Willamette operational model streamflow data

1 Introduction

The Willamette operational model will simulate the regulation of 13 dams in the Willamette River Basin (Figure 1). The expected output will be outflow and hydropower production from 8 of the 13 projects. The operations also depend on the inflow values measured at certain control points along the catchment. For this reason the input to the model will be the inflow entering each reservoir as well as at the control points. In this document the data source and water balance equations used are summarized.

2 Data sources

To simulate the reservoirs operations we need to use historical inflow data to the reservoirs at the headwater and historical local flows for downstream reservoirs and control points. For the reservoirs inflow and local flows data, we will use the historical streamflows provided by BPA[1]. For the control points local flows we use measurement from USGS stations[2].

3 Balance equations

Table 1 describes the data types used in the balance equations:

ID	Data type	Note
5H	Average daily observed streamflow or project outflow	BPA data used to determine local flows
5A	Average daily inflow into projects (provided by the project owners or calculated as H-$\Delta Storage$)	BPA data used to determine reservoirs input
5E	Average daily evaporation at site	BPA data used to determine reservoirs input
in	average daily reservoir/station inflow	INPUT to the model to be derived from data records or calculated at each time step
loc	average daily local flow (incremental flow between adjacent stations/projects)	INPUT to the model to be derived from data records
out	average daily simulated reservoir outflow	OUTPUT to be simulated

Table 1: Data types description

3.1 Reservoirs balance equations

Figure 3 provides a representation of the reservoirs network. In previous models of the Willamette water system (HEC-ResSim, ResSim Lite, ENVISION), only two reservoirs receive outflow from upstream projects: Lookout Point and Foster. For these two project we need to calculate the local flows (incremental flow between consecutive dams) using the balance equations 1:

[1] https://www.bpa.gov/p/Power-Products/Historical-Streamflow-Data/Pages/Historical-Streamflow-Data.aspx

[2] https://waterdata.usgs.gov/or/nwis/uv?search_criteria=search_station_nm&submitted_form=introduction

Figure 1: Map of the Willamette RB along with the modeled reservoirs and control points

ID	Reservoir
HCR	Hills Creek
LOP	Lookout Point
DEX	Dexter
FAL	Falls Creek
COT	Cottage Grove
DOR	Dorena
CGR	Cougar
BLU	Blue River
FRN	Fern Ridge
GPR	Green Peter
FOS	Foster
BCL	Big Cliff
DET	Detroit

ID	Control point
SAL	Salem
ALB	Albany
JEF	Jefferson
MEH	Mehama
HAR	Harrisburg
VID	Vida
JAS	Jasper
GOS	Goshen
WAT	Waterloo
MON	Monroe
FOS	Foster

Figure 2: List of reservoirs and control points IDs

$$\begin{aligned} LOP_{loc} &= LOP5A - HRC5H \\ FOS_{loc} &= FOS5A - GPR5H \end{aligned} \tag{1}$$

Reservoirs Dexter and Detroit are instead treated as run-of-river type of plants (i.e., no storage, their inflow is equal to their outflow which is divided between spill and generation). Therefore, no rule curve or constraint is needed to simulate their operation (only gate specific physical constraints). Using these assumptions and the equations reported in the BPA modified streamflow description (Chapter 3.7 Willamette Basin) we can formulate the following water balance equations:

$$\begin{aligned} HCR_{in} &= HCR5A \\ LOP_{in} &= HCR_{out} + LOP_{loc} + LOP5E \\ DEX_{in} &= LOP_{in} \\ FAL_{in} &= FAL5A \\ DOR_{in} &= DOR5A \\ CGR_{in} &= CGR5A \\ BLU_{in} &= BLU5A \\ FRN_{in} &= FRN5M \\ GPR_{in} &= GPR5A \\ FOS_{in} &= GPR_{out} + FOS_{loc} \\ DET_{in} &= DET5A \\ BCL_{in} &= DET_{in} \end{aligned} \tag{2}$$

As it's made clear in the equations, Lookout Point and Foster inflows will be calculated at each simulation step, based on the simulated upstream releases.

3.2 Control points balance equations

Some operations constraints are based on the inflow at specific control points in the catchment (in red on the map of Figure 1). Therefore the inflow at the control points needs to be calculated at

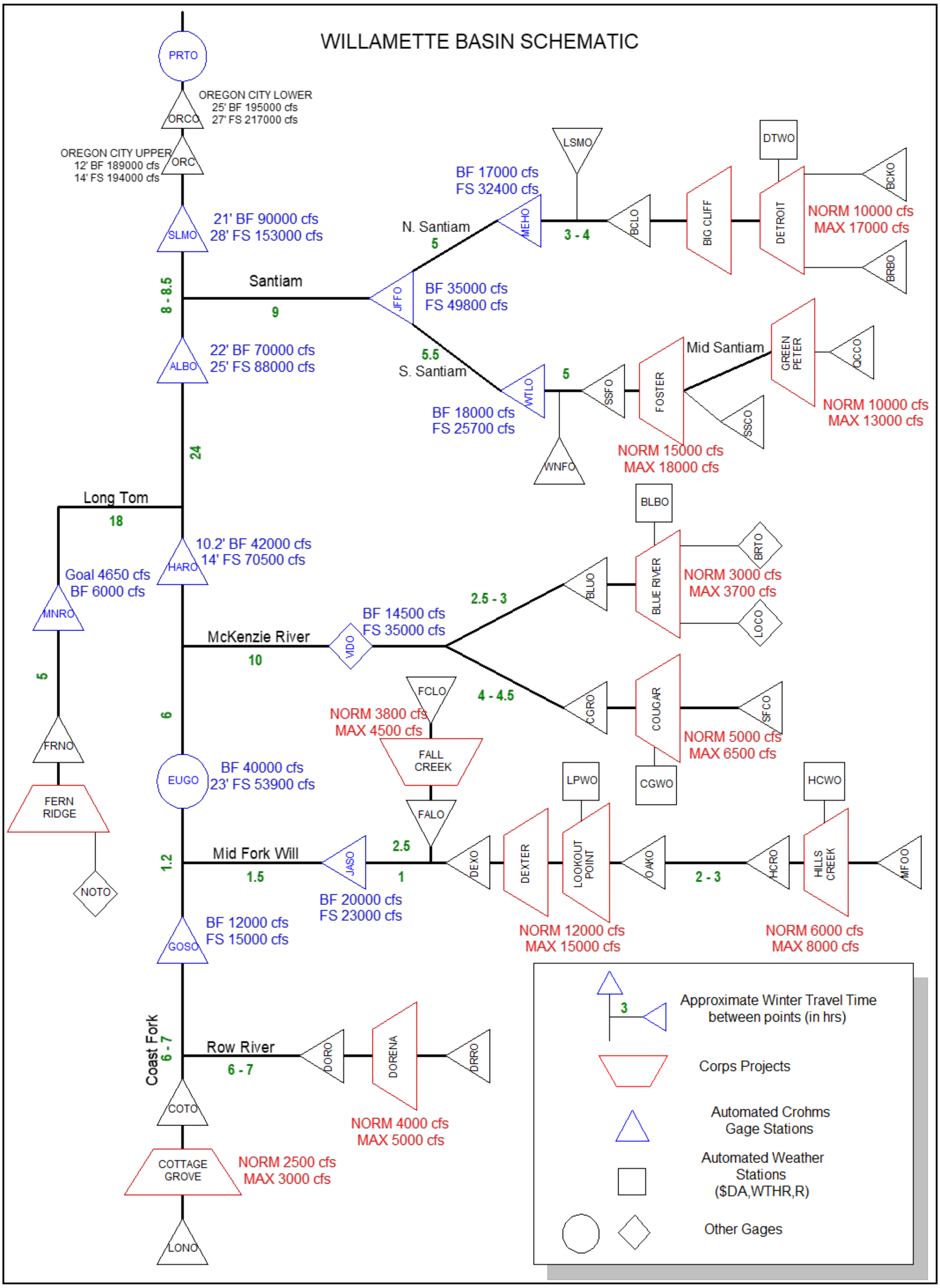

Figure 3: Willamette reservoirs network and travel times

Reservoir Name	note	SAL	ALB	JEF	MEH	HAR	VID	JAS	GOS	WAT	MON	FOS
Hills Creek Lake												
Lookout Point Lake												
Dexter Reservoir	*run-of-river*	*Null*	*Null*	*Null*	*Null*	*Null*	*Null*	*Null*	*Null*	*Null*	*Null*	*Null*
Fall Creek Lake												
Dorena Lake												
Cottage Grove Lake												
Fern Ridge Reservoir												
Cougar Reservoir												
Blue River Reservoir												
Green Peter Reservoir												
Foster Reservoir												
Detroit Reservoir												
Big Cliff Reservoir	*run-of-river*	*Null*	*Null*	*Null*	*Null*	*Null*	*Null*	*Null*	*Null*	*Null*	*Null*	*Null*

Figure 4: Control points/reservoirs lookup table

each simulation step by summing the simulated outflows from upstream reservoirs/stations and historical local inflows:

$$
\begin{aligned}
SAL_{in}(t) &= ALB_{in}(t) + JEF_{in}(t) + SAL_{loc}(t) \\
JEF_{in}(t) &= WAT_{in}(t) + MEH_{in}(t) + JEF_{loc}(t) \\
MEH_{in}(t) &= BCL5H(t) + MEH_{loc}(t) \\
WAT_{in} &= FOS5H(t) + WAT_{loc}(t) \\
ALB_{in}(t) &= MON_{in}(t-1) + HAR_{in}(t-1) + ALB_{loc}(t) \\
MON_{in}(t) &= FER5H(t) + MON_{loc}(t) \\
HAR_{in}(t) &= VID_{in}(t)GOS_{in}(t) + JAS_{in}(t) + HAR_{loc}(t) \\
VID_{in}(t) &= CGR5H(t) + BLU5H(t) + VID_{loc}(t) \\
JAS_{in}(t) &= DEX5H(t) + FAL5H(t) + JAS_{loc}(t) \\
GOS_{in}(t) &= COT5H(t) + DOR5H(t) + GOS_{loc}(t)
\end{aligned}
\tag{3}
$$

Historical local inflows can be derived from historical outflows (provided by BPA) and inflow records at USGS stations by inverting balance Equations 3. The travel times were derived from Figure 3 provided by the USACE [1]. Many reservoirs can be influenced by a single control point (e.g Salem) and many control points can be influenced by a single reservoir. Figure 3.2 reports all control points and corresponding affected reservoirs.

References

[1] USACE. Willamette basin guide standard operating procedures (sop) for reservoir control center. Technical report.