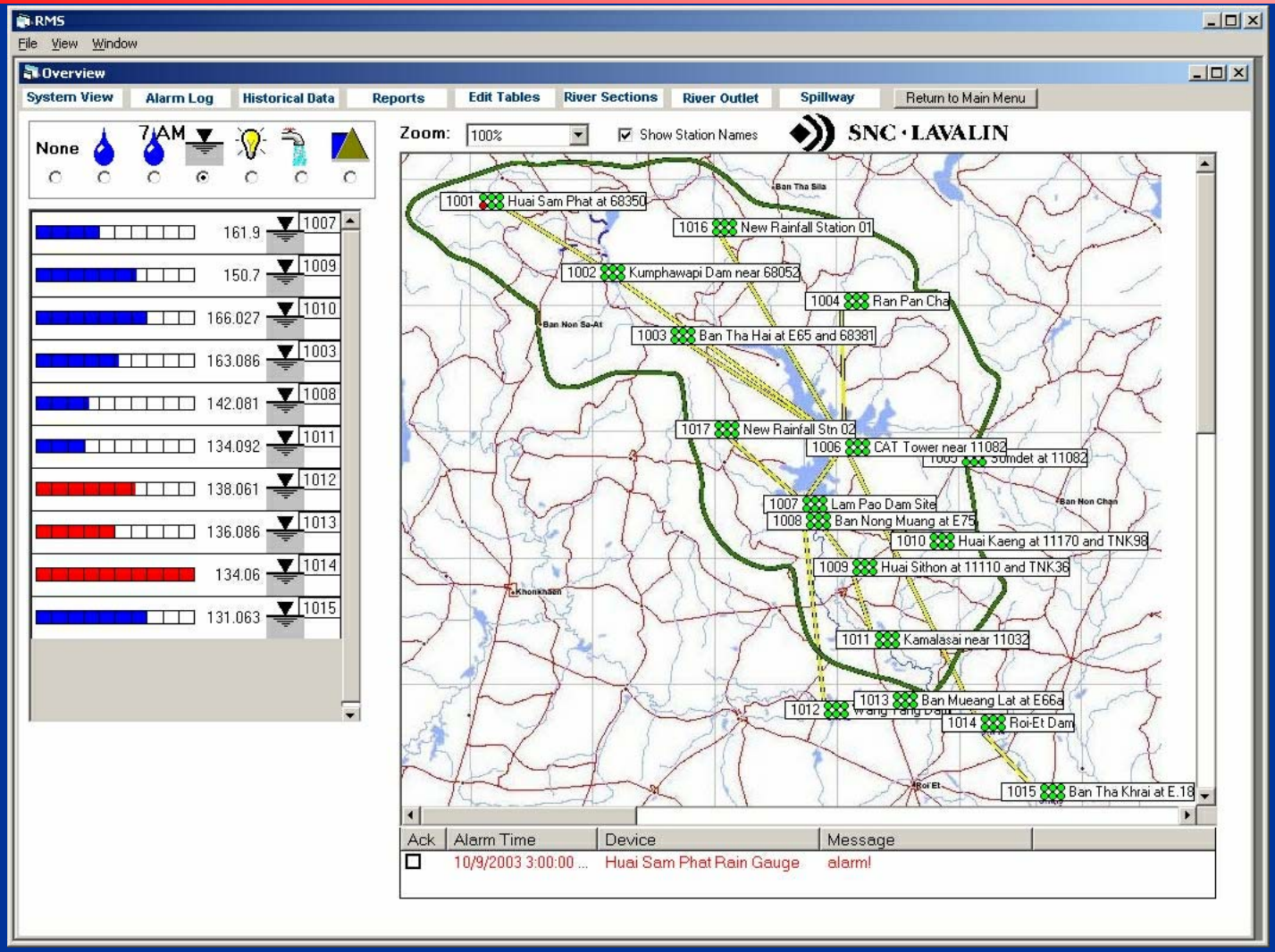
Data Management



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Forecast Mode

- **Automatic mode**
  - **Update at each hour**
- **Evaluation of inundation extents for the next 10 days**
  - **Review of reservoir operation**
  - **Presentation of the flood extents for specified time steps**
  - **Animation of the flood extents**
    - → Along the river and at specific river sections
- **Results available by every user**

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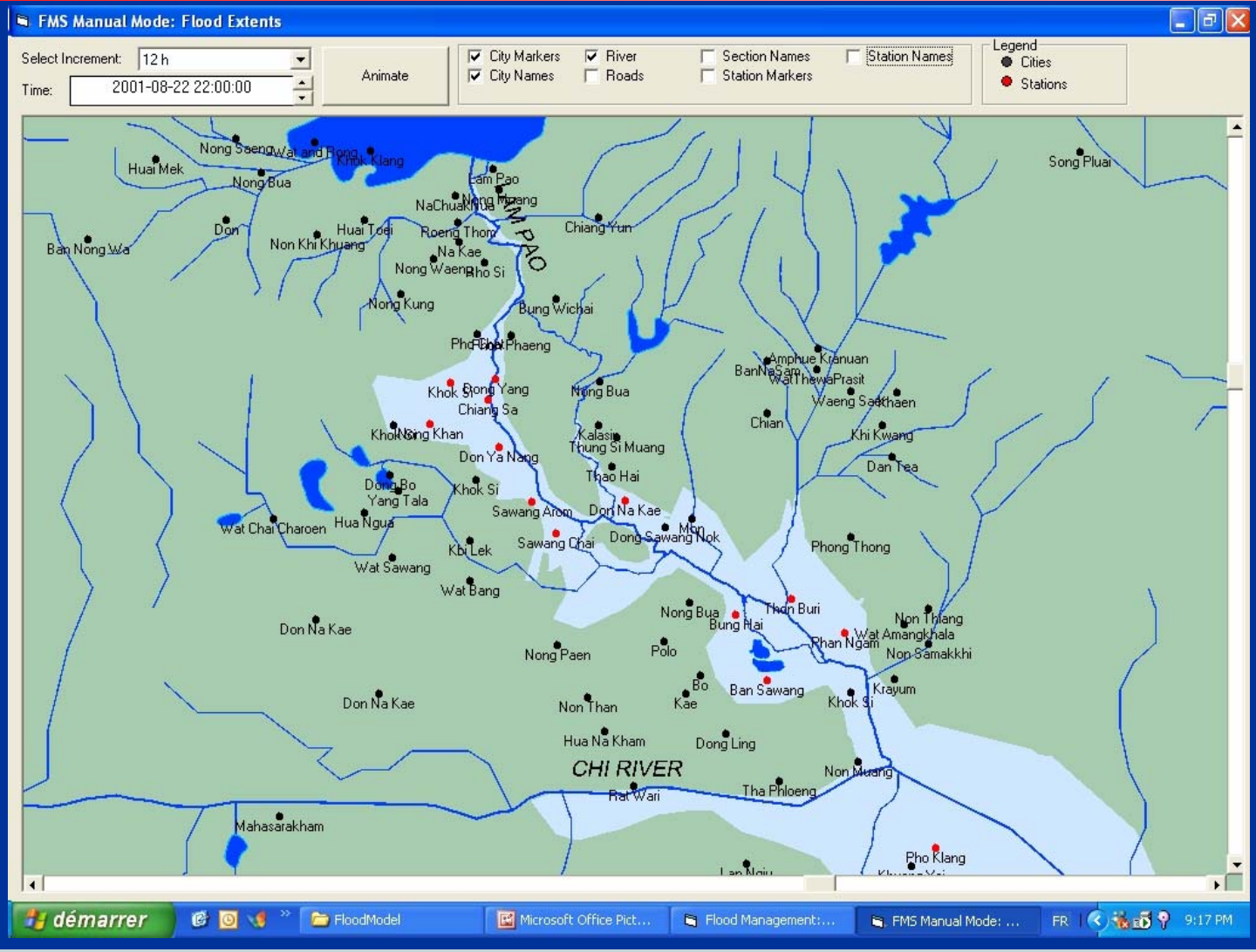
Simulation Mode

- Evaluation of inundation extents for conditions specified by the user
  - Historical data from large flood
  - Historical data with modifications
  - Observed data in real-time with modification of the forecasted rainfall
  - Changes in reservoir operation rules

The simulation mode is only available to specified users

Typical flood inundation map



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Questions ?