Integration of long-term radionuclide transport models MOIRA-LAKE and MOIRA-RIVER into Hydrological Dispersion Module of JRODOS

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Outline

- Introduction. The MOIRA DSS
- Objectives of the Work Package.
- Integration tasks
- Validation and application scenarios
- MOIRA Lake scenarios:
  - Lake Palancoso (Spain)
  - Lake Kozhanovskoe (Russia)
  - Lake Svyatoye (Belarus)
- MOIRA River scenarios:
  - Ebro – Ascó NPP (Spain)
- FDMA model and tests
- Conclusions

Decision Suport System (1)

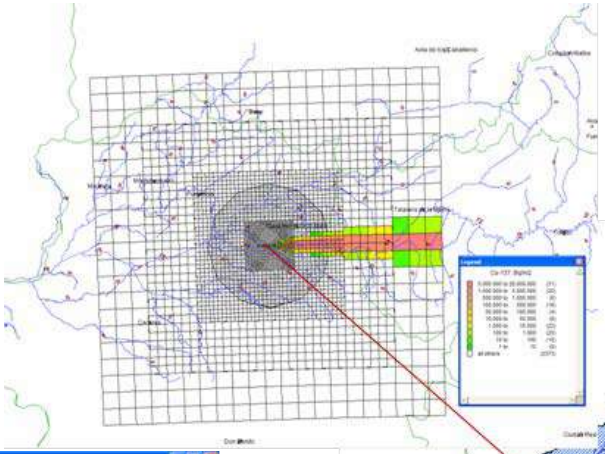
- MOIRA is a Decision Support System (DSS) developed during Euratom FP4 (MOIRA, COMETES) and FP5 (EVANET-HYDRA). Implemented and applied to different scenarios in Spain, France, Italy, Chernobyl affected areas, etc. More than 20 users. Significant feedback from end-users during EURANOS (CAT2DEM19), NERIS-TP (PENTA), CURIEX-13.
- The purpose of MOIRA is to help characterizing the radiological situation and selecting adequate management strategies for different aquatic ecosystems contaminated by radionuclides.
- MOIRA is not aimed at emergency situations, but rather at management strategies for the long-term. It complements JRODOS-HDM. Some users suggested integration of both systems.
- Based on validated models for predicting the dynamic behaviour of ^{137}Cs and ^{90}Sr in **lakes, rivers and drainage areas** and well as the effect of selected countermeasures to reduce the contamination levels.
  - To analyse complex rivers systems and catchments it is limited to the definition of not more than 20 river branches and reaches.
  - The models have been validated against historical data form several lakes and rivers.

Decision Suport System (2)

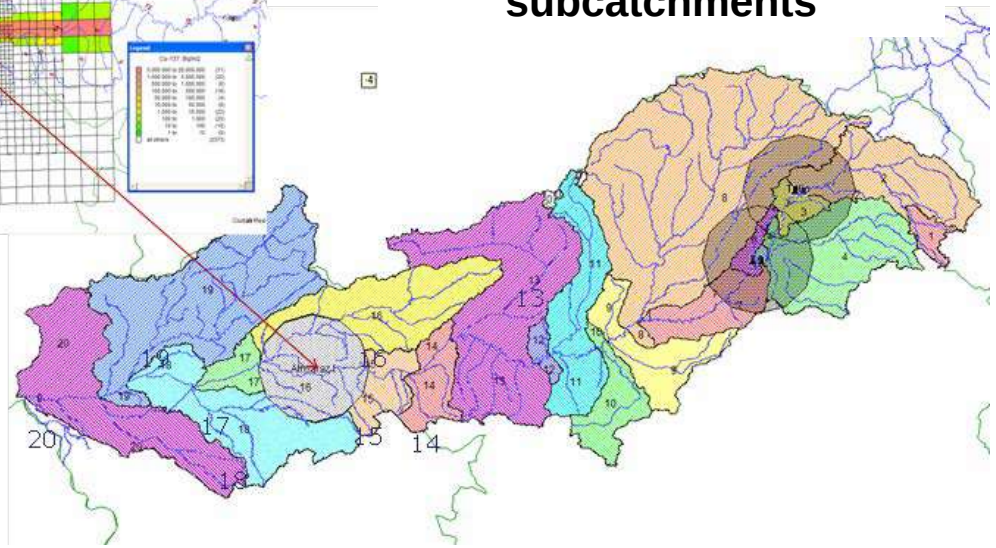
- To asses the impact of physical and chemical countermeasures on the lake ecological quality, MOIRA uses a **Lake Ecosystem Index (LEI)** (Håkanson et al., 2000).
- The DSS also has models to assess doses to man and biota (fish) and to evaluate the residual dose after implementing countermeasures affecting the direct human exposure to contaminated elements.
- Data storage and analysis tools (Geographical Information System, GIS, and data bases) (Hofman, 2004).
- MOIRA runs in a simple Windows PC (but needs MapInfo® GIS and PowerSim®)

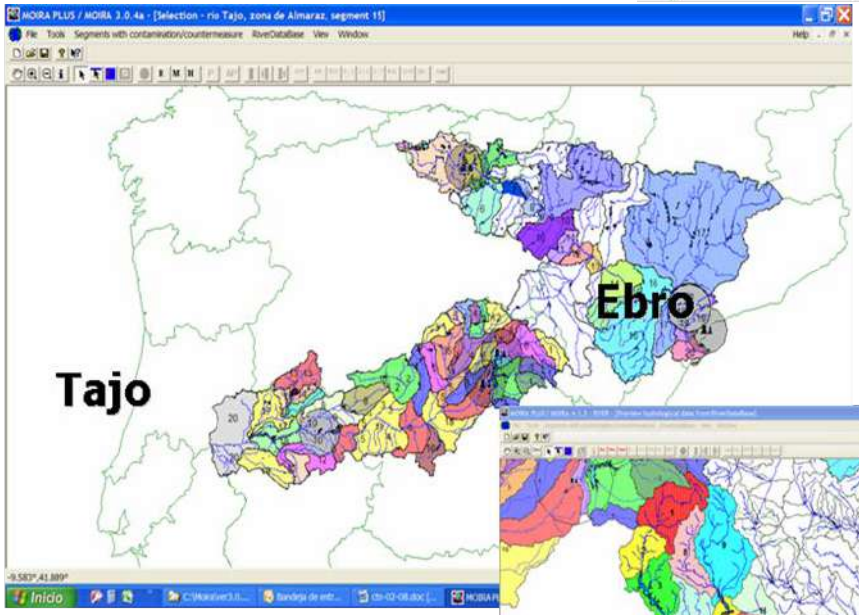
Adaptation of MOIRA GIS to Spanish Rivers

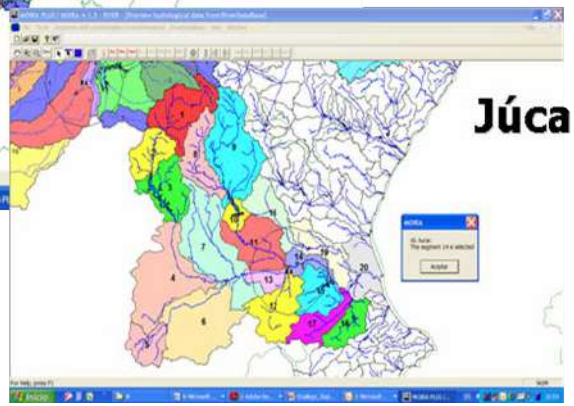
PREPARE



Linking of JRODOS maps of ground deposited activity to MOIRA river subcatchments







Characterization of Spanish rivers

MOIRA

Objectives of the work package

PREPARE

The integration of the main MOIRA models into JRODOS has a main objective:

To increase the capabilities of JRODOS-HDM

i. Modelling the long-term fate of radionuclides (^{137}Cs and ^{90}Sr) in freshwater systems for predictions of the radiation doses via aquatic exposure pathways, by integrating the lake and river models from the MOIRA DSS;

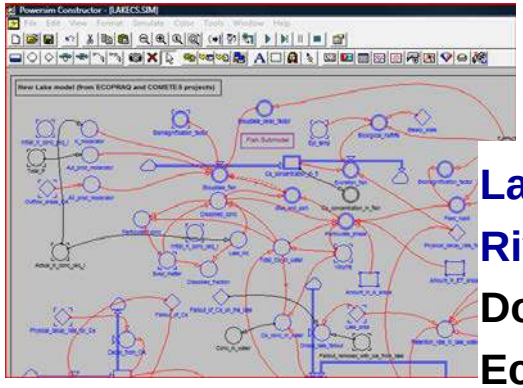
ii. Modelling the efficiency of countermeasures to reduce radionuclide concentrations in water, sediments and fish and the resulting doses after an accident, based on MOIRA DSS models and FDMA.

Integration of MOIRA Lake and River models into JRODOS

PREPARE

MOIRA DSS (standalone)

Powersim®



Lake Model

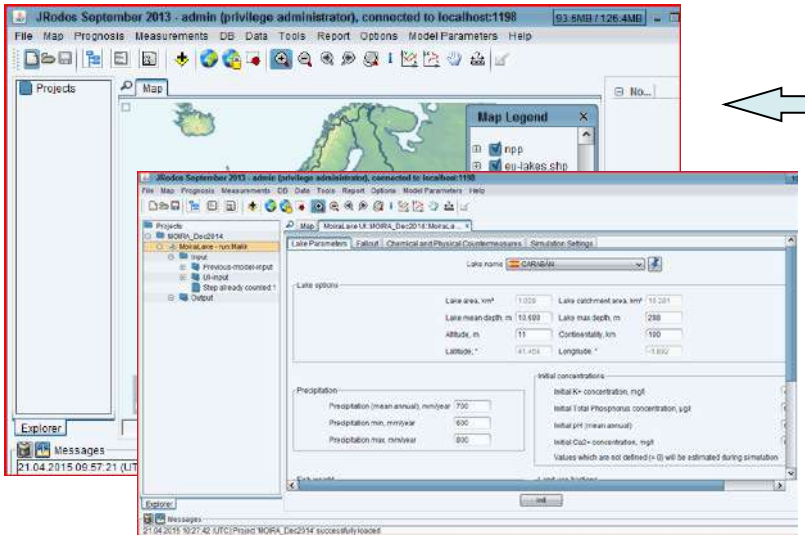
River Model

Dose Model

Economic Model

Decision analysis MAA

JRODOS DSS



MOIRA Lake and River Models are developed as FORTRAN codes and compiled into .dll

Models are integrated as plug-ins

Integration of MOIRA Lake and River models into JRODOS

PREPARE

Main elements

- Development of the MOIRA Models (Lake, River, LEI) as Fortran modules (based on their Powersim® implementations in the MOIRA DSS)
- Development of the model-specific JRODOS User Interface Java modules
- Establishment of the data exchange between models and user interface
- Transfer of the GIS data available in the MOIRA DSS into the JRODOS GIS (instead of the actual MapInfo based systems in MOIRA).
- Integration into the overall JRODOS structure:
  - Getting environment contamination input data from LSMC model.
  - Connecting MOIRA models results to FDMA to assess radiation doses and affected population.
  - Select information and manage reporting in JRODOS.

Countermeasures available for simulation in the new MOIRA-JRODOS system

Application of chemical agents (in Lakes) (Time dependent)	Application of physical measures (Time dependent)	Application of social restrictions (in FDMA) (in user defined periods)
• Potash treatment • Direct liming • Wetland liming • Fertilisation	• Removal of sediments (Lakes and Rivers) • Removal of snow and ice (Lakes) • Water flow diversion between segments (Rivers)	• Bans on fish consumption • Bans on water ingestion • Bans on irrigation  

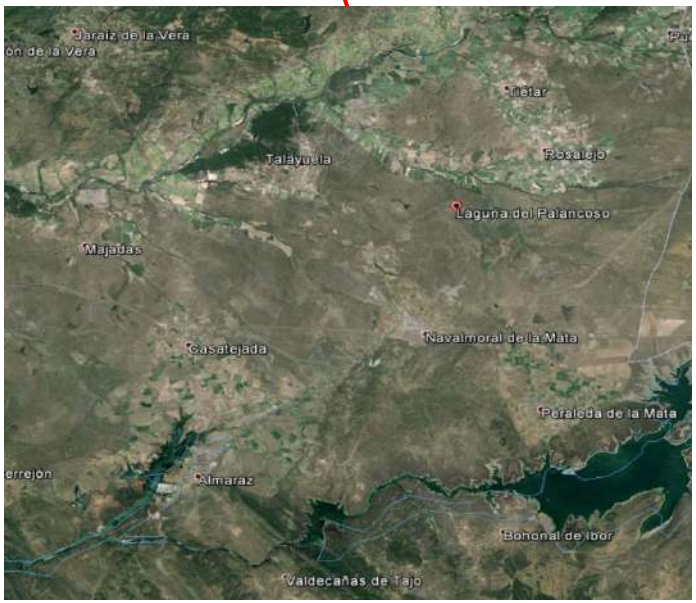
Verification / application tasks

PREPARE

- Based on well-studied cases (by UPM). Previously run with MOIRA DSS.
- Lake scenarios:
  - Lake Palancoso (Spain)
  - Lake Kozhanovskoe (Russia)
  - Lake Svyatoye (Belarus)
- River scenarios:
  - Ebro – Ascó NPP (Spain)
  - Tagus – Almaraz NPP (Spain)
- Bugs detection and QA
- User interface improvements

Test case MOIRA-Lake: Palancoso, Spain

- Located in Navalmoral de la Mata, Cáceres (Spain), in a Special Bird Protection Zone (ZEPA)
- 25 m from Almaraz NPP. A severe accident sequence from the PSA study was assumed
- This scenario was used in 2007 in the EURANOS – CAT2DEM19 demonstration project of the MOIRA DSS



Input data related to the lake:

Lake area	***0.1 km²***
Lake catchment area	***0.5 km²***
Lake mean depth	***3 m***
Lake max depth	***5 m***
Altitude	***270 m***
Continentality	***300 km***
Latitude	***39.97º N***
Longitude	***-5.55º W***

Initial K+ concentration	***0.5 mg/L***
Initial Total Phosphorus concentration	***10 µg /L***
Initial pH (mean anual)	***6.75***
initial Ca2+ concentration	***10.02 mg/L***

Piscivores (e.g. pike or large perch)	***1000 g ww***
Bentivores	***350 g ww***
Omnivores (e.g. median perk or roach)	***100 g ww***
Planktivores	***40 g ww***
Annual fish production (from fish farms)	***0 kg/year***

Test case MOIRA-Lake: Palancoso, Spain

PREPARE

Input data related to the lake (as in JRODOS user interface):

Lake area, km²	0.1	Lake catchment area, km²	0.5
Lake mean depth, m	3	Lake max depth, m	5
Altitude, m	270	Continentality, km	300
Latitude, °	39.97	Longitude, °	5.326

Initial K+ concentration, mg/l	0.5
Initial Total Phosphorus concentration, µg/l	10
Initial pH (mean annual)	6.75
Initial Ca2+ concentration, mg/l	10.02

Values which are not defined (or zeros) will be estimated during simulation

Piscivores (e.g. pike or large perch), g ww	1,000
Benthivores, g ww	350
Omnivores (e.g. median perch or roach), g ww	100
Planktivores, g ww	40
Annual fish production (from fish farms), kg/year	0

Test case MOIRA-Lake: Palancoso, Spain

PREPARE

Input data related to the lake environment:

Precipitation (mean anual)	***525 mm/year***
Precipitation max	***600 mm/year***
Precipitation min	***450 mm/year***

Forest	***24.9%***
Oil plants	***2.14%***
Cereals	***21.31%***
pasturage	***18.2%***
Root vegetables	***5%***

Soil type	***Sand (including flood plains)***
Bedrock type	***Sedimentary metamorphized (altered)***

Fallout input data:

Year of fallout (YYYY)	***2007***
Month of fallout (1-12)	***3 (March)***
Deposition Cs-137 on lake	***1E5 Bq/m^2***
Deposition Cs-137 on catchment	***1E5 Bq/m^2***
Deposition Sr-90 on lake	***1E3 Bq/m^2***
Deposition Sr-90 on catchment	***1E3 Bq/m^2***

Test case MOIRA-Lake: Palancoso, Spain

PREPARE

Input data related to the lake environment:

Precipitation (mean annual), mm/year	525
Precipitation min, mm/year	450
Precipitation max, mm/year	600

Forest, %	24.9
Oil plants, %	2.14
Cereals, %	21.31
Pasturage, %	18.2
Root vegetables, %	5

Soil type	Sand (including flood plains)
Bedrock type	Sedimentary metamorphized (altered)

Fallout input data:

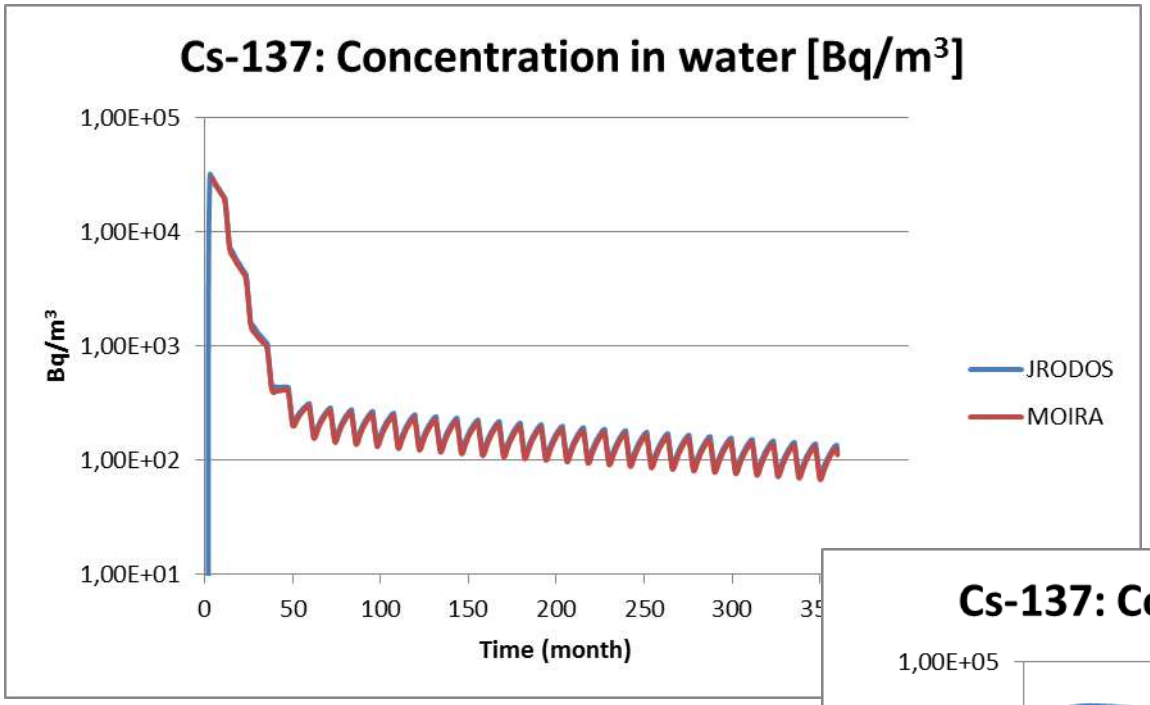
Fallout

Year of fallout	2007
Month of fallout	3
Deposition Cs-137 on lake, Bq/m²	1E5
Deposition Cs-137 on catchment, Bq/m²	1E5
Deposition Sr-90 on lake, Bq/m²	3E5
Deposition Sr-90 on catchment, Bq/m²	3E5

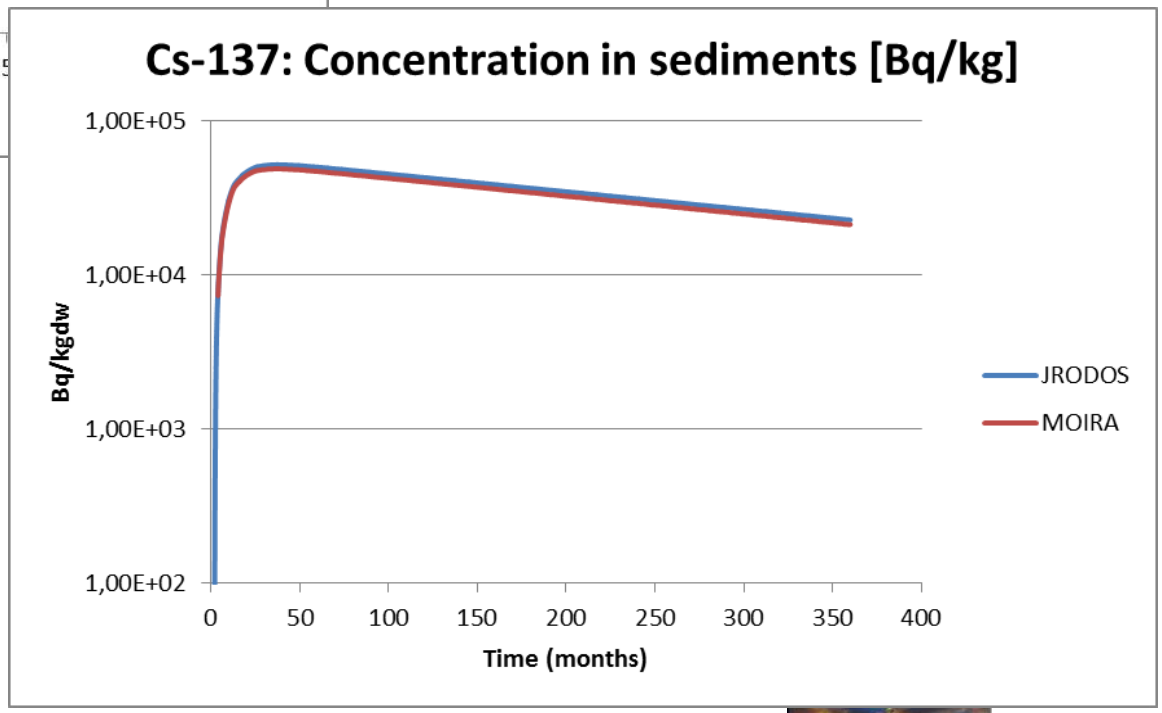
(•) Standalone
( ) ADM

Load fallout

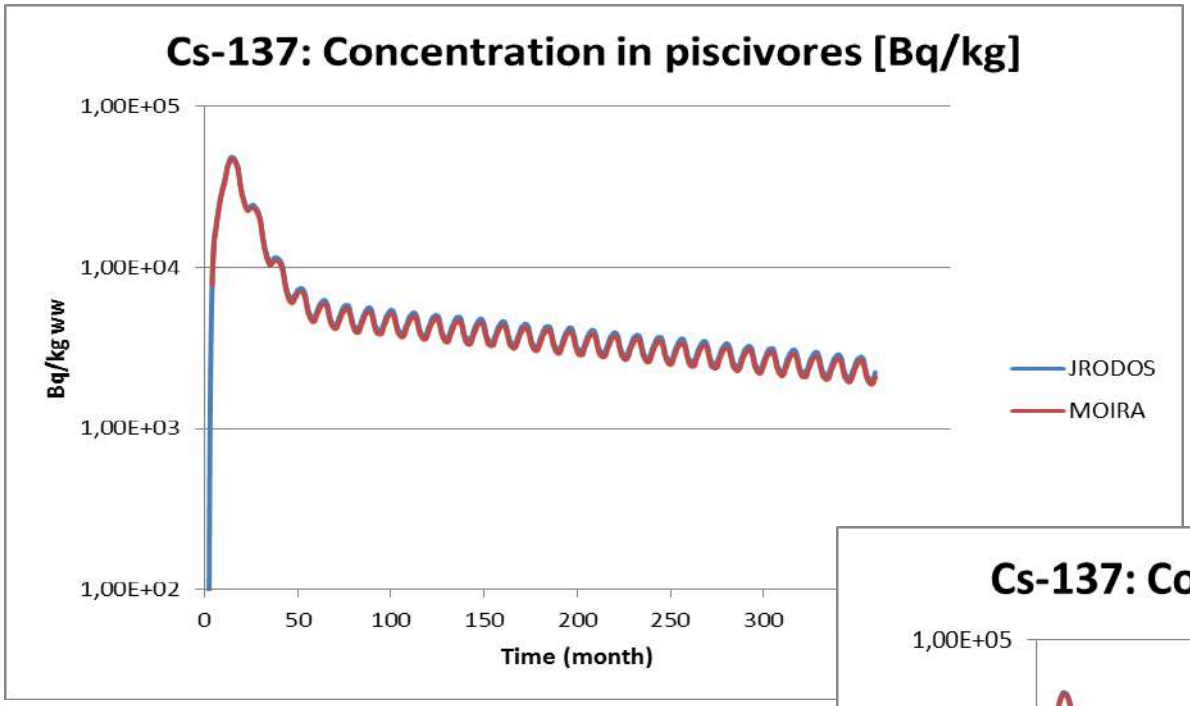
Test case MOIRA-Lake: Palancoso, Spain



Comparison of results between the original MOIRA Lake model (in Powersim®) and the JRODOS-MOIRA Lake



Test case MOIRA-Lake: Palancoso, Spain



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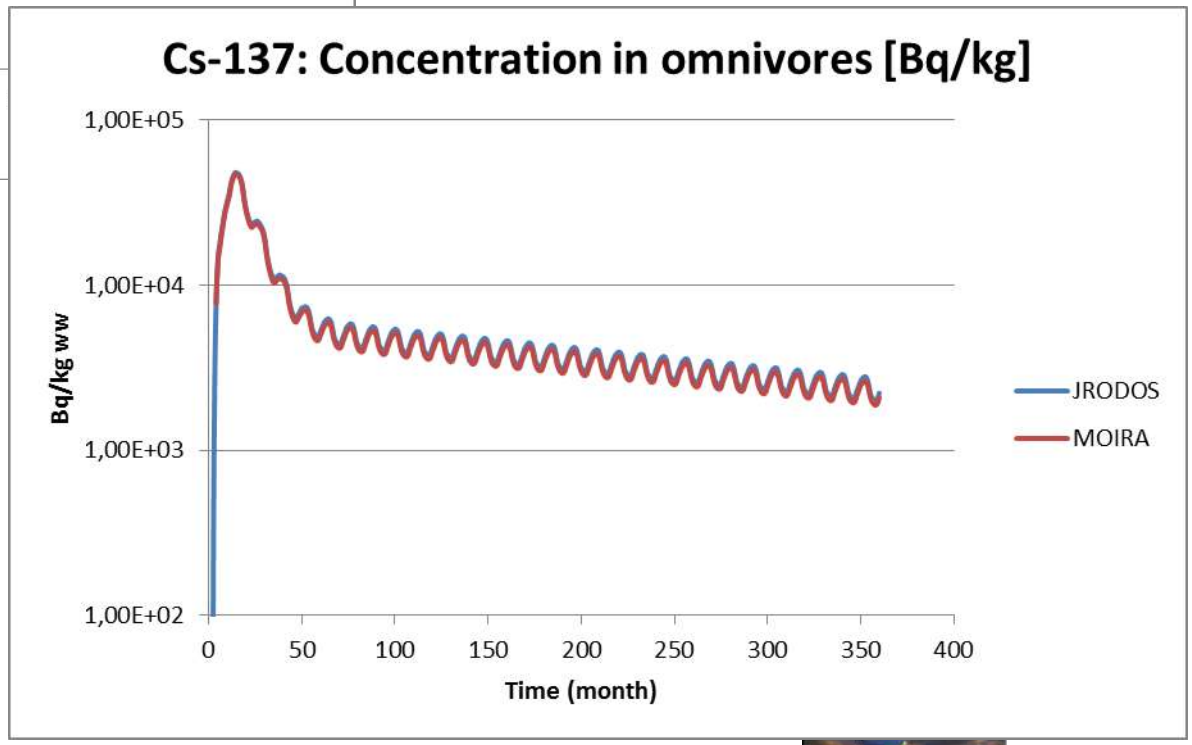
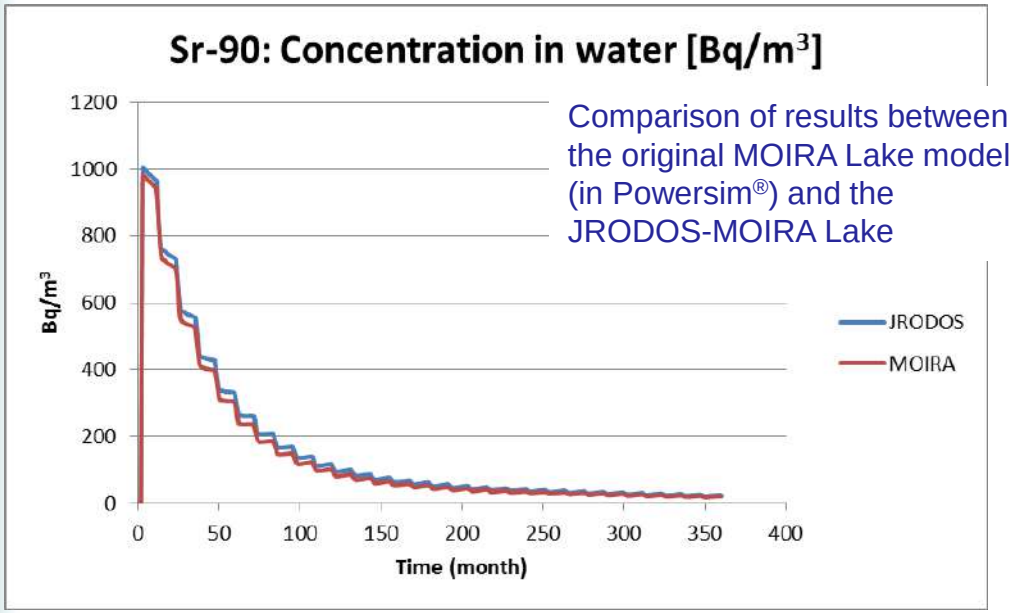
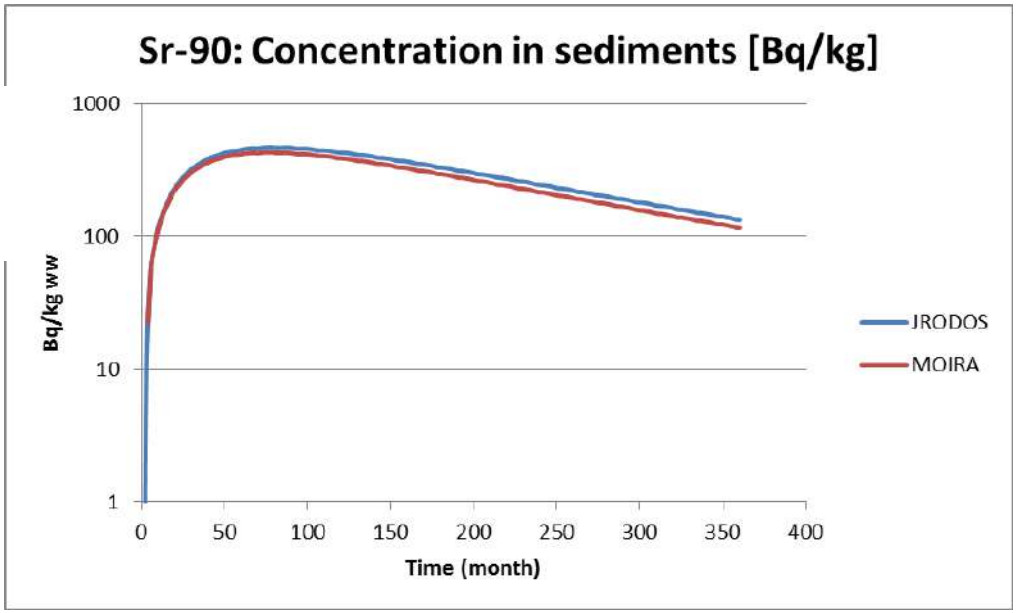


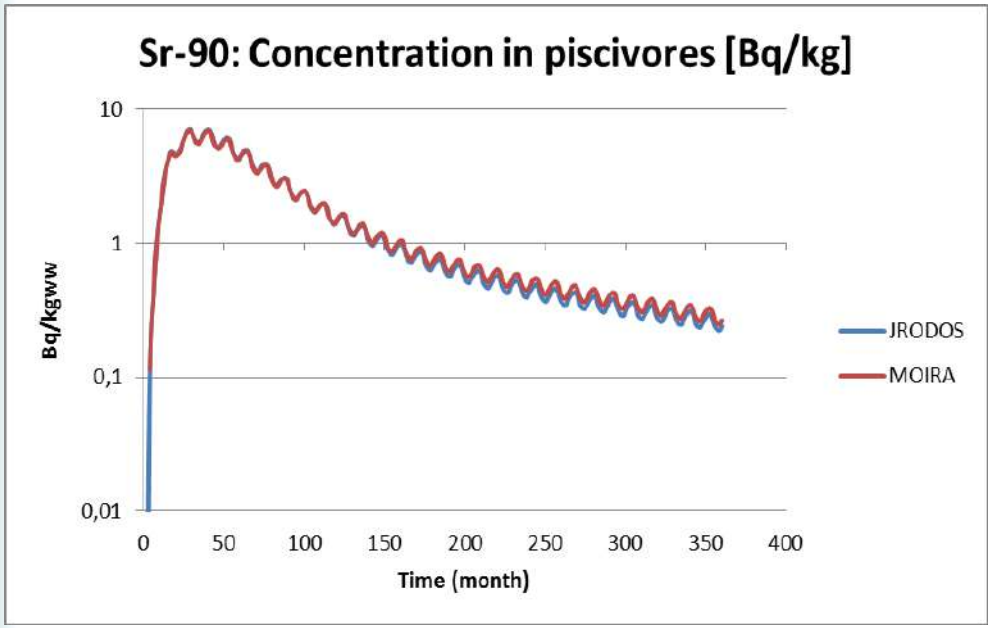
Test case MOIRA-Lake: Palancoso, Spain

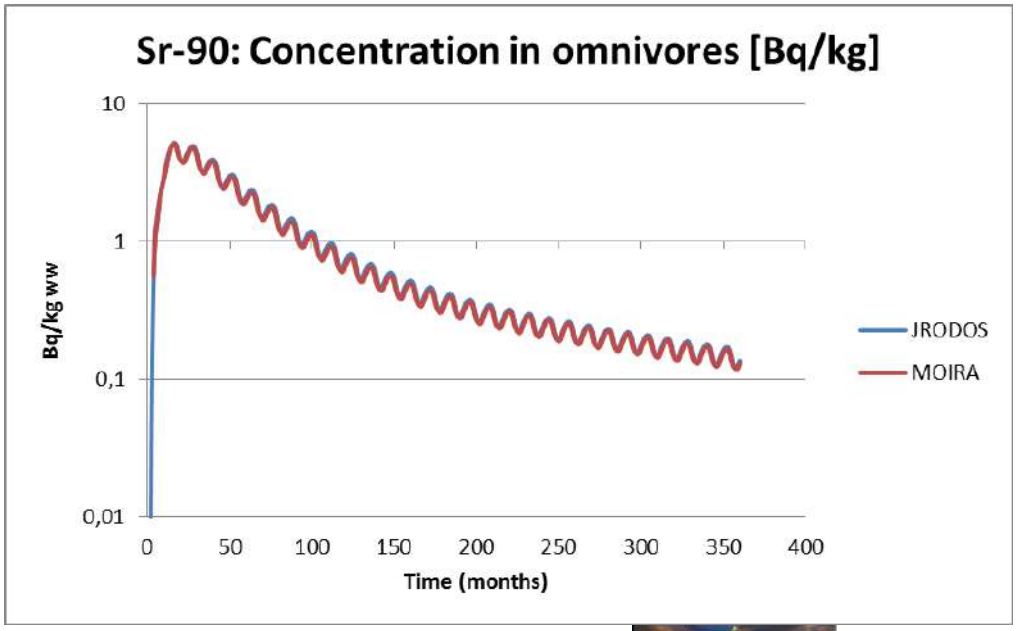
PREPARE



Comparison of results between the original MOIRA Lake model (in Powersim®) and the JRODOS-MOIRA Lake





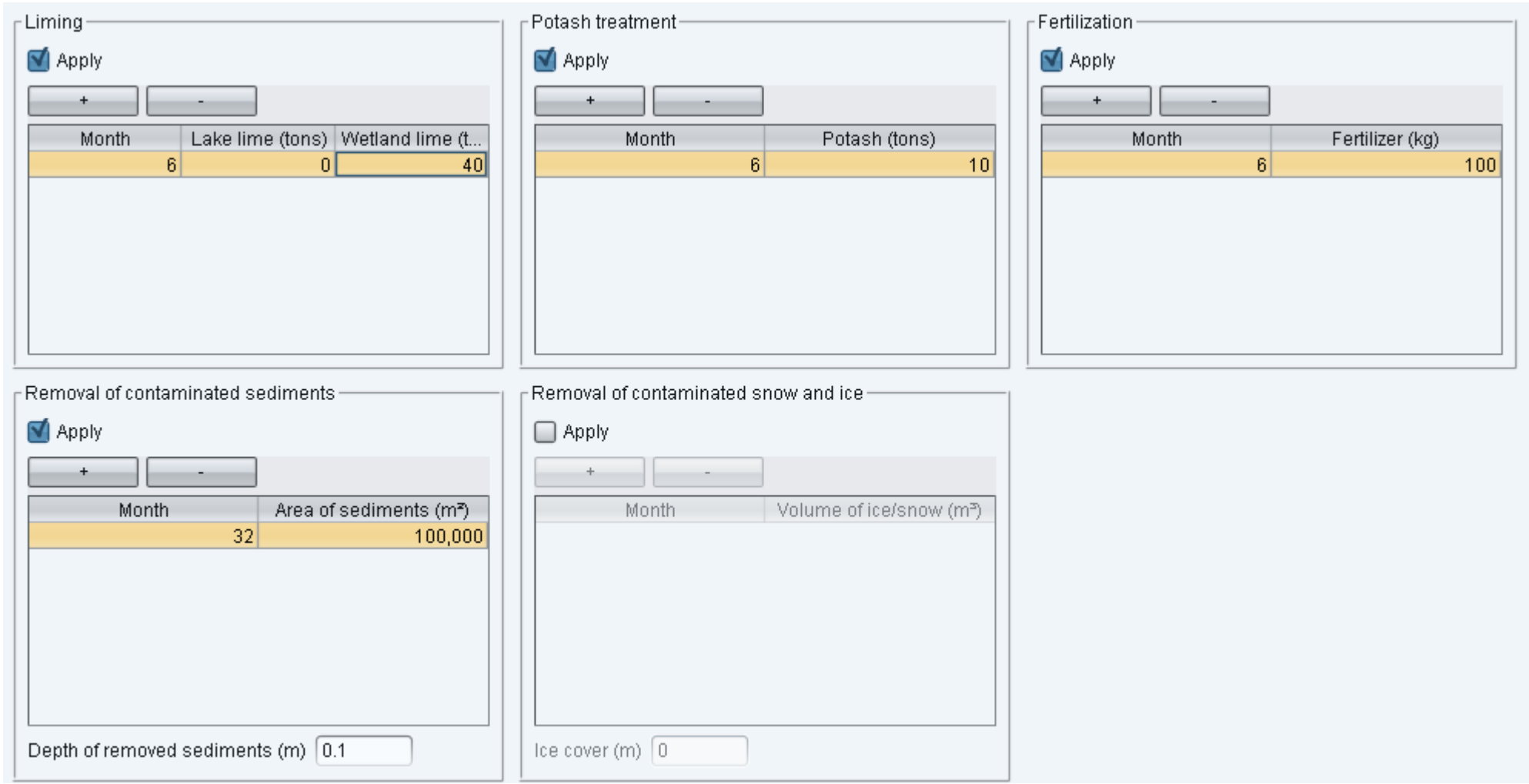


Tests of the Countermeasures models

Month	*Lime in wetlands (tons)*	*Potash (tons)*	*Fertilization (kg)*	*Removed sediments Area (m^2)*	*Potash 8 years (tons)*	*Distributed lime in wetlands (tons)*
6	***40***	***10***	***100***	***-***	***5***	***30***
18	***-***	***-***	***-***	***-***	***5***	***25***
30	***-***	***-***	***-***	***-***	***5***	***-***
32	***-***	***-***	***-***	***100.000***	***-***	***-***
42	***-***	***-***	***-***	***-***	***5***	***25***
54	***-***	***-***	***-***	***-***	***5***	***-***
66	***-***	***-***	***-***	***-***	***5***	***25***
78	***-***	***-***	***-***	***-***	***5***	***-***
90	***-***	***-***	***-***	***-***	***5***	***25***

Depth of removed sediments 0.1 m.

Tests of the Countermeasures models (user interface in JRODOS)

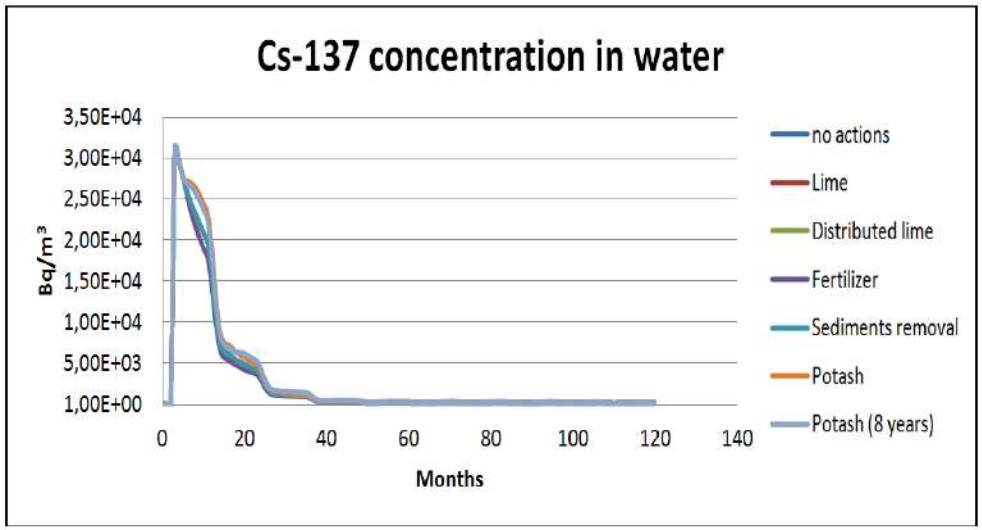


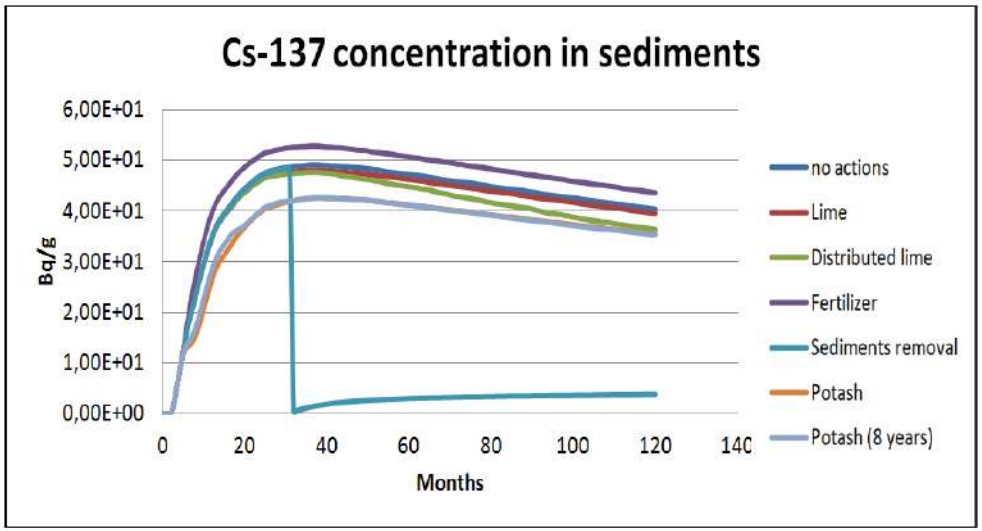
Test case MOIRA-Lake: Palancoso, Spain

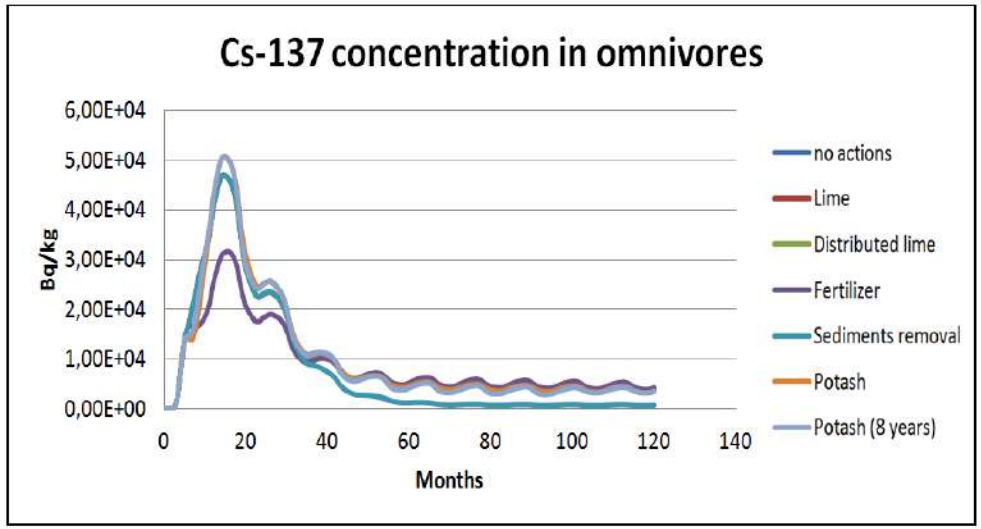
PREPARE

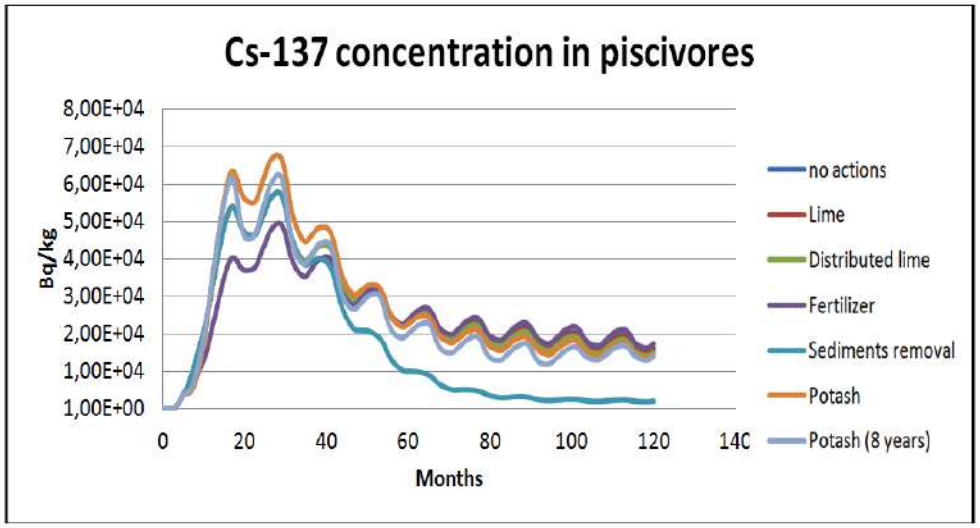
Tests of the Countermeasures models (Cs-137)

The obtained results are identical to those in the original MOIRA DSS







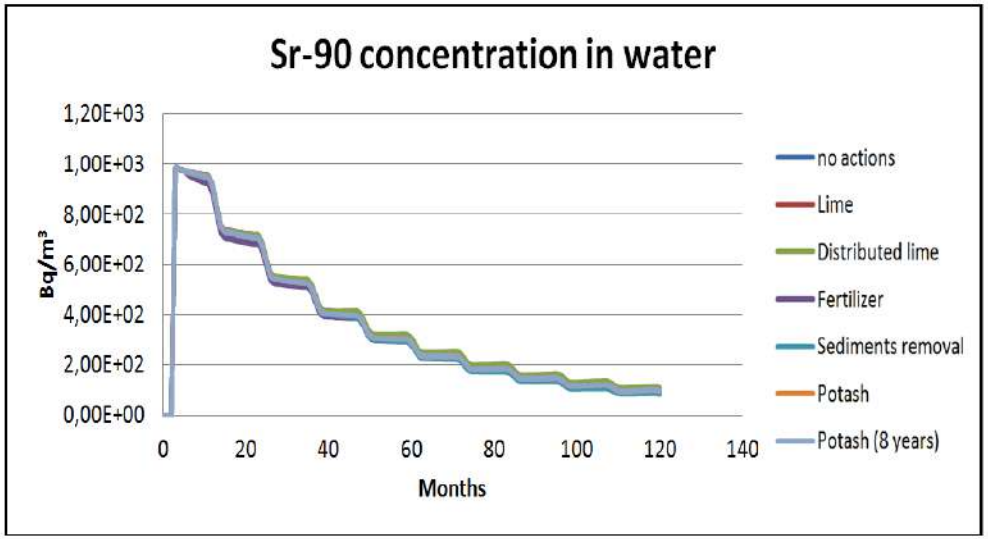


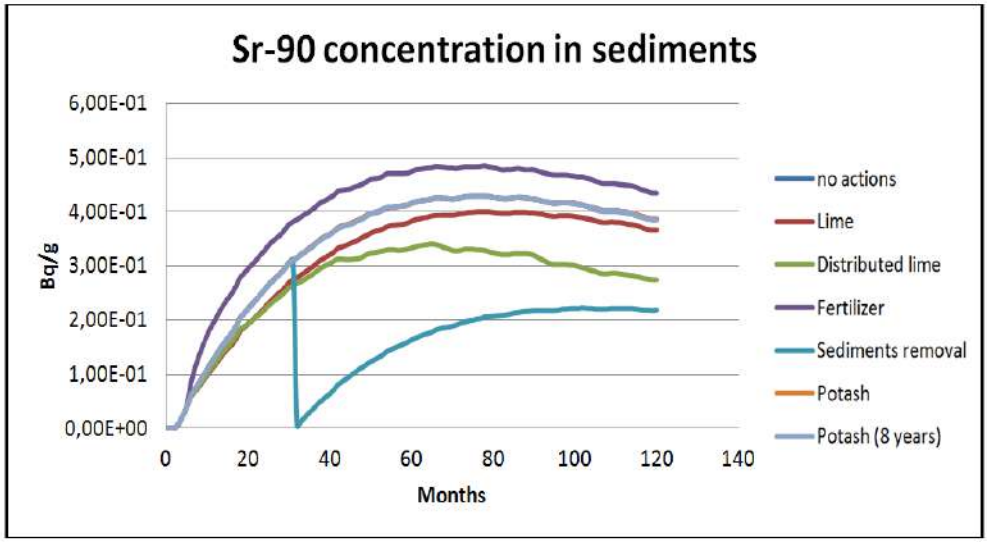
Test case MOIRA-Lake: Palancoso, Spain

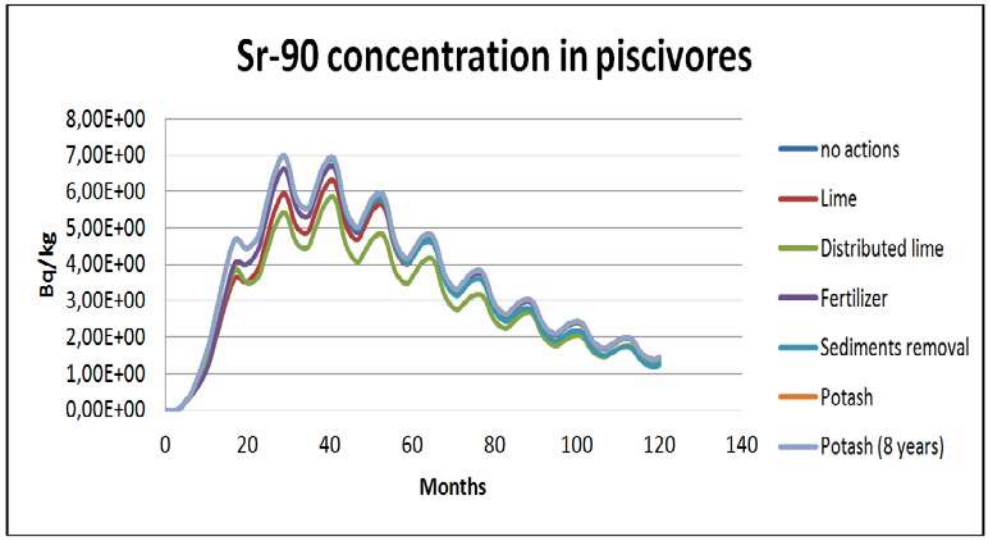
PREPARE

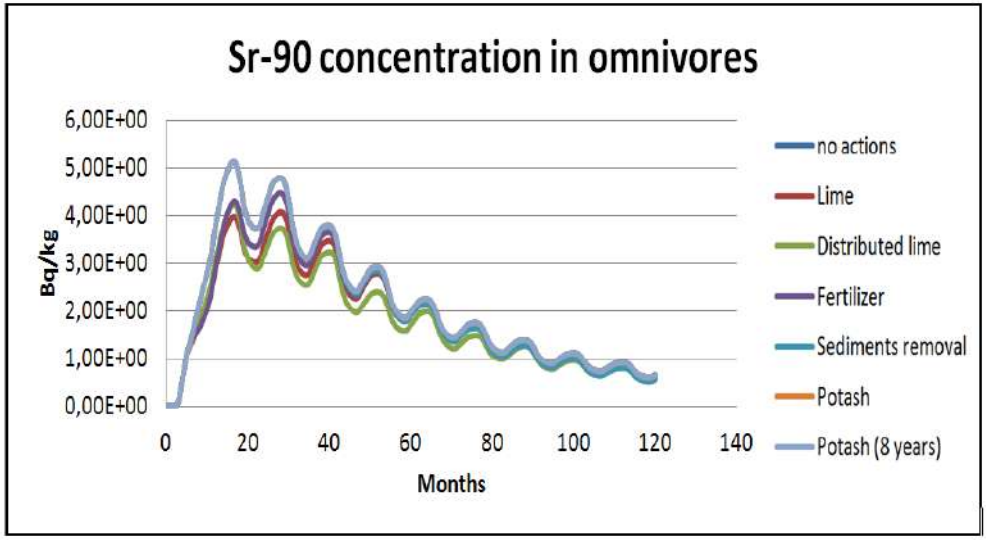
Tests of the Countermeasures models (Sr-90)

The obtained results are identical to those in the original MOIRA DSS





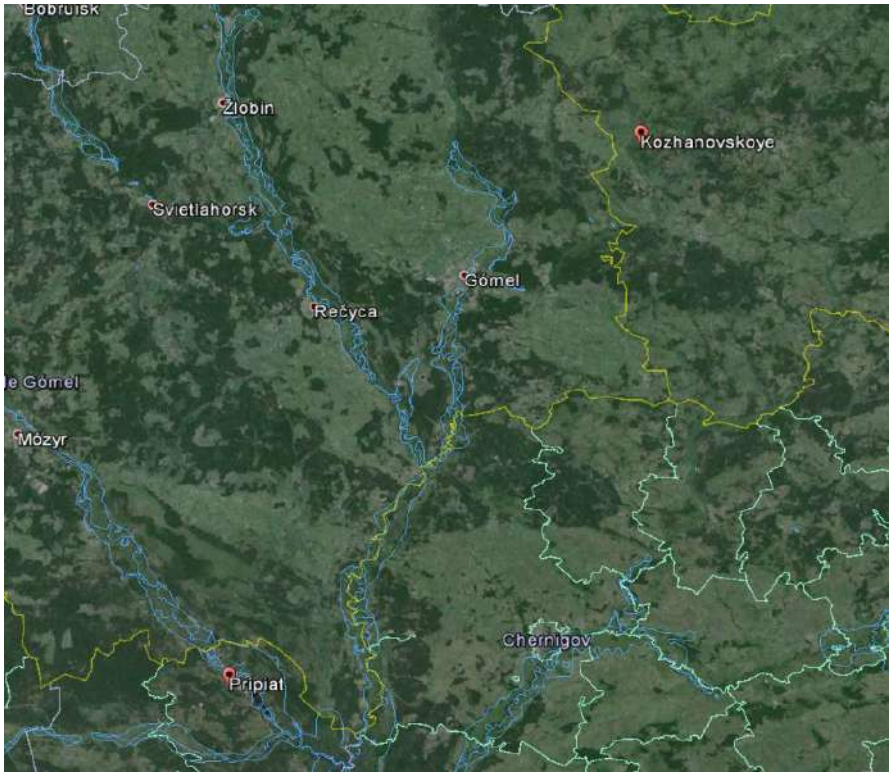


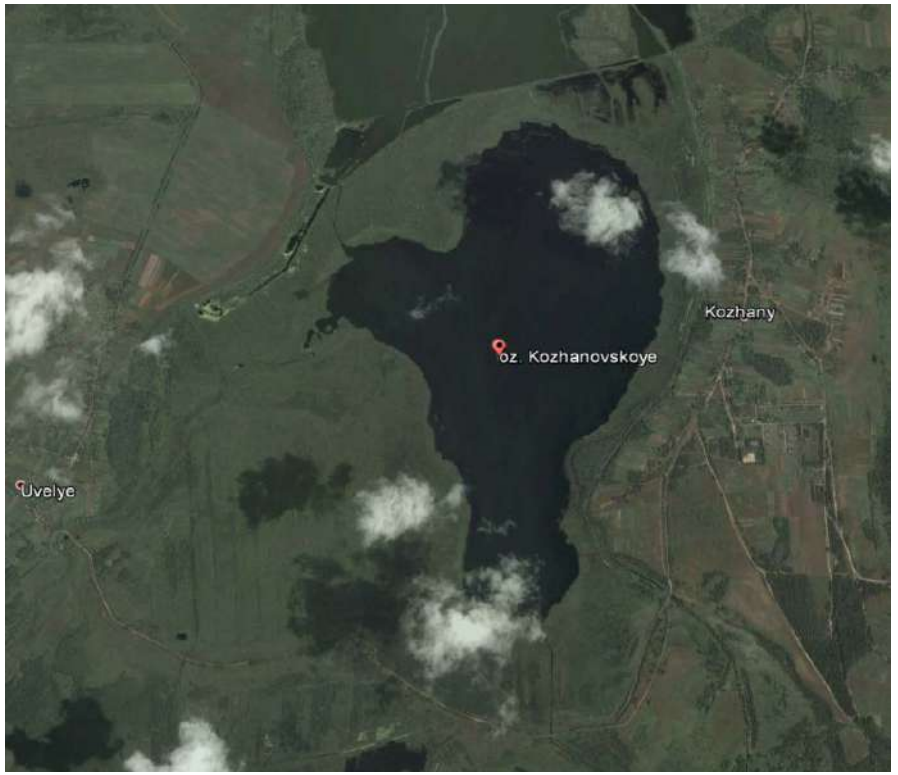


Test case MOIRA-Lake: Kozhanovskoe, Russia

PREPARE

- One of the test cases of COMETES project. Data provided by I. Kryshev and T. Sazykina (SPA Typhoon)
- Near Gomel, Bryanks region, Russia. Contaminated by the Chernobyl accident
- In 1998 the lake was granted the status of a radio-ecological reservation; fishery in the lake is forbidden because of high levels of fish contamination with ^{137}Cs
- Empirical data was available for some period





Input data related to the lake:

Lake area	***6.25 km²***
Lake catchment area	***25 km²***
Lake mean depth	***1.5 m***
Lake max depth	***2.5 m***
Altitude	***75 m***
Continentality	***1000 km***
Latitude	***52.5º N***
Longitude	***31.4 º W***
Initial K+ concentration	***1.7 mg/L***
Initial Total Phosphorus concentration	***30 µg /L***
Initial pH (mean annual)	***7***
initial Ca2+ concentration	***37.5 mg/L***

Piscivores (e.g. pike or large perch)	***1000 g ww***
Bentivores	***350 g ww***
Omnivores (e.g. median perk or roach)	***100 g ww***
Planktivores	***40 g ww***
Annual fish production (from fish farms)	***0 kg/year***

Input data related to the lake (as in JRODOS user interface):

Lake area, km²	6.25	Lake catchment area, km²	25
Lake mean depth, m	1.5	Lake max depth, m	2.5
Altitude, m	75	Continentality, km	1,000
Latitude, °	52.5	Longitude, °	31.4

Initial K+ concentration, mg/l	1.7
Initial Total Phosphorus concentration, µg/l	30
Initial pH (mean annual)	7
Initial Ca2+ concentration, mg/l	37.5

Values which are not defined (or zeros) will be estimated during simulation

Piscivores (e.g. pike or large perch), g ww	1,000
Benthivores, g ww	350
Omnivores (e.g. median perch or roach), g ww	100
Planktivores, g ww	40
Annual fish production (from fish farms), kg/year	0

Input data related to the lake environment :

Precipitation (mean anual)	***625 mm/year***
Precipitation max	***No data***
Precipitation min	***No data***
Forest	***70 %***
Oil plants	***1 %***
Cereals	***5 %***
pasturage	***10 %***
Root vegetables	***14 %***
Soil type	***Organic (including all podzol soils)***
Bedrock type	***Sedimentary metamorphized (altered)***

Fallout input data:

Year of fallout (YYYY)	***1986***
Month of fallout (1-12)	***4 (April)***
Deposition Cs-137 on lake	***6E5 Bq/m^2***
Deposition Cs-137 on catchment	***6E5 Bq/m^2***
Deposition Sr-90 on lake	***No data***
Deposition Sr-90 on catchment	***No data***

Input data related to the lake environment (as in JRODOS user interface):

Precipitation (mean annual), mm/year	625
Precipitation min, mm/year	0
Precipitation max, mm/year	0

Forest, %	70
Oil plants, %	1
Cereals, %	5
Pasturage, %	10
Root vegetables, %	14

Soil type	Organic (including all podzol soils)
Bedrock type	Sedimentary metamorphized (altered)

Fallout input data (as in JRODOS user interface):

Fallout

Year of fallout	1986
Month of fallout	4
Deposition Cs-137 on lake, Bq/m²	6E5
Deposition Cs-137 on catchment, Bq/m²	6E5
Deposition Sr-90 on lake, Bq/m²	0E0
Deposition Sr-90 on catchment, Bq/m²	0E0

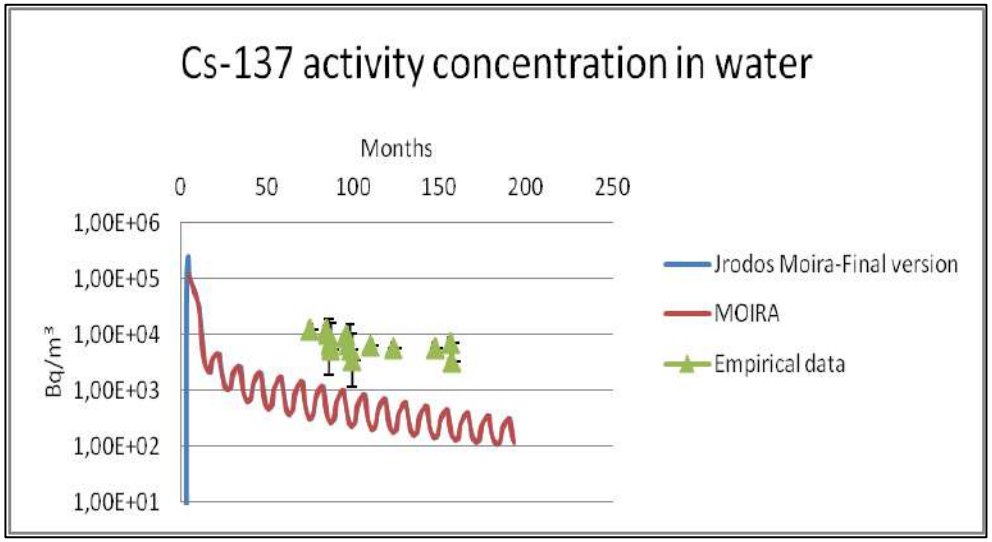
(•) Standalone

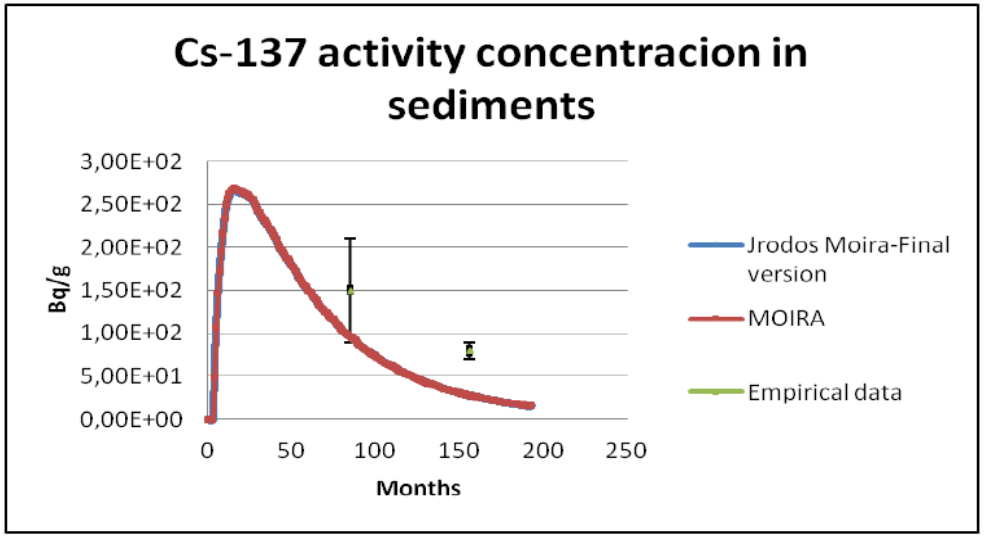
( ) ADM

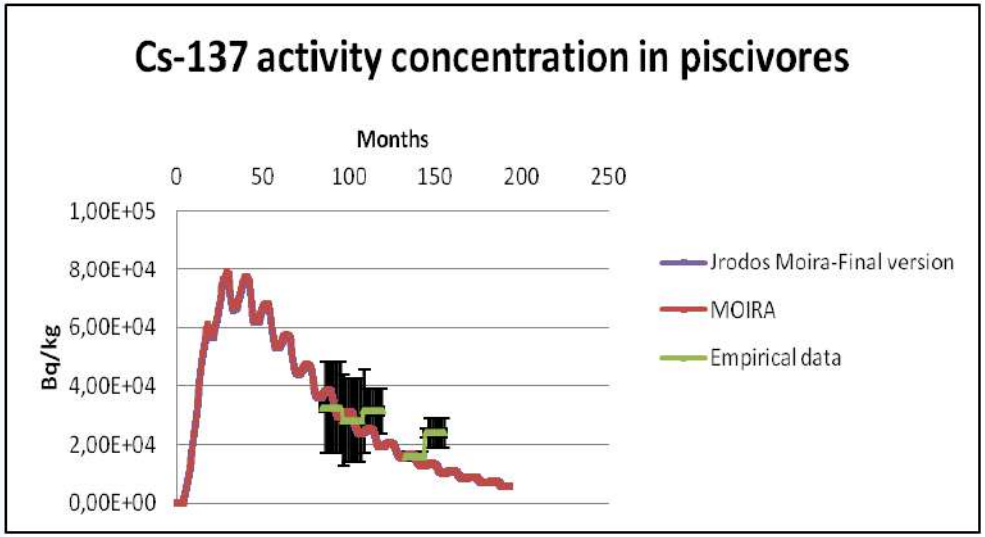
Load fallout

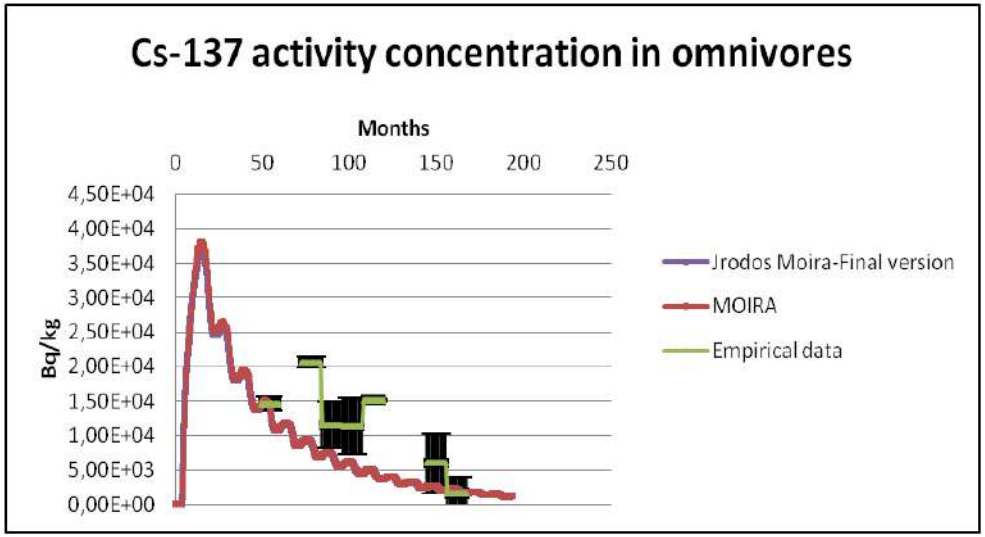
Test case MOIRA-Lake: Kozhanovskoe, Russia

PREPARE









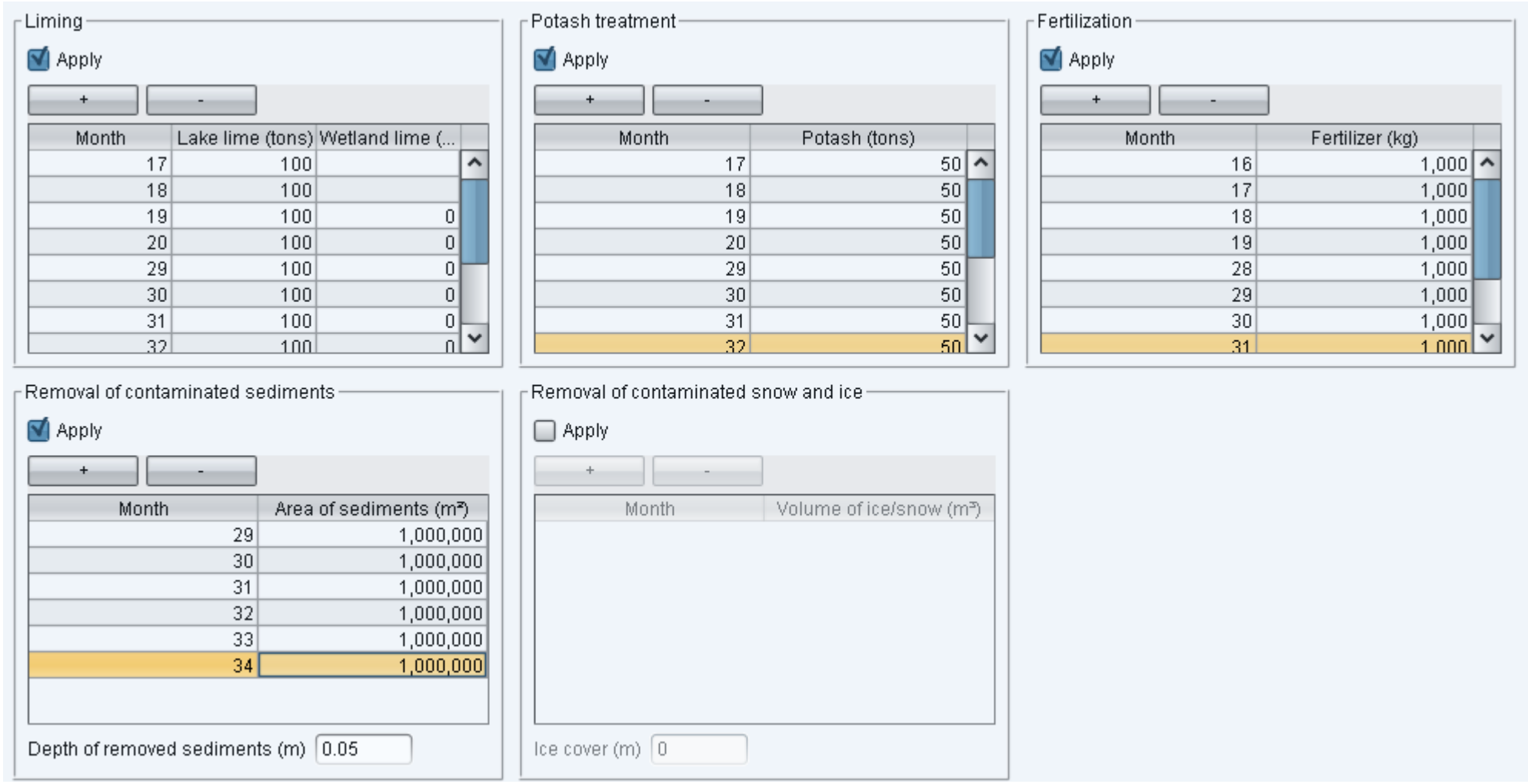
Comparison of results between the original MOIRA Lake model (in Powersim®) and the JRODOS-MOIRA Lake. Empirical data are also shown.

Tests of the Countermeasures models

Month	Lime in wetlands (tons)	Lime in lake (tons)	Potash (tons)	Fertilization (kg)	Removed sediments Area (m^2)
16	-	-	-	1.000	-
17	-	100	50	1.000	-
18	400	100	50	1.000	-
19	-	100	50	1.000	-
20	-	100	50	-	-
28	-	-	-	1.000	-
29	-	100	50	1.000	1.000.000
30	400	100	50	1.000	1.000.000
31	-	100	50	1.000	1.000.000
32	-	100	50	-	1.000.000
33	-	-	-	-	1.000.000
34	-	-	-	-	1.000.000
40	-	100	50	1.000	-
41	-	100	50	1.000	-
42	400	100	50	1.000	-
43	-	100	50	1.000	-
44	-	100	50	-	-

Depth of removed sediments 0.05 m.

Tests of the Countermeasures models (user interface in JRODOS)



Liming

Apply

\+ -

Month	Lake lime (tons)	Wetland lime (...
17	100	
18	100	
19	100	0
20	100	0
29	100	0
30	100	0
31	100	0
32	100	0

Potash treatment

Apply

\+ -

Month	Potash (tons)
17	50
18	50
19	50
20	50
29	50
30	50
31	50
32	50

Fertilization

Apply

\+ -

Month	Fertilizer (kg)
16	1,000
17	1,000
18	1,000
19	1,000
28	1,000
29	1,000
30	1,000
31	1,000

Removal of contaminated sediments

Apply

\+ -

Month	Area of sediments (m²)
29	1,000,000
30	1,000,000
31	1,000,000
32	1,000,000
33	1,000,000
34	1,000,000

Depth of removed sediments (m) 0.05

Removal of contaminated snow and ice

Apply

\+ -

Month	Volume of ice/snow (m³)

Ice cover (m) 0

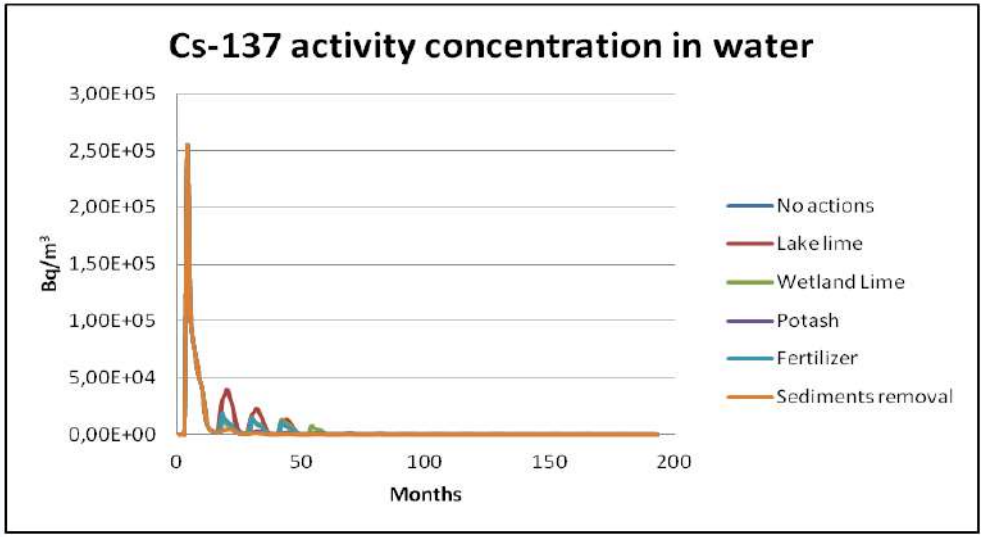
Tests of the Countermeasures models

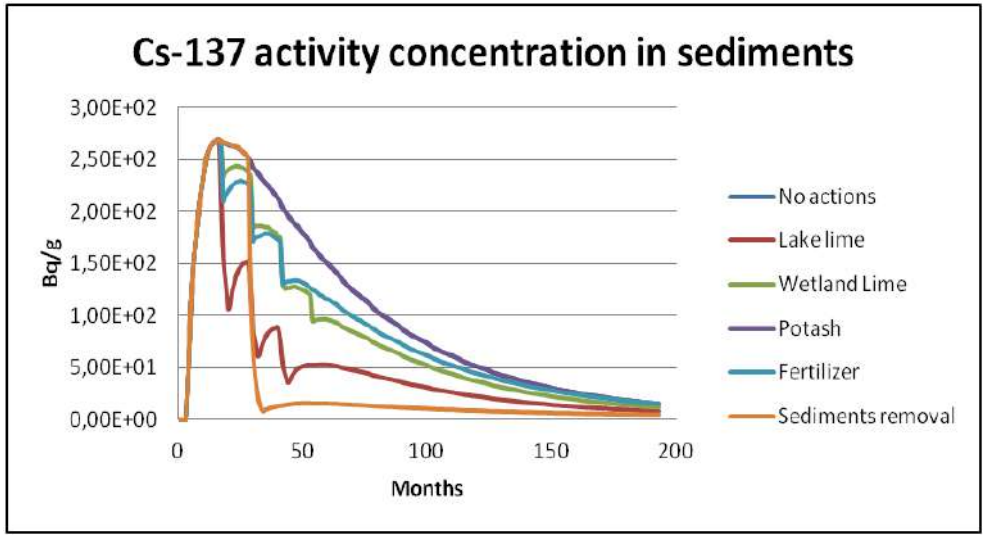
The obtained results are identical to those in the original MOIRA DSS

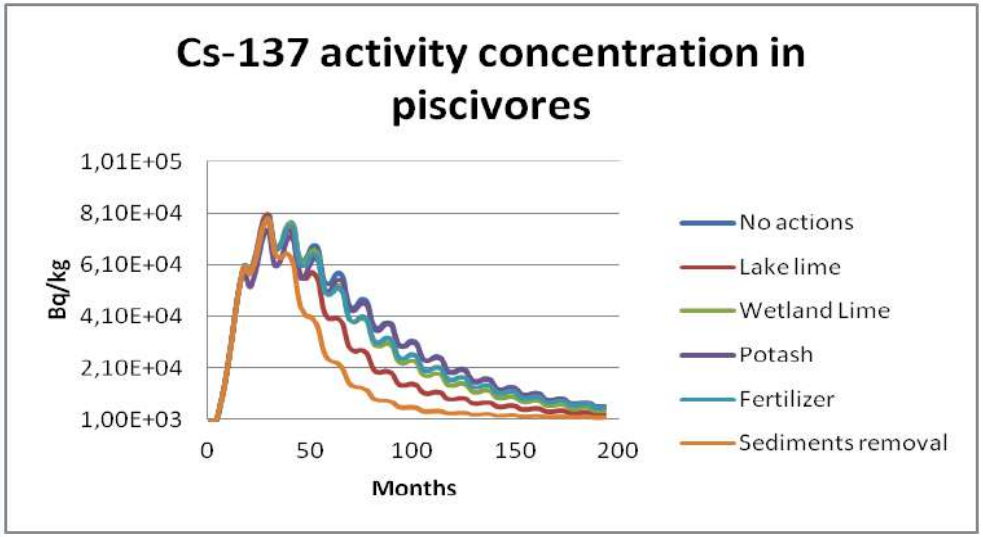
Case	Lake Ecosystem Index LEI
No actions	1,33679
Lake lime	1,543545
Potash	1,33679
Sediments removal	1,33679
Fertilization	1,67716
Wetland lime	1,46198

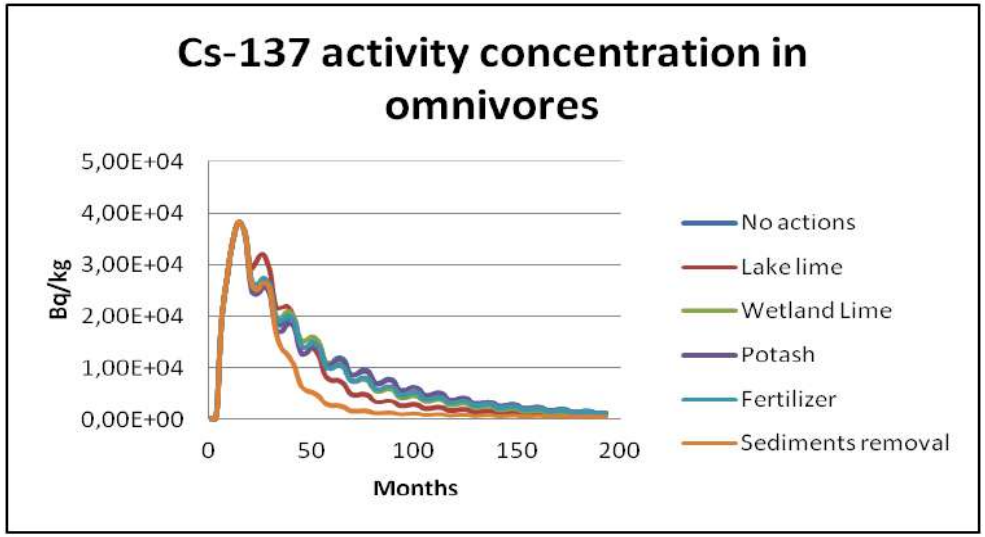
Tests of the Countermeasures models

The obtained results are identical to those in the original MOIRA DSS





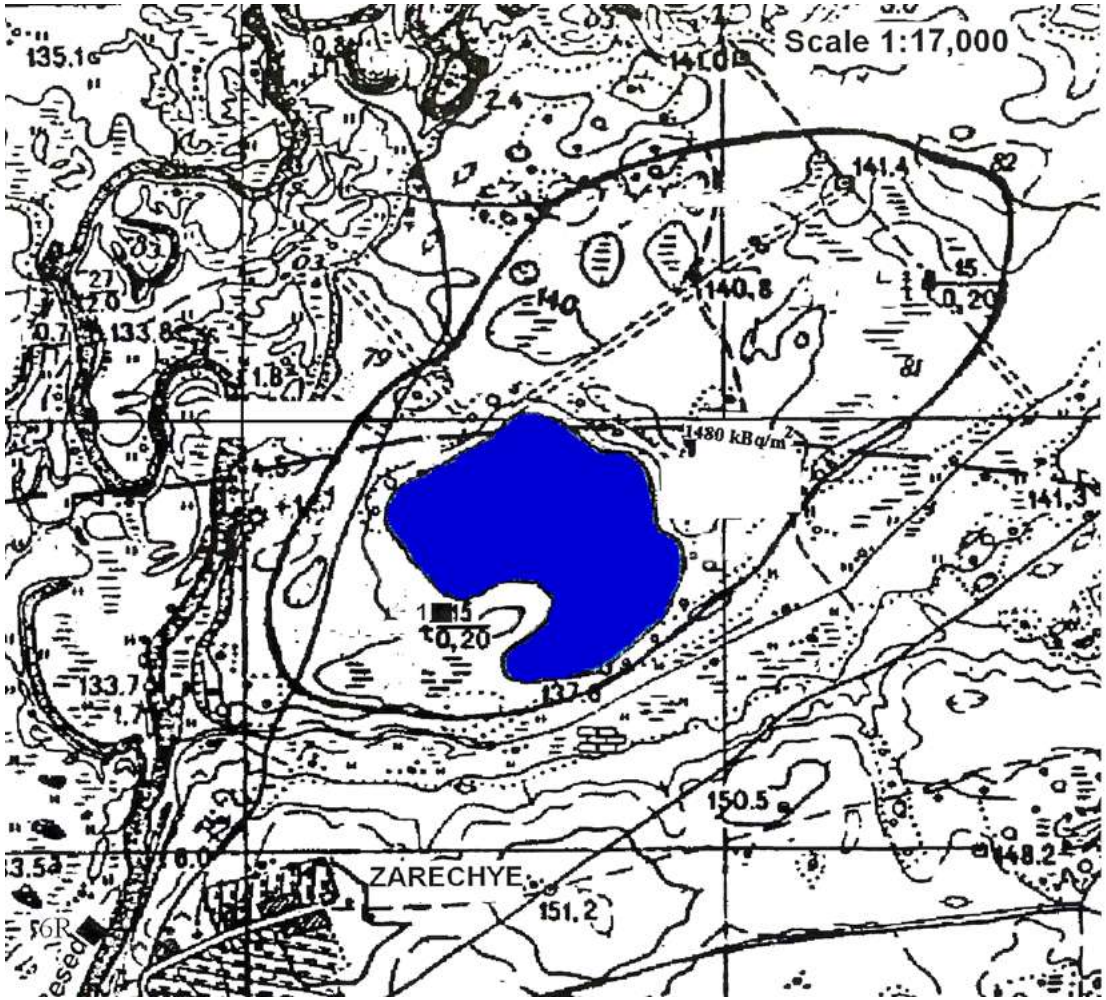


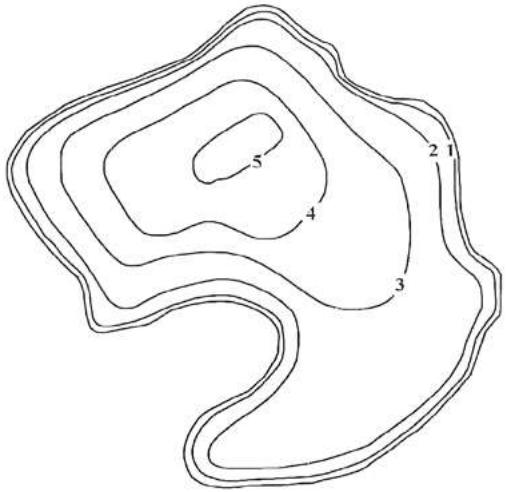


Test case MOIRA-Lake: Svyatoye, Belarus

PREPARE

- One of the test cases of EVANET-HYDRA project. Data provided by J.Smith (CEH, UK)
- Is a closed lake, located 225 km from ChNPP and 30 km southeast of Kostyukovichy town in Belarus





Bathymetry of lake (scale 1:10,000). Depth in m.

Test case MOIRA-Lake: Svyatoye, Belarus

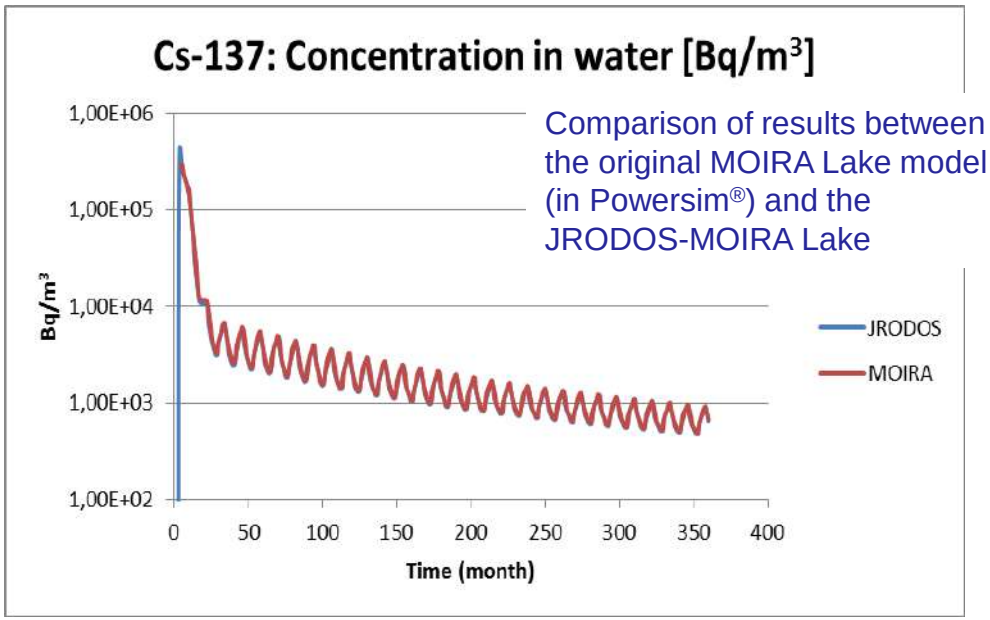
PREPARE

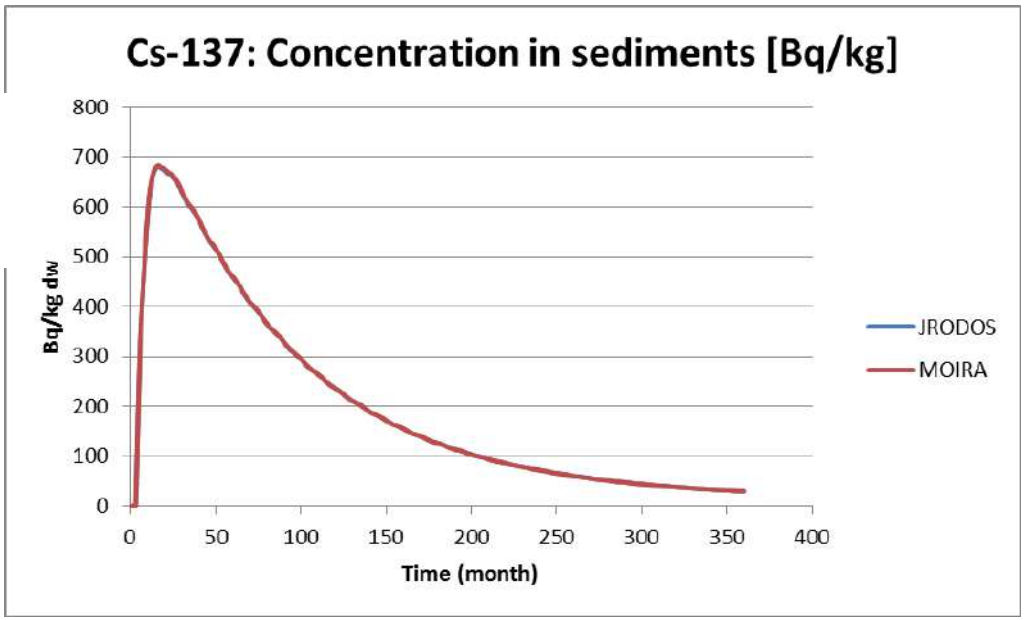
DRIVING PARAMETERS OF THE LAKE MODEL	VALUES
Surface area (km^2)	0.25
Catchment area (km^2)	1.2
Maximum depth (m)	5.2
Average depth (m)	2.9
Continentality (km)	700
Altitude (m.a.s.l)	150
Latitude (°N)	53.3
Annual average precipitation (mm/year)	800
pH	7.3
Initial Ca concentration (mg/l)	20
[K] (mg/l)	1
Total phosphorus (µg/l)	56
Soil type	Clay
Average fallout in the lake surface (kBq/m^2)	1.6E3
Average fallout in the catchment (KBq/m^2)	1.48E3
Simulation period/ timestep (months)	360/0.0125

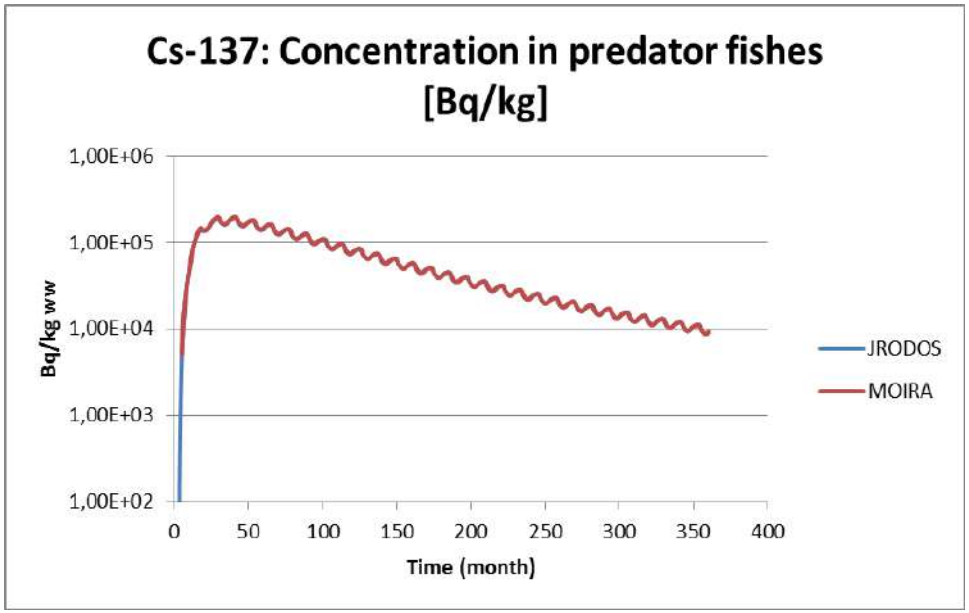
Test case MOIRA-Lake: Svyatoye, Belarus

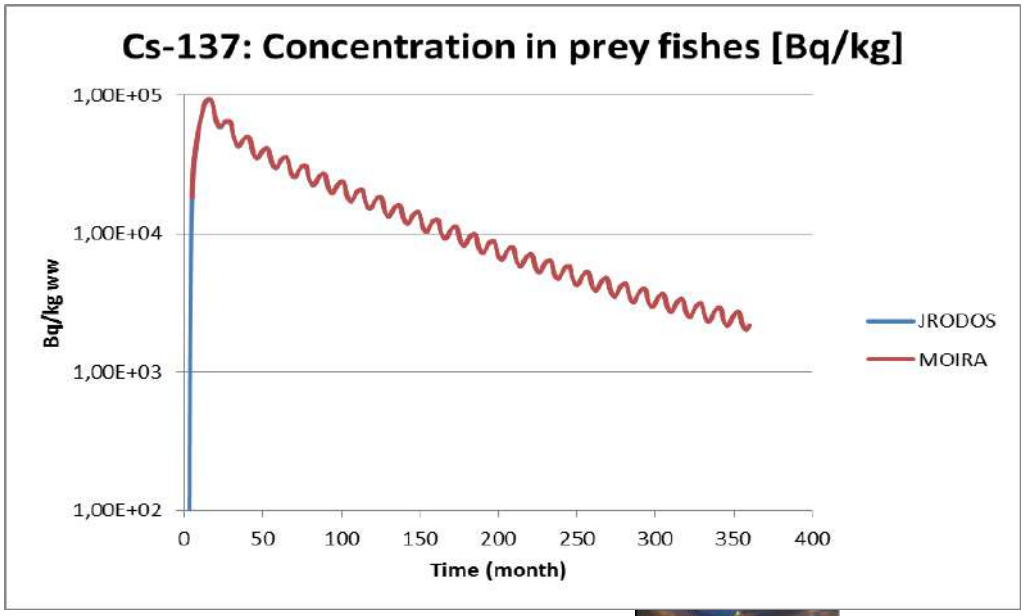
PREPARE

Comparison of results between the original MOIRA Lake model (in Powersim®) and the JRODOS-MOIRA Lake



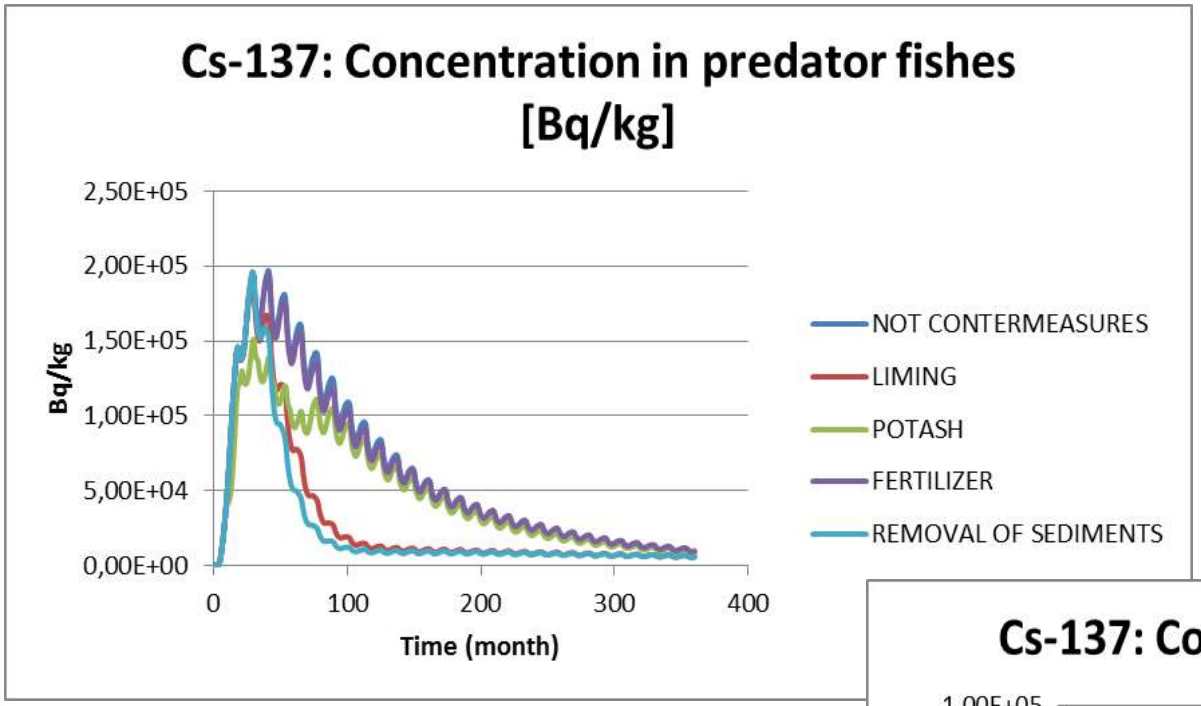






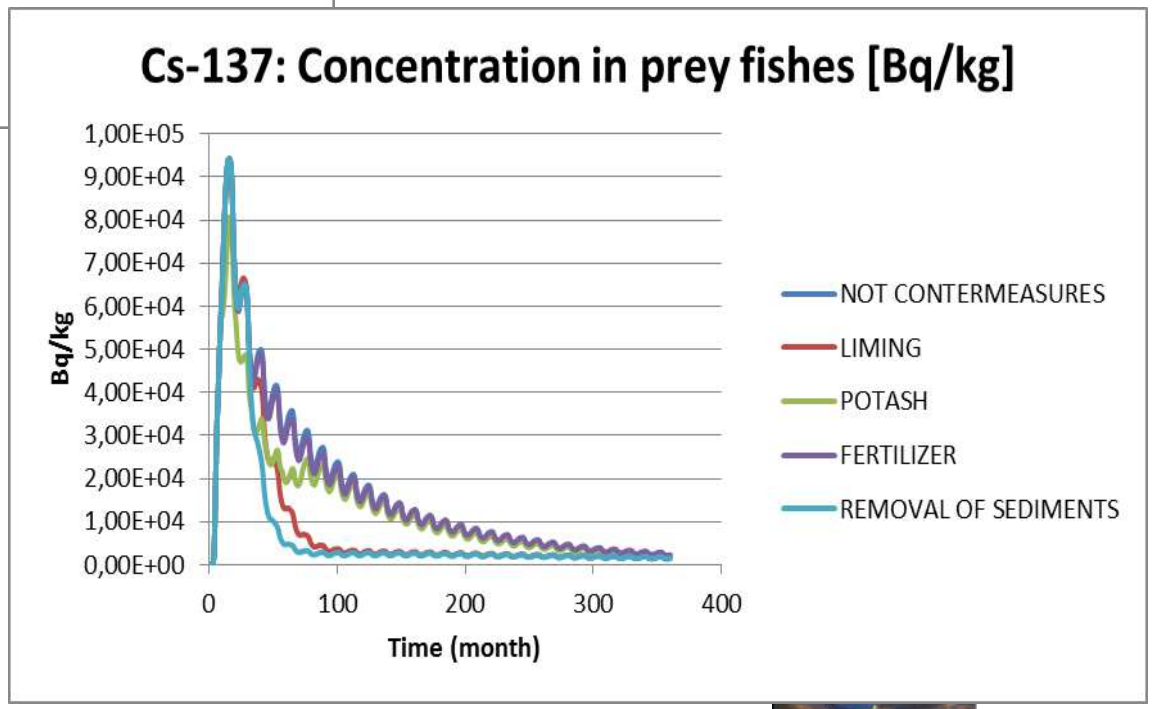
Test case MOIRA-Lake: Svyatoye, Belarus

PREPARE

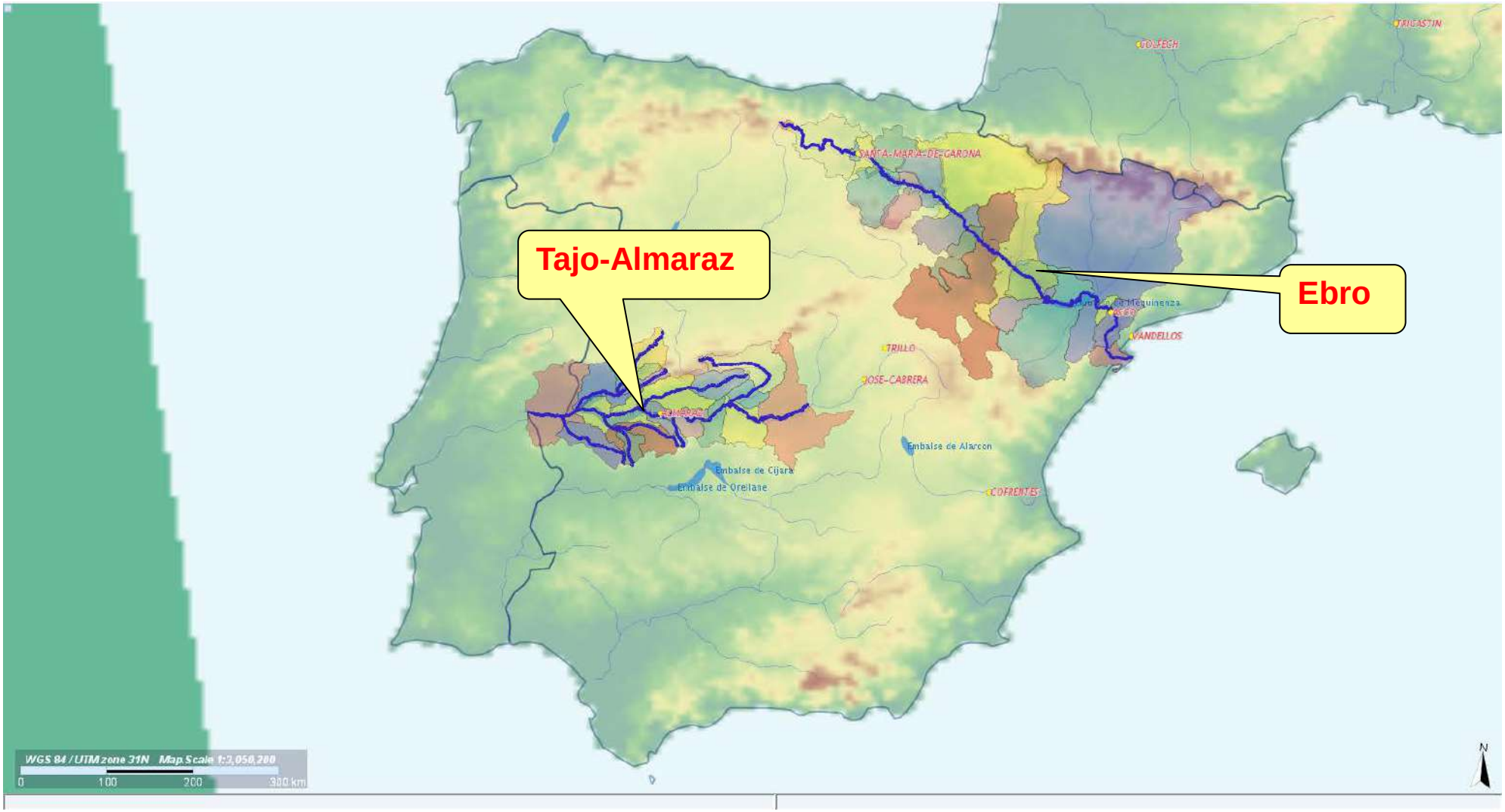


Tests of the Countermeasures models

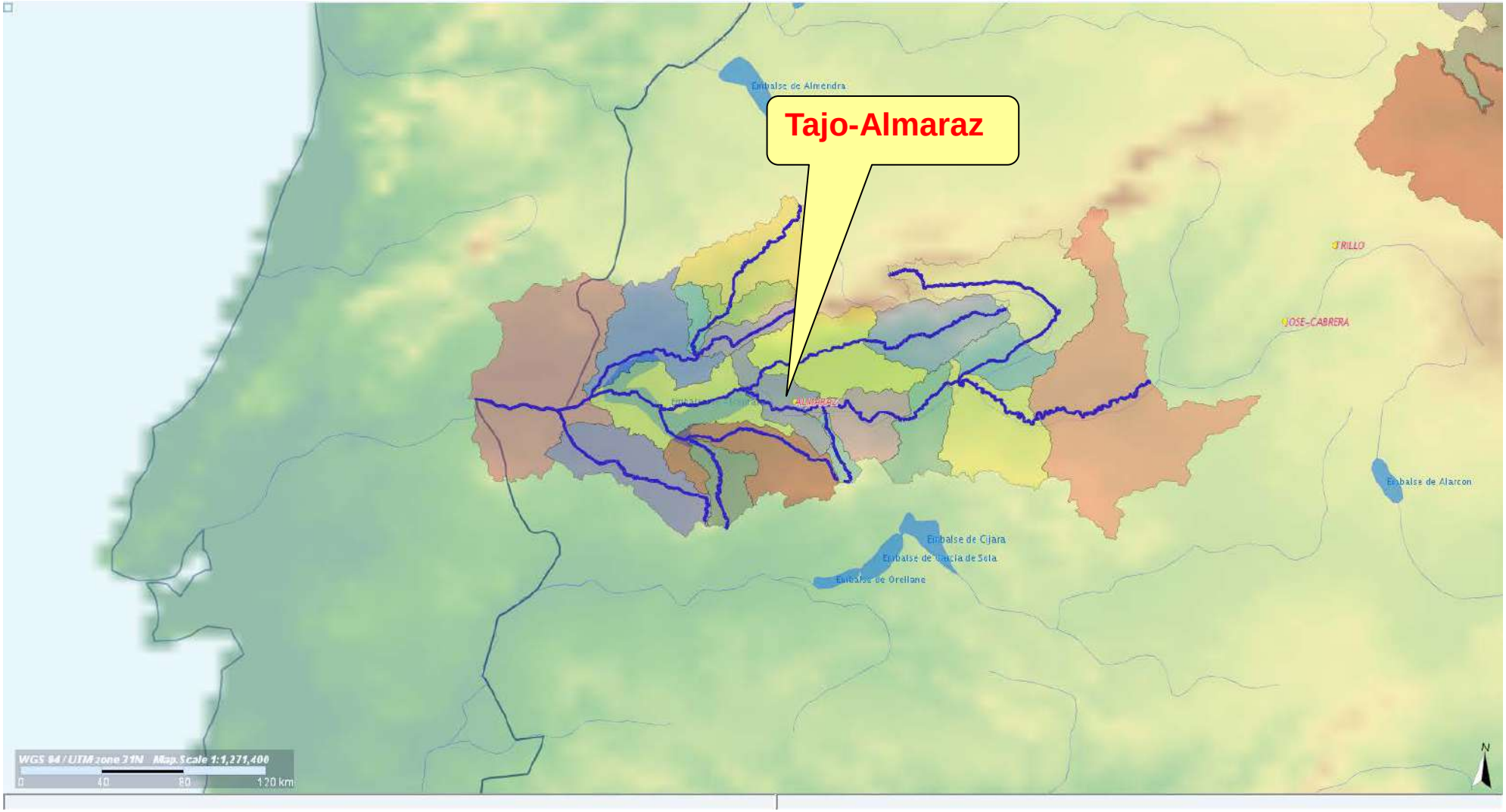
The obtained results are identical to those in the original MOIRA DSS



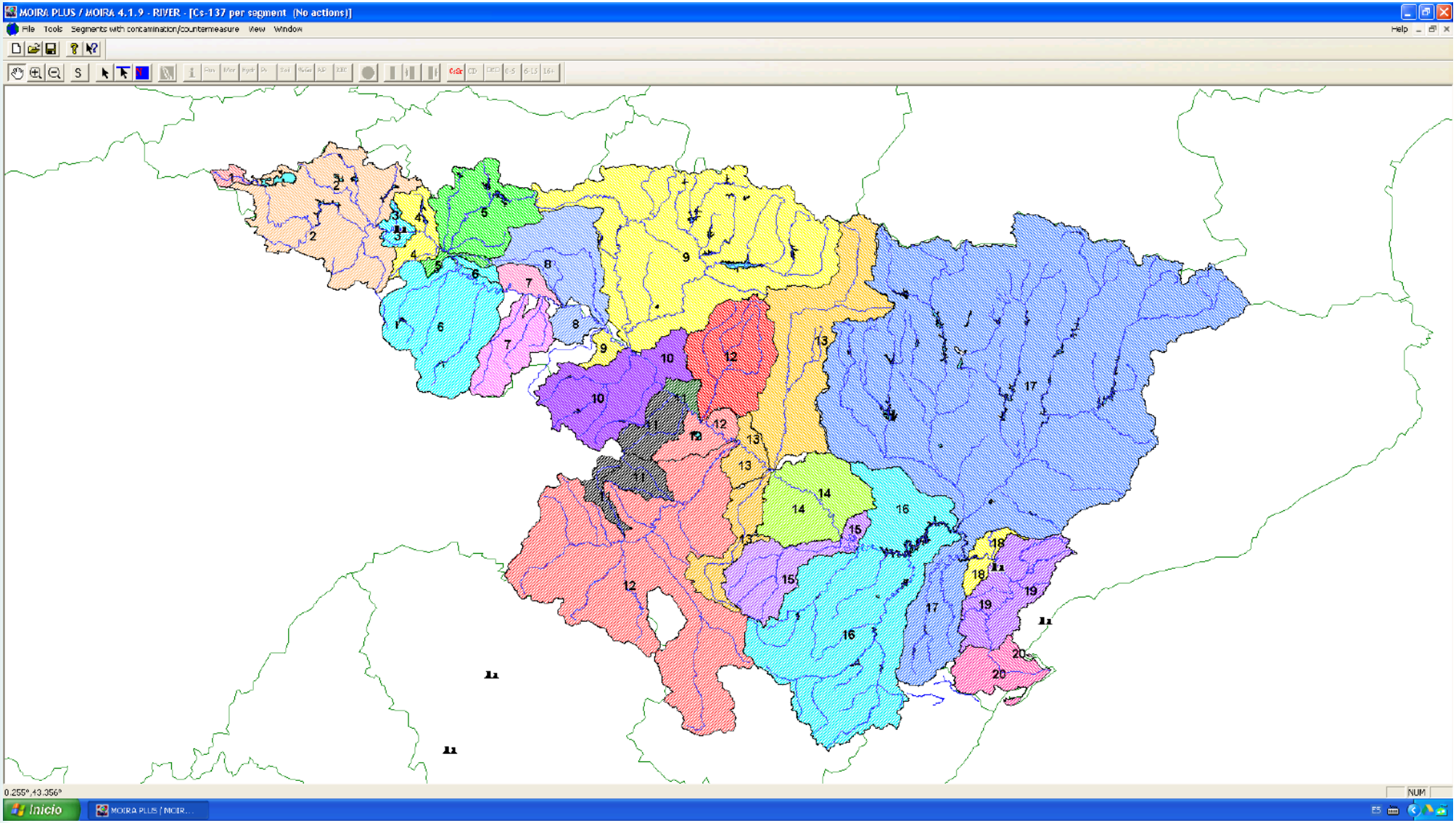
Implementation of Spanish rivers in JRODOS GIS



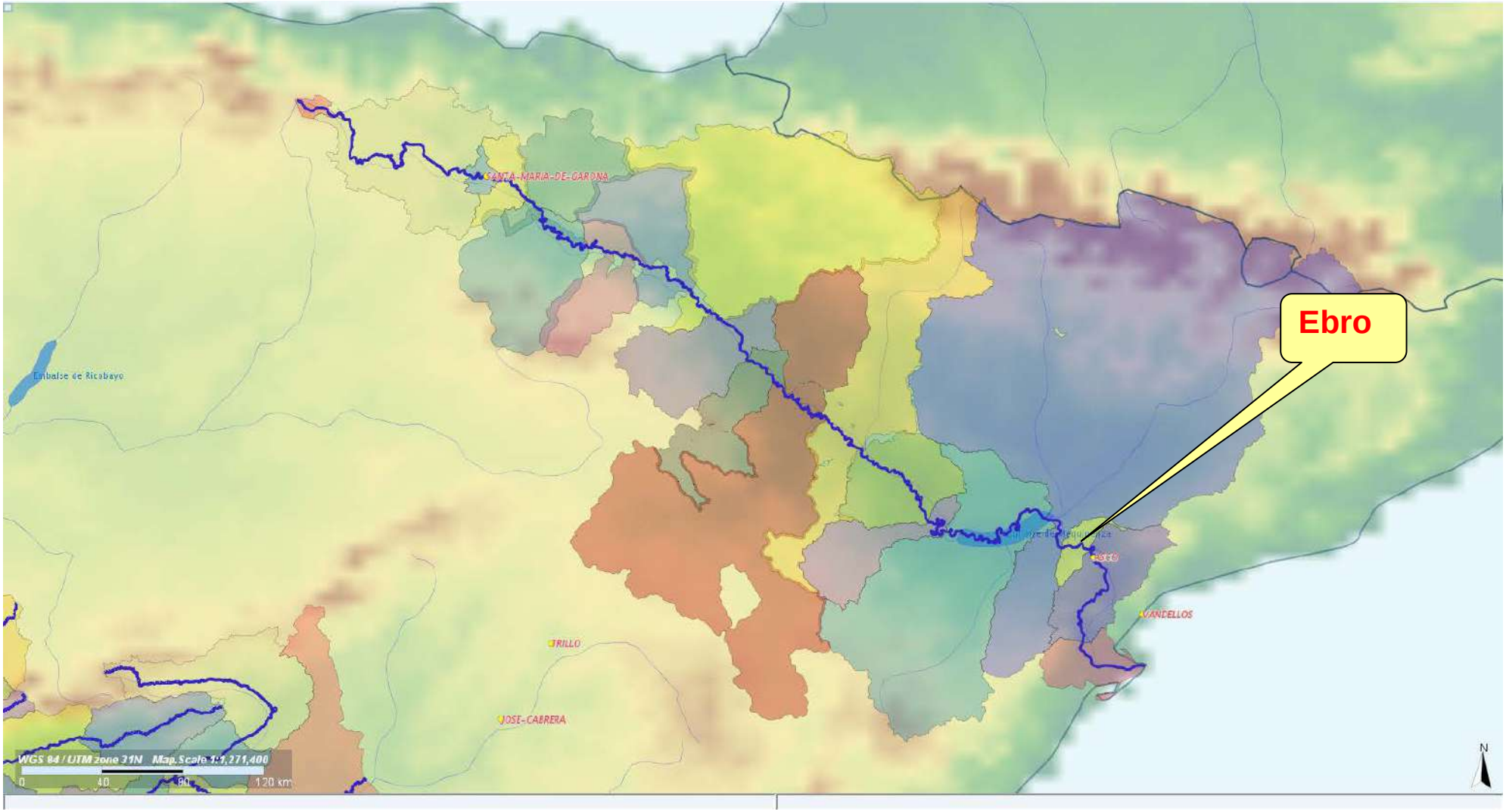
Implementation of Spanish rivers in JRODOS GIS



MOIRA-DSS. Ebro River



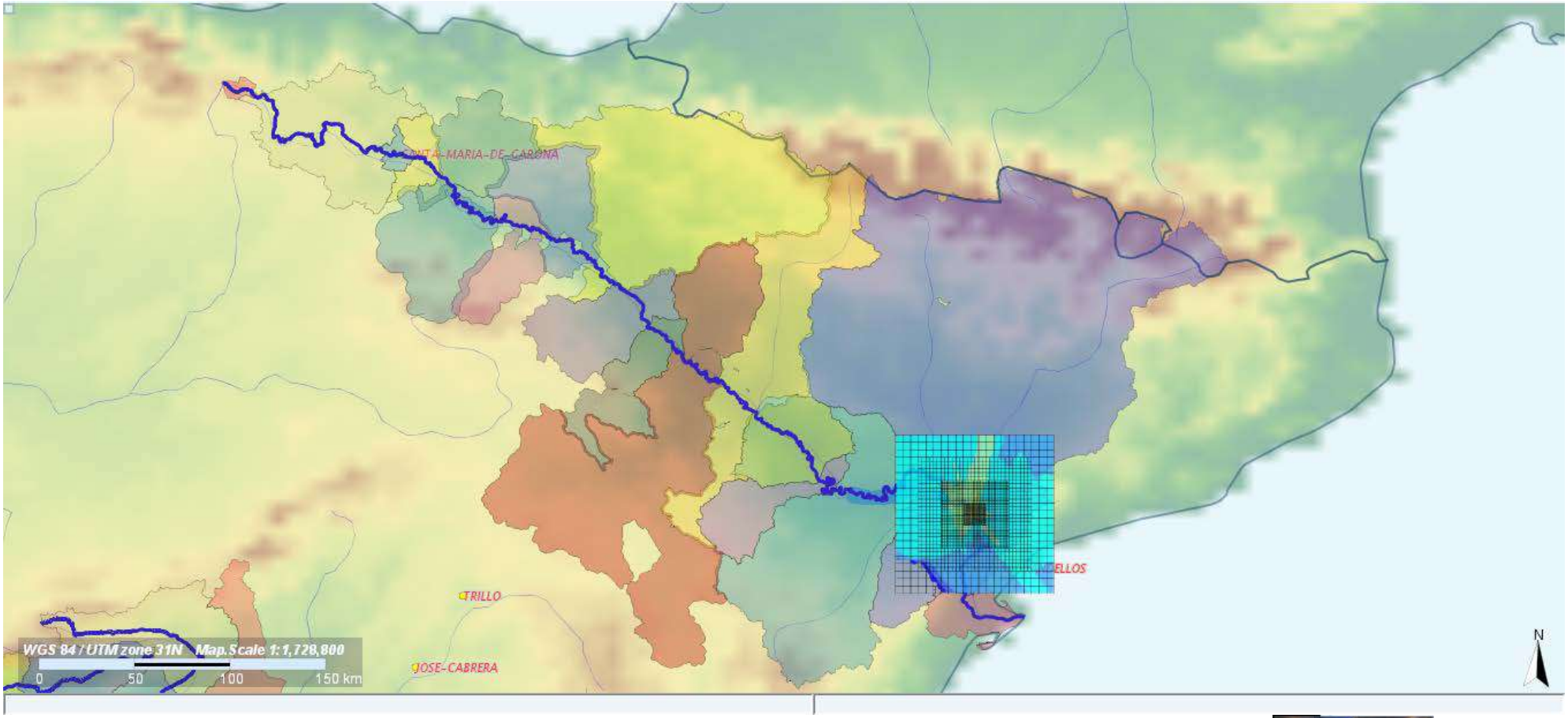
Implementation of Spanish rivers in JRODOS GIS



Test MOIRA-River module in JRODOS. Ebro river near Ascó NPP

PREPARE

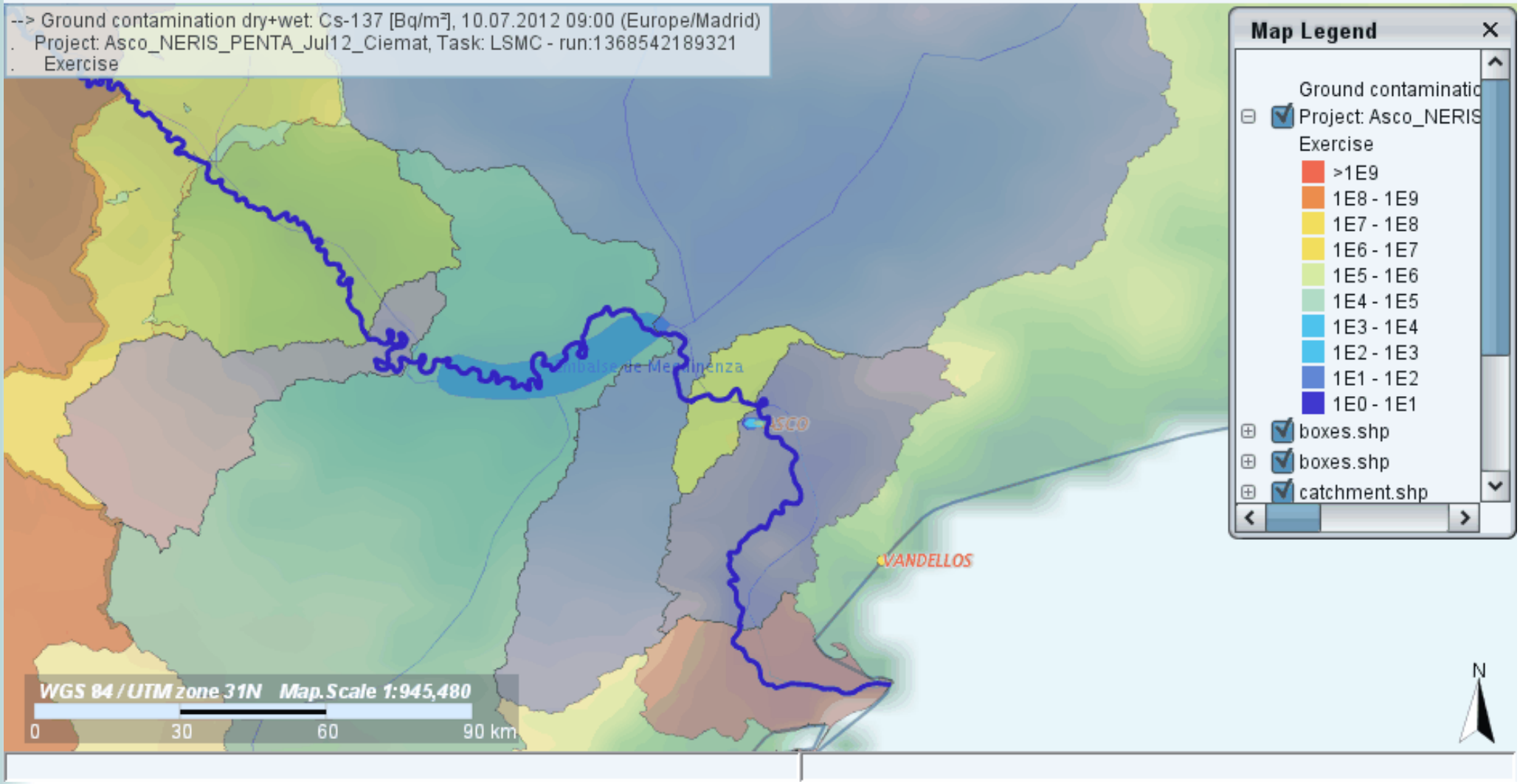
- Test case based on the NERIS-PENTA exercise (NERIS-TP project)
- Accident sequence based on the Action Plan post-Fukushima (stress-tests):
  - Large releases of long duration based on the specific study of Ascó NPP
  - Accident sequence caused by total loss of the internal and external power supply
  - Containment overpressure and filtered venting (system to be installed)
  - Total release of **Cs-137:1.7 E16 Bq ; Sr-90: 2.3 E15 Bq** / 92 hours duration



Test MOIRA-River module in JRODOS. Ebro river near Ascó NPP

PREPARE

Ground deposition of Cs-137 (dry+wet) simulated by LSMC JRODOS:



Test MOIRA-River module in JRODOS. Ebro river near Ascó NPP

PREPARE

Activity deposited on each subcatchment – calculated by hand with MapInfo tools and Excel

Cs-137 fallout (Bq/m²/month):

Box	Date	Left Catch.	Right Catch.	On Segment	Input Rate (Bq/mes)
1 to 15	Jul 2012 (6)	0	0	0	0
16	Jul 2012 (6)	669	186.2	427.6	0
17	Jul 2012 (6)	387.6	1537	962.3	0
18	Jul 2012 (6)	36720	22160	29440	0
19	Jul 2012 (6)	11630	27040	19335	0
20	Jul 2012 (6)	37.12	0.03791	18.58	0

Sr-90 fallout (Bq/m²/month):

Box	Date	Left Catch	Right Catch	On Segment	Input Rate (Bq/mes)
1 to 15	Jul 2012 (6)	0	0	0	0
16	Jul 2012 (6)	106.3	29.63	67.965	0
17	Jul 2012 (6)	61.99	244.7	153.345	0
18	Jul 2012 (6)	5881	3522	4701.5	0
19	Jul 2012 (6)	1852	4313	3082.5	0
20	Jul 2012 (6)	0.006018	5.892	2.95	0

Test MOIRA-River module in JRODOS. Ebro river near Ascó NPP

PREPARE

Activity deposited on each subcatchment – calculated by the new algorithm in JRODOS

Average deposition on catchment, Bq/m²

Year of fallout: 2012

Month of fallout: 7

Box	Cs-137 on left catchment	Cs-137 on right catchment	Sr-90 on left catchment	Sr-90 on right catchment
1	0E0	0E0	0E0	0E0
2	0E0	0E0	0E0	0E0
3	0E0	0E0	0E0	0E0
4	0E0	0E0	0E0	0E0
5	0E0	0E0	0E0	0E0
6	0E0	0E0	0E0	0E0
7	0E0	0E0	0E0	0E0
8	0E0	0E0	0E0	0E0
9	0E0	0E0	0E0	0E0
10	0E0	0E0	0E0	0E0
11	0E0	0E0	0E0	0E0
12	0E0	0E0	0E0	0E0
13	0E0	0E0	0E0	0E0
14	0E0	0E0	0E0	0E0
15	0E0	0E0	0E0	0E0
16	7.01E2	1.71E2	1.11E2	2.73E1
17	3.86E2	1.58E3	6.18E1	2.51E2
18	3.64E4	2.26E4	5.83E3	3.6E3
19	1.16E4	2.7E4	1.85E3	4.3E3
20	3.16E1	1.03E0	5.01E0	1.63E-1

○ Standalone

◉ ADM

Load fallout

Test MOIRA-River module in JRODOS. Ebro river near Ascó NPP

PREPARE

Activity deposited on each box – calculated by the new algorithm in JRODOS

Average deposition on box, Bq/month

Year of fallout: 2012

Month of fallout: 7

Box	Cs-137 on box	Sr-90 on box
1	0E0	0E0
2	0E0	0E0
3	0E0	0E0
4	0E0	0E0
5	0E0	0E0
6	0E0	0E0
7	0E0	0E0
8	0E0	0E0
9	0E0	0E0
10	0E0	0E0
11	0E0	0E0
12	0E0	0E0
13	0E0	0E0
14	0E0	0E0
15	0E0	0E0
16	4.36E2	6.93E1
17	9.81E2	1.56E2
18	2.95E4	4.71E3
19	1.93E4	3.07E3
20	1.63E1	2.59E0

Calculate from deposition on catchments

Input rate, Bq/m²

Box	Cs-137	Sr-90
1	0E0	0E0
2	0E0	0E0
3	0E0	0E0
4	0E0	0E0
5	0E0	0E0
6	0E0	0E0
7	0E0	0E0
8	0E0	0E0
9	0E0	0E0
10	0E0	0E0
11	0E0	0E0
12	0E0	0E0
13	0E0	0E0
14	0E0	0E0
15	0E0	0E0
16	0E0	0E0
17	0E0	0E0
18	0E0	0E0
19	0E0	0E0
20	0E0	0E0

Test MOIRA-River module in JRODOS. Ebro river near Ascó NPP

PREPARE

Description of the complex catchment-river system. Data required for customisation.

River name: Ebro

General | Watercourse structure | Spring (m³/month) | Precipitation (m³/(m²*month)) | Evaporation (m³/(m²*month)) | Runoff left catchment (m³/(m²*month)) | Runoff right catchment (m³/(m²*month)) | Planned water withdrawal (m³/month) | Flux to boxes (m³/month)

Box	Water body characteristic	Empirical box depth (m)	Empirical box width (km)	Box length (km)	Exponential parameter depth	Coefficient depth	Exponential parameter width	Coefficient width	Fase (months)	Left catchment area (km²)	Right catchment area (km²)
1	1	0	0	38.288	0.447	0.164	0.46	10	0	91.5	66.7
2	1	0	0	148.112	0.447	0.164	0.46	10	0	2,144	1,888
3	3	7.15	0.128	21.755	7.15	7.15	0.128	0.128	-3	134.1	114.1
4	1	0	0	20.051	0.447	0.164	0.46	10	0	411.8	317.8
5	1	0	0	26.339	0.447	0.164	0.46	10	0	1,460	204.6
6	1	0	0	45.694	0.447	0.164	0.46	10	0	208	2,304
7	1	0	0	56.03	0.447	0.164	0.46	10	0	372.7	1,400
8	1	0	0	37.391	0.447	0.164	0.46	10	0	399.1	342.7
9	1	0	0	33.58	0.447	0.164	0.46	10	0	6,563	216.3
10	1	0	0	26.491	0.447	0.164	0.46	10	0	462.4	2,085
11	1	0	0	20.789	0.447	0.164	0.46	10	0	204.7	729.9
12	1	0	0	57.497	0.447	0.164	0.46	10	0	204.5	554
13	1	0	0	32.237	0.447	0.164	0.46	10	0	226.1	327.3
14	1	0	0	75.11	0.447	0.164	0.46	10	0	1,063	1,051
15	1	0	0	40.522	0.447	0.164	0.46	10	0	170.3	1,477
16	3	8	3.2	107.543	8	8	3.2	3.2	-3	1,467.4	6,696
17	3	8.5	9.3	21.338	8.5	8.5	9.3	9.3	-2	23,390	1,770
18	3	8.5	9.3	19.396	8.5	8.5	9.3	9.3	-2	213.5	195.7
19	1	0	0	73.773	0.447	0.164	0.46	10	0	1,235	674.2
20	1	0	0	42.746	0.447	0.164	0.46	10	0	286	706.4

Test MOIRA-River module in JRODOS. Ebro river near Ascó NPP

PREPARE

Description of the complex catchment-river system. Data required for customisation.

River name

General | Watercourse structure | Spring (m³/month) | Precipitation (m³/(m²*month)) | Evaporation (m³/(m²*month)) | Runoff left catchment (m³/(m²*mon

Box	Water body characteristic	Empirical box depth (m)	Empirical box width (km)	Box length (km)	Exponential parameter depth	Coefficient depth	Exp
1	1	0	0	28.289	0.447	0.164	
2	1	0	0	148.112	0.447	0.164	
3	3	7.15	0.128	21.755	7.15	7.15	
4	1	0	0	20.051	0.447	0.164	
5	1	0	0	26.339	0.447	0.164	
6	1	0	0	45.694	0.447	0.164	
7	1	0	0	56.03	0.447	0.164	
8	1	0	0	37.391	0.447	0.164	
9	1	0	0	33.58	0.447	0.164	
10	1	0	0	26.491	0.447	0.164	
11	1	0	0	20.789	0.447	0.164	
12	1	0	0	57.497	0.447	0.164	
13	1	0	0	32.237	0.447	0.164	
14	1	0	0	75.11	0.447	0.164	
15	1	0	0	40.522	0.447	0.164	
16	3	8	3.2	107.543	8	8	
17	3	8.5	9.3	21.338	8.5	8.5	
18	3	8.5	9.3	19.396	8.5	8.5	
19	1	0	0	73.773	0.447	0.164	
20	1	0	0	42.746	0.447	0.164	

Test MOIRA-River module in JRODOS. Ebro river near Ascó NPP

PREPARE

Description of the complex catchment-river system. Data required for customisation.

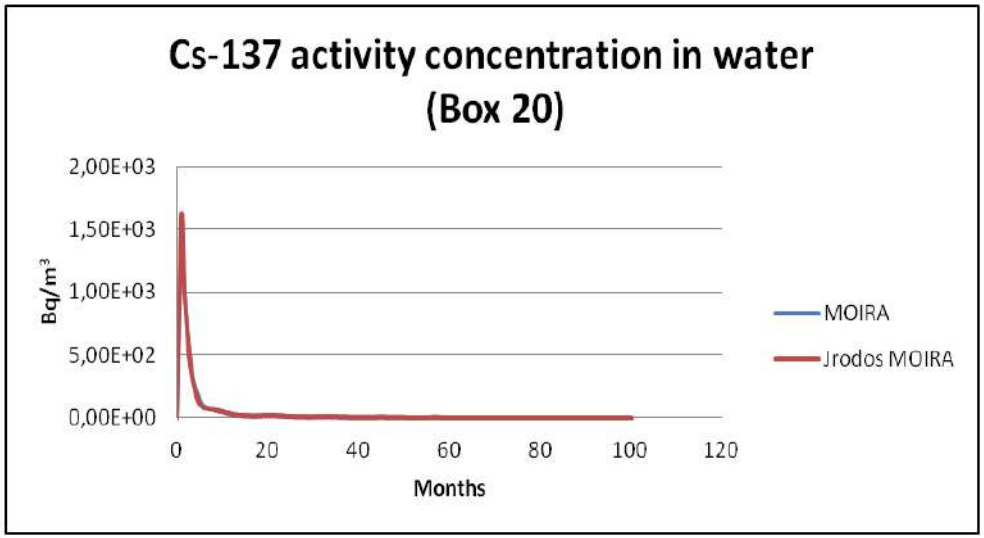
River name: Ebro

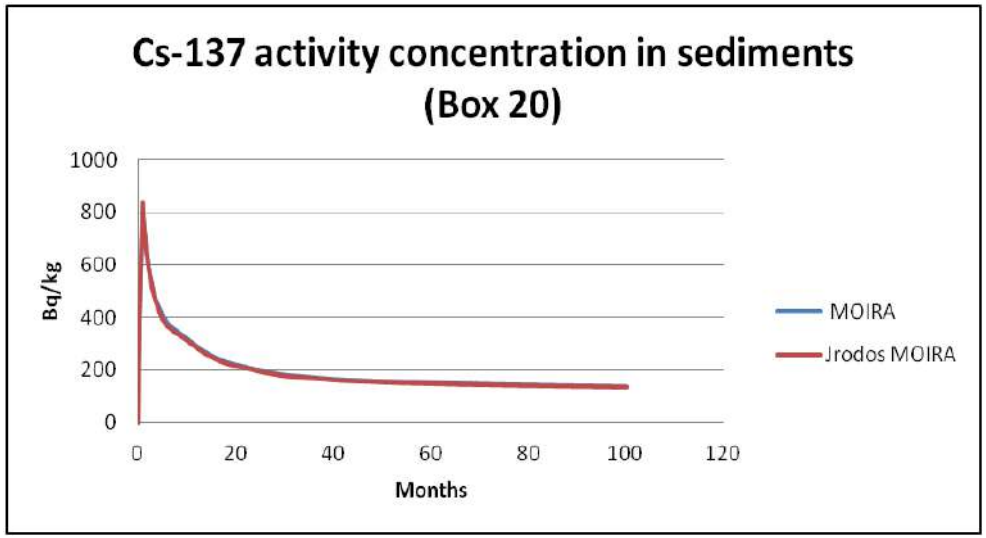
noff left catchment (m³/(m²*month))	Runoff right catchment (m³/(m²*month))	Planned water withdrawal (m³/month)	Flux to boxes (m³/month)

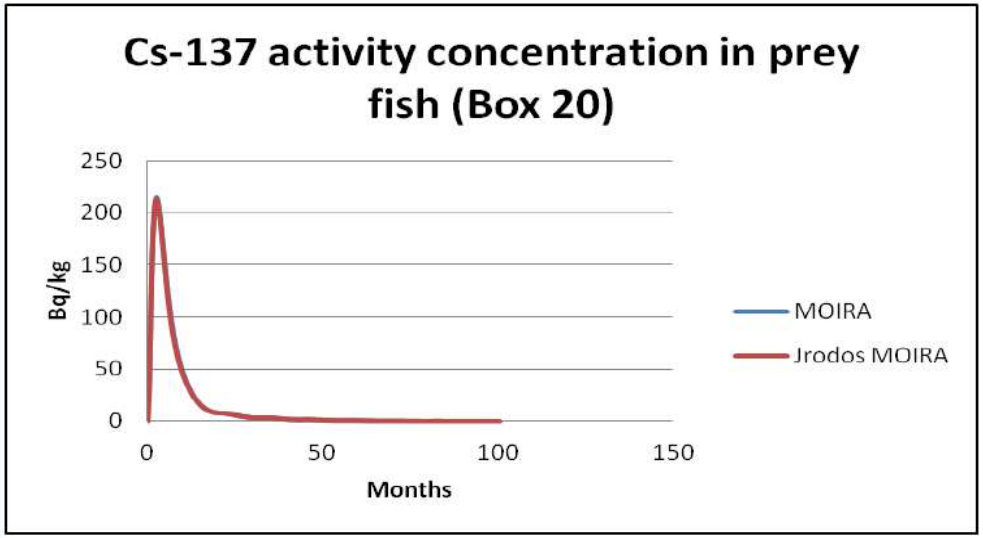
r depth	Coefficient depth	Exponential parameter width	Coefficient width	Fase (months)	Left catchment area (km²)	Right catchment area (km²)
0.447	0.164	0.46	10	0	81.5	66.7
0.447	0.164	0.46	10	0	2,144	1,888
7.15	7.15	0.128	0.128	-3	134.1	114.1
0.447	0.164	0.46	10	0	411.8	317.8
0.447	0.164	0.46	10	0	1,460	204.6
0.447	0.164	0.46	10	0	208	2,304
0.447	0.164	0.46	10	0	372.7	1,400
0.447	0.164	0.46	10	0	399.1	342.7
0.447	0.164	0.46	10	0	6,563	216.3
0.447	0.164	0.46	10	0	462.4	2,085
0.447	0.164	0.46	10	0	204.7	729.9
0.447	0.164	0.46	10	0	204.5	554
0.447	0.164	0.46	10	0	226.1	327.3
0.447	0.164	0.46	10	0	1,063	1,051
0.447	0.164	0.46	10	0	170.3	1,477
8	8	3.2	3.2	-3	1,467.4	6,696
8.5	8.5	9.3	9.3	-2	23,390	1,770
8.5	8.5	9.3	9.3	-2	213.5	195.7
0.447	0.164	0.46	10	0	1,235	674.2
0.447	0.164	0.46	10	0	286	706.4

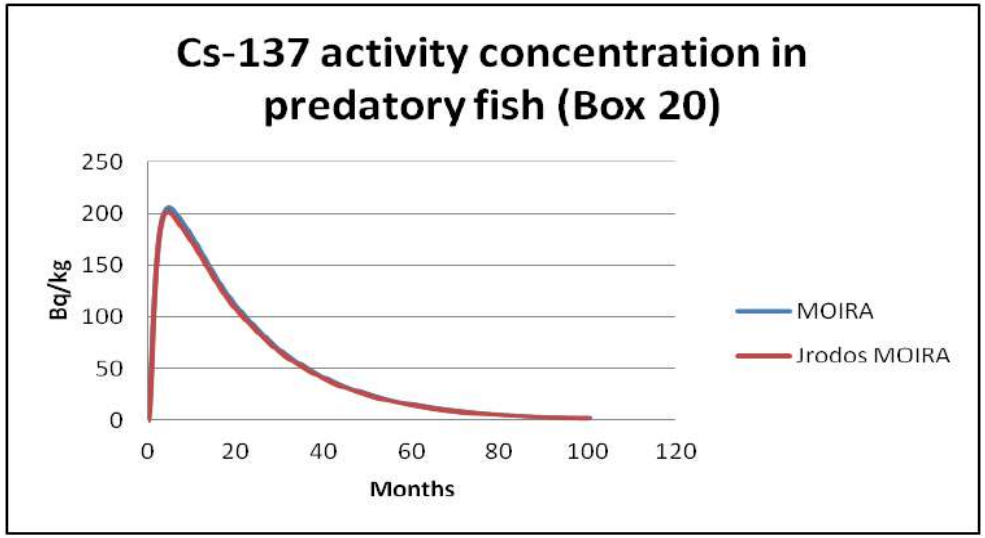
Test MOIRA-River module in JRODOS. Ebro river near Ascó NPP

PREPARE



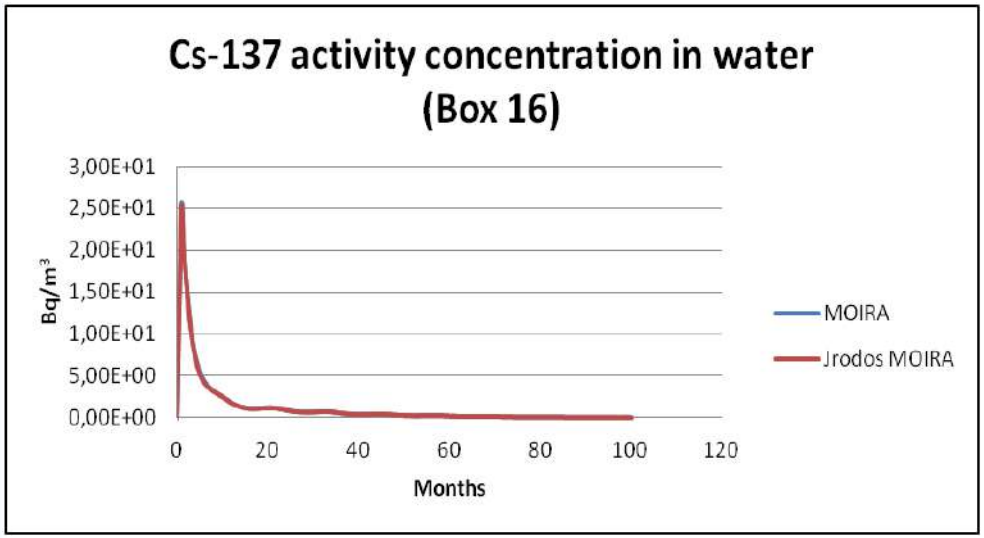


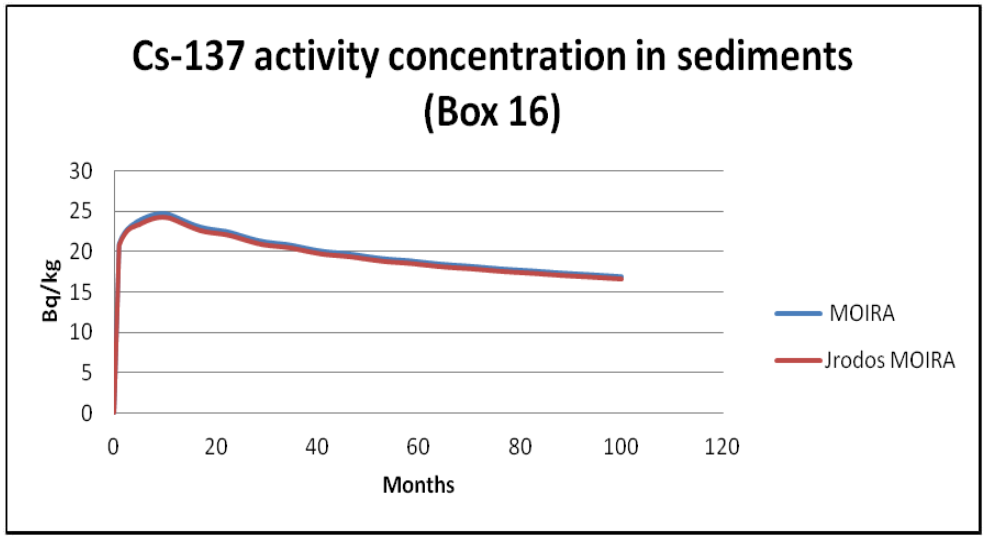


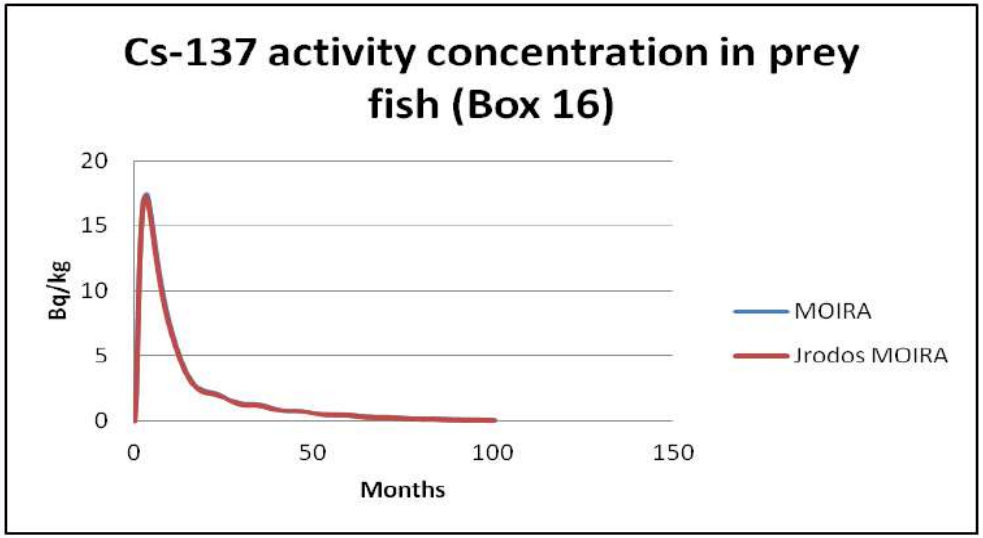


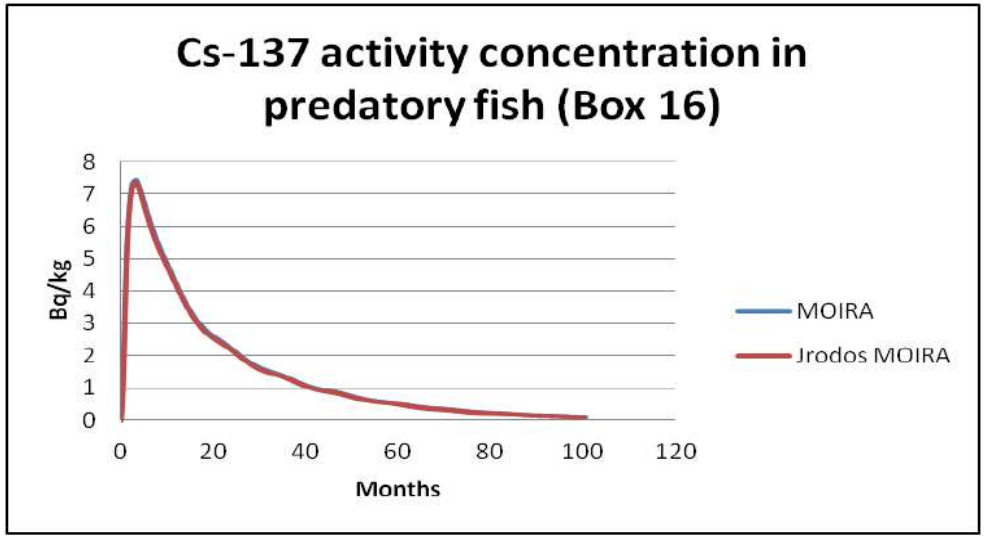
Comparison of results between the original MOIRA River model (in Powersim®) and the JRODOS-MOIRA River

Test MOIRA-River module in JRODOS. Ebro river near Ascó NPP



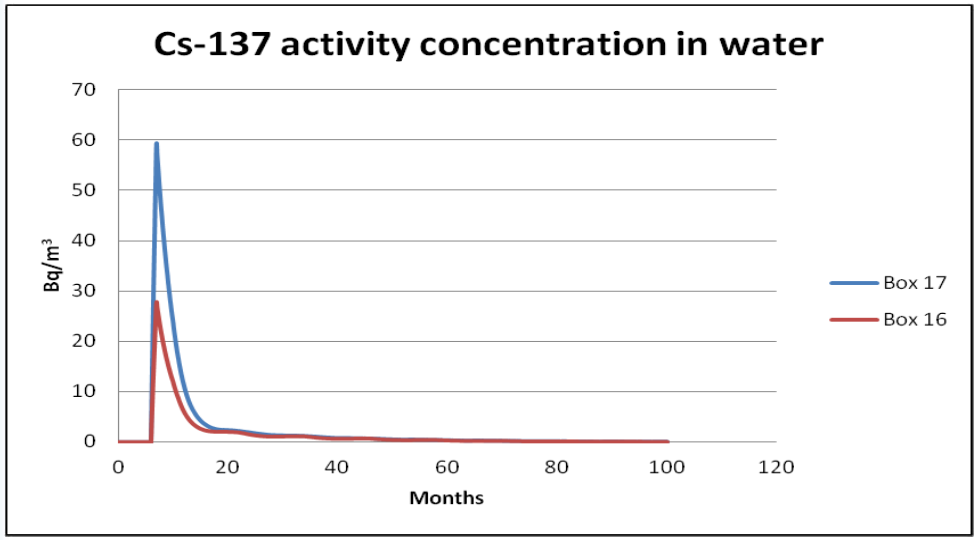


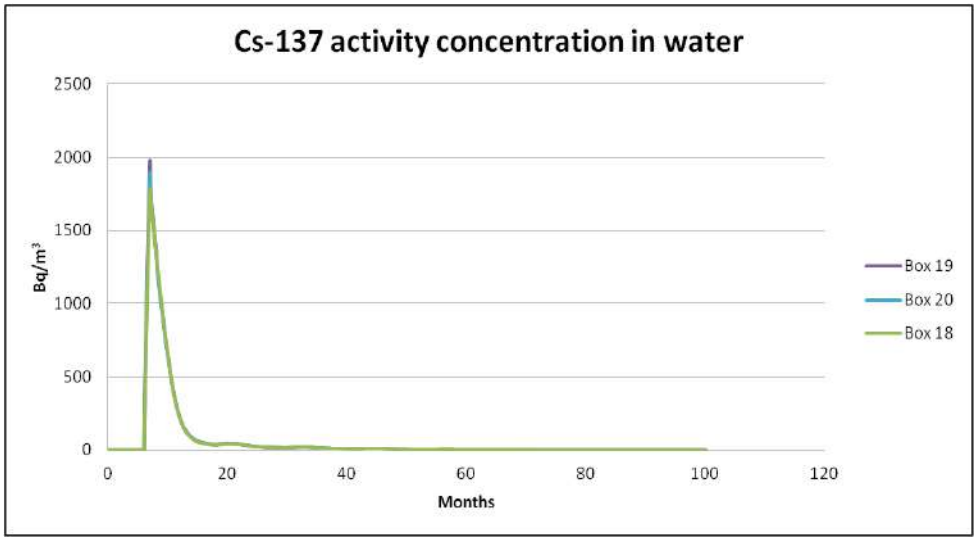


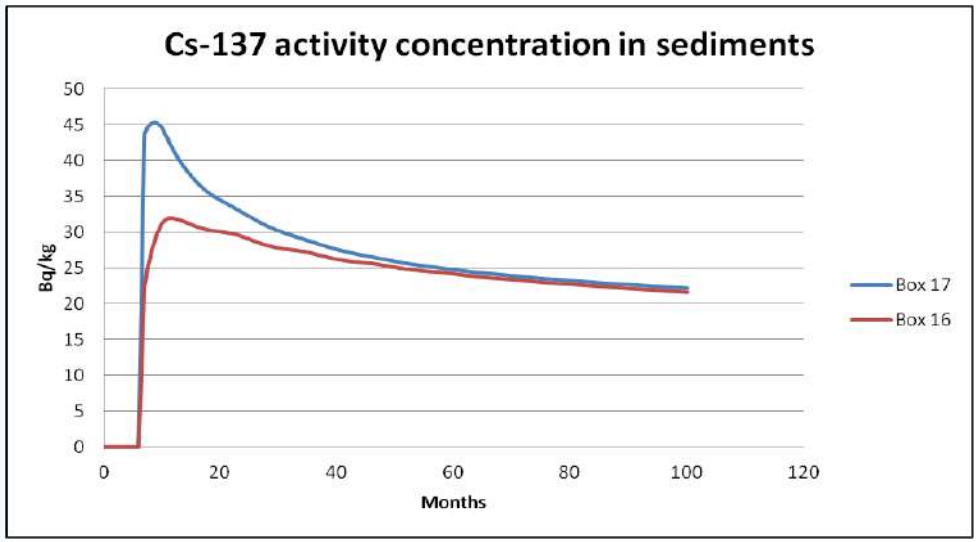


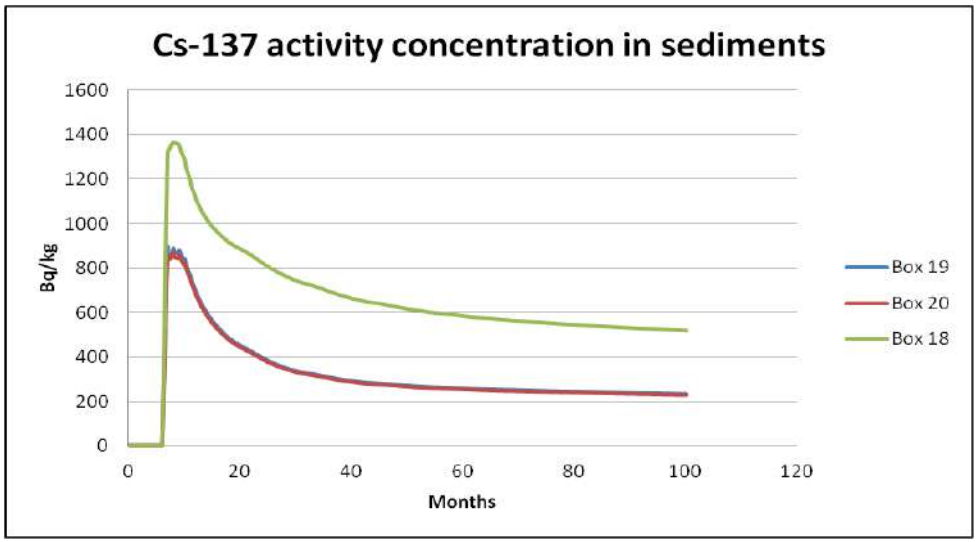
Comparison of results between the original MOIRA River model (in Powersim®) and the JRODOS-MOIRA River

Test MOIRA-River module in JRODOS. Ebro river near Ascó NPP



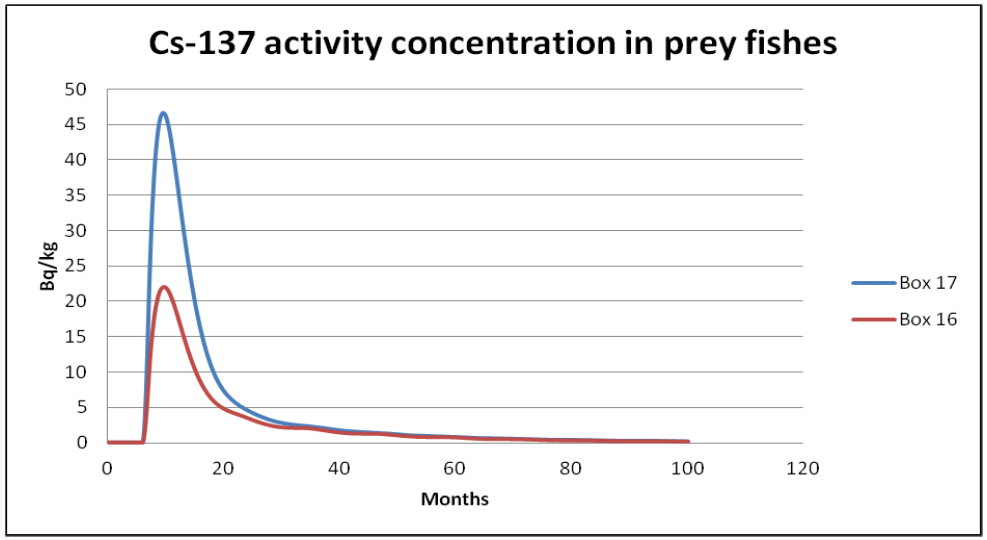


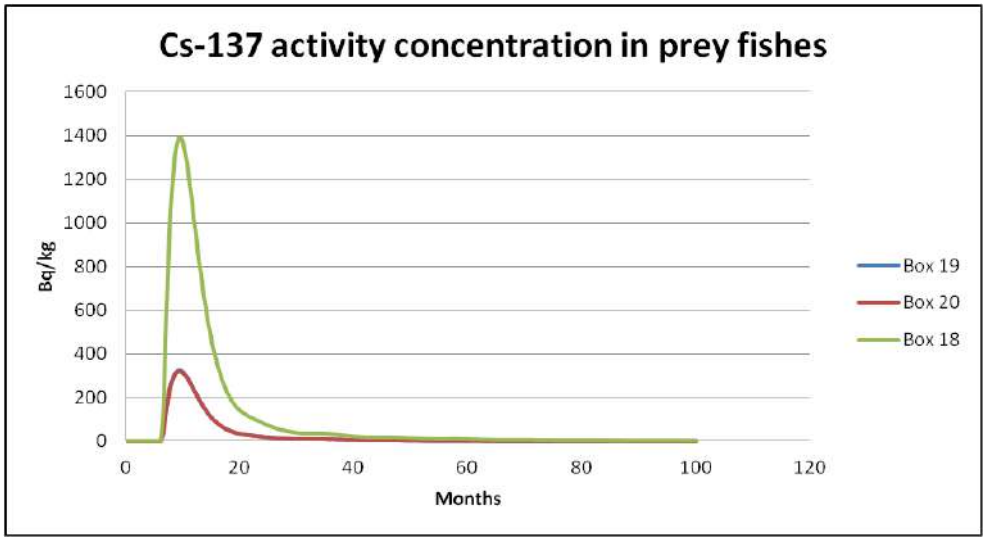


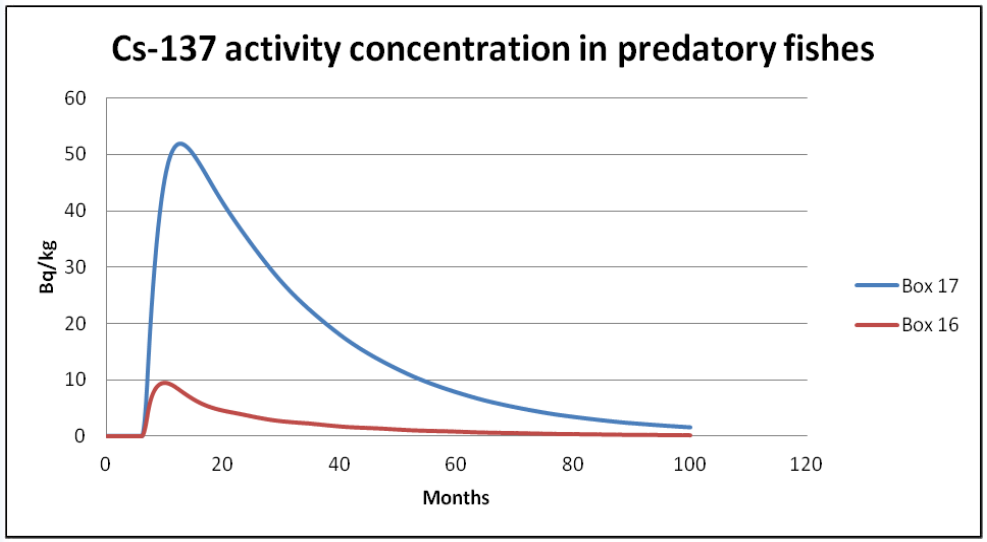


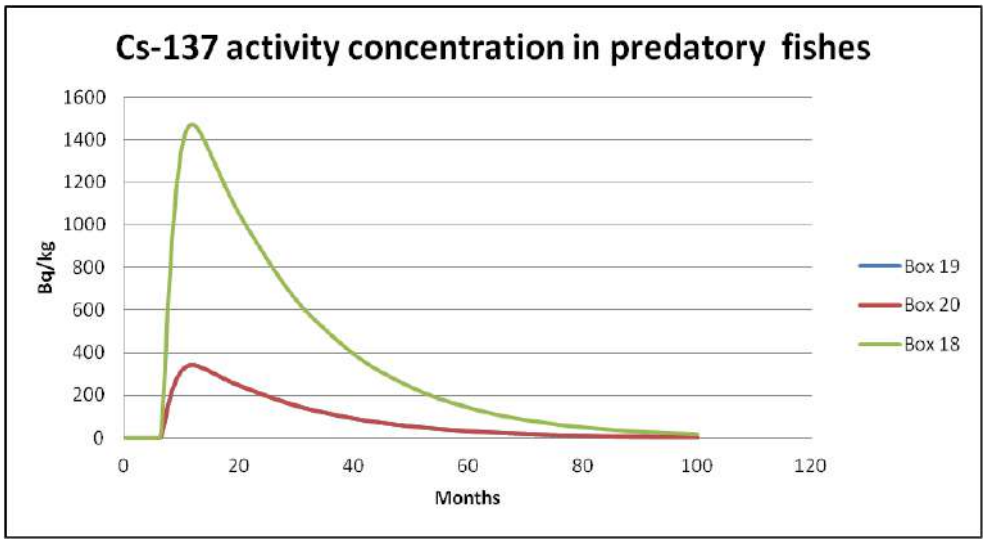
Comparison of results between the original MOIRA River model (in Powersim®) and the JRODOS-MOIRA River

Test MOIRA-River module in JRODOS. Ebro river near Ascó NPP



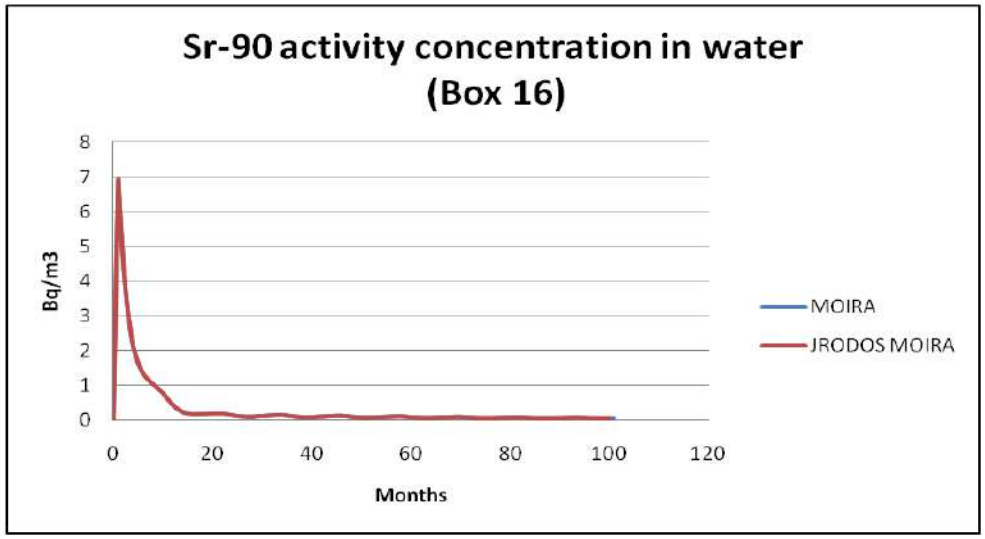


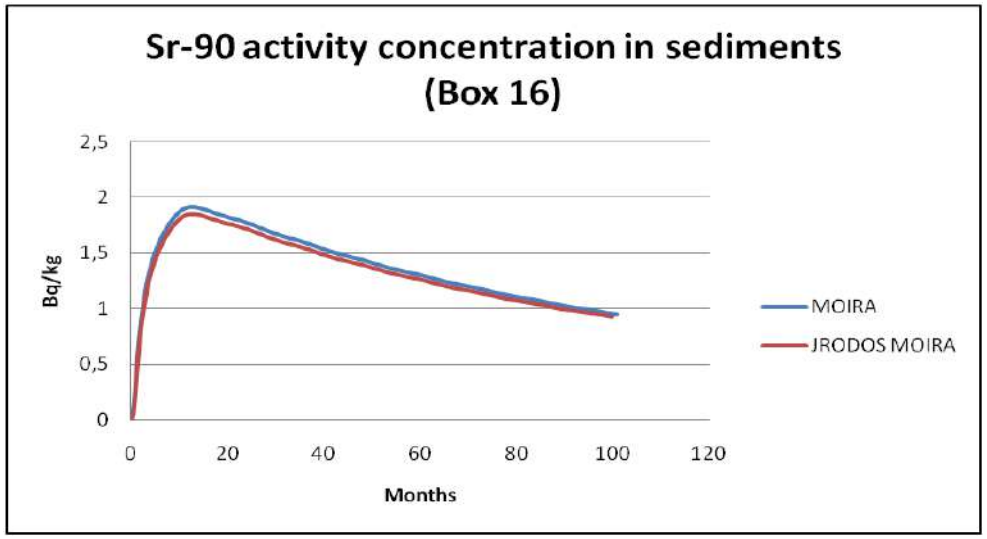


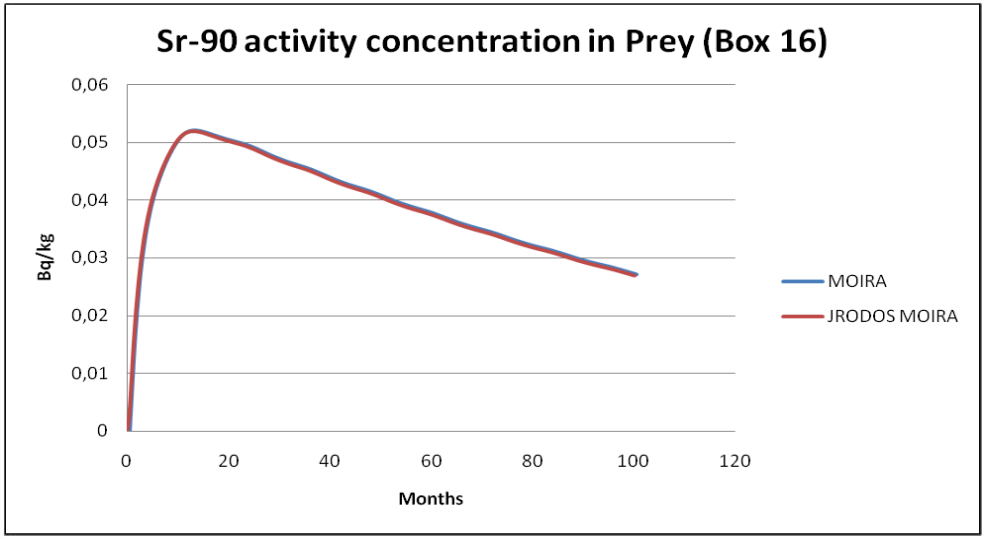


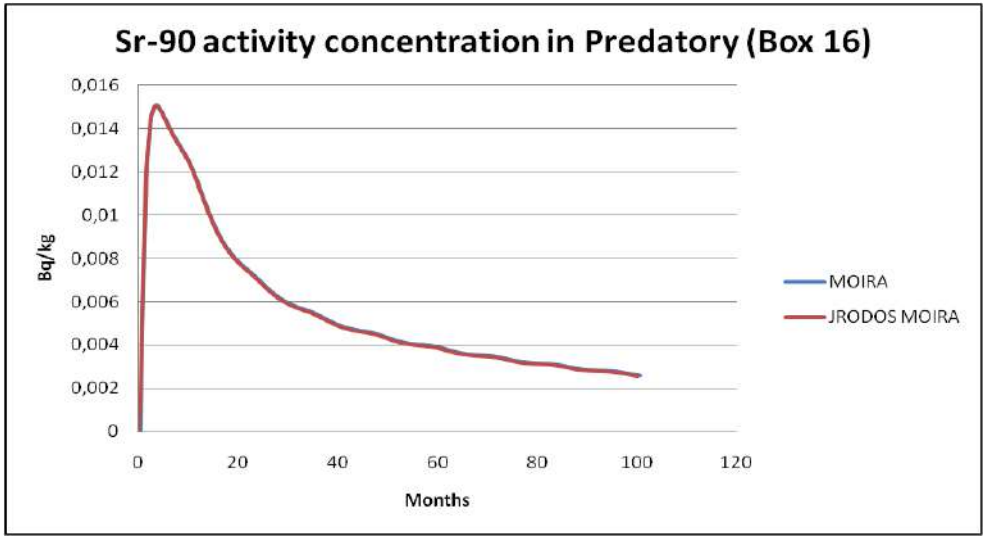
Comparison of results between the original MOIRA River model (in Powersim®) and the JRODOS-MOIRA River

Test MOIRA-River module in JRODOS. Ebro river near Ascó NPP





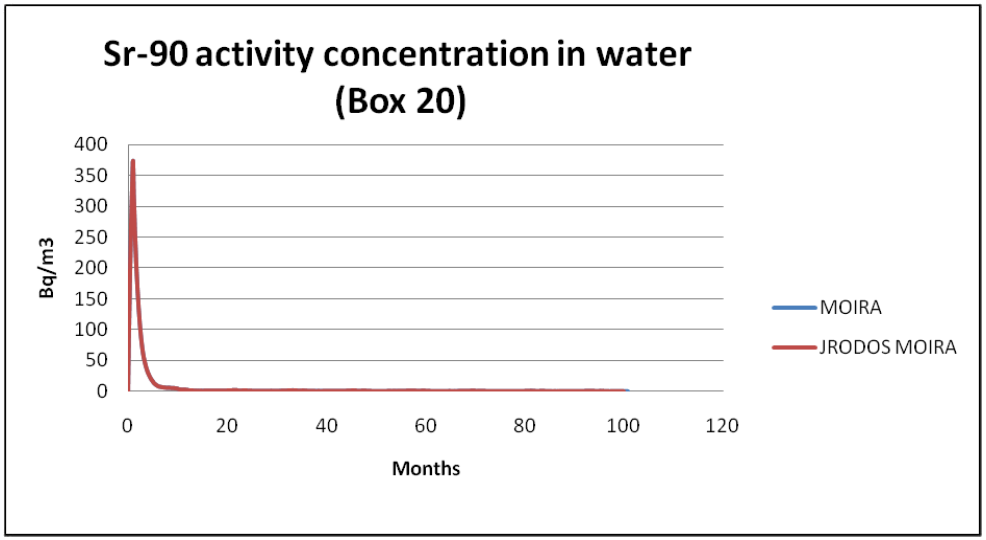


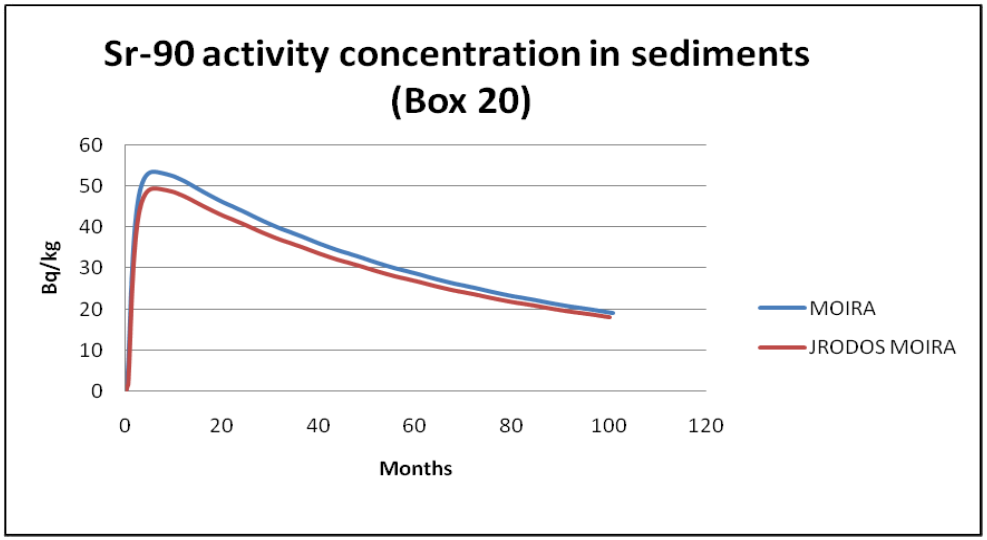


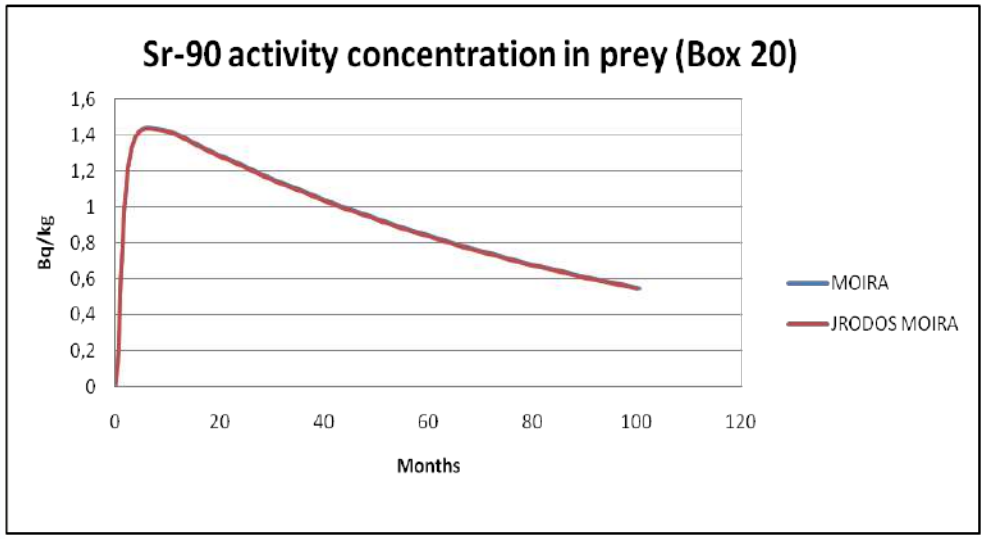
Comparison of results between the original MOIRA River model (in Powersim®) and the JRODOS-MOIRA River

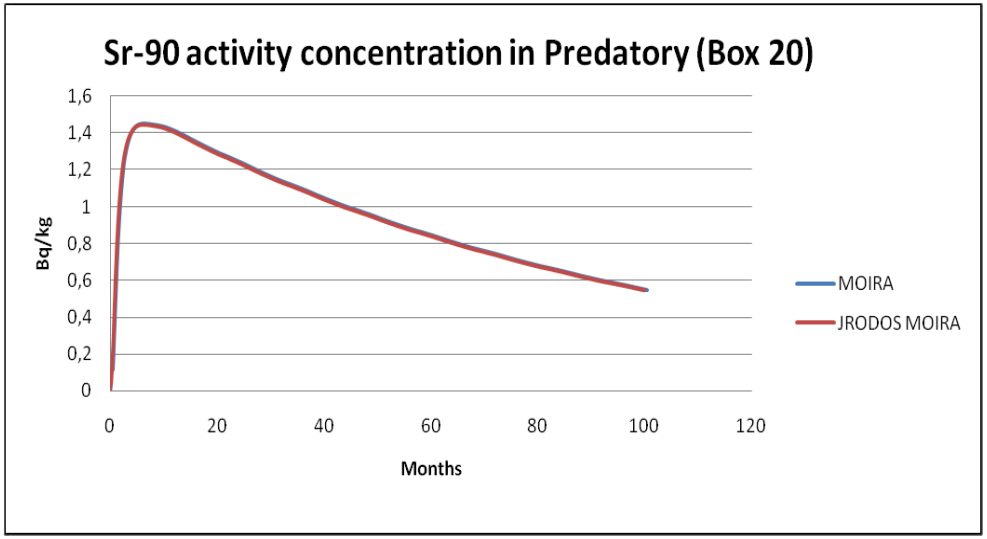
Test MOIRA-River module in JRODOS. Ebro river near Ascó NPP

PREPARE



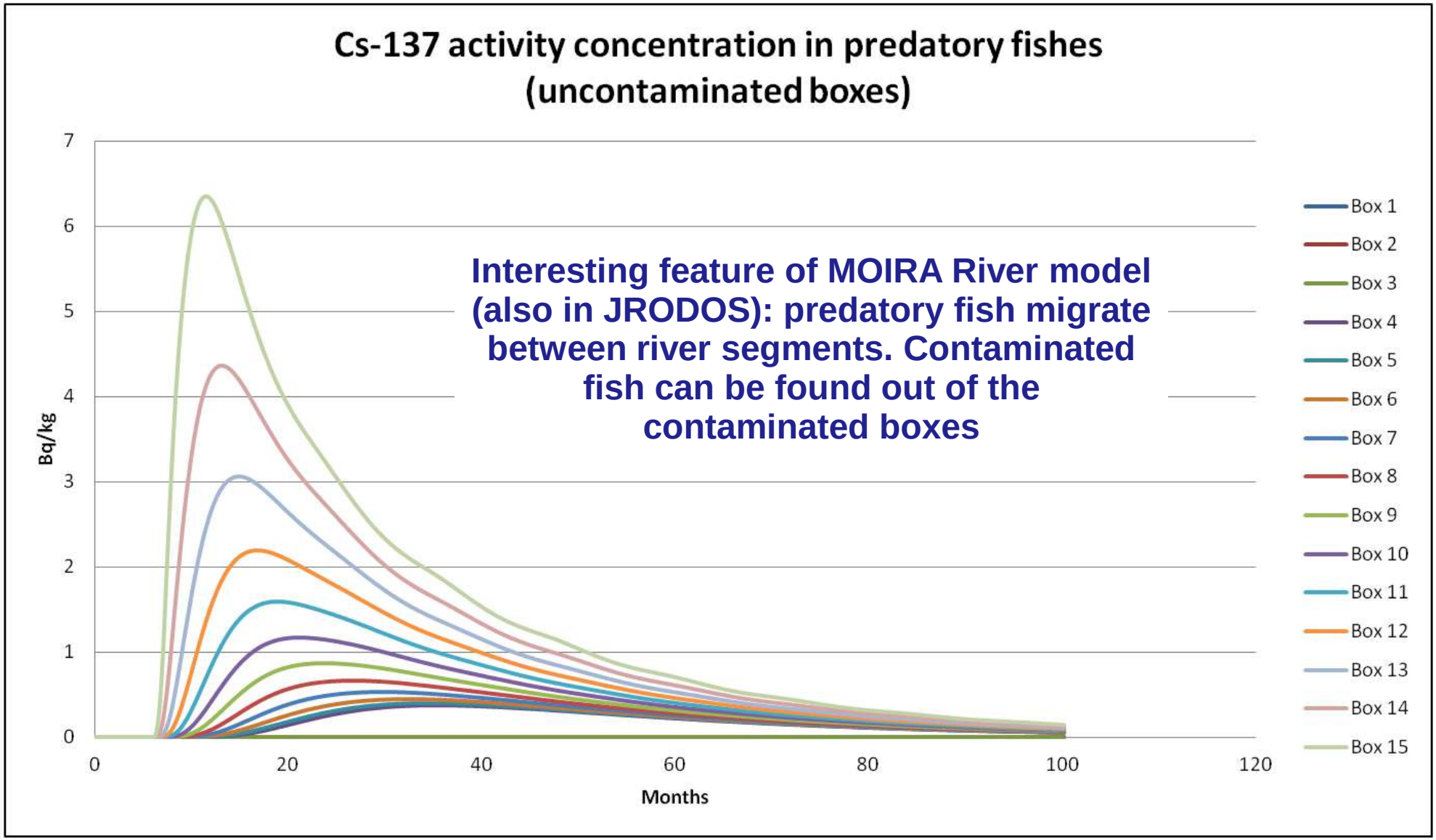




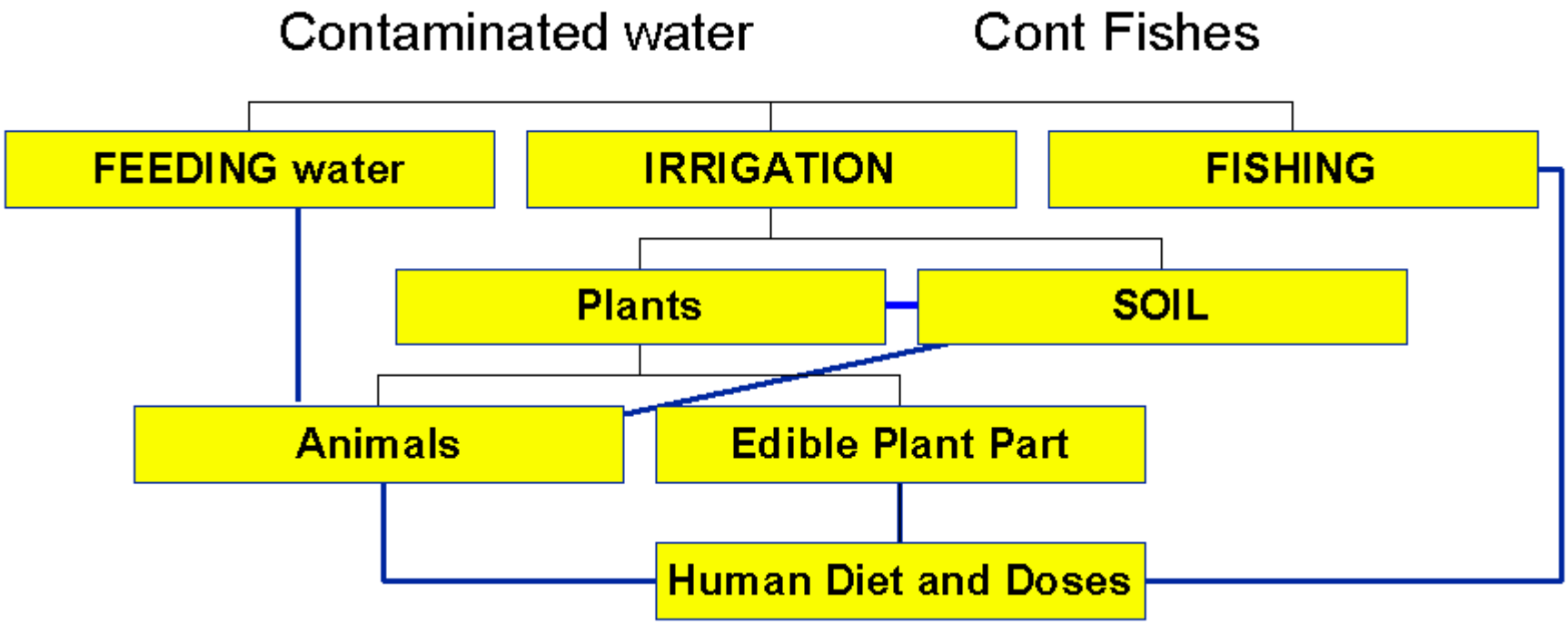


Comparison of results between the original MOIRA River model (in Powersim®) and the JRODOS-MOIRA River

Test MOIRA-River module in JRODOS. Ebro river near Ascó NPP

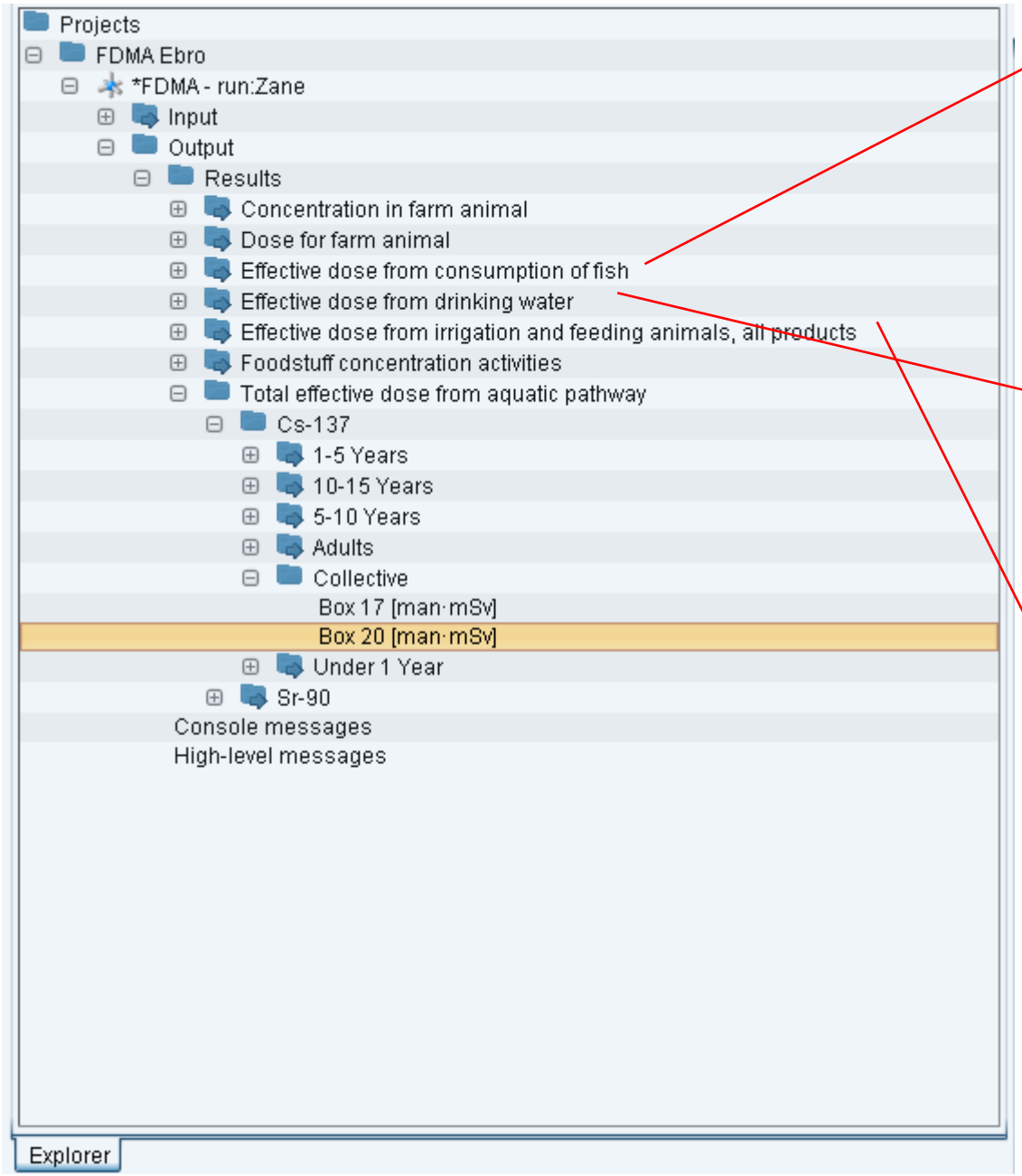


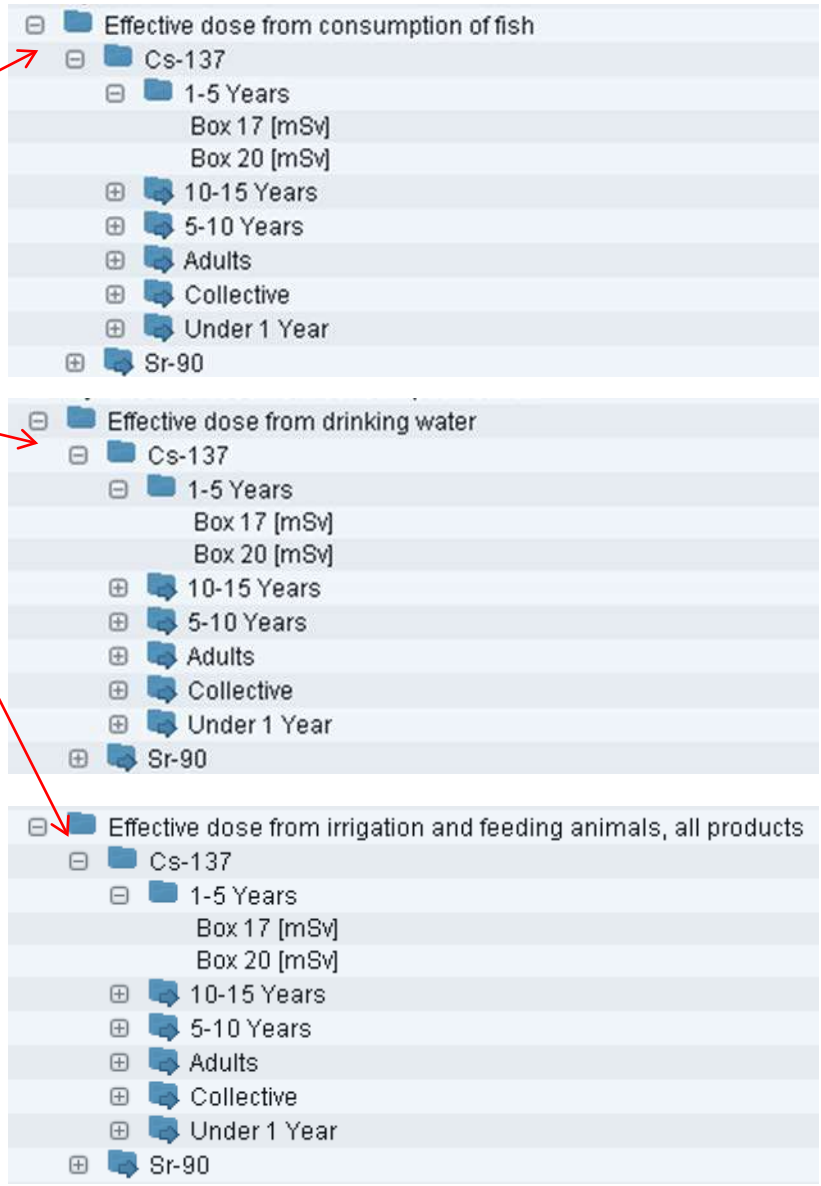
FDMA Aquatic Exposure Pathway Scheme



FDMA Results tree

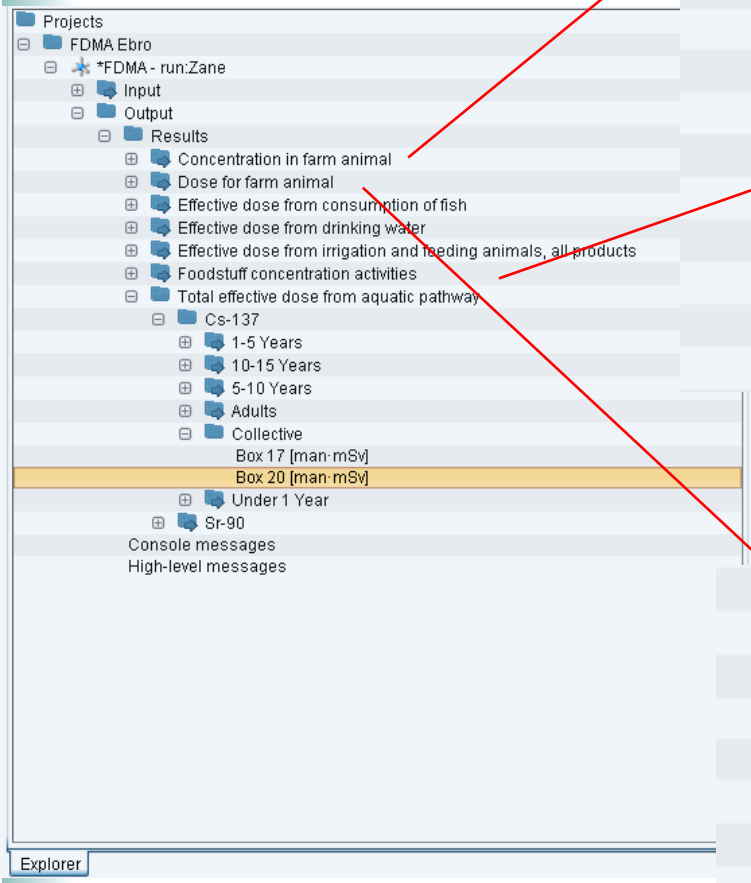
PREPARE





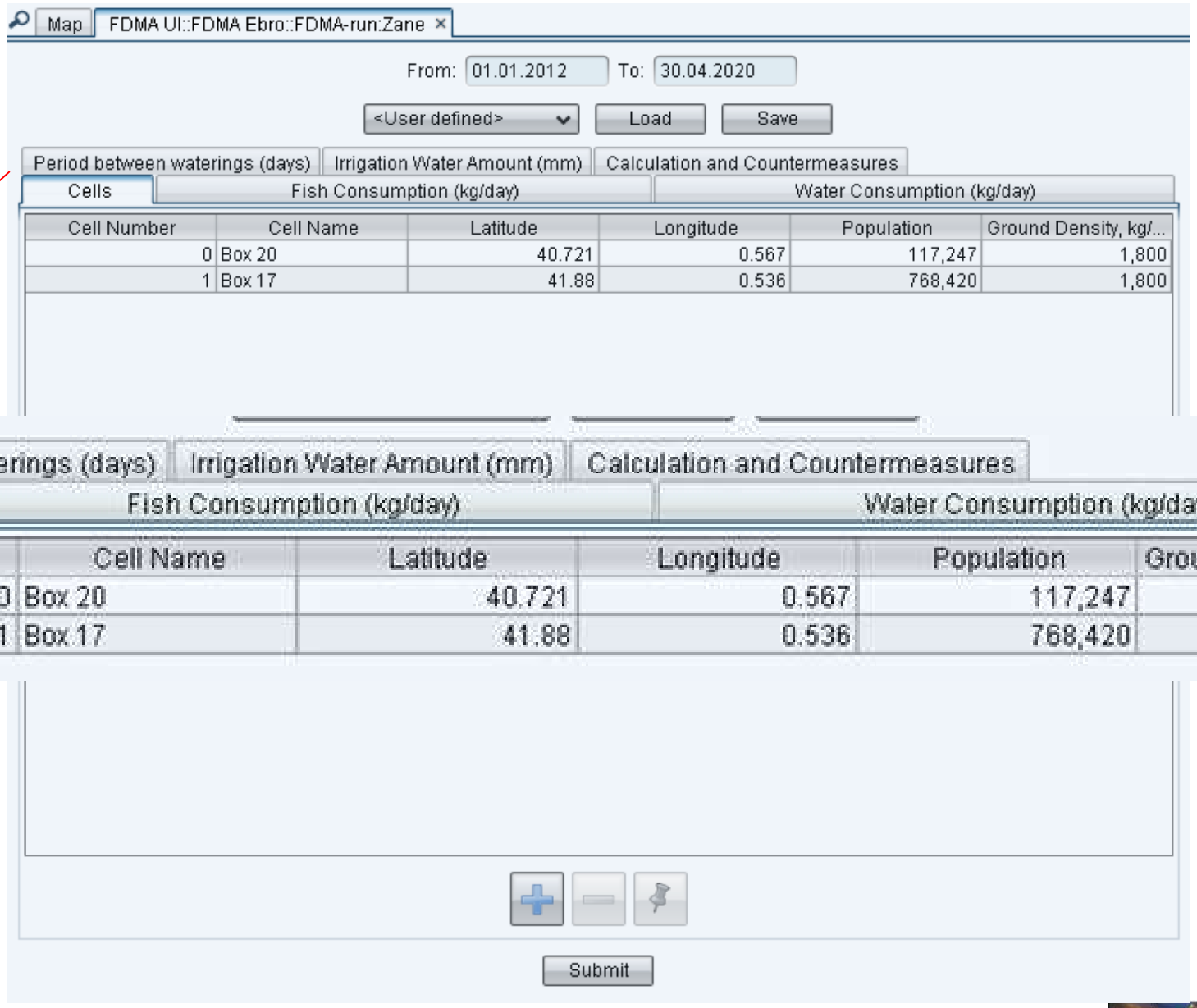
FDMA Results tree

PREPARE



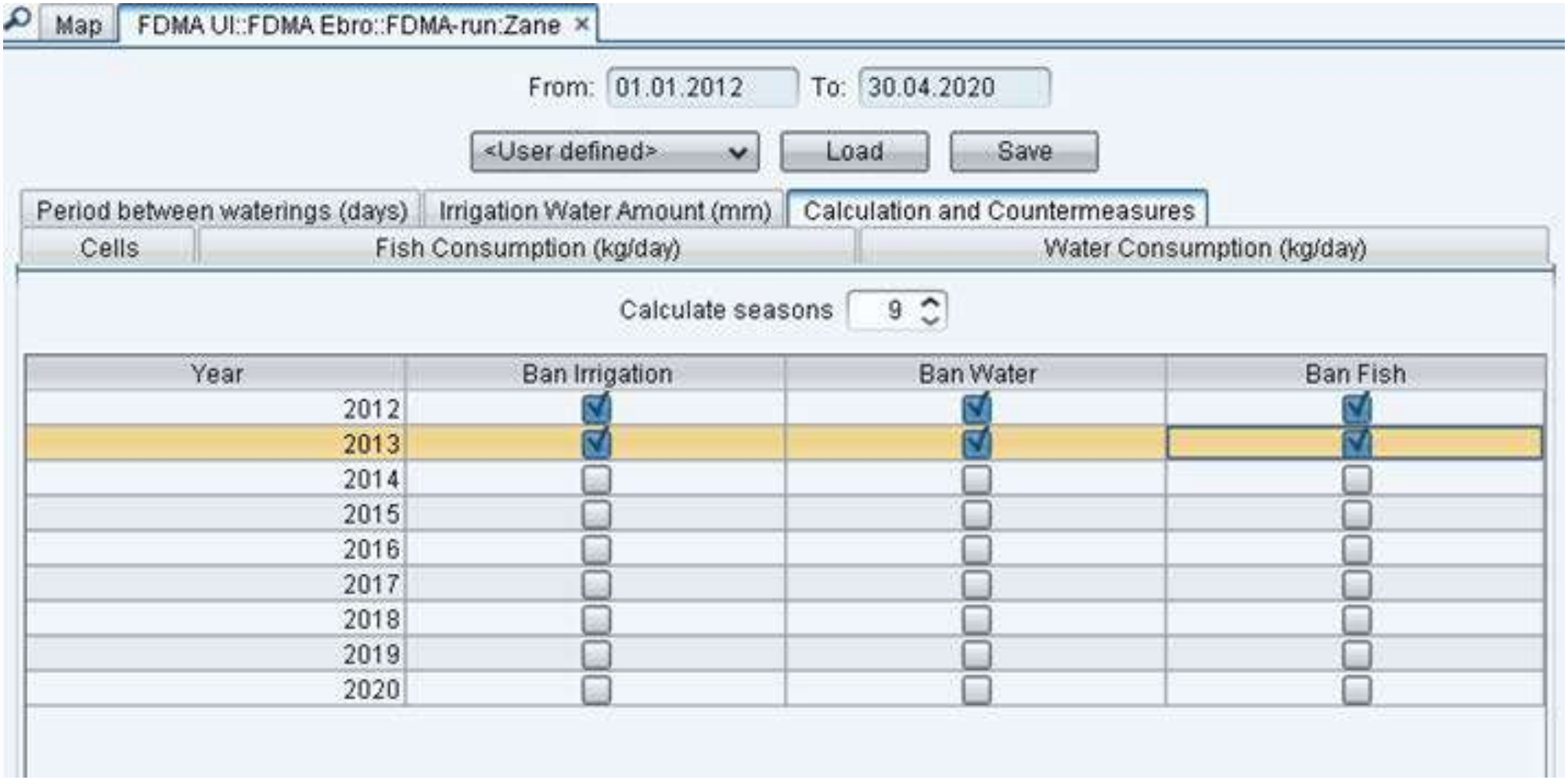
GUI for FDMA

PREPARE



Definition of simple Countermeasures in FDMA

PREPARE

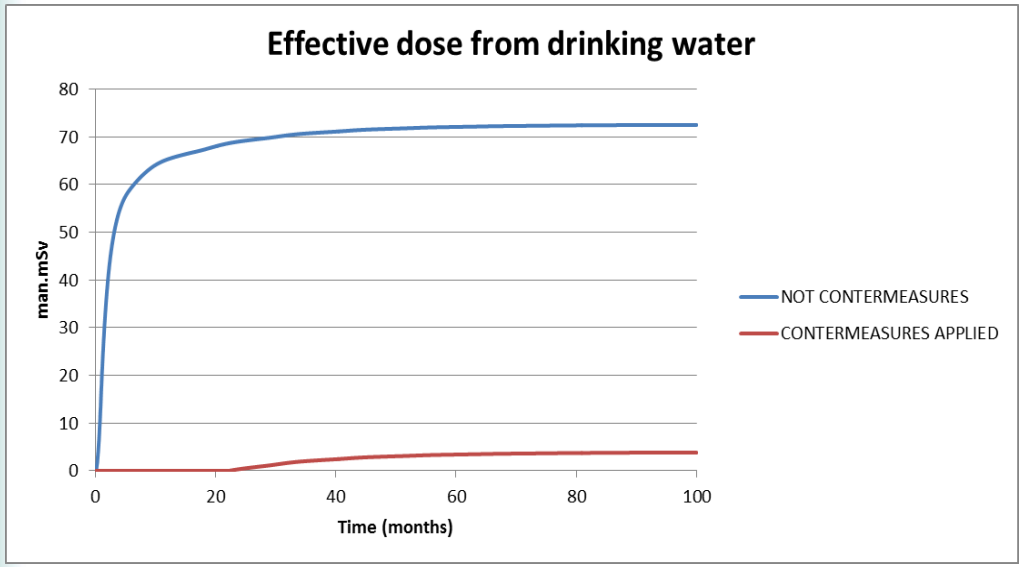


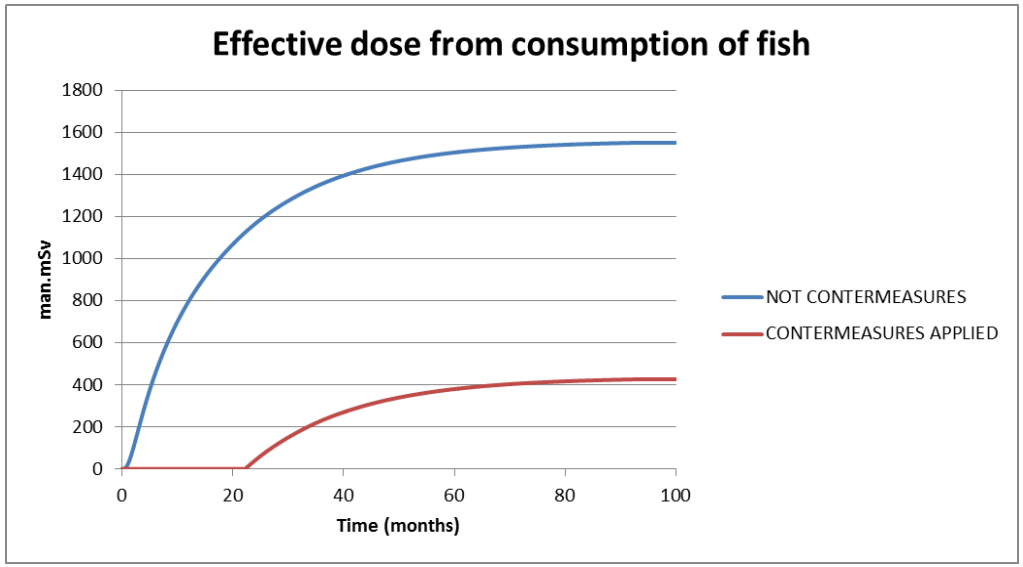
Year	Ban Irrigation	Ban Water	Ban Fish
2012	☑	☑	☑
2013	☑	☑	☑
2014	☐	☐	☐
2015	☐	☐	☐
2016	☐	☐	☐
2017	☐	☐	☐
2018	☐	☐	☐
2019	☐	☐	☐
2020	☐	☐	☐

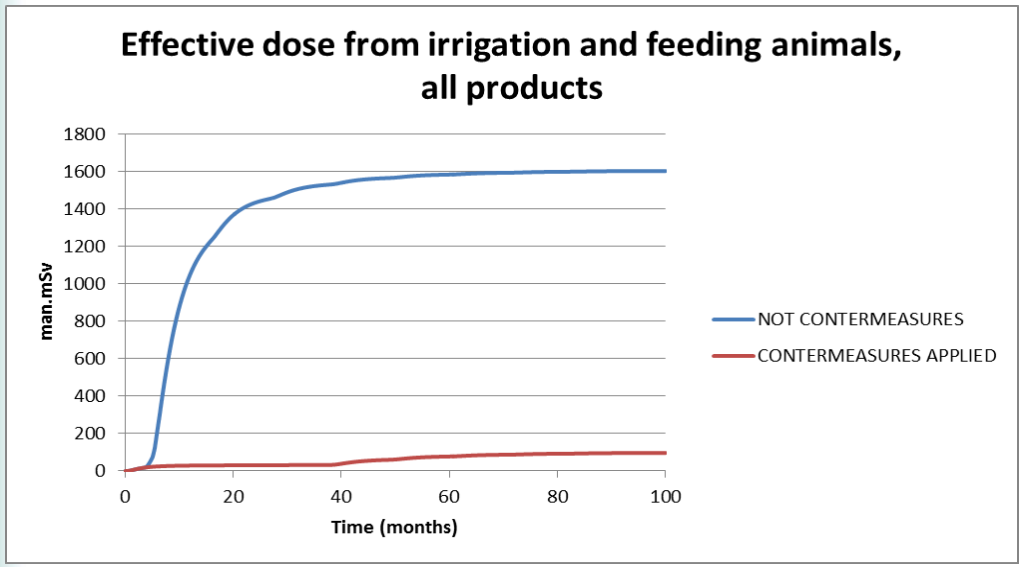
Test MOIRA-River module in JRODOS. Ebro river near Ascó NPP

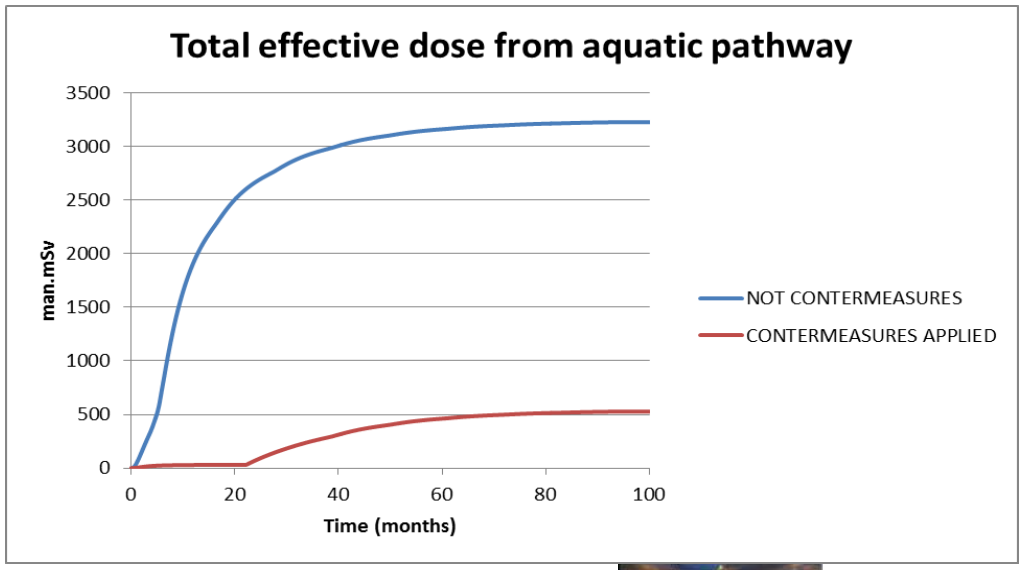
PREPARE

Collective doses, Cs-137, Box 20





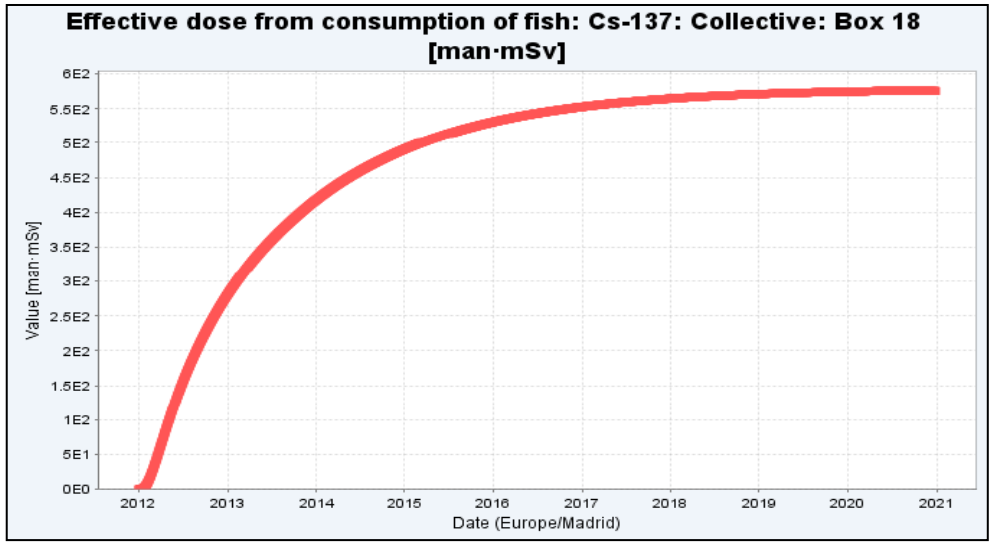


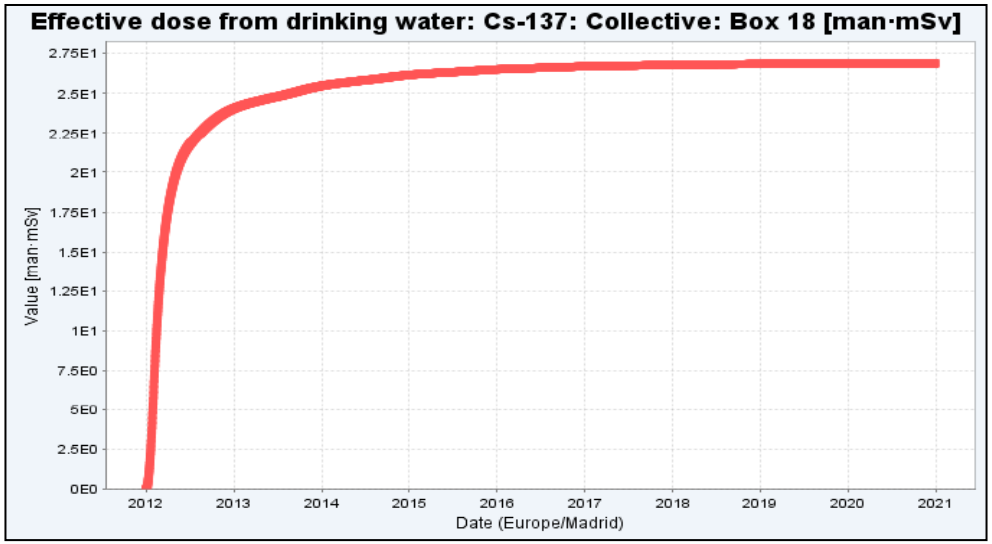


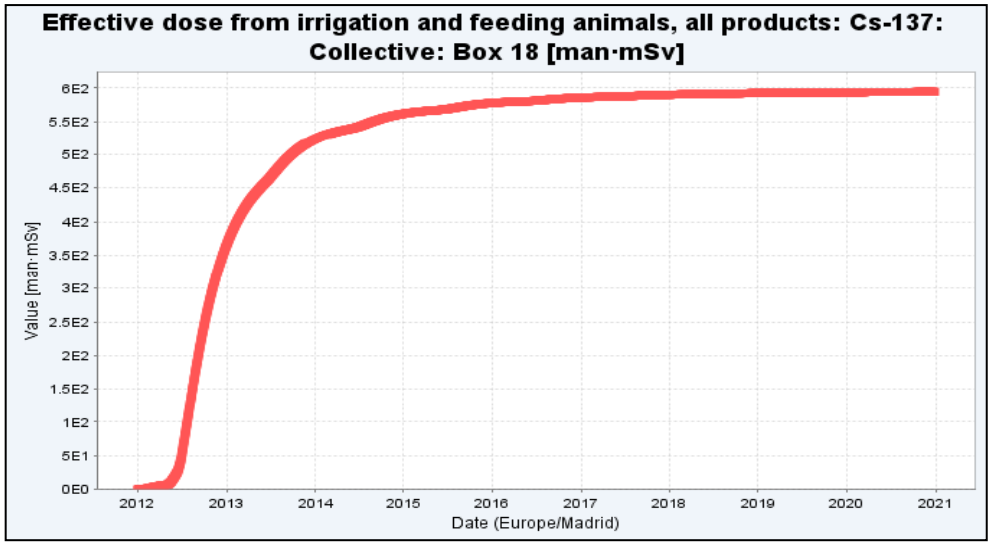
Test MOIRA-River module in JRODOS. Ebro river near Ascó NPP

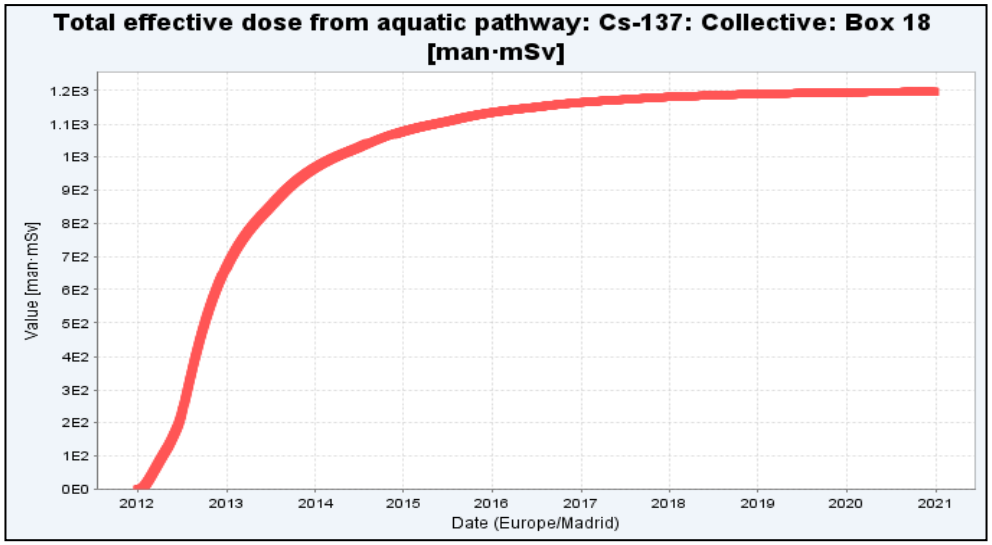
PREPARE

Collective doses, Cs-137, Box 18



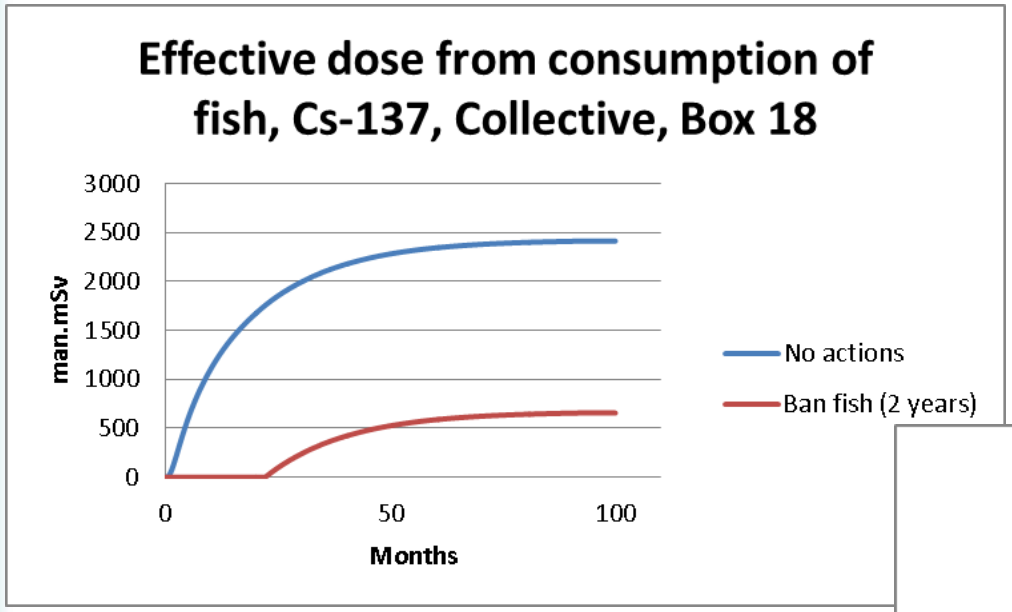


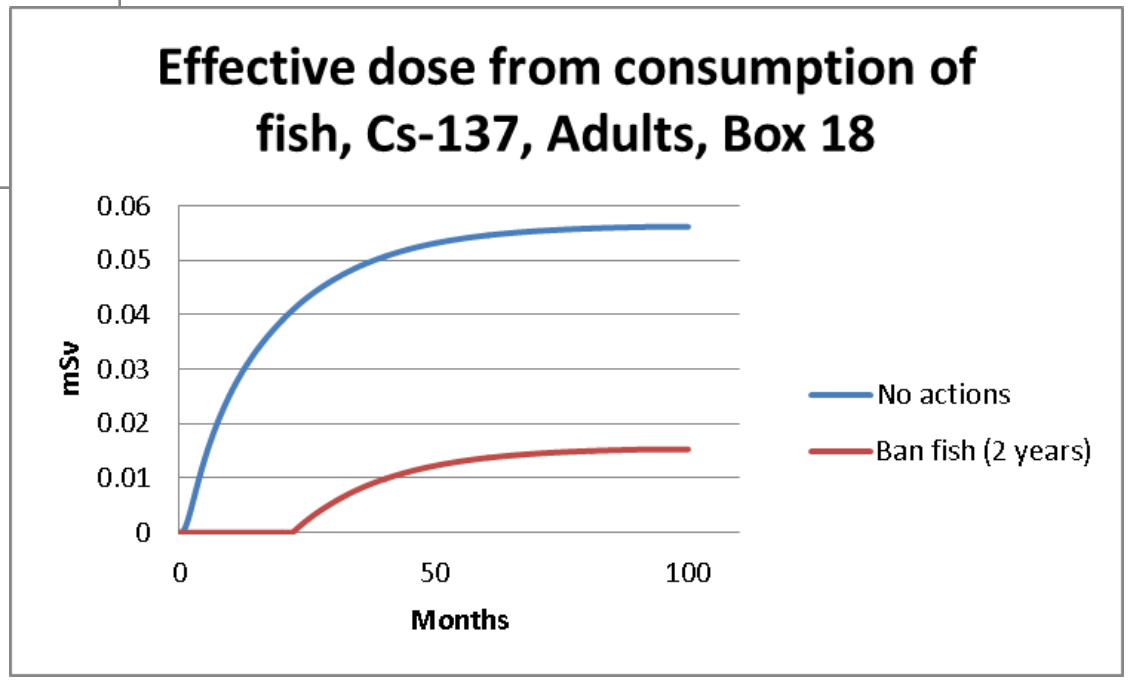




Collective and individual dose from fish ingestion, Cs-137, Box 18

(with ban fish and without countermeasures)





CONCLUSIONS

PREPARE

- After the project, JRODOS has increased the capabilities by incorporating new modules from MOIRA DSS, which allow to model the long-term fate of radionuclides (^{137}Cs and ^{90}Sr) in freshwater systems: lakes and rivers.
- The new models also estimate the effectiveness of countermeasures to reduce radionuclide concentrations in water, sediments and fish.
- The new modules, integrated with the food and dose model FDMA, also assess radiation dose to people and livestock, as well as the impact of bans to reduce doses.
- Test cases show a correct integration of the MOIRA Lake and River models, as well as the GIS and fallout distribution tools.

Many thanks for your attention

Any questions

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The research leading to these results has received funding from the European Atomic Energy Community Seventh Framework Programme [FP7/2007-2011] [FP7/2012-2013] under grant agreement n° [323287].