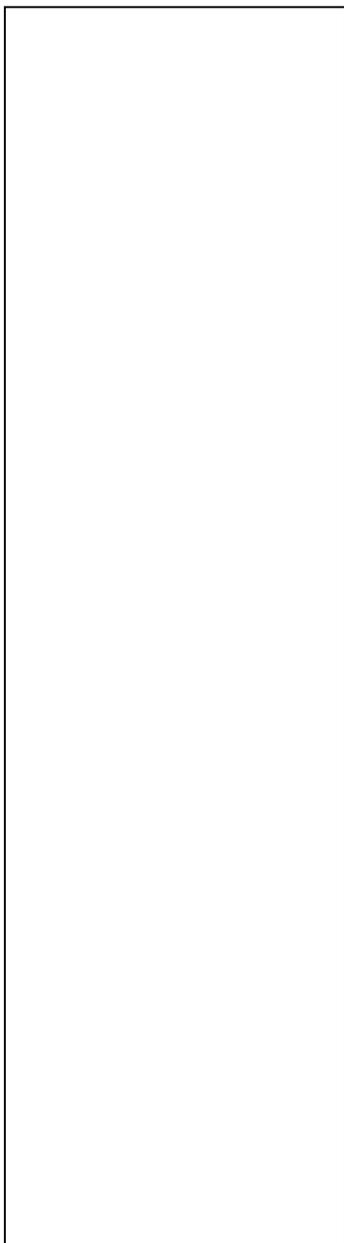
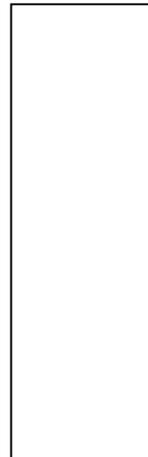




User's Guide **KALMAN**

Waqua-with-Kalman

WAQUA forecasts using a time invariant
Kalman filter



Version : 1.2, September 16, 2010
Maintenance : see www.helpdeskwater.nl/waqua
Copyright : Rijkswaterstaat

CONTENTS

1	About the User's Guide Waqua-with-Kalman.....	3
2	Flow Chart.....	5
3	Input and Output Files.....	7
3.1	Input files	7
3.1.1	Extra user input	7
3.1.2	Kalman SDS File	7
3.2	Output Files.....	8
3.2.1	Extensions to WAQUA's LDS	8
3.2.2	Message file	8
4	The Kalman Filter Process	9

1 **ABOUT THE USER'S GUIDE WAQUA-WITH-KALMAN**

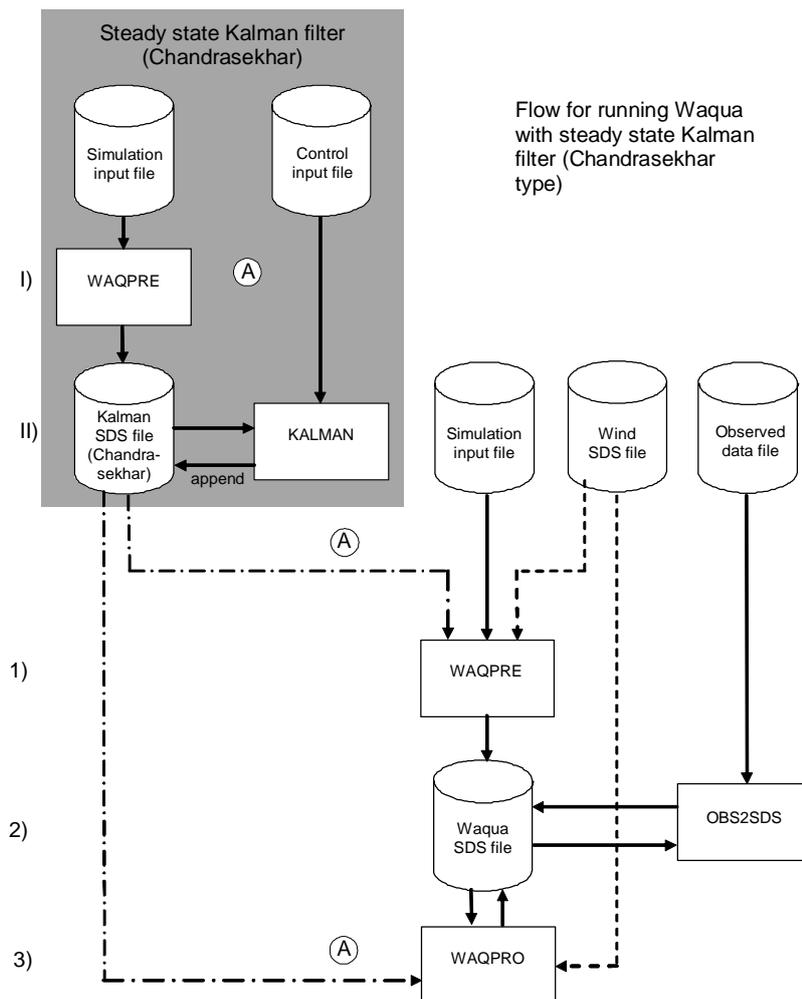
This User's Guide discusses the use of a time invariant Kalman filter in WAQUA forecasts. The Kalman filter gain is computed by program KALMAN (refer to the User's Guide Kalman Processor).

Especially short term forecasts of storm surges can be improved considerably with a Kalman filter. The implemented filter is time invariant. It is computed once for a given model and a given set of waterlevel stations using linearized WAQUA equations.

In the current release only 2 dimensional models in spherical coordinates are accepted.

Chapter 2 describes the general WAQUA-with-Kalman flow. Input and output files are described in chapter 3. Finally, chapter 4 describes the filter process in general terms.

2 FLOW CHART



Notes

- Only the parts of concern with respect to the Kalman filter are shown here. For a complete description of WAQPRO, refer to the "User's Guide WAQUA".
- WAQPRE reads the Kalman SDS file to check whether the WAQPRO model and the model used by KALMAN are consistent.
- OBS2SDS must have been executed before WAQPRO can start.
- If the filter contains wind noise parameters, a third SDS file with wind input is needed by WAQPRO.

3 INPUT AND OUTPUT FILES

This chapter will only describe new input and output in comparison with WAQUA-in-SIMONA (refer to the "User's Guide WAQUA").

New input consists of extra user input in the simulation input file for WAQPRE, a Kalman SDS file and an extension to the LDS of WAQUA.

New output consists of extra restart information and some new messages which can be generated by WAQUA

3.1 Input files

As already mentioned, the input of WAQUA-in-SIMONA is extended with

- Extra user input in the simulation input file.
- A Kalman SDS file.

3.1.1 Extra user input

Kalman filtering in WAQUA is activated by naming the Kalman SDS file and experiment in the simulation input file. WAQPRE will perform extra tests to check whether the model on which the Kalman filter was computed is consistent with the WAQUA model.

The section **GENERAL** is extended with:

```
KALMAN
  SDS_KALMAN=[text]
  EXP_KALMAN=[text]
```

Explanation:

KALMAN

SDS_KALMAN=[text]

EXP_KALMAN=[text]

- O** This key-word identifies the start of the Kalman sub-section. Kalman filtering will be activated when this key-word is specified.
- M** The name of the Kalman SDS file.
- M** The name of the Kalman experiment.

3.1.2 Kalman SDS File

The Kalman SDS file is created by the Kalman-in-SIMONA process. Refer to the "User's Guide Kalman Processor" for detailed information.

3.2 Output Files

The next output files are extended by WAQUA-with-KALMAN:

- Extensions to the LDS of WAQUA.
- The message file.:

3.2.1 Extensions to WAQUA's LDS

When the KALMAN key-word was specified in the simulation input file, WAQPRE will have created and initiated the next two sub-arrays:

COEFF_GENERAL is extended with time-independent subarray IREFKM(2). It is a character*80 array containing:

kalsds	the name of the Kalman SDS file
kalexp	the name of the Kalman experiment

RESTART_FLOW is extended with time independent subarray KALMAN(2*mnmaxk+2*noroco) containing:

wukal(mnmaxk)	Wind noise on u-velocities
wvkal(mnmaxk)	Wind noise on v-velocities
cirkal(2,noroco)	noise on the uncertain boundary conditions

The processor WAQPRO of WAQUA-with-Kalman will also need observed data available in compound array COEFF_OBS. This array is created by OBS2SDS and described in the "Gebruikers-handleiding OBS2SDS" (in dutch only).

RESTART_FLOW enables a restart of WAQPRO with Kalman filter. The noise values resulting from the Kalman filter computation are saved at map times (ref. SOLUTION_FLOW).

3.2.2 Message file

The messages file waqpro-m.<runid> will contain extra informative and error messages for the Kalman filter part when appropriate.

The report file contains an extra set of output when COEFF_OBS is available in the SDS file, which must be always the case when running with the Kalman filter. This set shows the mean, standard deviation and maximum absolute deviation per waterlevel station with observed data in relation to the computed waterlevels.

4 THE KALMAN FILTER PROCESS

The Kalman filter is activated in WAQPRO as soon as the first observed data are available. At that moment WAQUA's state is updated and the wind and boundary noise is initiated. After this time step the WAQUA process is intervened as follows:

after time+ $\frac{1}{2}$ dt:

1. The boundary noise is updated with the requested time correlation (ref. "User's Guide Kalman Processor").
2. The boundary noise is assimilated in the boundary conditions (waterlevels)

after time+dt:

1. The boundary noise is updated with the requested time correlation.
2. The boundary noise is assimilated in the boundary conditions.
3. The wind noise is assimilated in the u- and v-velocities computed by WAQPRO.
4. The wind noise is updated with the requested time correlation.
5. When new observed data becomes available:
 - a. The residuals are computed. Missing data ("dummies") are estimated using the Kalman filter.
 - b. The computed waterlevels, u- and v-velocities are adapted with the filter in order to meet the physical measurements. This goes for the waterlevels at the open waterlevel boundaries as well.
 - c. Wind and boundary noise is updated.

At the current release there are no special facilities for the dryfall procedure. Potential dry points in the computational grid for which the Kalman filter is computed are always filtered as described above. This may turn dry points into wet and vice versa. An investigation is going to check whether this is a correct procedure.