Experience on using JRODOS - ERMIN in an exercise

Eduardo Gallego

Nuclear Engineering Department

Technical University of Madrid (UPM)

In collaboration with: Milagros Montero, CIEMAT
Christian Carbajal, UPM

Development of scenarios

Steps in developing the scenarios for use in the table-top exercise for Tarragona:

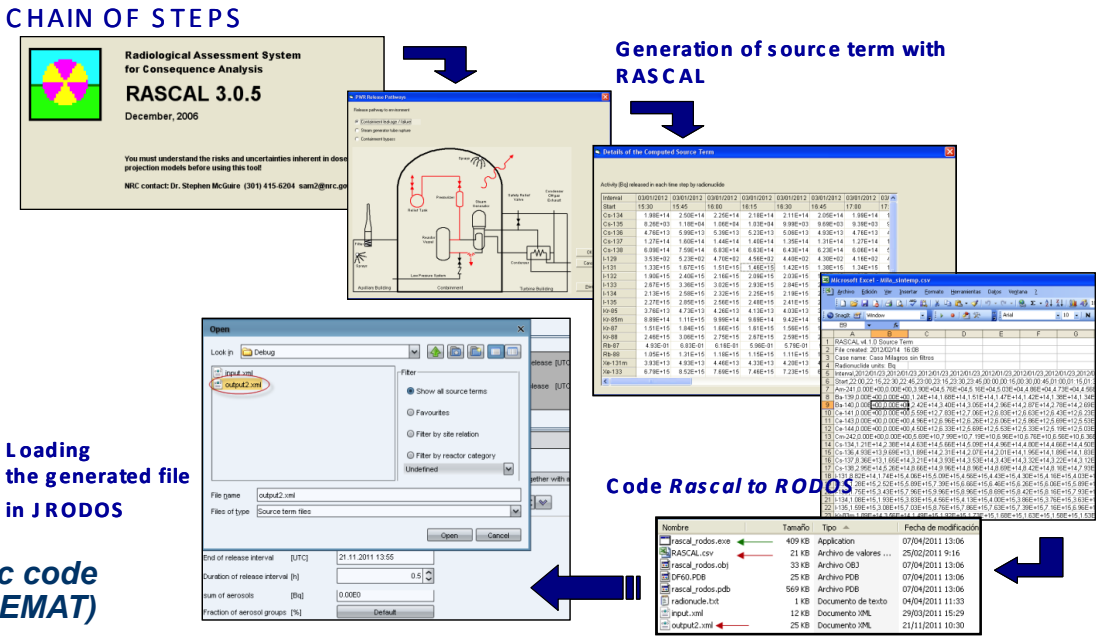
- Selecting the accident scenarios
  - Source Term
  - Meteorological conditions
  - Regional Data (Population, Land cover, Agricultural Production, Dietary Habits)
- Modelling consequences of the accident
  - Using JRODOS, ERMIN, MOIRA
- Testing intervention strategies, proposing alternatives
  - Selection of vulnerable zones regarding response to radiological impact.
  - Selection of potential countermeasures from **ERMIN** for urban management, **Handbooks** for agricultural production, **MOIRA** for freshwater uses and contamination of catchment.

Source Term

- 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 PBq / Cs-134: 2.4 PBq . 92 hours duration
- Analysed with RASCAL code to provide a full source term input to JRODOS system

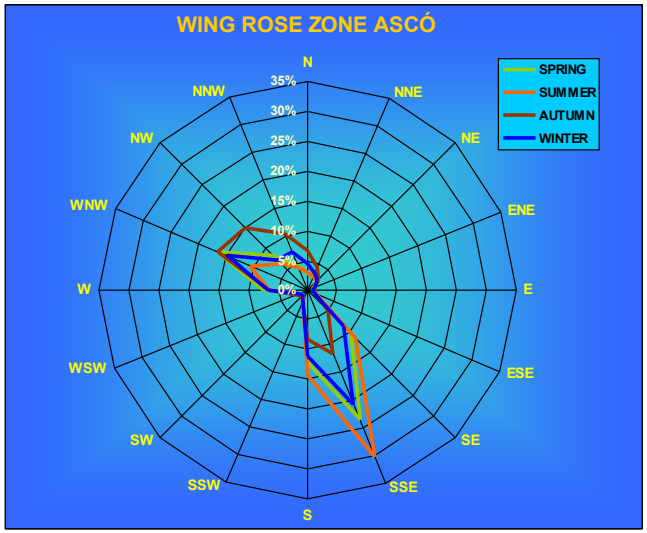
RASCAL CODE (Radiological Assessment System for Consequence AnaLysis)

The Source Term module calculates a time-dependent source term for a wide variety of accidents based on plant conditions for many different facility types.



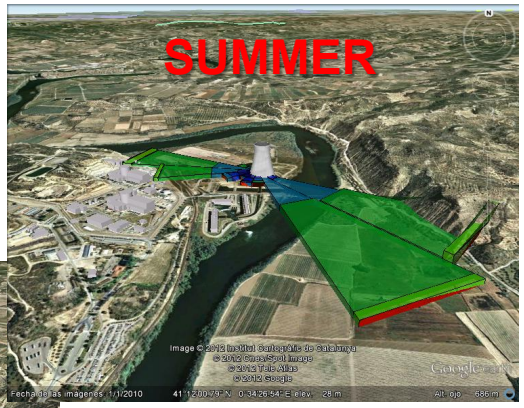
Coupling "RASCAL to RODOS" (specific code developed by CIEMAT)

Selecting Meteorological Data



Characteristic meteorology selected:

- **Summer season (July):** winds from SSE (from sea to valley). Focus on impact on agriculture.
- **Winter season (January):** winds from WNW (from valley to sea). Focus on urban contamination (Vinebre village).



Wind speed direction (blowing from))

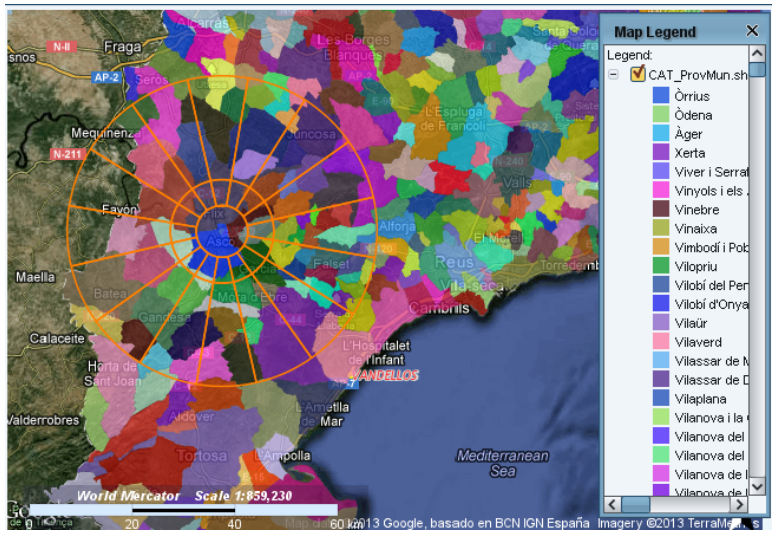
Source of Meteorological data:

Numerical weather prediction data: Prognostic meteorological data taken from the national weather service (AEMET) in the format required by RODOS.

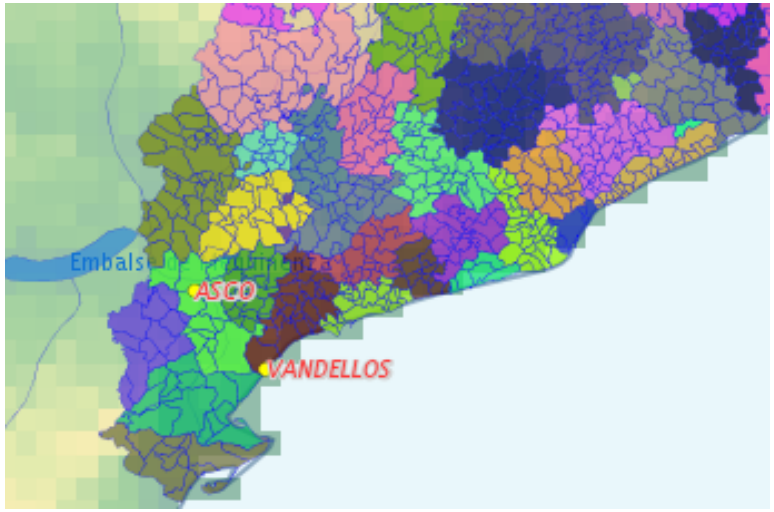
Customising Regional Data

Regional Data for the surrounding zone of Ascó and incorporation into JRODOS system

codine	Name	Population	Suface (km^2)	Density
43019	Ascó	1634	74,32	21,99
43048	Corbera d'Ebr	1171	53,47	21,90
43056	Fatarella (La)	1130	56,48	20,01
43058	Figuera (La)	135	18,67	7,23
43060	Flix	4061	115,98	35,01
43065	Garcia	594	52,05	11,41
43085	Molar (El)	297	22,97	12,93
43093	Móra d'Ebre	5795	44,89	129,09
43094	Móra la Nova	3238	15,79	205,07
43099	Palma d'Ebre	425	38,22	11,12
43125	Riba-roja d'Eb	1336	99,48	13,43
43152	Torre de l'Espa	679	27,91	24,33
43177	Vinebre	459	26,42	17,37
Zone I	**TOTAL**	**20954**	**647**	**32,40**



Surrounding municipalities



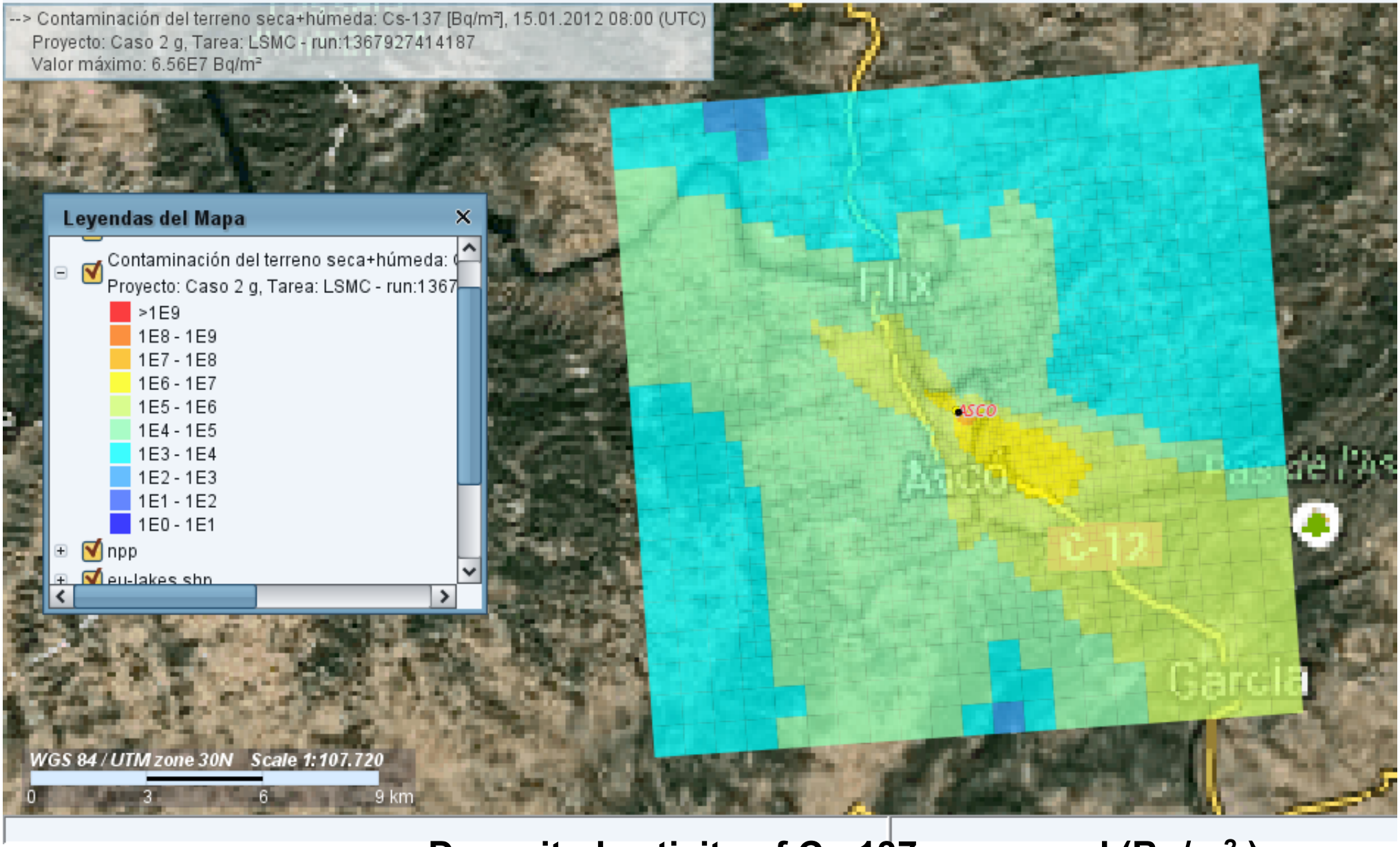
Agricultural regions in the area

Land cover	Total	Percent (%)
Coniferous	30255,12	46,73
Olivar	11163,13	17,24
fruit	9428,89	14,56
Shrubland	5822,60	8,99
labor	2454,41	3,79
vineyard	2163,09	3,34
Rangeland and grassland	1172,58	1,81
water	1023,45	1,58
unproductive	1018,80	1,57
broadleaved	245,69	0,38
rice	0,00	0,00
TOTAL SURFACE (Ha)	**64747,76**	**100,00**

Modelling with JRODOS

Deposited activity of Cs-137 on ground (Bq/m²)

Modelling with JRODOS



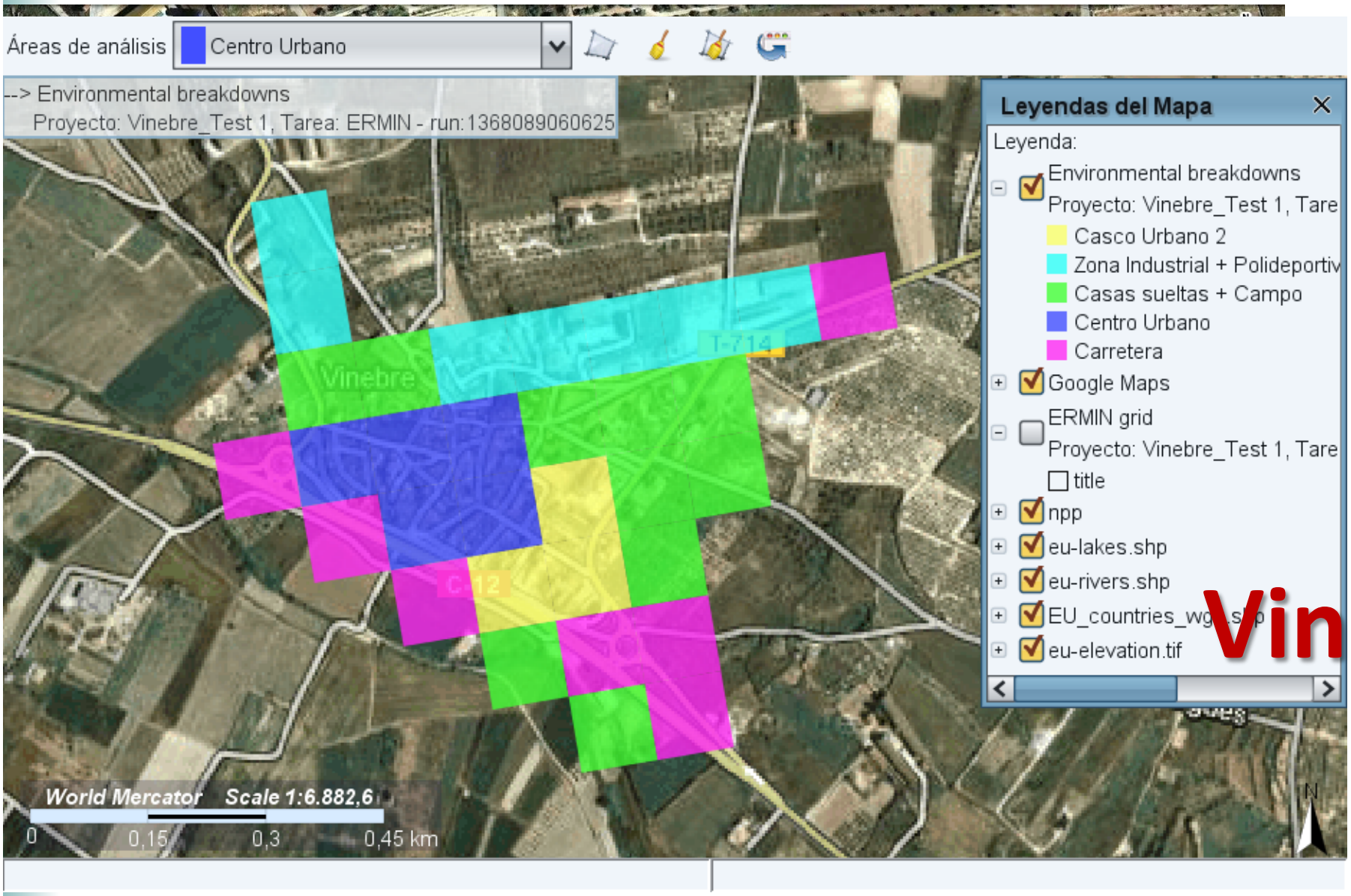
Deposited activity of Cs-137 on ground (Bq/m²)

ERMIN. Modelling Vinebre

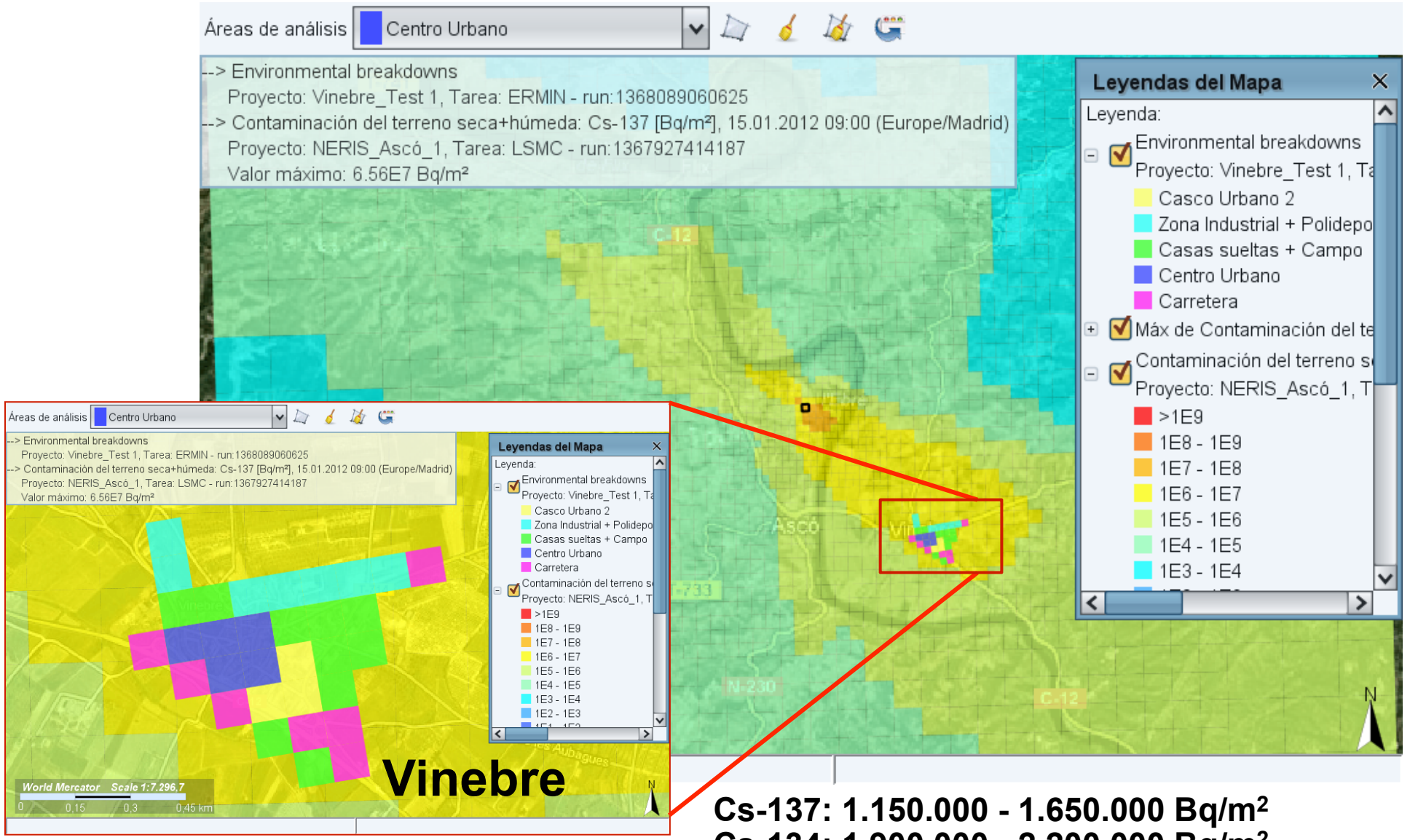
5 environments considered

- Town centre: “Street of terraced houses” , indicating that there are no trees and little ground paved.
- Town centre 2: Same as above but indicating the existence of trees in small quantity.
- Road: "Great outdoor area" particularized as parking.
- Industrial and sports area: a distribution of 50% of "Industrial Construction" and "Great outdoor area" particularized as sports facilities.
- Loose + Country Houses: a distribution of 50% of "Great outdoor area" particularized as a park, and "Semi-detached houses with basement," indicating the existence of abundant trees and some pavement.

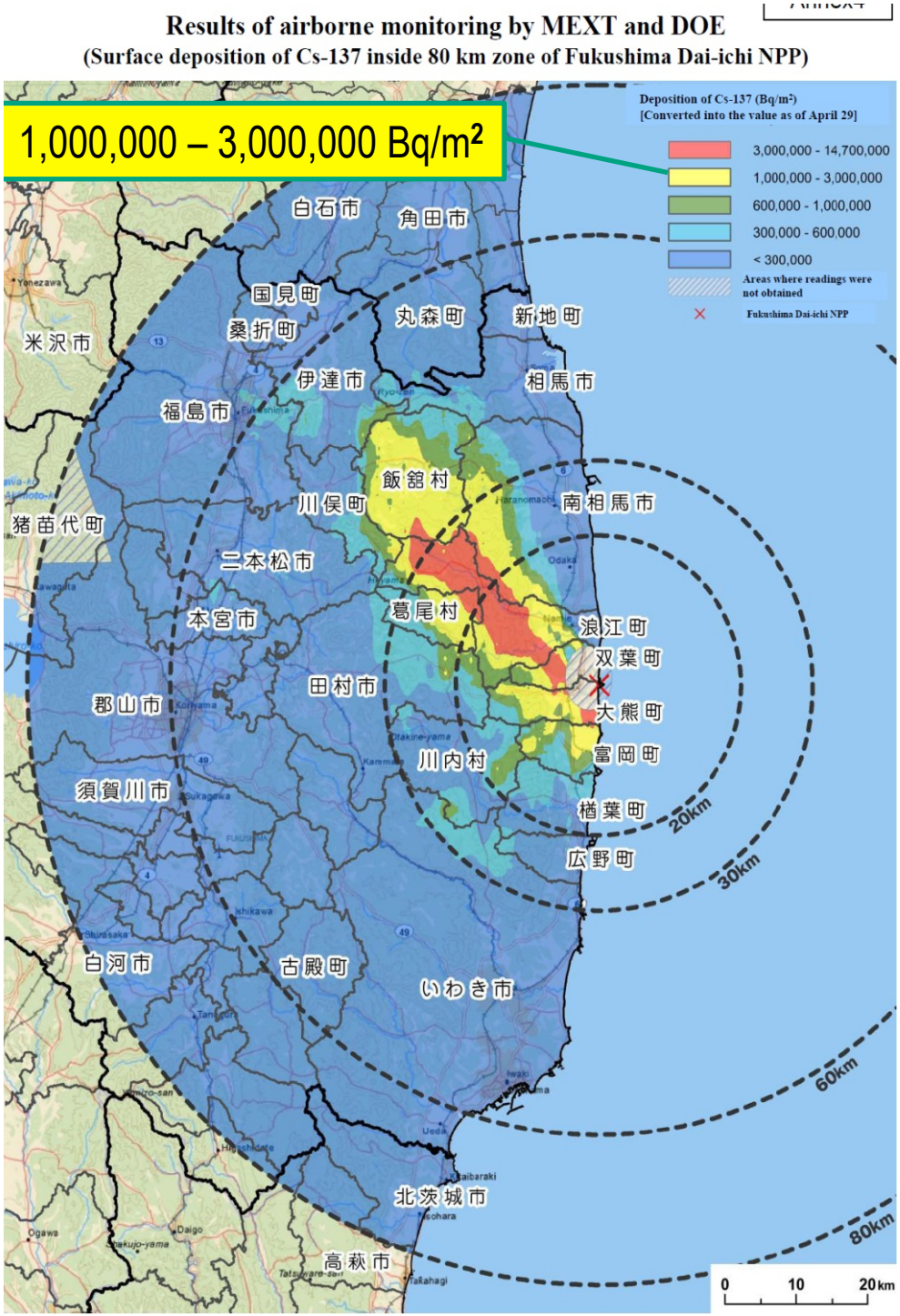
ERMIN. Customization – inhabited zones types. Near Ascó.

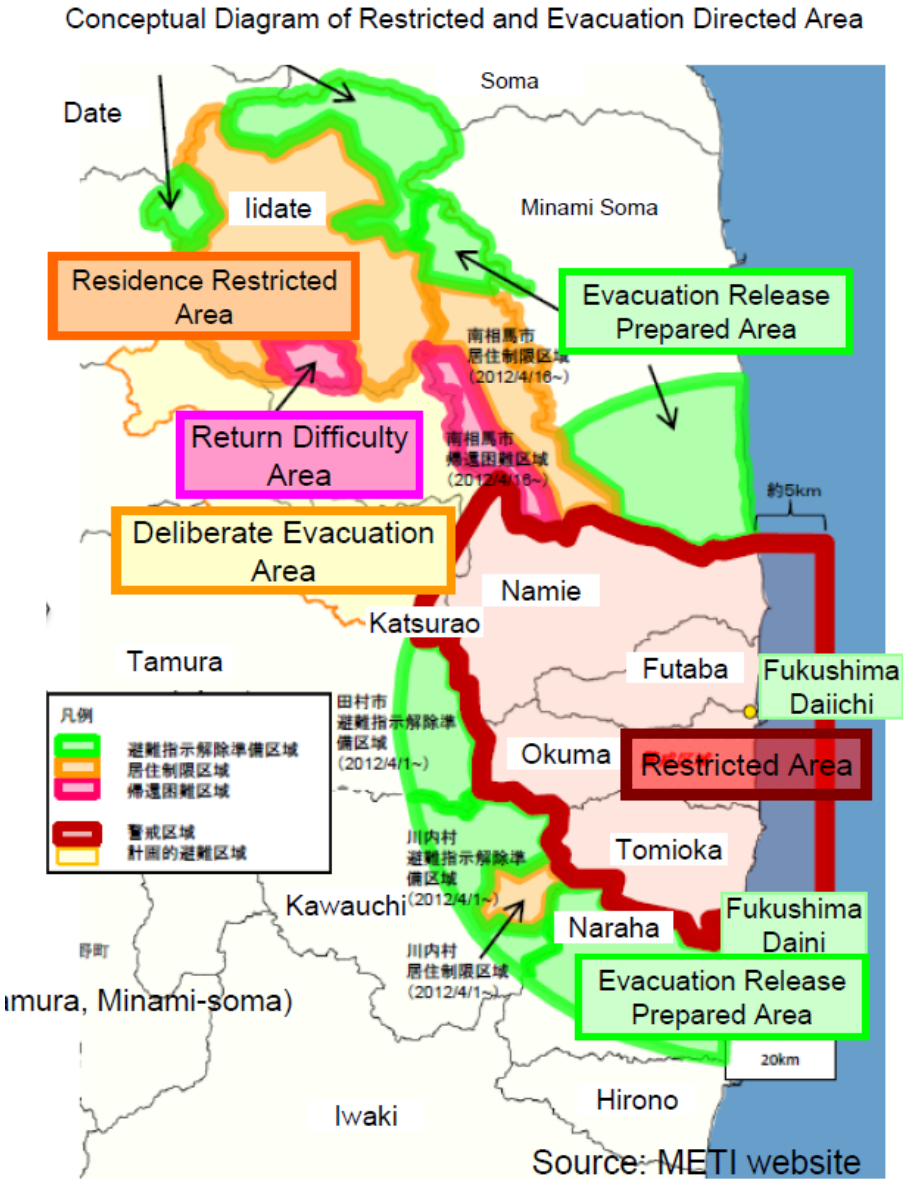


Total ground deposit of Cs-137 (Bq/m^2) in the near zones after the simulated accident



Cs-137: 1.150.000 - 1.650.000 Bq/m^2
Cs-134: 1.900.000 - 2.200.000 Bq/m^2

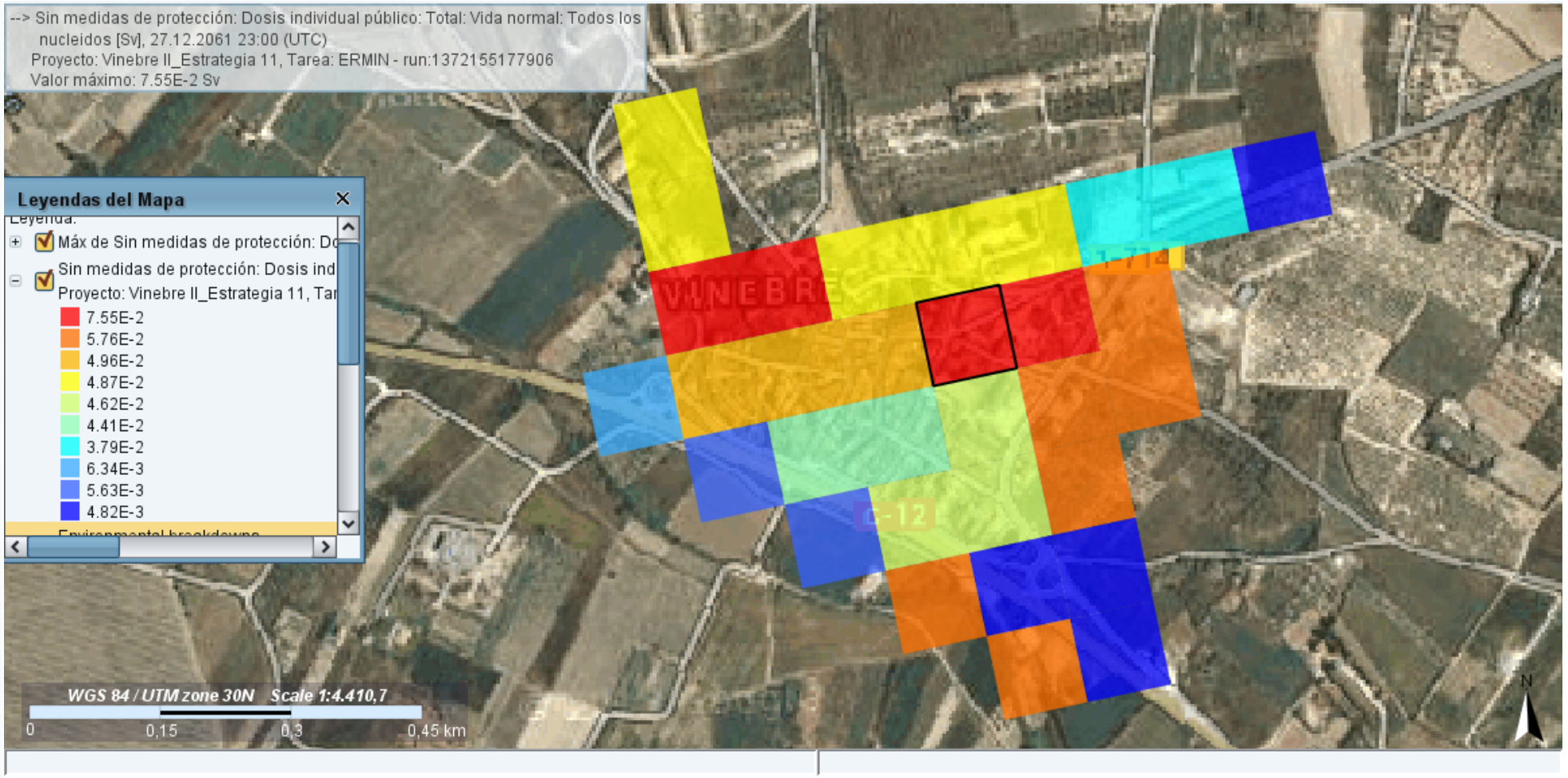




Reference from Fukushima:
Residence Restricted Area
(decontamination)

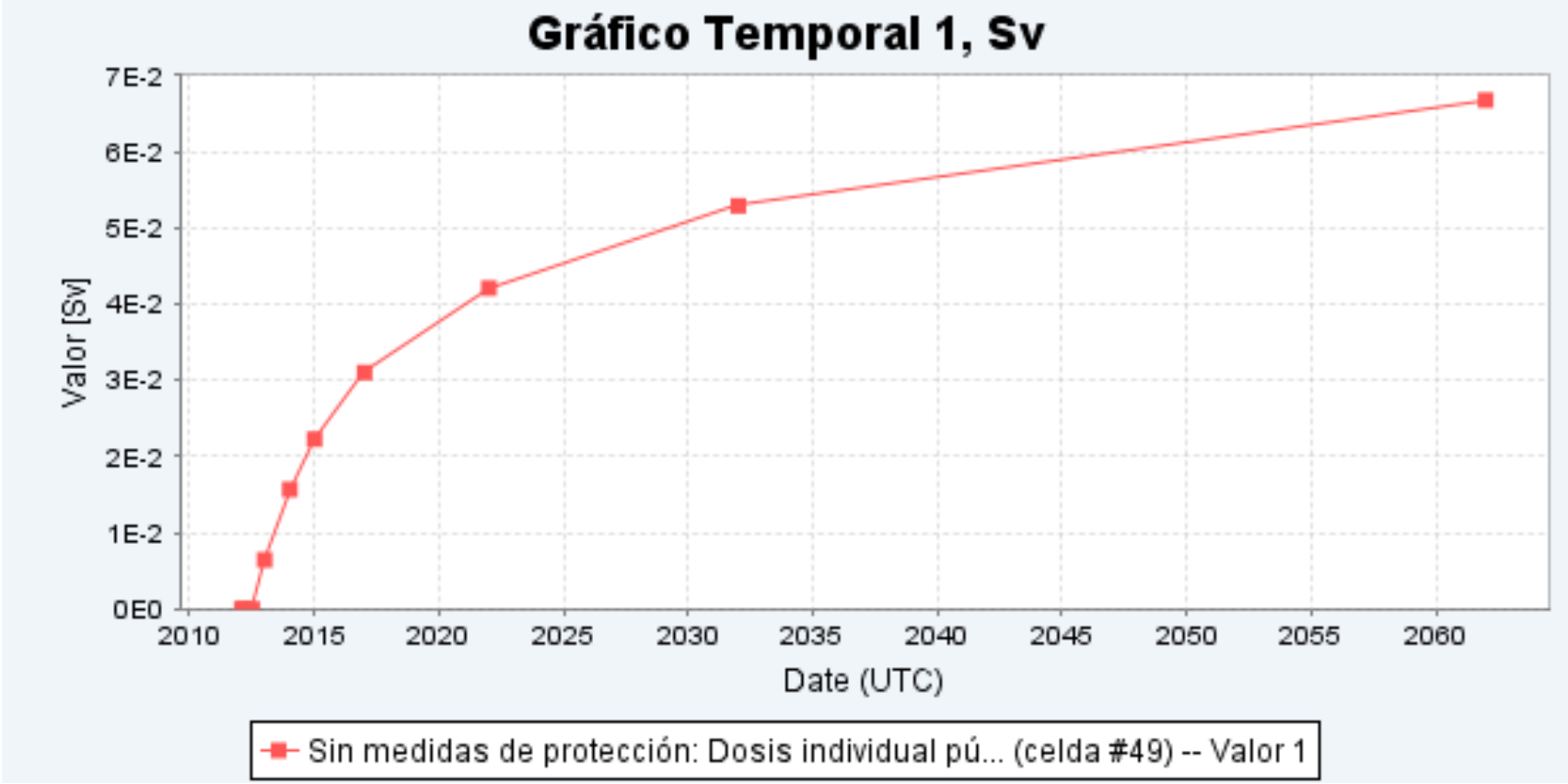
Cumulated Effective Dose after 50 years

(without protective measures; normal life conditions)



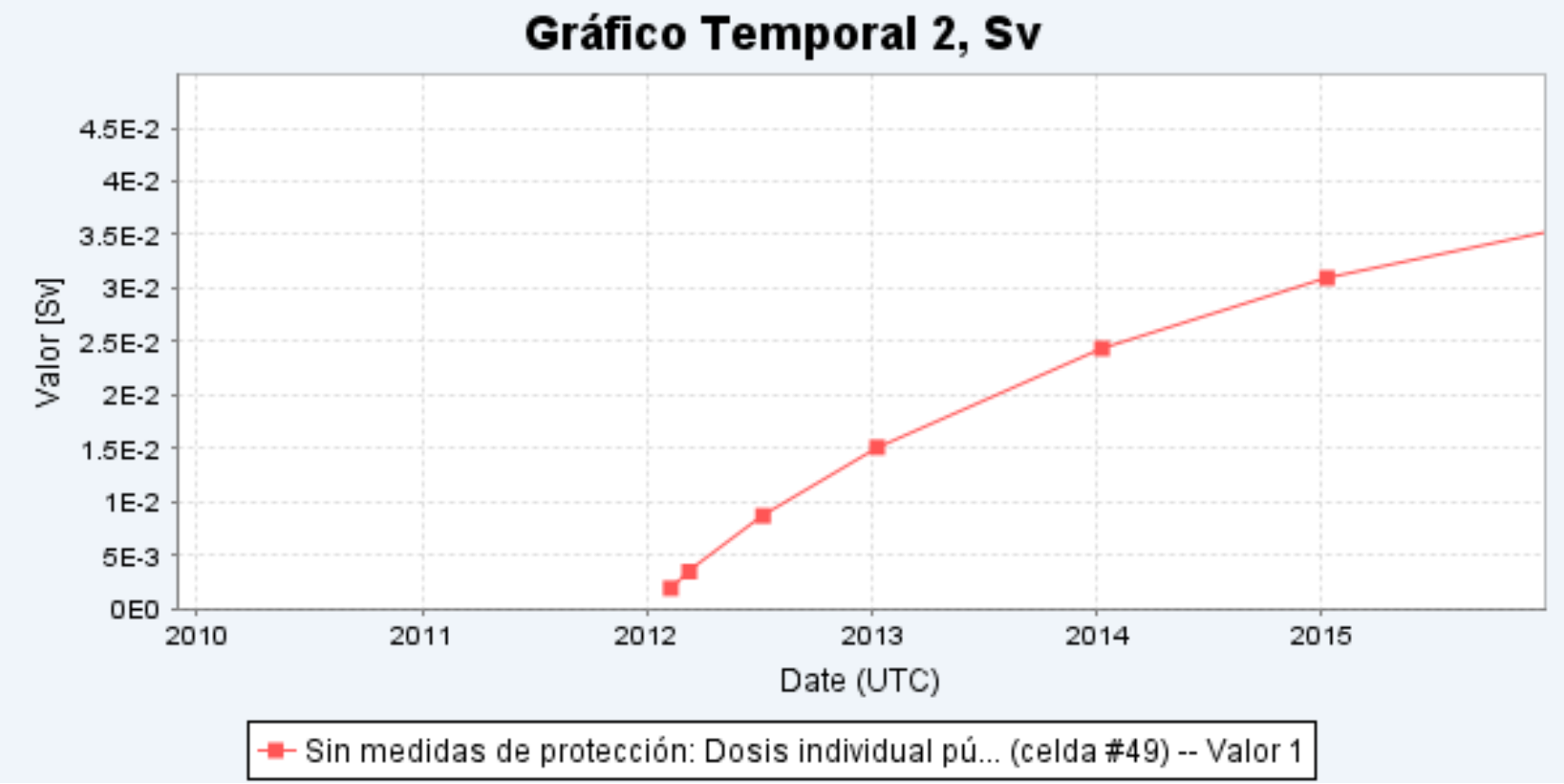
Evolution of the Cumulated Effective Dose in 50 years

(without protective measures; normal life conditions)

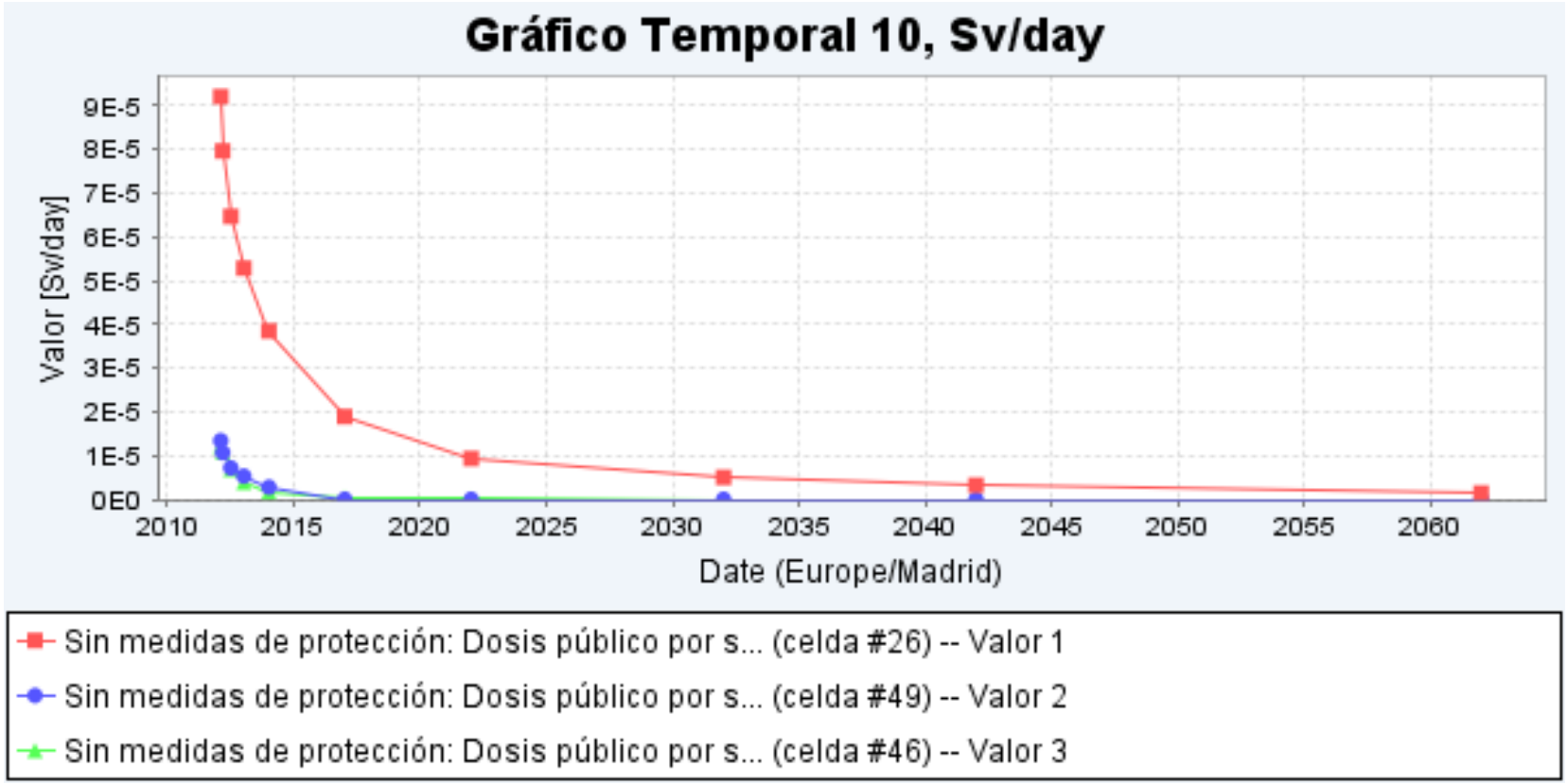


Evolution of the Cumulated Effective Dose in 4 years

(without protective measures; normal life conditions)



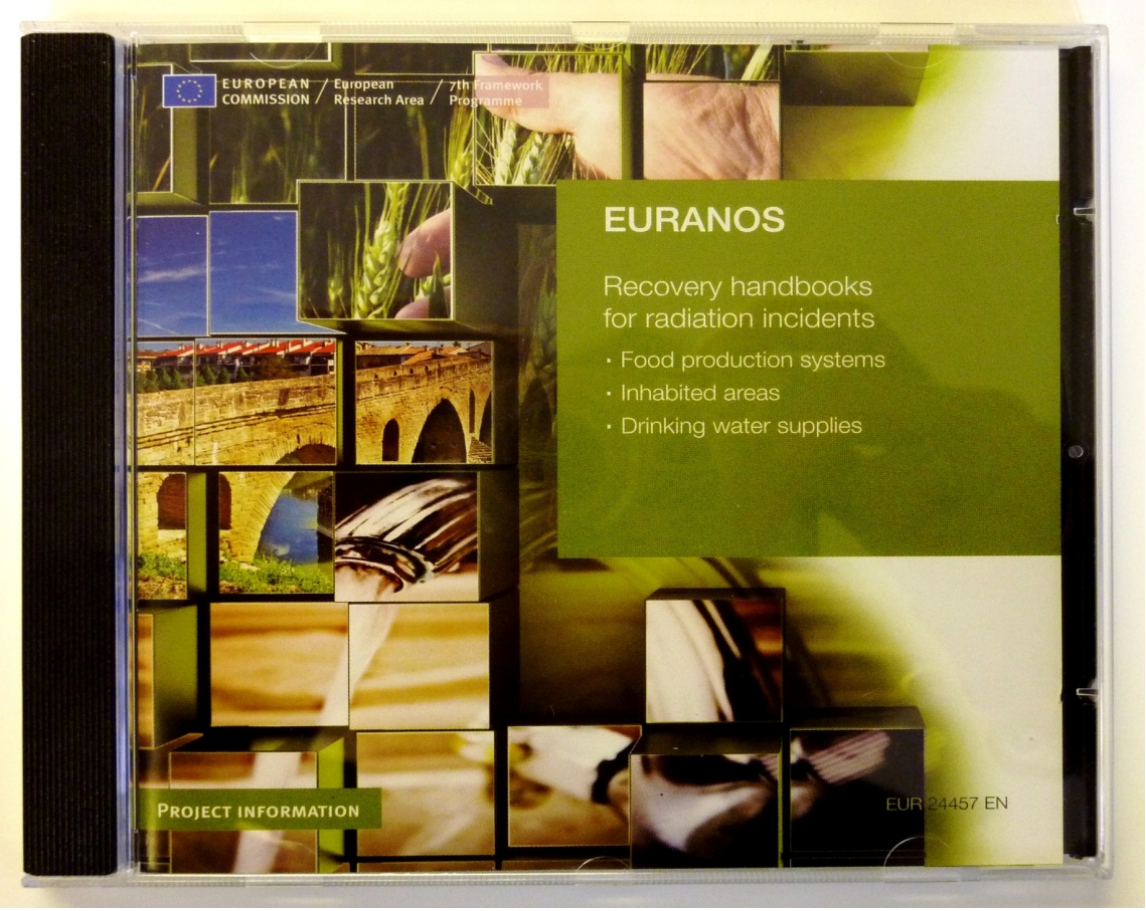
Surfaces and its importance in the external dose. Example



Vinebre Scenario: Evolution of the dose rate to an adult contributed by different contaminated surfaces in urban areas.
From top to down: small areas of grass - trees - roads and paved areas.

Although the values are taken from different cells, the overall behavior is similar in the whole area

EURANOS recovery handbooks for management of food production systems, inhabited areas and drinking water supplies



- Translated into Spanish
- Being widely disseminated

Decision framework

Determine nature and extent of contamination

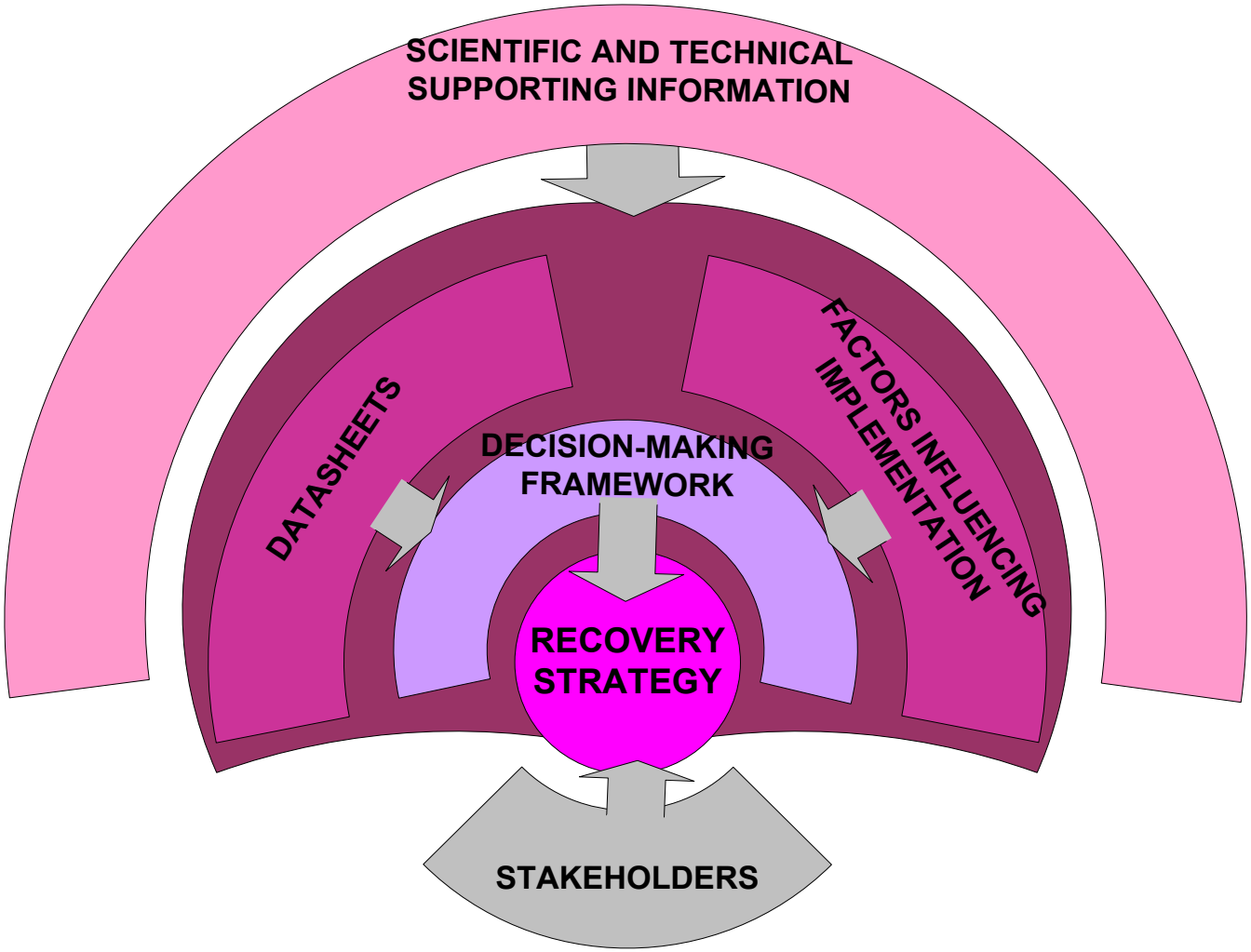
Estimate doses to people from different surfaces

Consider management options for these surfaces

Eliminate unsuitable management options

Carry out detailed evaluation of remaining options

General structure of the handbook for inhabited areas



Handbook for inhabited areas

Inhabited areas

- Buildings, roads and paved areas
- Soils, grass, trees and shrubs
- Specialised industrialised surfaces

Sources of contamination

- Accidents at nuclear power plants
- Weapons transport accidents

Timescales

- After emergency phase - a year later

Radionuclides of interest

- Alpha: ^{226}Ra+, ^{235}U+, ^{238}Pu, ^{239}Pu, ^{241}Am
- Beta: ^{90}Sr/^{90}Y, ^{99}Mo/^{99m}Tc, ^{106}Ru, ^{144}Ce
- Gamma: ^{60}Co, ^{75}Se, ^{95}Zr, ^{95}Nb, ^{103}Ru, ^{131}I, ^{132}Te, ^{134}Cs, ^{136}Cs, ^{137}Cs, ^{140}Ba, ^{140}La, ^{169}Yb, ^{192}Ir

Handbook for inhabited areas. Factors analysed

- Spatial and temporal
- Effectiveness
- Protection of workers
- Waste disposal
- Societal and ethical aspects
- Environmental impact
- Economic cost
- Information and communication issues

NERIS-TP

Handbook for inhabited areas. Datasheet template

Name of manageme	
Objective	
Other benefits	
Management option description	
Target	
Targeted radionuclides	
Scale of application	
Contamination pathway	
Exposure pathway pre intervention	
Time of application	
Constraints	Provides informat that have to be co option.
Legal constraints	
Social constraints	
Environmental constraints	
Effectiveness	Provides informa management optio
Management option effectiveness	
Factors influencing effectiveness of procedure	
Feasibility	Provides informati required to carry o
Required specific equipment	
Required ancillary equipment	
Required utilities and infrastructure	
Required consumables	
Required skills	
Required safety precautions	
Other limitations	

Name of management option	
Waste	Some management options create waste, the management of which must be carefully considered at the time the option is selected.
Amount and type	
Possible transport, treatment and storage routes	
Factors influencing waste issues	
Doses	Provides information on how the management option leads to changes in the distribution of dose to individuals and populations.
Incremental dose	
Intervention Costs	Provides information on the direct costs that may be incurred from implementing the management option.
Equipment	
Consumables	
Operator time	
Factors influencing costs	
Compensation costs	
Waste cost	
Assumptions	
Communication needs	
Side effect evaluation	Provides information on side-effects incurred following implementation of the management option.
Ethical considerations	
Environmental impact	
Agricultural impact	
Social impact	
Other side effects	
UK Stakeholder opinion	
Practical experience	
Key references	

Datasheets for Inhabited Areas

59 datasheets

- Pre-release and early phase (7)
- Restrict access (4)
- Buildings –external surfaces (10)
- Buildings – internal surfaces (6)
- Precious objects (1)
- Roads and paved areas (6)
- Soil, grass and plants (14)
- All outside areas (2)
- Trees and shrubs (2)
- Specialised industrial surfaces (7)

EURANOS Handbook for Inhabited Areas. Selection table for buildings (example)

Table 7.11 Selection table of management options for buildings

When to apply	Early (E) (days-weeks)	Medium-Long (M/L) (months-years)
Restrict access		
Permanent relocation from residential areas (8)		
Prohibit public access to non-residential areas (9)		
Restrict workforce access (time or personnel) to non-residential areas (10)		
Temporary relocation from residential areas (11)		
External surfaces		
Demolish buildings (12)		
Firehosing (13)		
High pressure hosing (14)		
Mechanical abrasion of wooden walls (15)		
Peelable coatings (49)		
Roof brushing (16)		
Roof cleaning with pressurised hot water (17)		
Roof replacement (18)		
Sandblasting (19)		
Snow removal (50)		
Tie down (fixing contamination to the surface) (20)		
Treatment of walls with ammonium nitrate (21)		
Indoor surfaces and objects		

Key:	
	Recommended with few constraints
	Recommended but requires further evaluation to overcome some constraints
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis

ERMIN. Countermeasures modelled (1)

Countermeasure	ID	Scale	Surface
Relocation	8	-	-
Firehosing paved	29	-	Road, pavement, other paved
Firehosing roofs	13	-	Roof
Firehosing walls	13	-	Walls
High pressure hosing paved	31	-	Road, pavement other paved,
High pressure hosing roofs	16	-	Roof
High pressure hosing walls	16	-	Walls
Mechanical abrasion of wooden walls	20	-	Walls
Peelable coatings	49	-	Road, pavement, other paved, roof, walls
Roof brushing	14	-	Roof
Roof cleaning with pressurised hot water	17	-	Roof
Sandblasting walls	15	-	Walls
Treatment with ammonium nitrate	19	-	Walls
Vacuum cleaning interior surfaces	22	-	Internal surfaces
Vacuum sweeping paved	30	-	Road, pavement, other paved
Washing interior surfaces	23	-	Internal surfaces
Cover with asphalt-small scale	44	Small	Grass, plants, soil
Cover with clean soil-large scale	40	Large	Grass, plants, soil
Cover with clean soil-small scale	40	Small	Grass, plants, soil

The ID refers to the countermeasure in the Generic European Inhabited Area Handbook where more information can be found.

ERMIN. Countermeasures modelled (2)

Tie-down to with bitumen	34	-	Road, pavement, other paved
Tie-down to with sand	34	-	Road, pavement, other paved
Turning paving slabs	33	-	Pavement, other paved
Deep ploughing	47	Large	Grass, plants, soil
Manual digging	43	Small	Grass, plants, soil
Ploughing	46	Large	Grass, plants, soil
Rotovating	42	Small	Grass, plants, soil
Skim and burial ploughing	48	Large	Grass, plants, soil
Triple digging	45	Small	Grass, plants, soil
Tie-down to buildings with vinacryl	21	-	Roof, walls
Tie-down to with water	34	-	Road, pavement, other paved
Tie-down with paint/lignin-large scale	41	Large	Grass, plants, soil
Tie-down with paint/lignin-small scale	41	Small	Grass, plants, soil
Tie-down with water-large scale	41	Large	Grass, plants, soil
Tie-down with water-small scale	41	Small	Grass, plants, soil
Concrete paving stone removal-small scale	32	-	Pavement, other paved
Grass cutting-large scale	35	Large	Grass
Grass cutting-small scale	35	Small	Grass
Manual top soil and turf or plant removal-small scale	39	Small	Grass, plants, soil
Mechanical top soil and turf or plant removal-large scale	38	Large	Grass, plants, soil
Mechanical top soil and turf or plant removal-small scale	38	Small	Grass, plants, soil
Plant removal-large scale	36	Large	Plants
Plant removal-small scale	36	Small	Plants
Road surface removal	32	-	Road
Roof replacement	18	-	Roof
Surface removal and removal of furniture etc	25	-	Internal surfaces
Tree removal and replacement	52	-	Trees and shrubs
Tree removal/pruning	52	-	Trees and shrubs

The ID refers to the countermeasure in the Generic European Inhabited Area Handbook where more information can be found.

ERMIN. Countermeasures modelled (3)

Countermeasure	ID	Scale	Surface
Turf harvesting and reseed-large scale	37	Large	Grass
Turf harvesting and reseed-small scale	37	Small	Grass
Turf harvesting-large scale	37	Large	Grass
Turf harvesting-small scale	37	Small	Grass
Concrete paving stone removal and replacement-small scale	32	-	Pavement
Concrete paving stone removal and replacement-small scale	32	-	Other paved
Manual top soil and turf or plant removal and soil replacement-small scale	39	Small	Grass, plants, soil
Manual top soil and turf removal and soil replacement and reseed-small scale	39	Small	Grass, plants
Manual top soil and turf removal and soil replacement and returf-small scale	39	Small	Grass
Mechanical top soil and turf or plant removal and soil replacement-large scale	38	Large	Grass, plants, soil
Mechanical top soil and turf or plant removal and soil replacement-small scale	38	Small	Grass, plants, soil
Mechanical top soil and turf or plant removal, soil replacement and reseed-large scale	38	Large	Grass, plants
Mechanical top soil and turf or plant removal, soil replacement and reseed-small scale	38	Small	Grass, plants
Mechanical top soil and turf removal, soil replacement and returf-large scale	38	Large	Grass
Mechanical top soil and turf removal, soil replacement and returf-small scale	38	Small	Grass
Road surface removal and replacement	32	-	Road
Turf harvesting and returf-large scale	37	Large	Grass
Turf harvesting and returf-small scale	37	Small	Grass

The ID refers to the countermeasure in the Generic European Inhabited Area Handbook where more information can be found.

ERMIN. Intervention strategies analysed (example)

Estrategia 1: NO COUNTERMEASURES

Estrategia 2: INTENSE DECONTAMINATION (+ prolonged evacuation for 60 días)

Town centre: Treatments	Starting day	Ending day
High pressure hosing paved areas	20	50
High pressure hosing walls	20	60
Roof cleaning with pressurised hot water	10	60
Washing interior surfaces	10	40
Mechanical top soil and turf or plant removal-small scale	20	60

Town centre 2: Treatments	Starting day	Ending day
Same treatments than for "Town centre" +		
Tree removal and replacement	10	70

Loose houses + fields: Treatments	Starting day	Ending day
High pressure hosing paved areas	20	40
High pressure hosing walls	10	30
Roof cleaning with pressurised hot water	10	30
Washing interior surfaces	10	20
Mechanical top soil and turf or plant removal-small scale	20	60
Tree removal and replacement	10	70

Roads: Tratamiento	Día de inicio	Día de finalización
High pressure hosing paved areas	10	30
Mechanical top soil and turf or plant removal-small scale	50	90
Tree removal and replacement	50	90

Industrial and sports area:

Treatments	Starting day	Ending day
High pressure hosing paved areas	20	50
High pressure hosing walls	20	60
Roof cleaning with pressurised hot water	10	60
Washing interior surfaces	10	30
Mechanical top soil and turf or plant removal-small scale	20	60
Tree removal and replacement	10	70

ERMIN. Intervention strategies analysed (example)

Estrategia 3: INTENSE DECONTAMINATION + POPULATION RELOCATION (100 DAYS)

Estrategia 4: SOFT DECONTAMINATON (+ prolonged evacuation for 60 days)

Town centre: Treatments	Starting day	Ending day
Vacuum sweeping paved	8	12
Firehosing paved	8	20
Firehosing walls	10	20
Firehosing roofs	10	20
Washing interior surfaces	8	20
Manual top soil and turf or plant removal-small scale	20	30

Town centre 2: Treatments	Starting day	Ending day
Same treatments than for "Town centre" +		
Plant removal-small scale	25	50
Tree removal/pruning	25	50

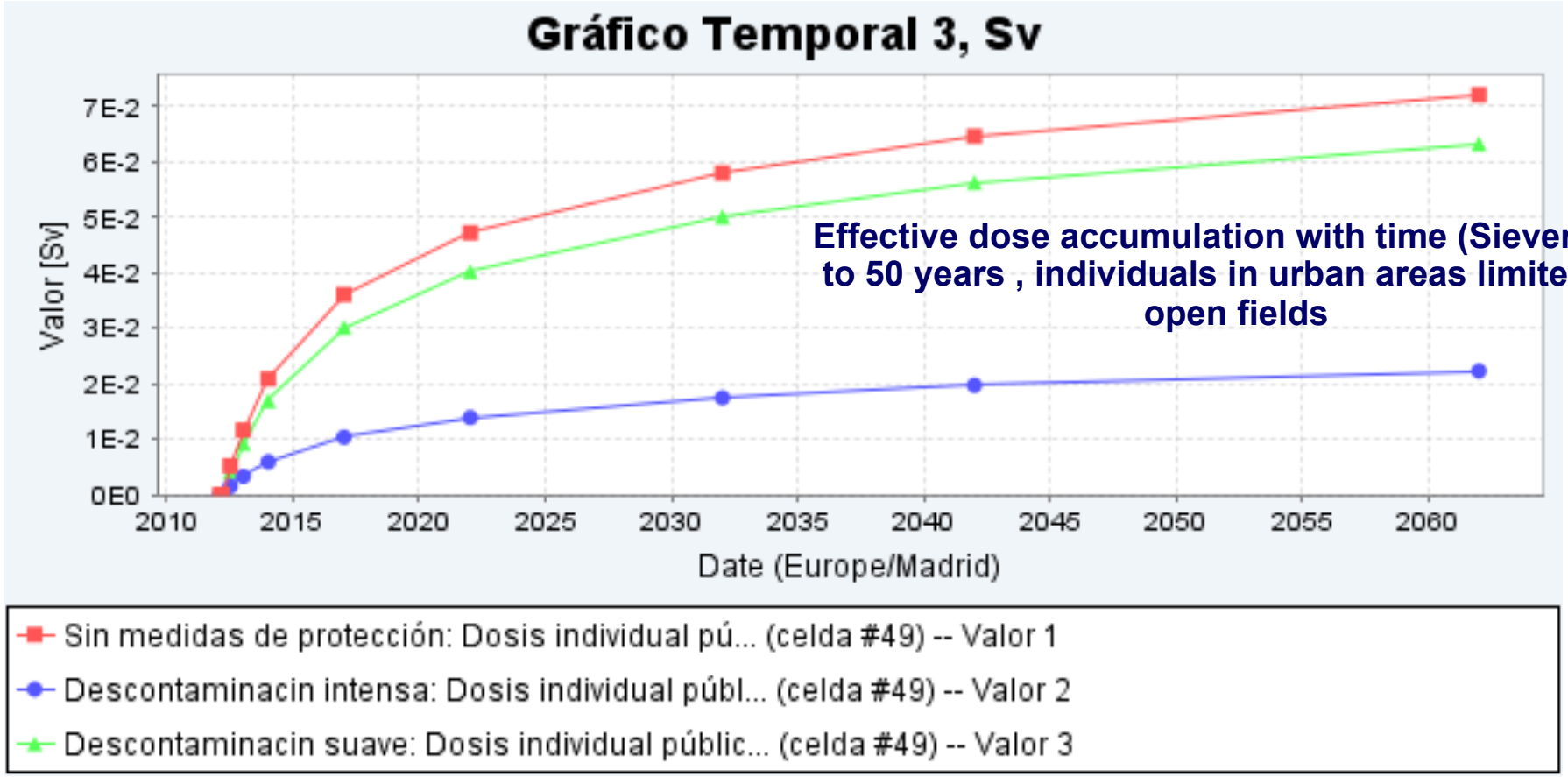
Loose houses + fields: Treatments	Starting day	Ending day
Vacuum sweeping paved	8	12
Firehosing paved	10	20
Firehosing walls	10	20
Firehosing roofs	10	20
Washing interior surfaces	8	20
Manual top soil and turf or plant removal-small scale	25	45
Tree removal/pruning	25	50

Roads: Treatments	Starting day	Ending day
Vacuum sweeping paved	15	50
Firehosing paved	15	50
Firehosing walls	15	50
Manual top soil and turf or plant removal-small scale	15	50
Plant removal-small scale	15	50
Tree removal/pruning	15	50

Industrial and sports area:

Treatments	Starting day	Ending day
Vacuum sweeping paved	20	30
Firehosing paved	20	30
Firehosing walls	10	25
Firehosing roofs	10	25
Washing interior surfaces	10	20
Manual top soil and turf or plant removal-small scale	30	50
Tree removal/pruning	10	40

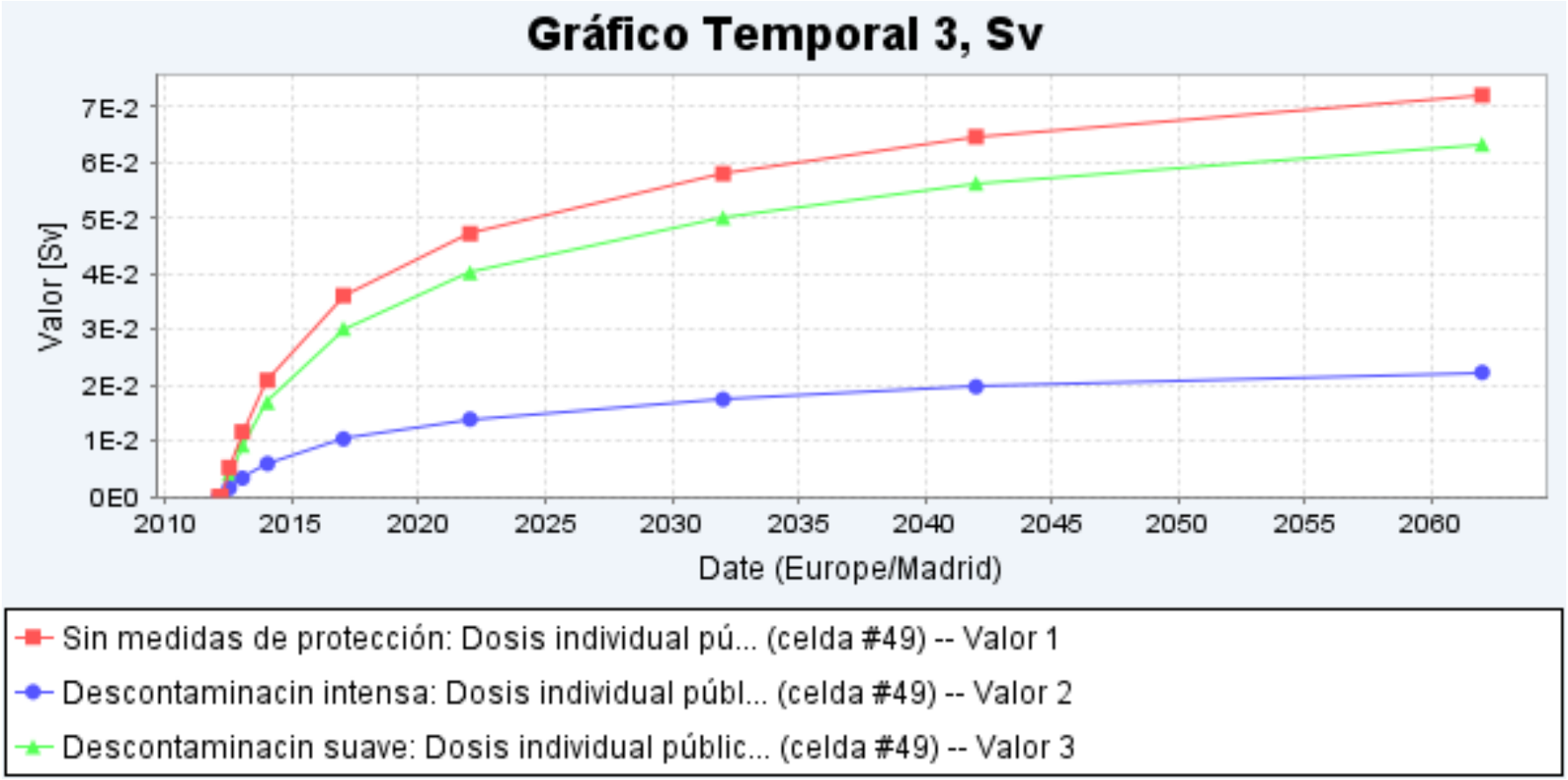
ERMIN. Intervention strategies analysed (example)



Effective dose accumulation with time (Sievert) up to 50 years , individuals in urban areas limited by open fields

- Without cleaning measures, the annual dose rate would take more than 20 years in lowering of 1 mSv/year (from 2032).
- With “soft" decontamination measures, the reference dose value for long-term would be reached a few years earlier (from 2030).
- And with measures of intense decontamination, in 6 - 7 years (from 2019).

ERMIN. Intervention strategies analysed (example)



Natural radiation in Vinebre is of the order of 2.15 milliSievert / year accumulated a total of 107.5 milliSievert in 50 years

ERMIN. Intervention strategies analysed (example)

Summary of the impact of each strategy with regard to different attributes

Impacts	Strategy 1: No countermeasures	Strategy 2: Intense Decontamination (evacuation 60 days)	Strategy 3: Intense Decontamination + population relocation (100 days)	Strategy 4: Soft Decontamination (evacuation 60 days)
Total Cost of strategy (Million EURO)	0	6,0	6,2	1,7
Amount of personnel required to implement the countermeasure strategy (Persons)	0	824	892	405
Maximum individual dose (mSv) in the first year (external+inhalation)	11,6	3,6	2,8	9,2
Maximum individual dose averted (mSv) in the first year	0	8,3	8,9	2,7
Maximum individual dose (mSv) received by workers	0	1,5	1,5	1,1
Radioactive waste generated (Tons)	0	8640	10500	11500
Maximum activity concentration in wastes (MBq/kg) (beta/gamma emmiters)	0	70,6	70,6	70,9

Current applications

- ERMIN was also applied to the development of the CURIEX exercise in November 2013
- A catalog of ERMIN environments has been developed for all the towns and villages near all NPPs in Spain by UPM
  - Based on Google Earth satellite images
  - It will allow a faster application for developing new future scenarios of post-accident analyses in all the nuclear sites

Many thanks!