

Modelos hidrogeológicos para la gestión de las aguas subterráneas

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MINISTERIO
DE CIENCIA, INNOVACIÓN
Y UNIVERSIDADES

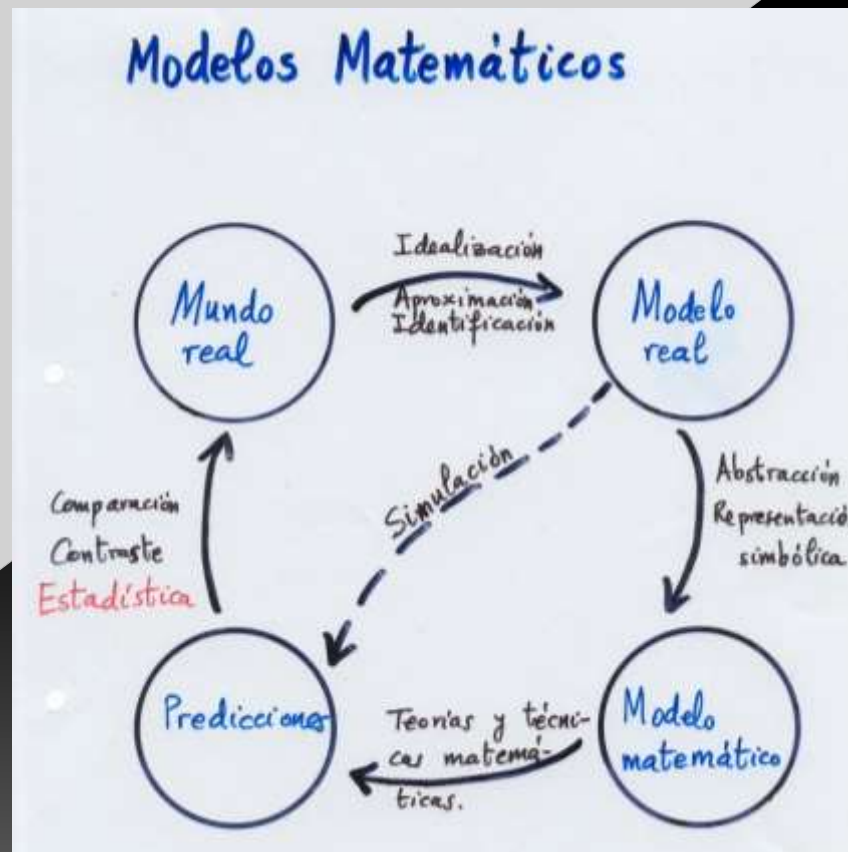


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y Minero de España

Índice

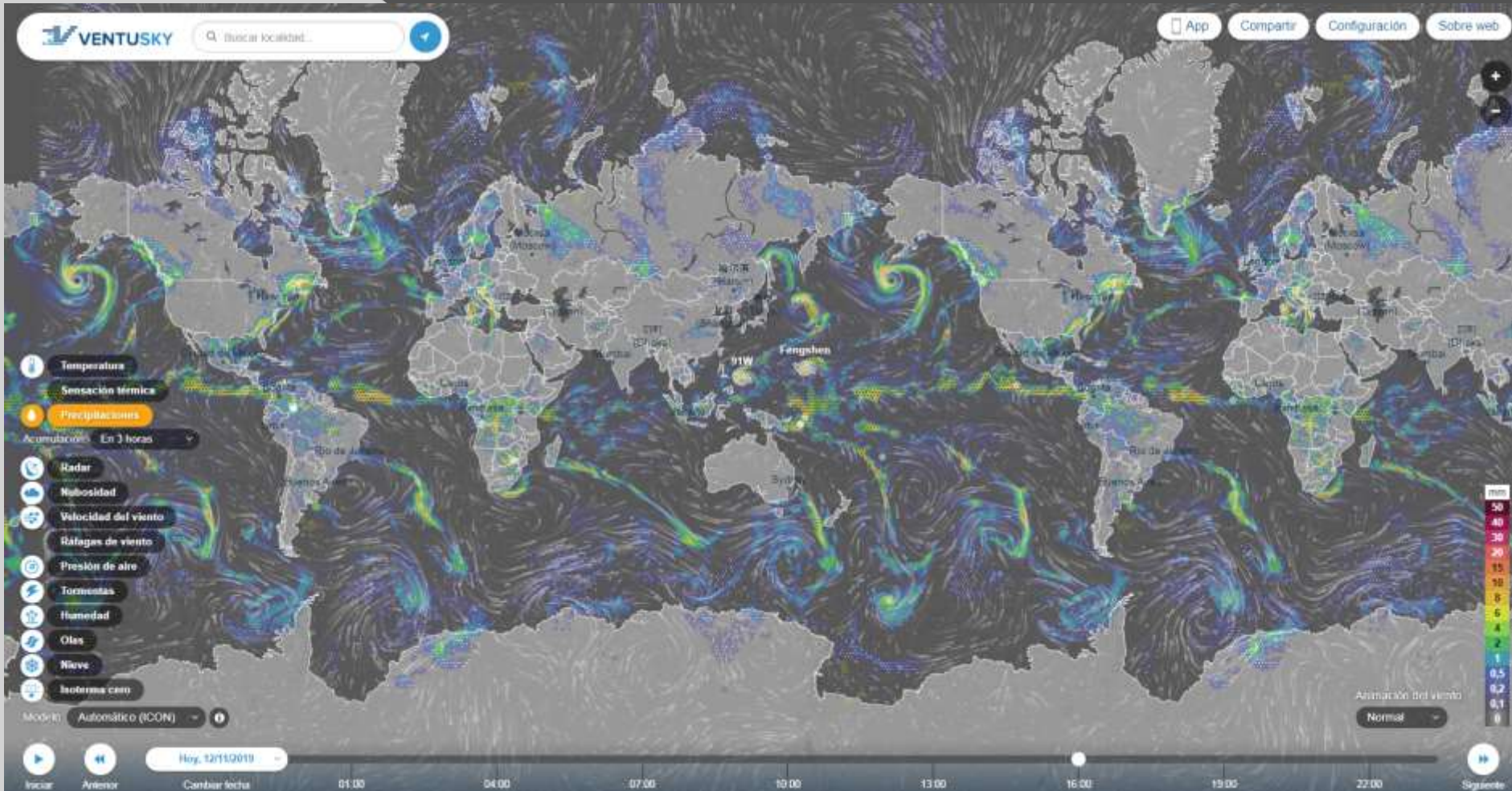
- ¿Por qué usar modelos para gestionar el agua subterránea?
- Concepto de modelo y ejemplos
- ¿Qué se necesita?
- Resultados
- Reflexiones

¿Por qué usar modelos para gestionar el agua subterránea?



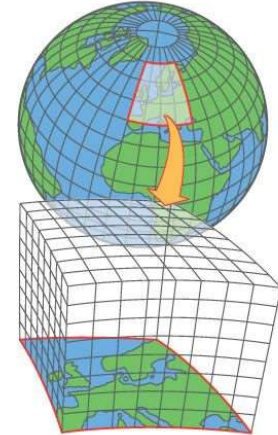
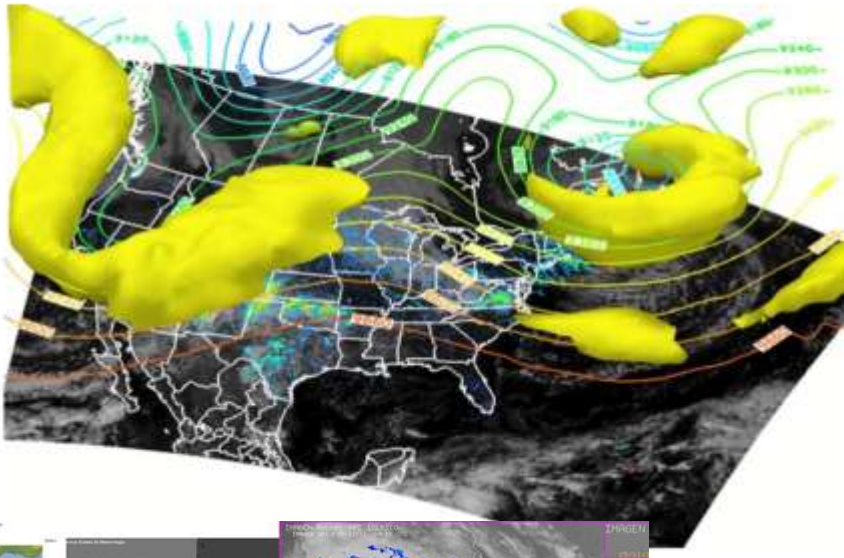
Similitud con los modelos de predicción meteorológica

Existen datos a escala mundial de temperatura, lluvia, viento...

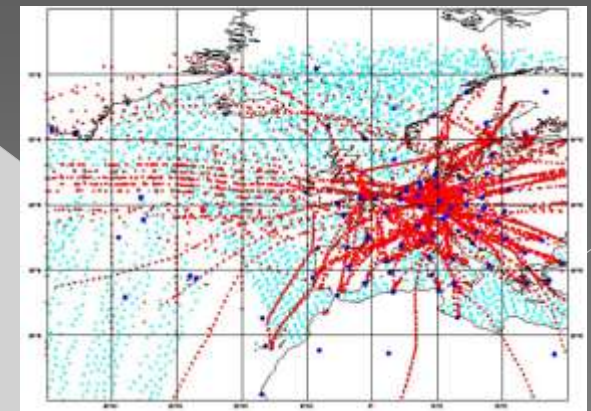
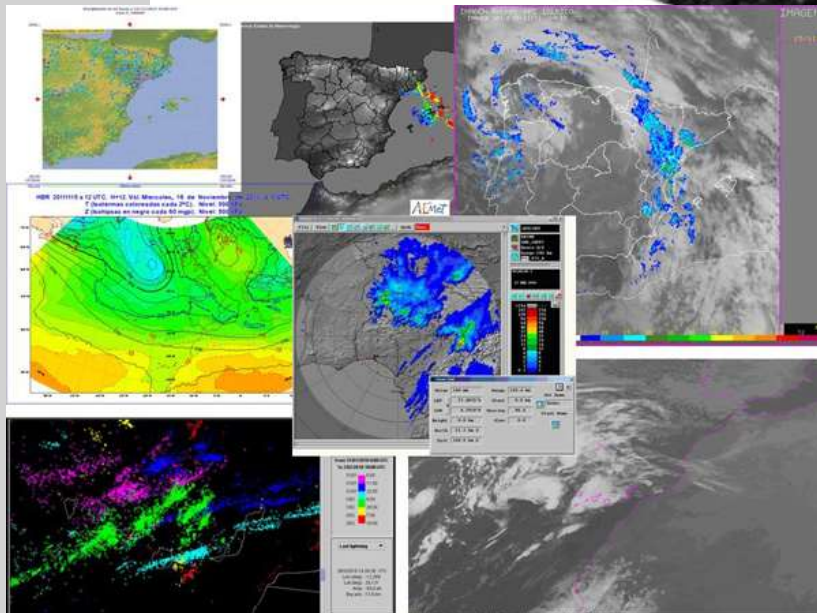


Son claves los modelos numéricos para la predicción meteorológica

Modelo numérico para la predicción



AEMET



http://www.aemet.es/es/idi/prediccion/prediccion_numerica

¿Por qué fallan los pronósticos?

11 Diciembre 2017 · TWC España

Hay una situación que a todos o a casi todos nos resulta familiar. Tras unos días de tiempo revuelto, alguien se acerca a nosotros con un paraguas en la mano bajo un cielo soleado y nos pregunta: [¿pero no han dicho que iba a llover?](#)



(Via Pxhere)

Sí, dijeron que iba a llover pero no llovió porque no se puede asegurar una previsión del tiempo con un cien por cien de acierto. El margen de error existe siempre porque la predicción meteorológica se basa en la probabilidad de lo que sucederá en la atmósfera, un fluido cuyo estudio y comprensión es extremadamente complejo.

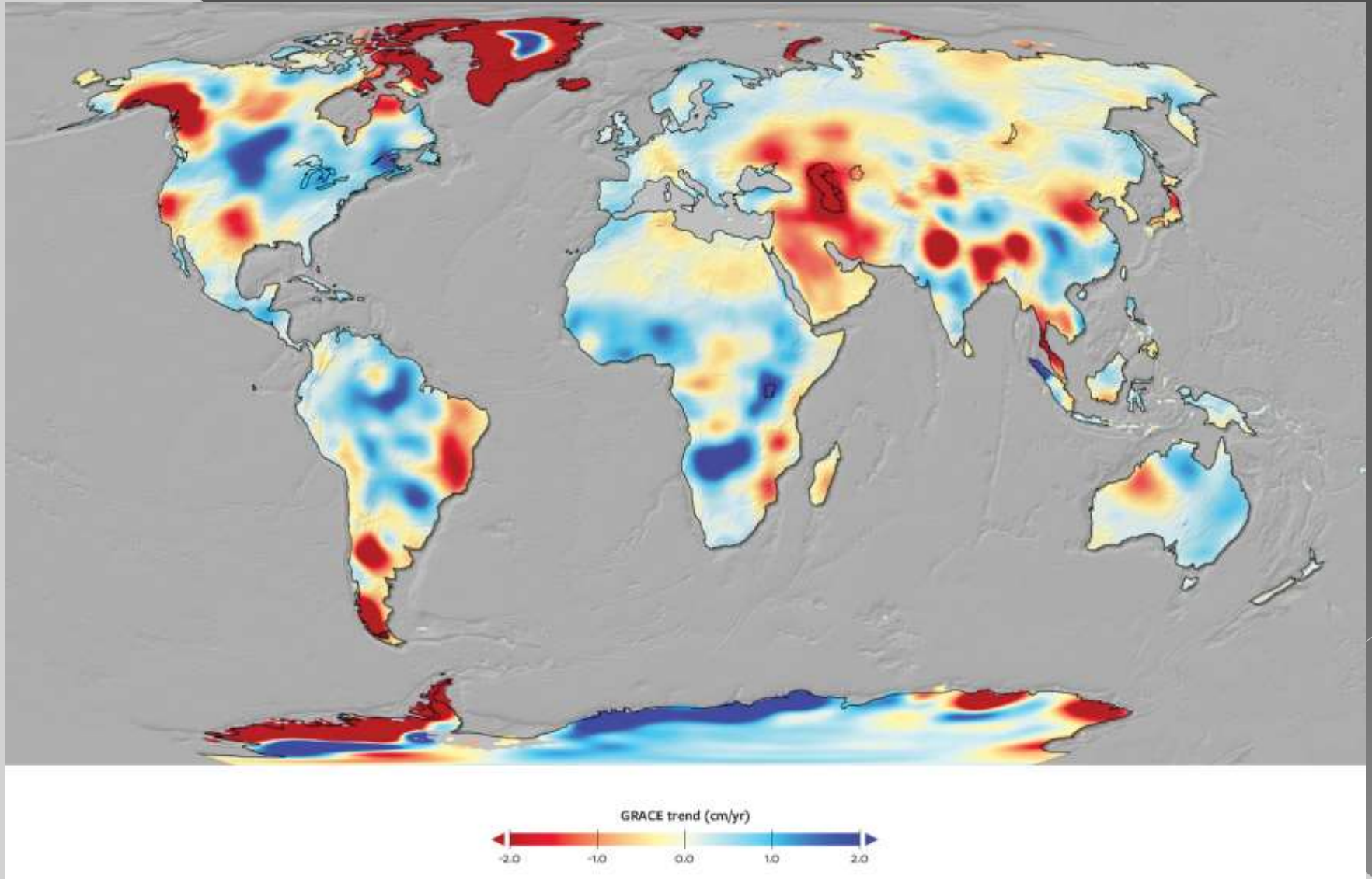
El sistema de ecuaciones no lineales que resuelve los problemas de la atmósfera de momento sigue ofreciendo probabilidades. Dada día más ajustadas, es cierto, porque se ha mejorado mucho la información que se obtiene de los modelos meteorológicos. Pero además de la información que se extrae hay que tener en cuenta otras variables geográficas.



(Via Pixabay)

Existen datos a escala mundial sobre el agua subterránea

Mapa de los cambios en la cantidad de agua del 2002 al 2016

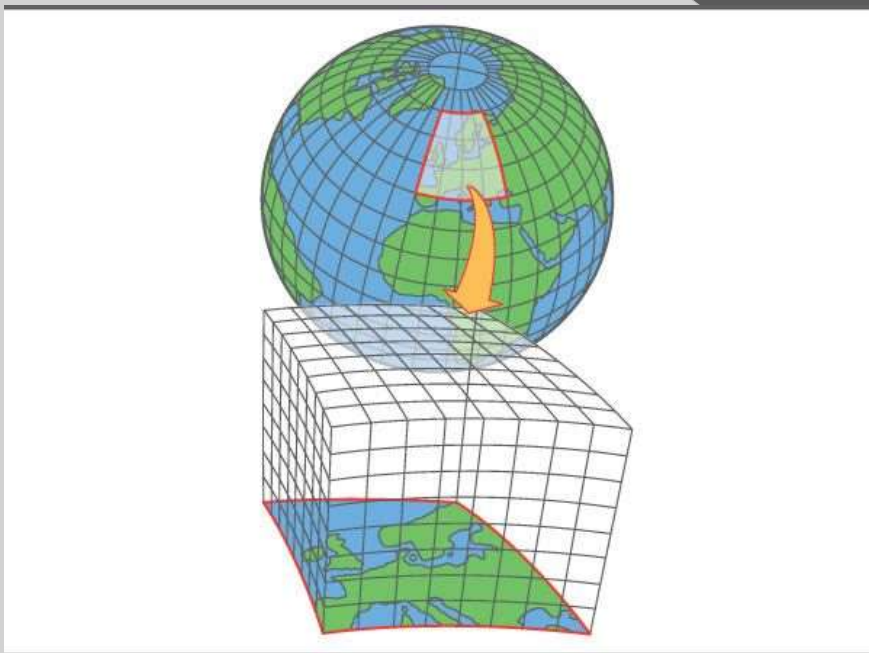


Es indudable la necesidad de los modelos numéricos de predicción meteorológica a pesar de los errores que tienen asociados

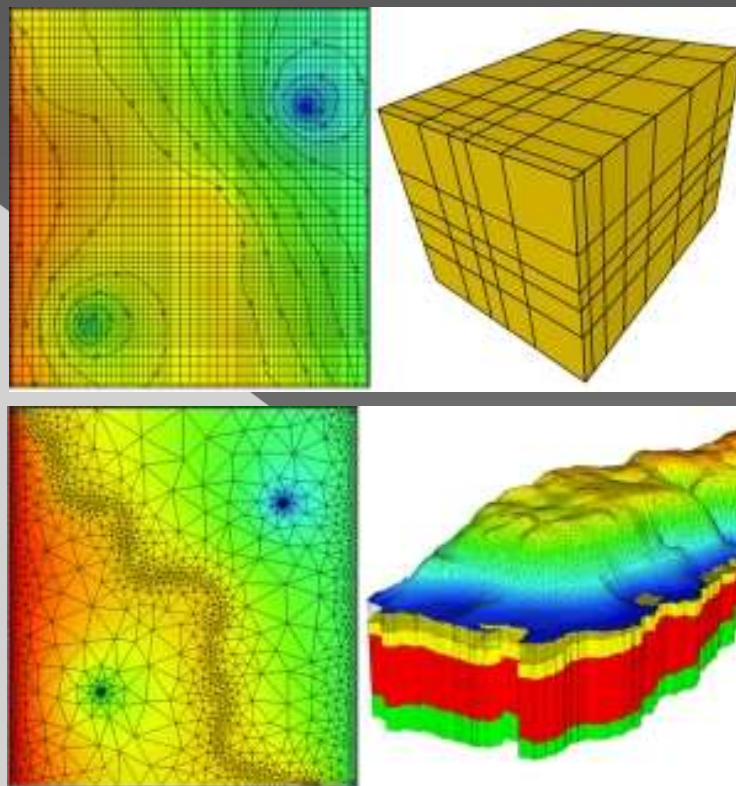
De igual modo:

Los **modelos numéricos son necesarios en la gestión de las aguas subterráneas**

Pero... a nivel **nacional su uso sigue no siendo “estándar”**



http://www.aemet.es/es/idi/prediccion/prediccion_numerica



<https://www.waterloohydrogeologic.com/2013/08/26/groundwater-modeling-numerical-methods-which-one-should-you-use/>

Mismas razones que encontramos para los modelos de aguas superficiales

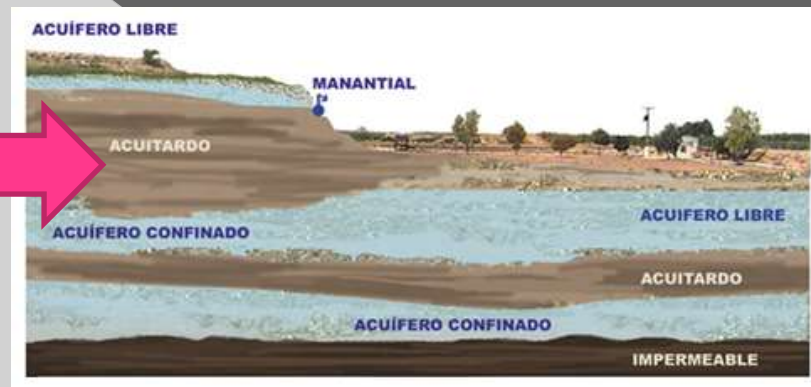


PARA TOMAR ACCIONES: Advierte a los Sistemas de prevención y atención de desastres sobre amenazas reconocida de inundación o sequía que pueden traer efectos sobre la población

PARA PREPARARSE: Indica la presencia de un fenómeno sin llegar a ser inminente los efectos sobre la población. Advierte sobre prepararse frente a la posible ocurrencia de la amenaza reconocida.

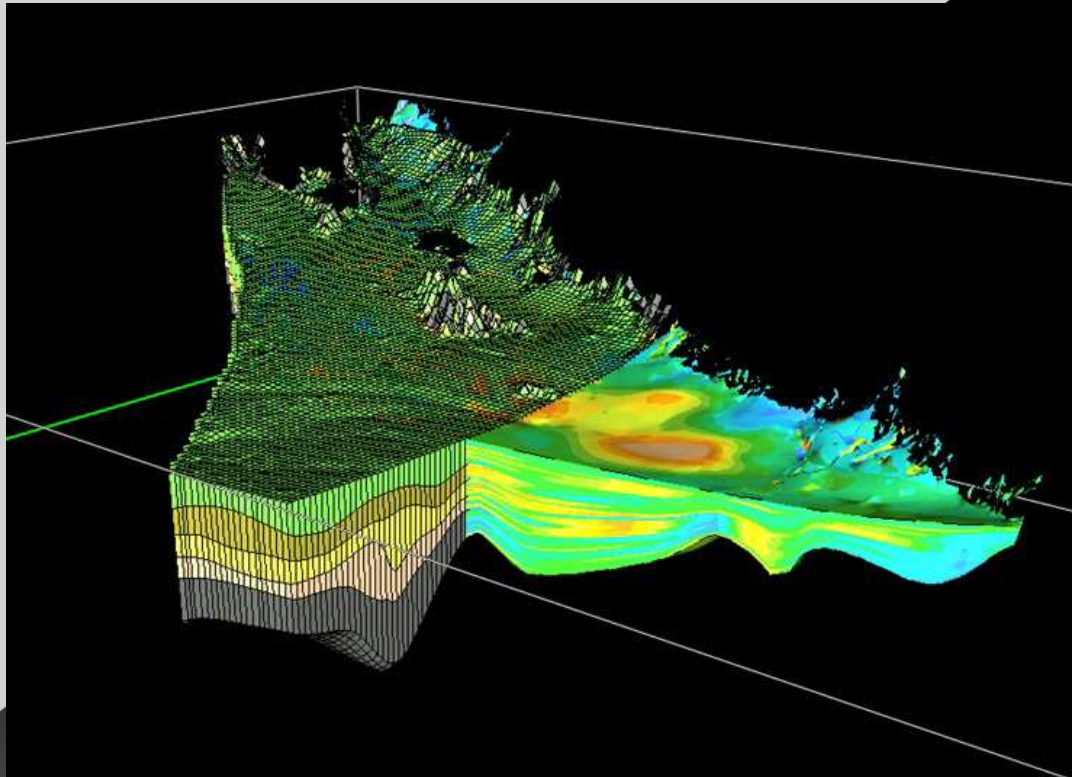
PARA INFORMARSE: Detección inicial de una amenaza reconocida sin llegar a ser inminente los efectos sobre la población. Es informativa.

CONDICIONES NORMALES: No hay amenaza reconocida



<https://hispagua.cedex.es/datos/hidrogeologia>

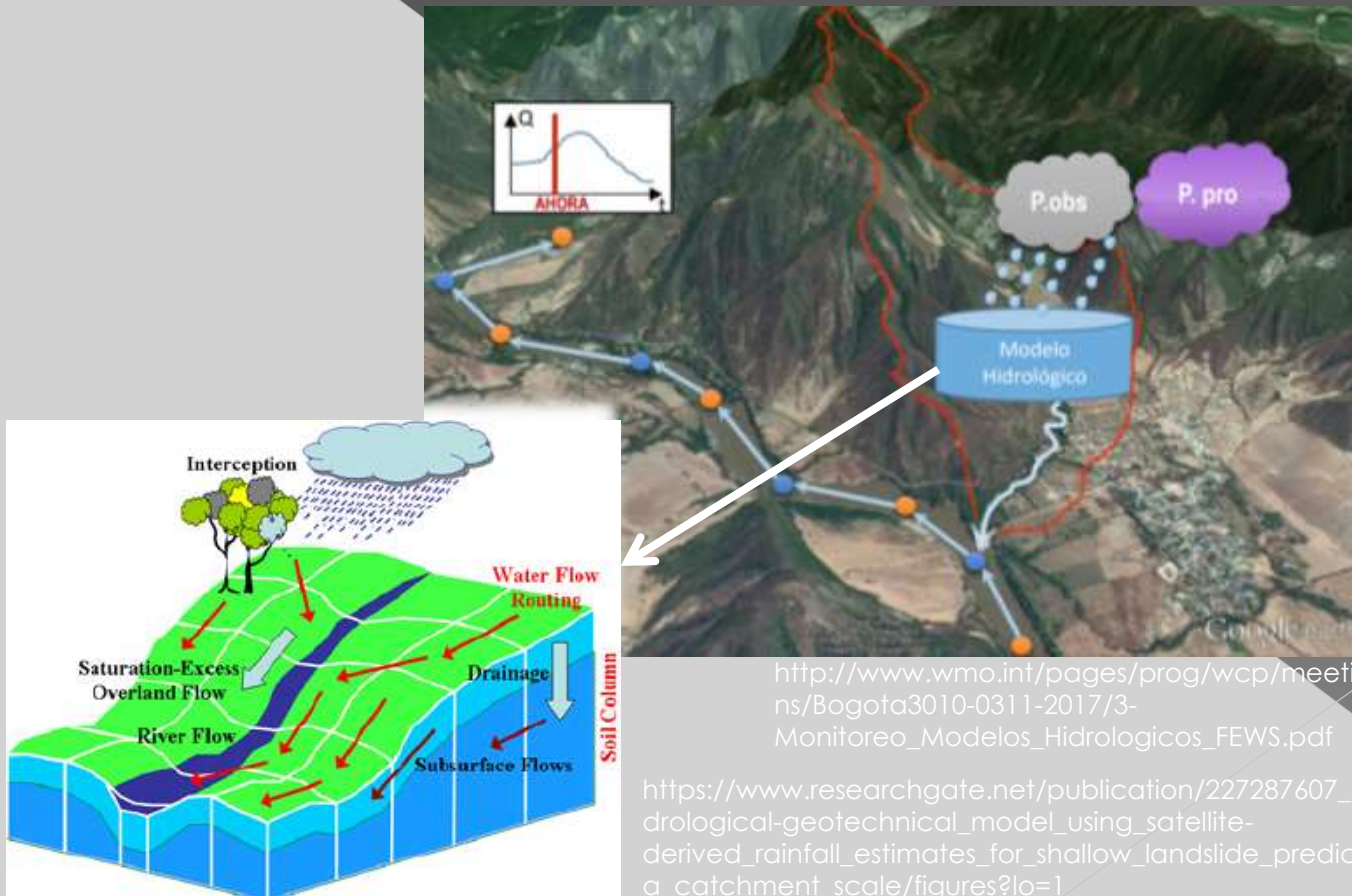
Concepto de modelo y ejemplos



<https://gssiwater.com/experts-in-groundwater-modeling/>

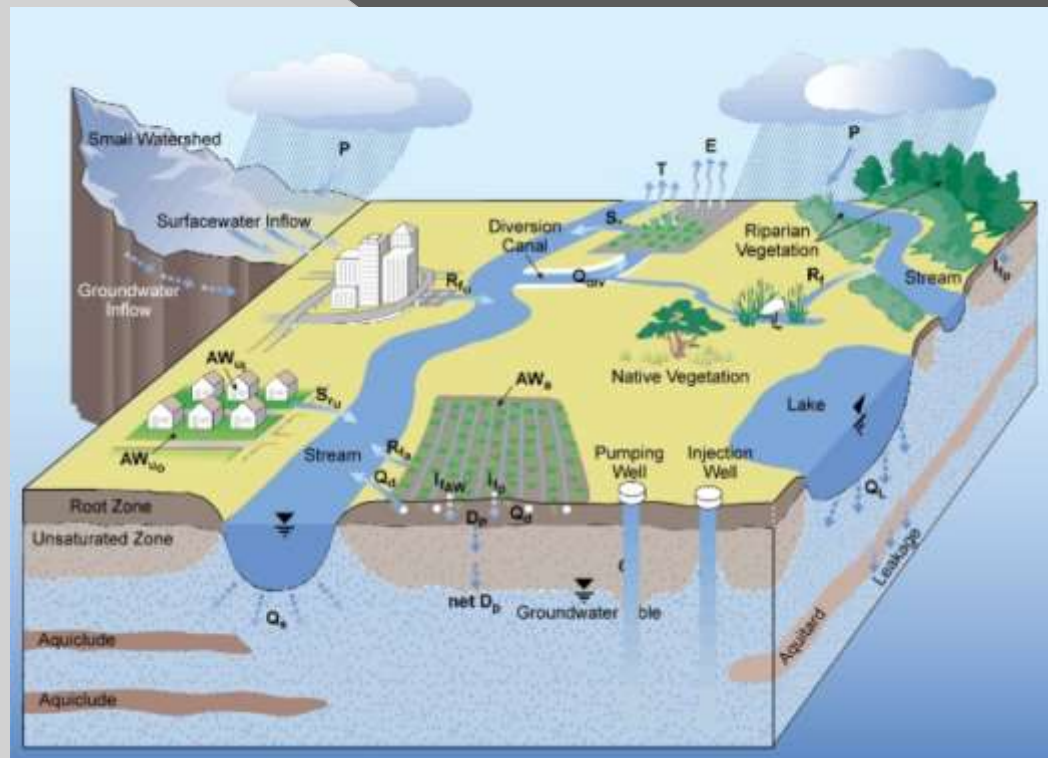
Modelo hidrológico

- Es una simplificación conceptual que se realiza con el ordenador para simular y predecir el movimiento y uso del agua.



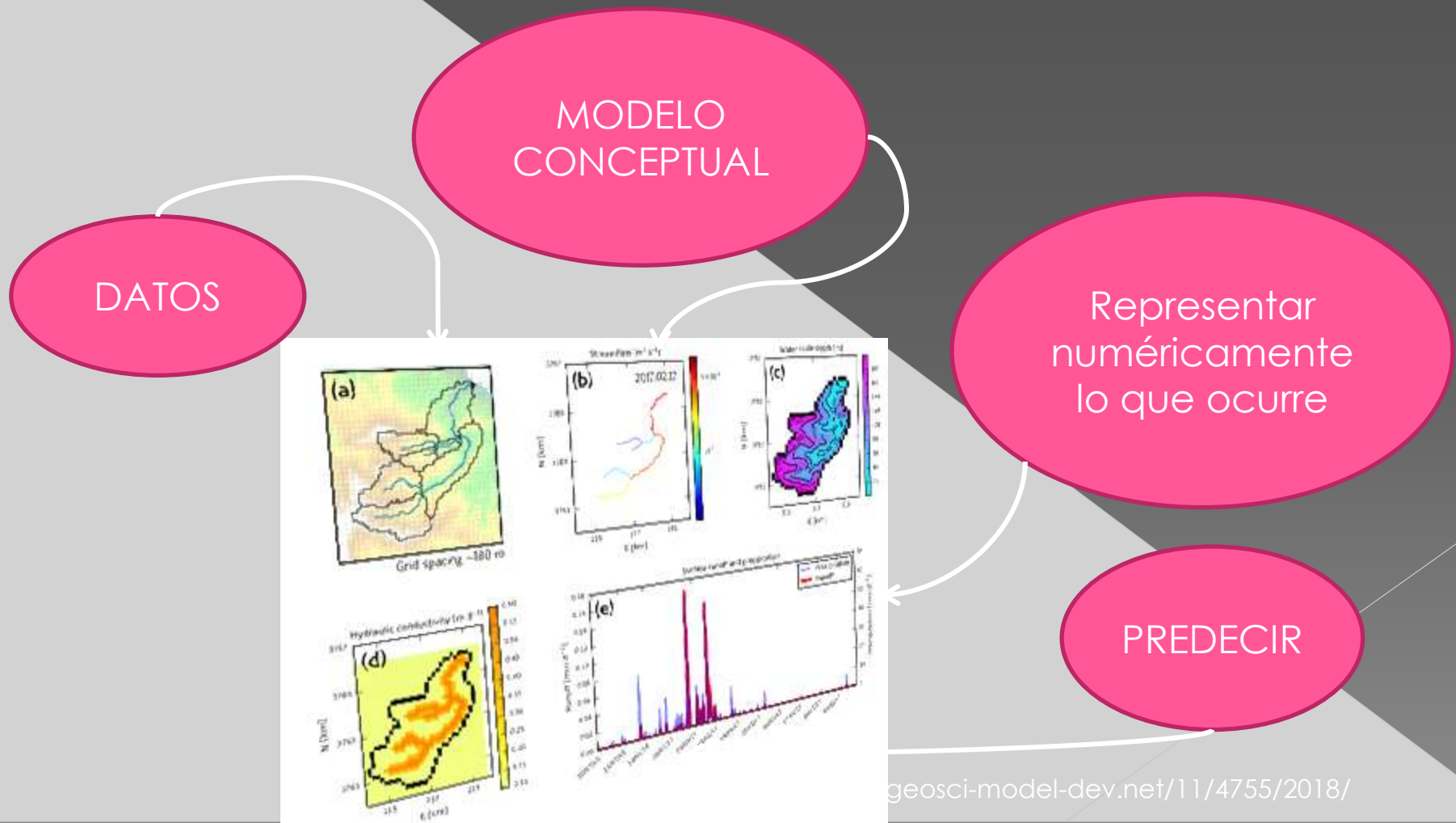
Modelo hidrogeológico

- Es una simplificación conceptual que se realiza con el ordenador para simular y predecir el movimiento y uso del agua **subterránea**.



Modelo hidrogeológico

- Proporciona un marco para organizar:



Ejemplos de aplicación

California Water Science Center

Sustainable Groundwater

California Groundwater Model Archive

SGM Home Sustainability Indicators **Planning Tools** Resources

Archivo con 37 modelos de acuíferos

Groundwater Modeling

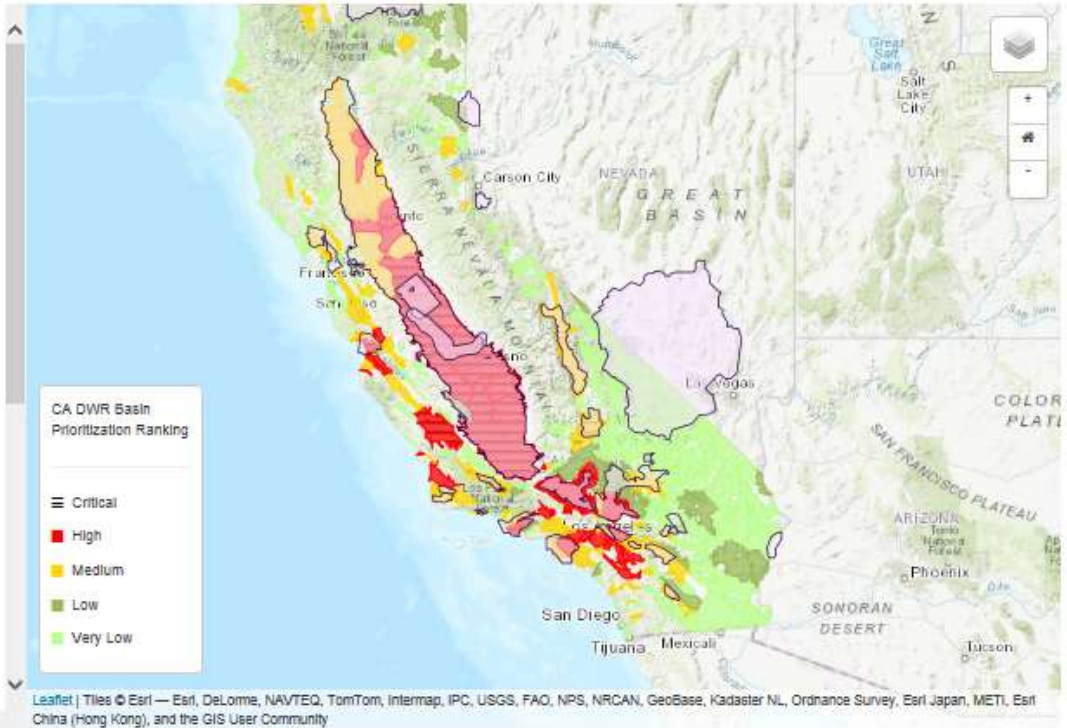
A hydrologic model is a simplified conceptual and computer model used to simulate and predict the movement and use of water. It takes into account various or all components of the landscape, aquifer system, and water cycle and provides a framework to organize data, knowledge, and understanding of hydrologic systems. Models can provide insights that water-resource managers need to plan effectively for future water demands and to answer scientific and management questions.

California Groundwater Model Archive

The USGS models shown on this site are in the public domain, and are freely available. They are based on MODFLOW and other public-domain USGS software. Links to publications and web resources associated with each model are shown in the table next to the model map. The associated model files for some of these models are currently available via links in this table; if a link is not available, and you would like to receive the model files, please contact Steve Phillips at sphillip@usgs.gov.

Click on a model on the map or in the list for detailed information and data downloads.

- [Antelope Valley](#)
- [Borrego Valley](#)
- [Carson Valley](#)
- [Central Valley Hydrologic Model](#)
- [Cuyama Valley](#)
- [Death Valley](#)
- [Fort Irwin, Bicycle Basin](#)
- [Fort Irwin, Irwin Basin Aquifer](#)
- [Fort Irwin, Langford Basin](#)
- [Goose Lake Basin](#)
- [Honey Lake Valley](#)
- [Indian Wells Valley](#)
- [Joshua Tree](#)
- [Lompoc Area](#)
- [Los Angeles, Central & West Coast Basins](#)
- [Modesto](#)
- [Modesto NAWQA TANC](#)
- [Mojave River Basin](#)
- [Owens Valley](#)
- [Pajaro Valley Aquifer System](#)
- [Parker Valley - Palo Verde - Cibola](#)



California Groundwater model archive

Santa Barbara

Model Detail

Year Published: 1998

Counties: Santa Barbara

Sustainability Indicator(s) Modeled: LVL, SEA, SW/GW (drn), WQ

Type of Model: Groundwater Flow Model with Density-Dependent Solute Transport Model
Modeling with Scenarios: Yes

Uncertainty Analysis: Parameter, Prediction
Optimization: Yes

Climate Change Analysis:

Advanced Analyses: Multi-Objective Trade-off Analysis

Model Data

Full Archive: [WRIR99-4246_Santa_Barbara_Opt.zip](#)

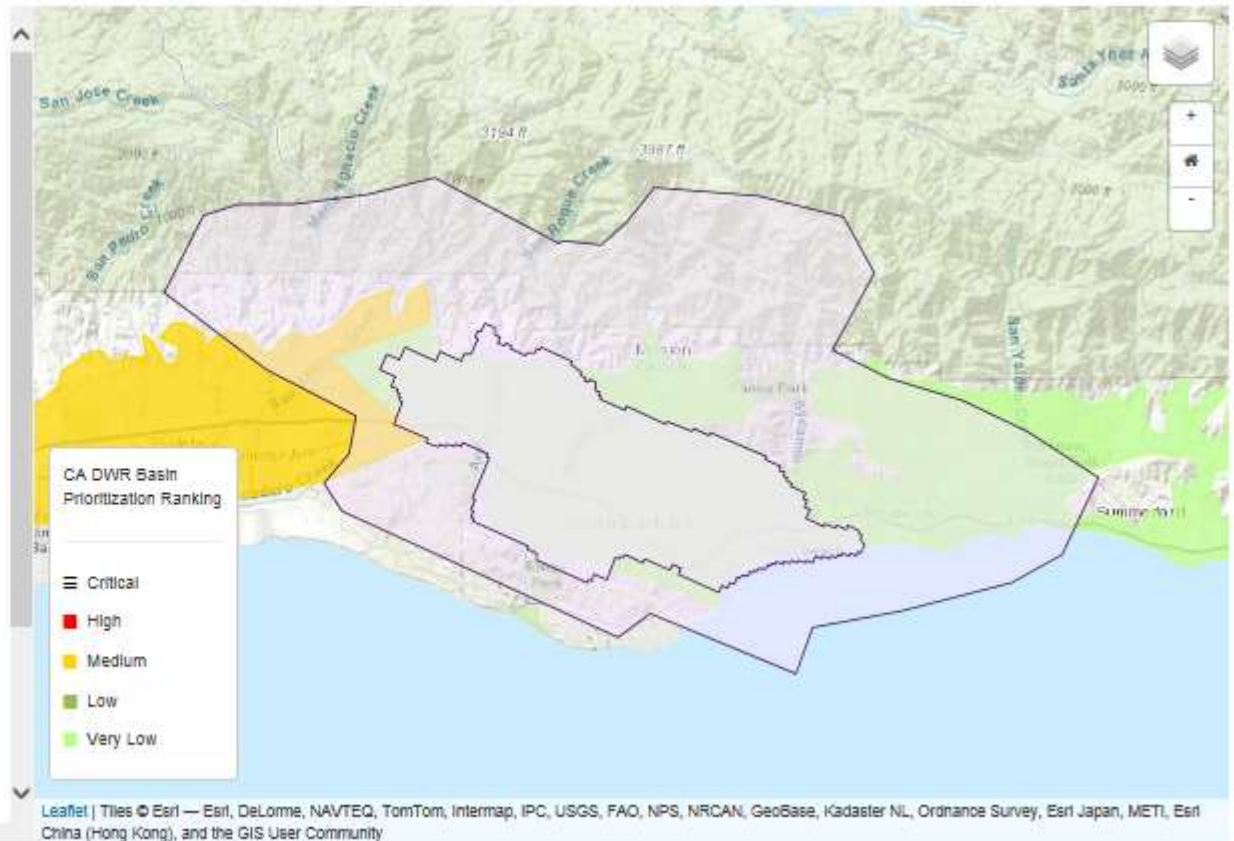
Model Input: [WRIR99-4246_Santa_Barbara_Opt-input.zip](#) (1.1 MB)

Model Output: [WRIR99-4246_Santa_Barbara_Opt-output.zip](#) (249 KB)

Additional Modules Needed:

Additional Datasets:

Publications



Publications

A simulation-optimization model for water-resources management, Santa Barbara, California

[Go to Website >>](#)

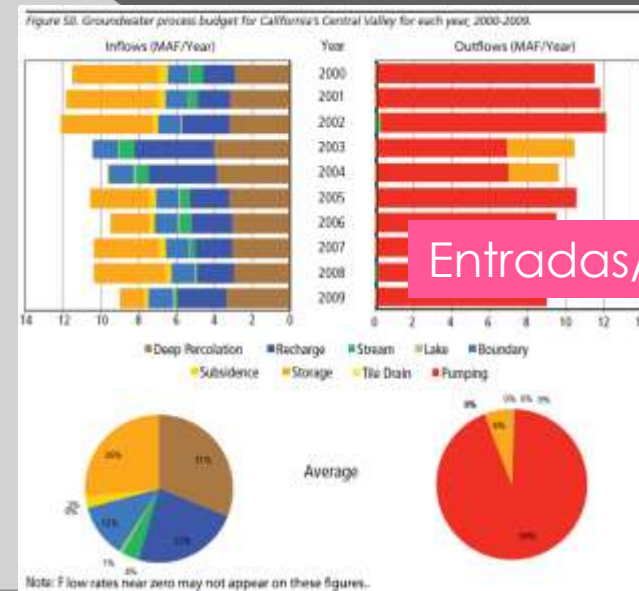
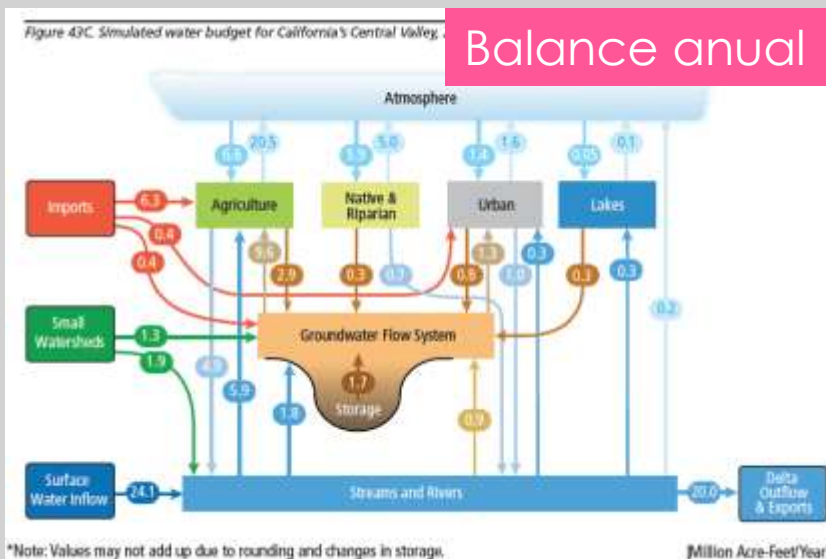
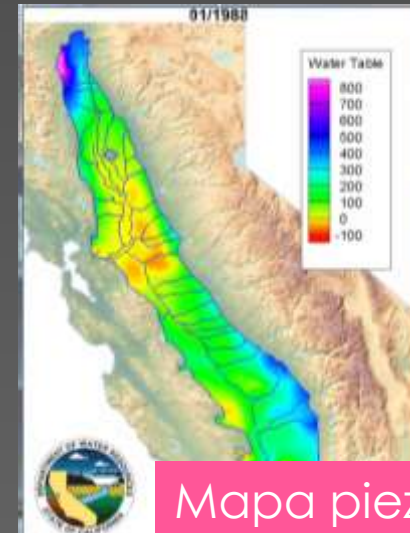
- Datos de entrada
- Resultados
- Informes, publicaciones
- Páginas web

<https://ca.water.usgs.gov/sustainable-groundwater-management/california-groundwater-modeling.html>

California Central Valley

<http://c2vsim.water.ca.gov/c2vsim/iwfm.html#>

<https://ca.water.usgs.gov/sustainable-groundwater-management/california-groundwater-modeling.html>





Latest outlook

Informes mensuales del Servicio Geológico Británico

Summary map



[Click on the image to view full size.](#)

This site provides an outlook for the water situation for the UK over the next three months and beyond. It should be used alongside [other sources of information](#) such as flood warnings, meteorological forecasts and water situation reports.

[Download the summary as a PDF](#)

Period: From October 2019 Issued on 08.10.2019 using data to the end of September 2019

Summary

The outlook for October is for normal to below normal river flows in parts of East Anglia and southern central England, with normal to above normal flows elsewhere. A similar pattern is expected to persist for the period to December. Groundwater levels are expected to be below normal in southern and eastern parts of England, and normal elsewhere. Over the period to December it is likely that many groundwater levels will return to normal, with below normal levels persisting in the Chilterns and the Chalk to the north of London.

Rainfall

September rainfall totals were generally above average across England and Wales, with the exception of parts of south-east England where rainfall was below normal. In Northern Ireland and southern Scotland rainfall was slightly above normal, but further north and west rainfall was below normal.

The rainfall outlook for October (issued by the Met Office on 26th September) is that above average precipitation is slightly more likely than below average precipitation. For October-November-December as a whole, above average precipitation is more likely than below average precipitation. The probability that UK average precipitation for October-November-December will fall into the driest of five categories is around 20% and the probability that it will fall into the wettest of five categories is between 25% and 30% (the 1981-2010 probability for each of these categories is 20%).

River flows

River flows in September were generally above average across the majority of the UK, with some notably high flows in Wales and northern England. Along the south coast of England and in northern Scotland flows were closer to normal, and areas of below normal flows persisted in East Anglia and southern central England.

During October river flows in most parts of the UK will be normal to above normal, with above normal flows most likely to occur in parts of central England. In contrast river flows in East Anglia and parts of southern central England are most likely to be normal to below normal. The same pattern of river flows is likely to persist during the October-December period.

Groundwater

Groundwater levels were below normal across the majority of the southern and eastern Chalk aquifer, notably so through the Chilterns into East Anglia. Elsewhere, levels were generally in the normal range, with localised exceptions.

Groundwater levels are expected to be below normal to notably low throughout most of the south-eastern Chalk over one month, but becoming more normal in the three month outlook, particularly along the south coast. In the north-west, levels are likely to be normal to above normal over one month, increasing to notably high levels at a number of sites in the three month forecast. Sites in central England and Wales show predominantly normal levels in both the one and three month forecasts.

Further information - October 2019

Comprehensive further information that supports the production of the Hydrological Outlook UK is available [here](#).

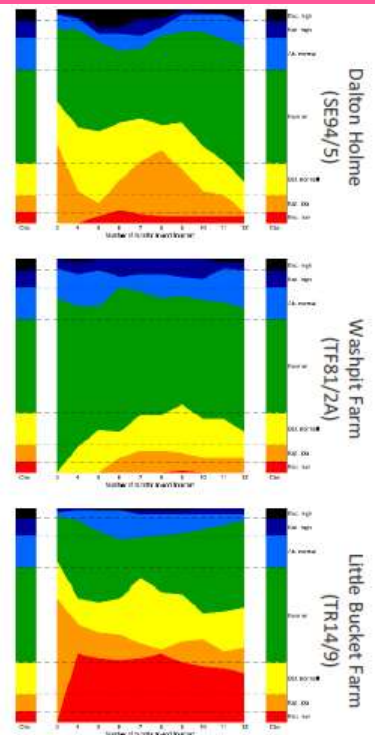
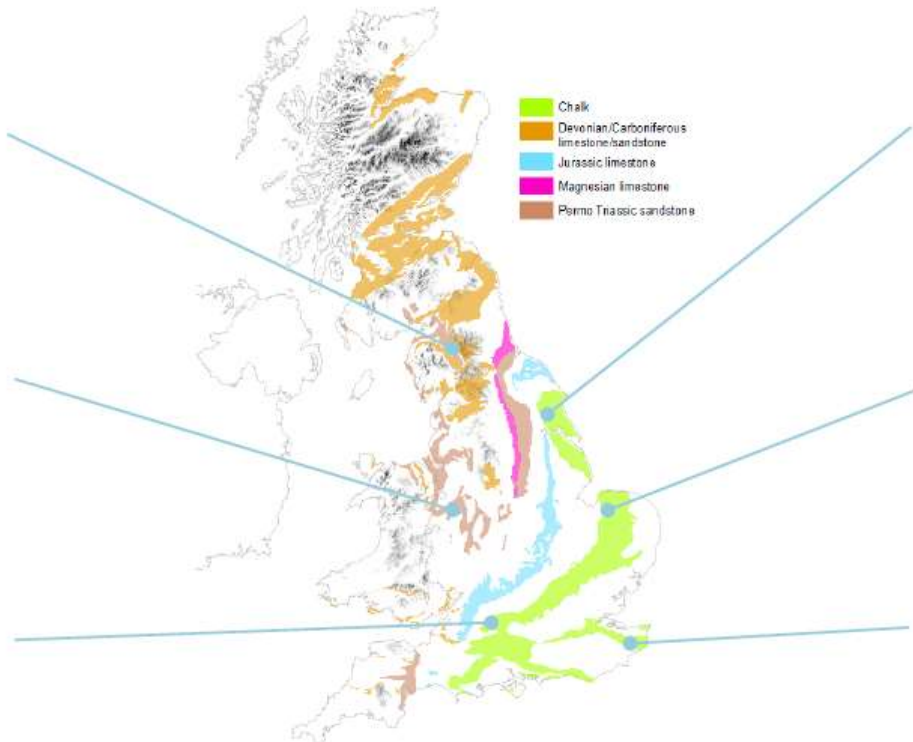
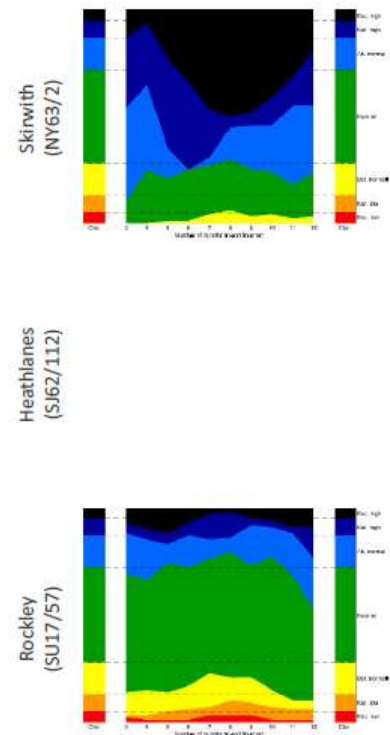
Outlook based on modelled groundwater from historical climate

Period: October 2019 – September 2020

Issued on 03.10.2019 using data to the end of September

Evaluación del estado de los acuíferos 3/12 meses futuros Según el nivel piezométrico

The be



This outlook is based on monthly ensembles of historical sequences of observed climate (rainfall and potential evapotranspiration) that form input to hydrological models. The outputs are probabilistic simulations of the average groundwater level over the forecast horizon (3 to 12 months ahead), at each location.

that fall within each the seven categories: exceptionally low, notably low, below normal, normal, above normal, notably high and exceptionally high. The monthly variations can be compared to the long-term average distribution of levels, which are shown as columns on the left and right of each graph.

the atmosphere and ocean..It is hence possible that some of the historical sequences used might be inconsistent with current large-scale atmospheric conditions and would therefore be unlikely to occur in the next few months.

The graphs show variation over time of the number of simulated groundwater levels in each monthly ensemble,

This outlook is based entirely on historical sequences and therefore does not contain any knowledge of the state of

<http://www.hydoutuk.net/latest-outlook>

The Hydrological Outlook UK provides an outlook for the water situation for the UK over the next three months and beyond. For guidance on how to interpret the outlook, a wider range of information, and a full description of underpinning methods, please visit the website: www.hydoutuk.net

¿Qué se necesita?



3 bloques

- ◉ Datos
- ◉ Modelo conceptual
- ◉ Código numérico

Datos

- Recarga
- Piezometría
- Conductividad hidráulica
- Almacenamiento
- Porosidad
- Geometría
- Condiciones de contorno
 - > Flujo (manantiales, humedales,...)
 - > Bombeos
 - > Ríos

Recarga por precipitación

- Diaria
- Cálculo de la escorrentía y la infiltración
 - > Mapas de precipitación/ T^a
 - > Mapas de suelo
 - > Mapas nivel freático

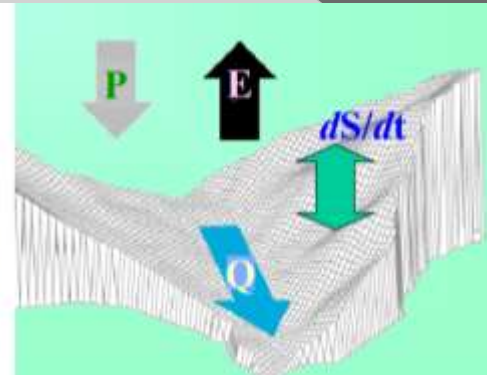


ECUACIÓN DE BALANCE DE AGUA

Precipitación = Escorrentía + Evapotranspiración
+ Cambios Almacenamiento

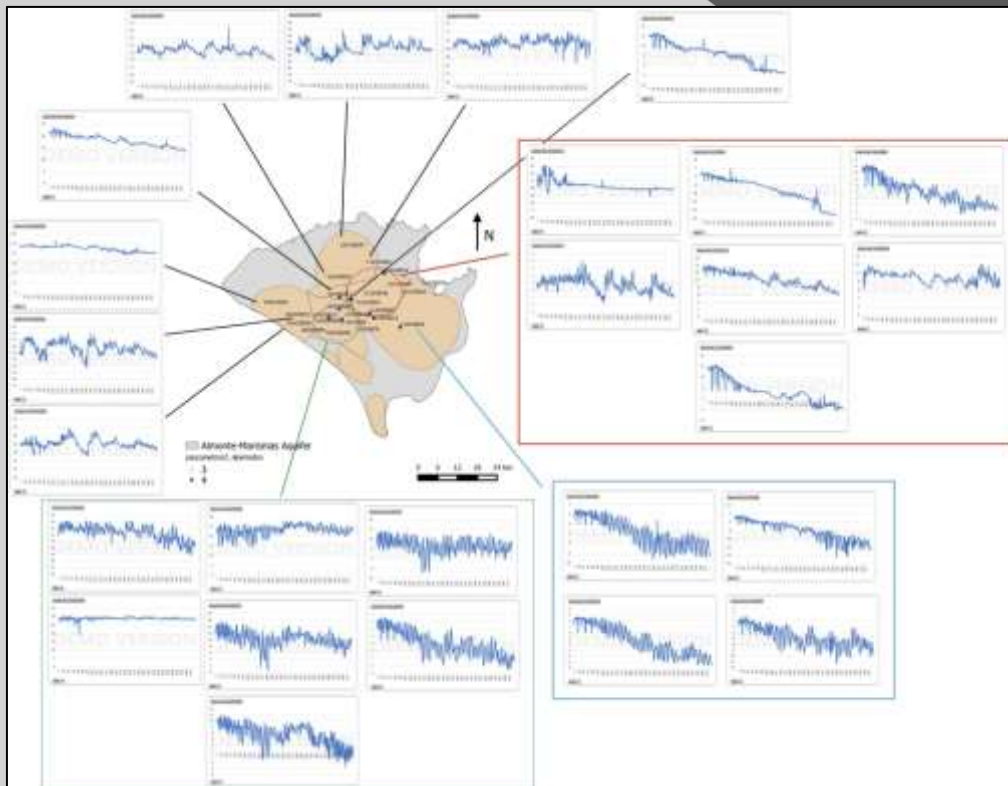


Visual Balan

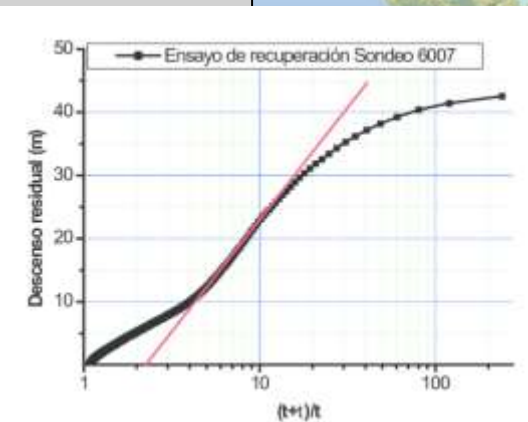
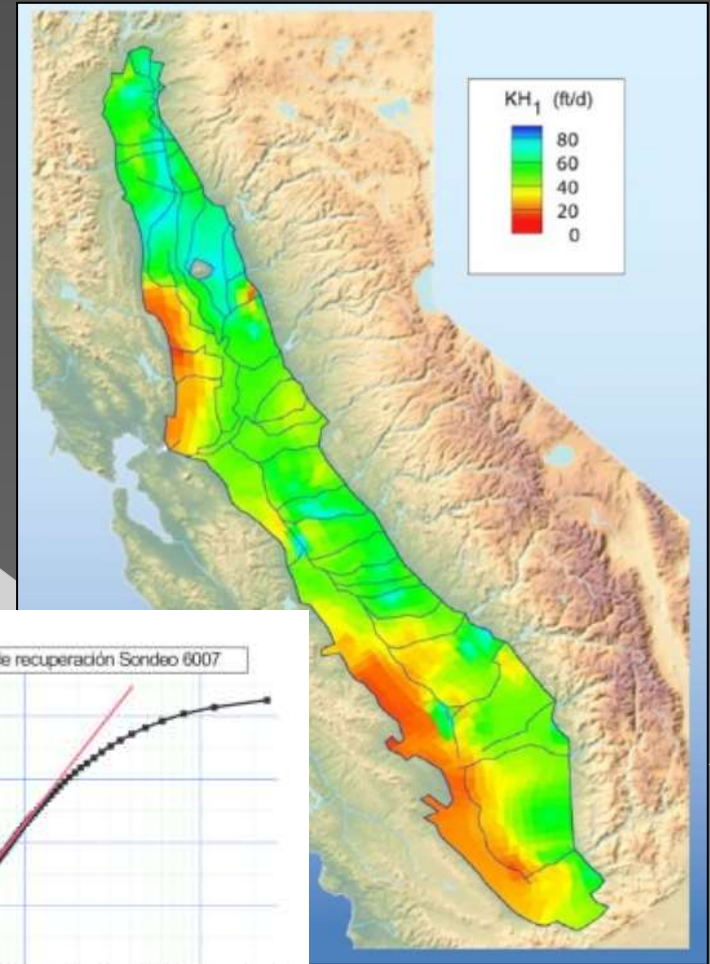
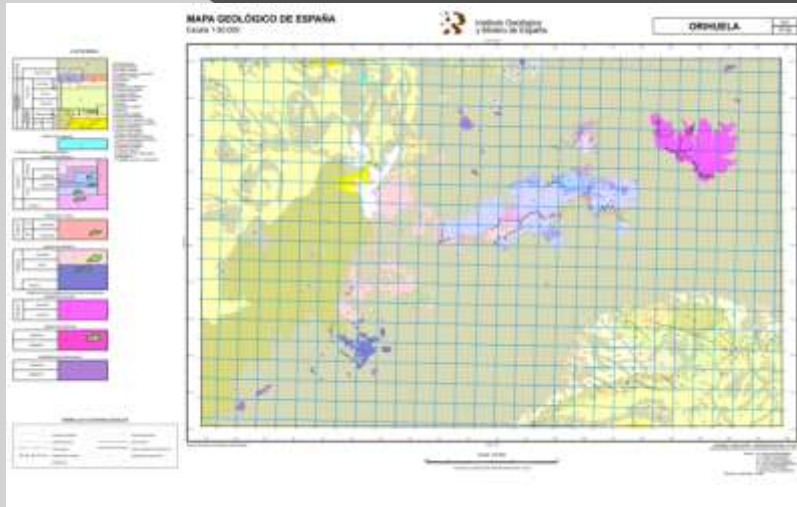


https://www.youtube.com/watch?v=P_3nT4BzMvw

Piezometría



Conductividad hidráulica

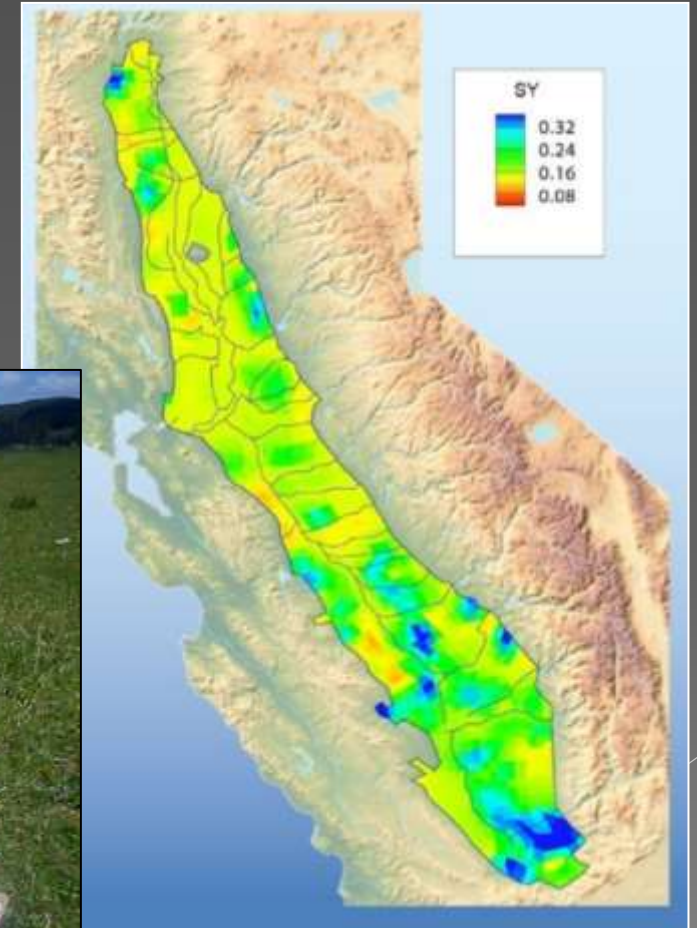
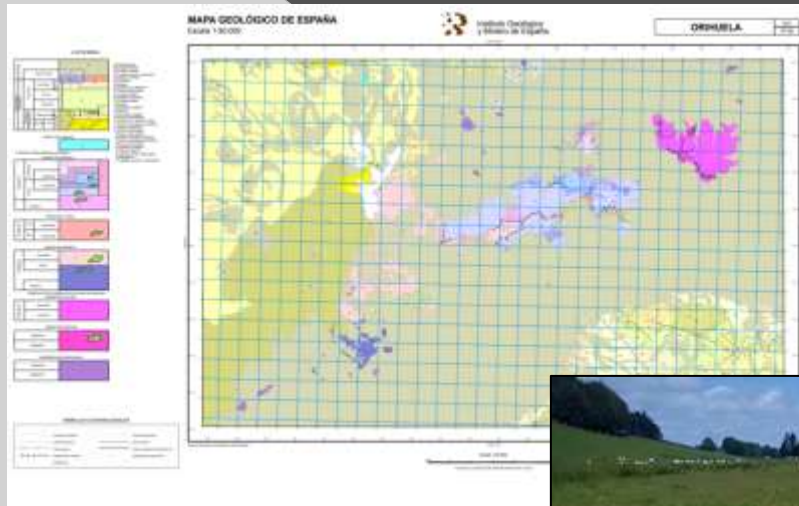


<https://ca.water.usgs.gov/sustainable-groundwater-management/california-groundwater-modeling.html>

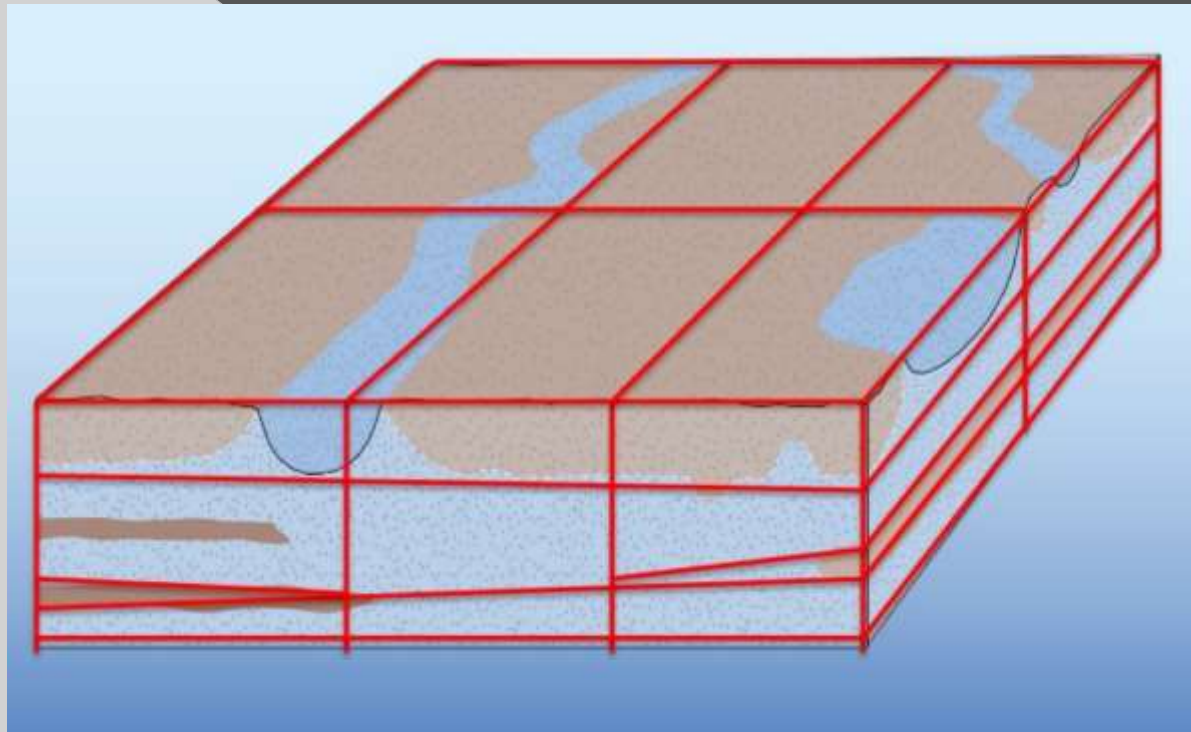
https://www.researchgate.net/publication/277361049_Analisis_hidrogeologico_de_la_escobreria_exterior_de_la_antigua_mina_de_As_Pontes/figures?lo=1&utm_source=google&utm_medium=organic

<http://muchik.com/prueba-de-bombeo/>

Almacenamiento/Porosidad



Geometría

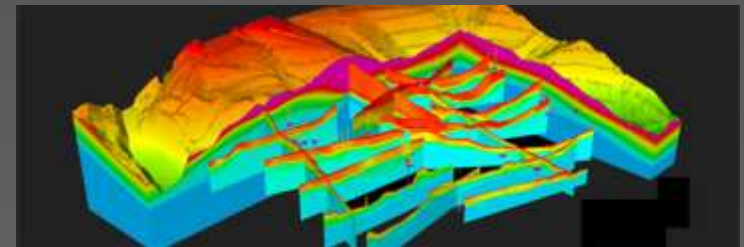
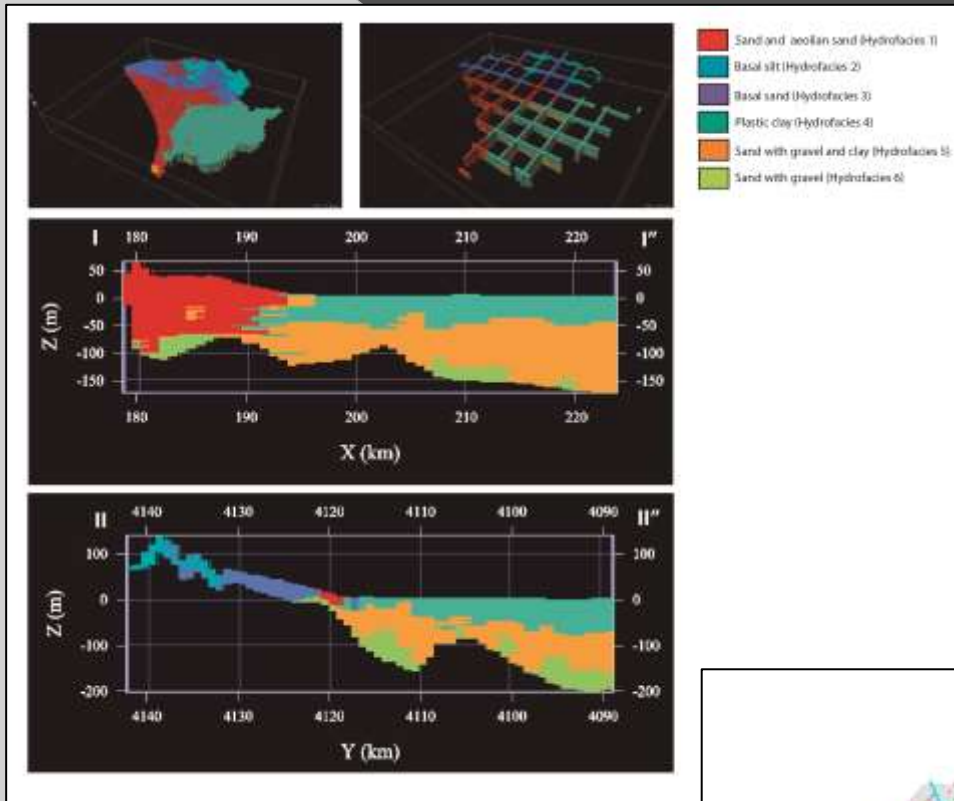


Resultados

- Niveles piezométricos
- Líneas de flujo
- Isopiezas
- Variación almacenamiento
- Recursos subterráneos

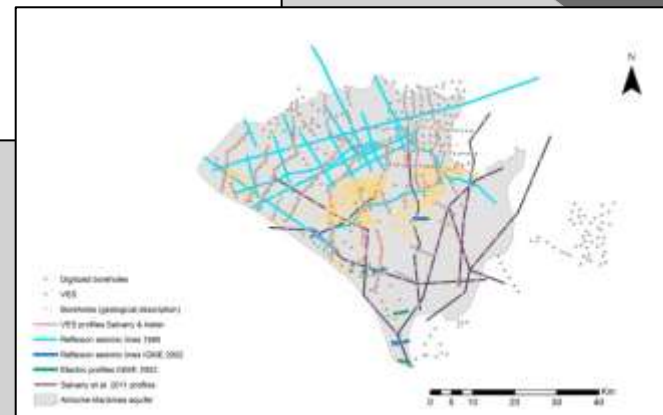


Geometría

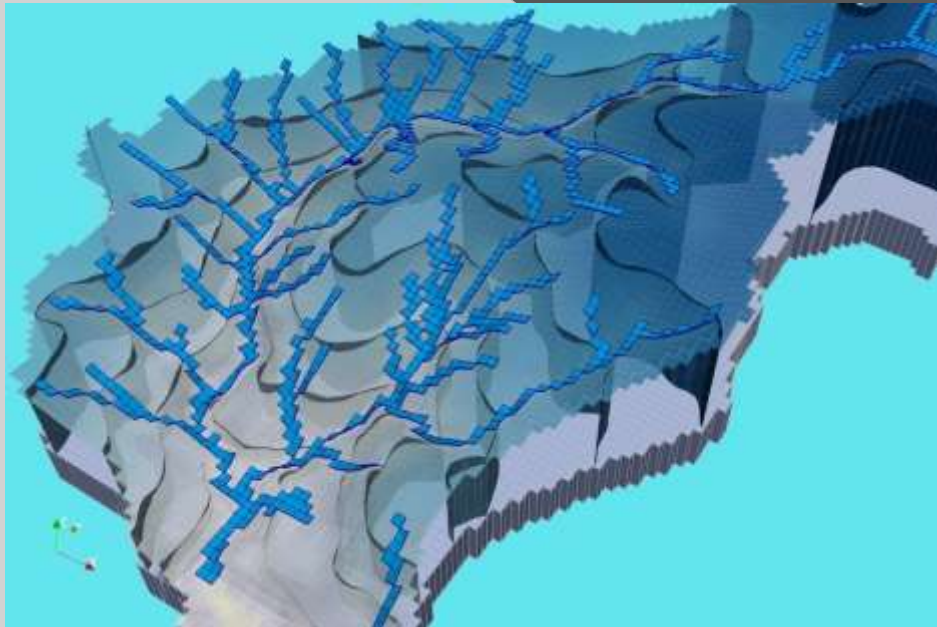


http://www.aquiferindia.org/Groundwater_Modeling.aspx

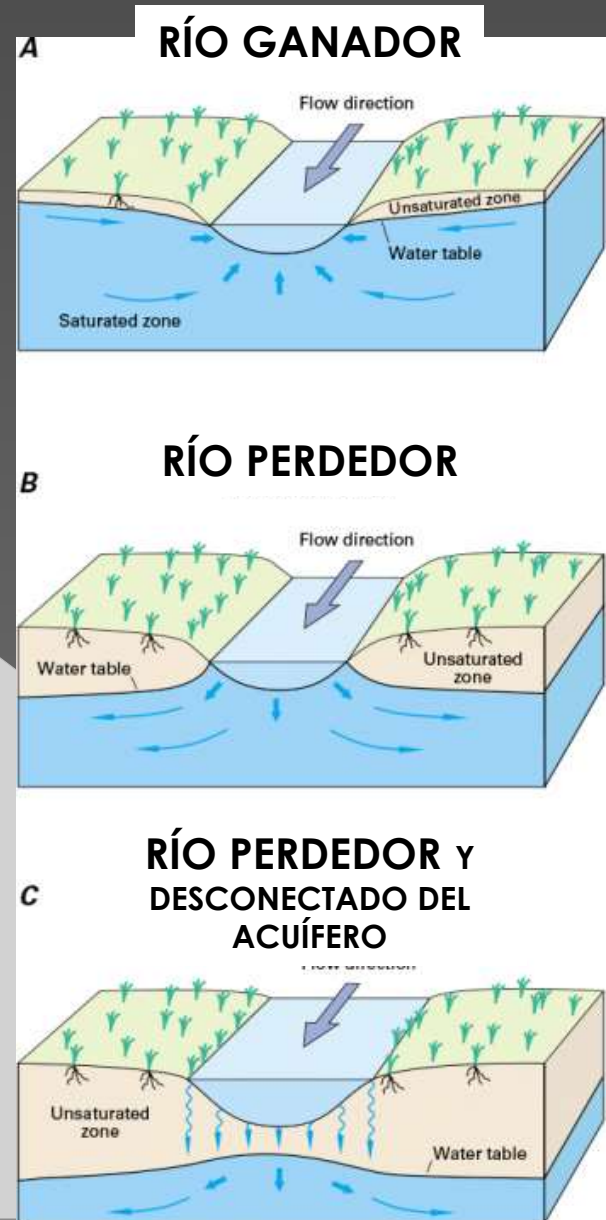
Naranjo et al. (2019)



Condiciones de contorno: Ríos

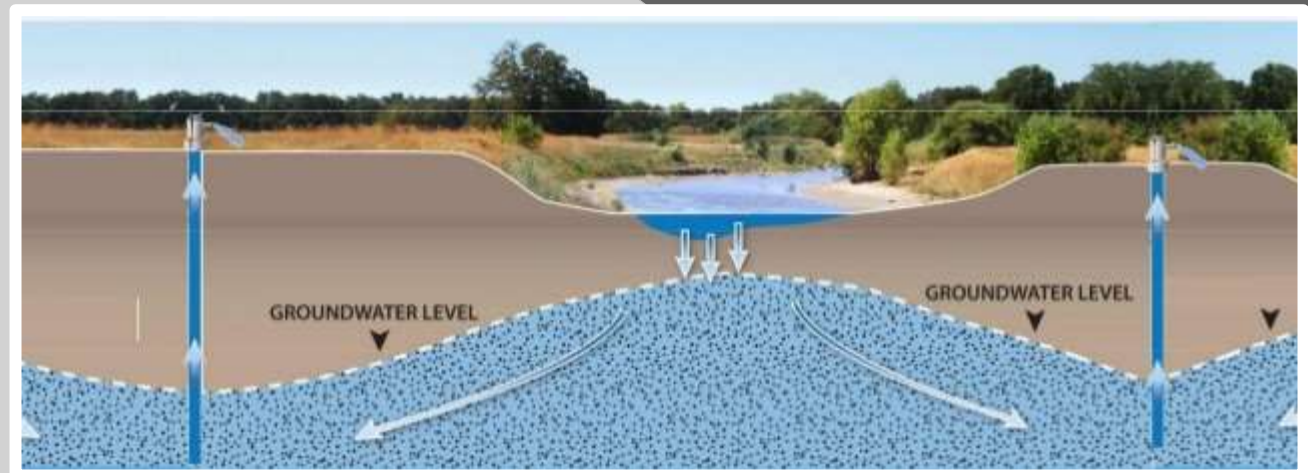
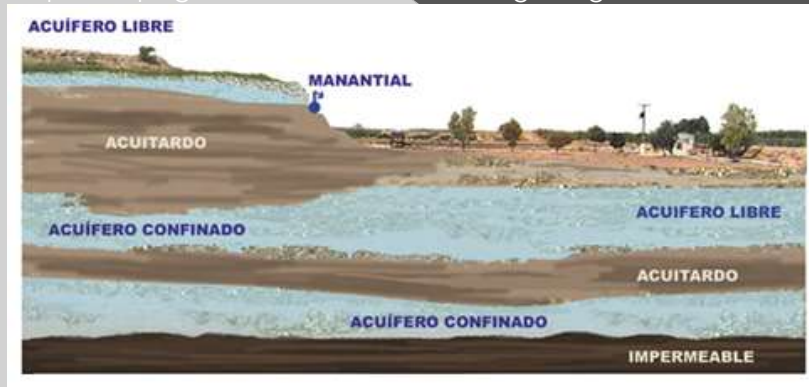


gidahatari.com



Condiciones de contorno: Manantiales, humedales

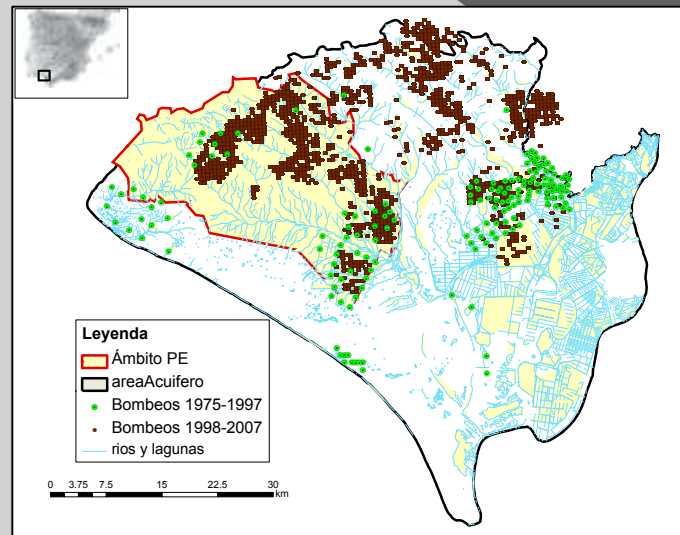
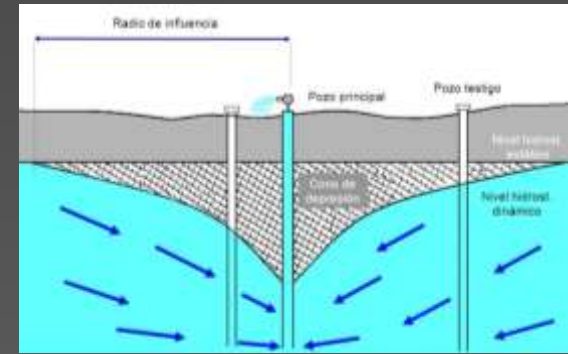
<https://hispagua.cedex.es/datos/hidrogeologia>



<https://www.slideshare.net/cpkumar/surface-water-and-groundwater-interaction>

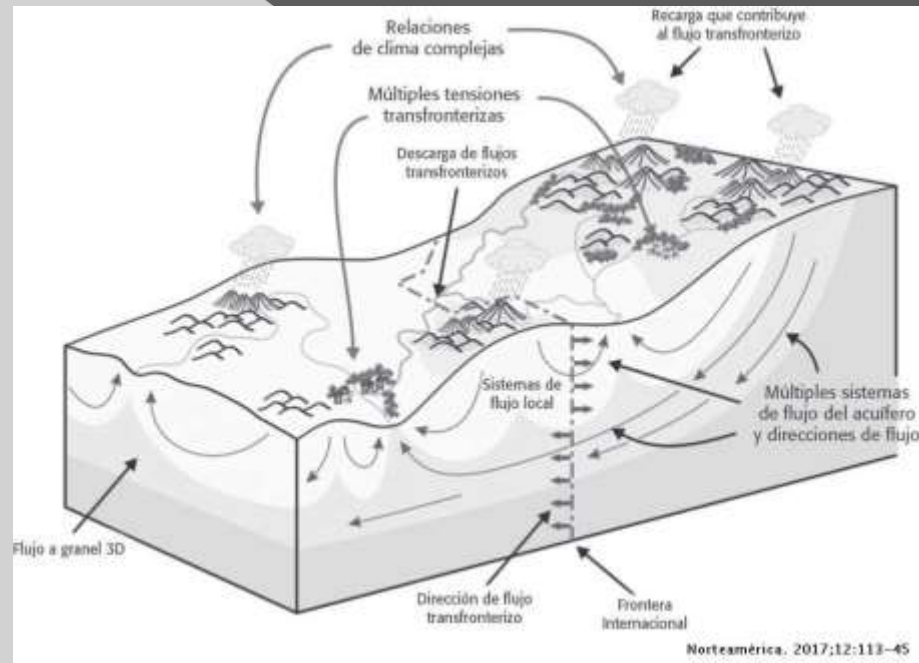
Condiciones de contorno: Bombeos

- ◉ Datos extracciones:
 - > Uso urbano, industrial y regadío



Modelo conceptual

- Describe cualitativamente el **funcionamiento del acuífero**, los procesos relevantes, las entradas y salidas al sistema, las propiedades físicas más importantes y su distribución espacial.
- Es una **representación esquemática** de la realidad que hacemos en función de los datos disponibles y el criterio de experto hidrogeológico.



Código numérico

- Es la representación matemática de los procesos físico-químicos que ocurren en el acuífero.

Groundwater Modeling Software Distribution Sites:

[USGS, Groundwater Modeling Software](#)
[EPA, Water Modeling Tools](#)
[EPA, Global Earth Observation System of Systems \(GEOSS\)](#)
[Integrated Groundwater Modeling Center, School of Mines, Colorado](#)
[Scientific Software Group \(commercial\)](#)
[Rockware, Inc. \(commercial\)](#)

Groundwater Modeling Software (public domain/free of charge):

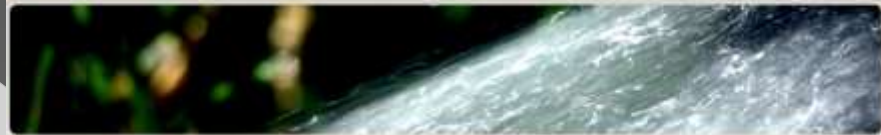
[MODFLOW \(USGS\)](#) - 3D finite difference, saturated flow
[MODFLOW Online Guide \(USGS\)](#) - online instructions to MODFLOW modules
[SUTRA \(USGS\)](#) - 2D/3D finite element, sat/unsat, variable density flow, transport, heat
[VS2DI \(USGS\)](#) - 2D finite difference, unsat flow & transport, heat flow
[MT3DMS \(University of Alabama\)](#) - 3D transport model to MODFLOW
[PHAST \(USGS\)](#) - 3D multicomponent, reactive transport (constant density flow and temperature)
[RT3D \(Pacific Northwest Laboratory\)](#) - MT3DMS + multispecies reactions
[TOUGH2 \(Lawrence Berkeley National Laboratory\)](#) - 3D multiphase/unsat flow & transport
[PFLOTRAN \(various US national laboratories\)](#) - 3D subsurface flow and reactive transport, unsat/sat, multiphase, porous/fracture, thermo-hydro-chemical
["Interactive Ground Water \(IGW\)" \(Michigan State Univ.\)](#) - integrated flow & transport
[ParFLOW \(Lawrence Livermore National Laboratory\)](#) - 3D large grid flow
[STOMP \(Pacific Northwest National Laboratory\)](#) - 3D multiphase flow & transport
[IWFEM \(Ca. DWR\)](#) - 3D finite element groundwater & surface water flow model
[Lizza-PAKP](#) and [WODASOLVER](#) - groundwater modeling software and GUI

GUIs for MODFLOW and other model codes:

[ModelMuse \(USGS, public domain\)](#) - GUI for MODFLOW, PHAST
[ModelMate \(USGS, public domain\)](#) - GUI for parameter estimation (UCODE with MODFLOW)
[FREEWAT](#) - plugin to ArcGIS-like open source [QGIS](#) as GUI for MODFLOW (open source)
[Groundwater Vistas](#)
[Visual Modflow Flex](#)
[Groundwater Modeling System \(GMS\)](#)
[Petrasim](#) (GUI for the TOUGH family of software, 3D modeling)
[EQUIS \(Earthsoft\)](#) - environmental data management software
[Argus ONE](#) (generic GUI - legacy/outdated software)

University of California, Division of Agriculture and Natural Resources

Groundwater



Groundwater Modeling Software (commercial):

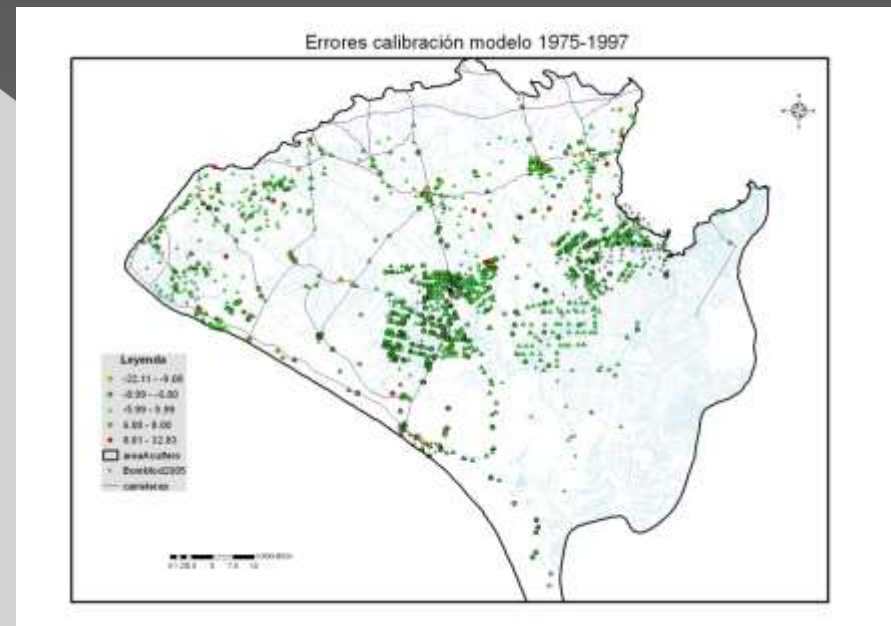
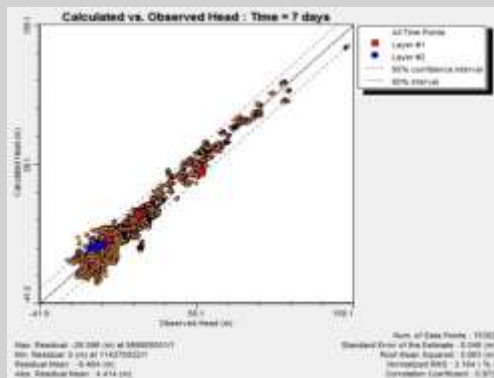
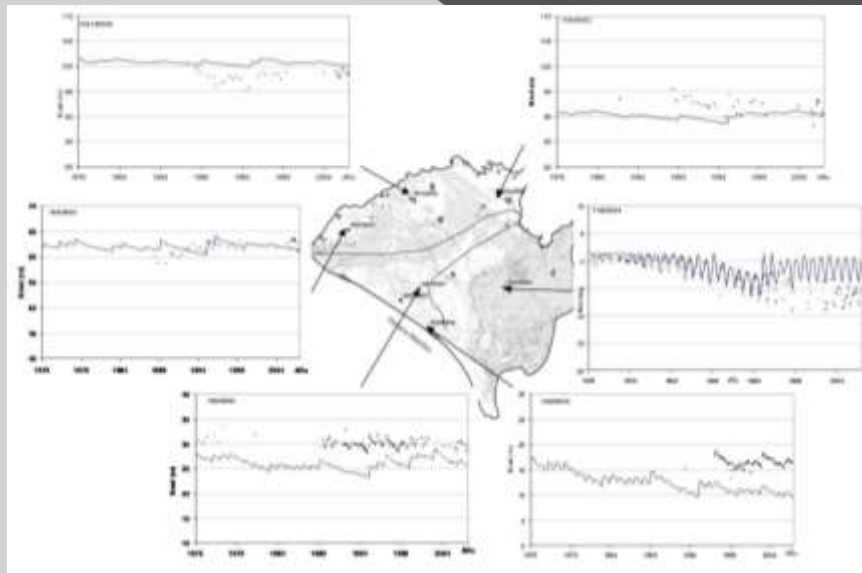
[MODHMS \(Hydrogeologic Inc\)](#) - MODFLOW based watershed model
[MODFLOW-SURFACT \(Waterloo Hydrologic\)](#) - MODFLOW w/unsat/multiphase flow
[FEFlow \(Wazy Ltd.\)](#) - 3D finite element flow & transport & watershed & heat
[MikeSHE \(DHI Water and Environment\)](#) - watershed model w/ MODFLOW
[HYDROGEOSPHERE](#) (integrated surface water/watershed/vadose zone/groundwater flow and process model)
[GFLOW](#) - analytic element method software, by Haitjema (not updated since 2007)
[AnaQSim](#) - GUI for the analytic element method

Groundwater Modeling Demonstrations and Reviews:

[Flow and Transport Modeling, Homogeneous and Heterogeneous Aquifers \(IGW\)](#)
[Digital Library, Flow and Transport Modeling \(IGW\)](#)
[Reviews of Groundwater Modeling Software \(IGWMC\)](#)
[Online Tool to Simulate Groundwater Age and Contaminant Trends in Wells \(USGS\)](#)
[Films by the Nation Committee on Fluid Mechanics](#)

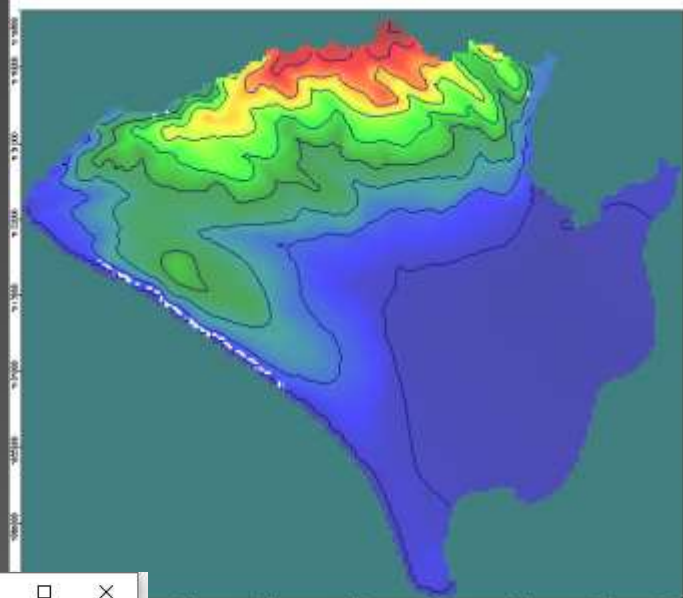
http://groundwater.ucdavis.edu/Materials/Groundwater_Modeling__Web-Links/

Calibración



Post-procesado

● Laborioso



Estacionario9.lst: Bloc de notas

Archivo Edición Formato Ver Ayuda

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 1, STRESS PERIOD

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/1
IN:		IN:	
STORAGE =	0.0000	STORAGE =	0.
CONSTANT HEAD =	0.0000	CONSTANT HEAD =	0.
RIVER LEAKAGE =	350.0122	RIVER LEAKAGE =	350.
RECHARGE =	214.0000	RECHARGE =	214.
SPECIFIED FLOWS =	45000.0000	SPECIFIED FLOWS =	45000.
TOTAL IN =	45564.0117	TOTAL IN =	45564.
OUT:		OUT:	
STORAGE =	0.0000	STORAGE =	0.
CONSTANT HEAD =	0.0000	CONSTANT HEAD =	0.
RIVER LEAKAGE =	45549.0117	RIVER LEAKAGE =	45549.
RECHARGE =	0.0000	RECHARGE =	0.
SPECIFIED FLOWS =	0.0000	SPECIFIED FLOWS =	0.
TOTAL OUT =	45549.0117	TOTAL OUT =	45549.
IN - OUT =	15.0000	IN - OUT =	15.
PERCENT DISCREPANCY =	0.03	PERCENT DISCREPANCY =	0.

MODOS711.bit: Bloc de notas

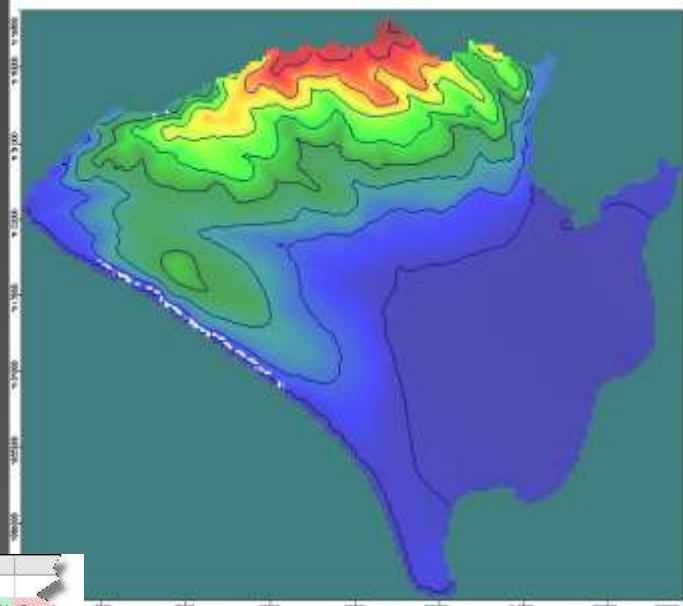
Archivo Edición Formato Ver Ayuda

CUMULATIVE

Stress Period	Time Step	Time	In: STORAGE	In: CONSTANT HEAD	In: WELLS	In: RIVER LEAKAGE	In: HEAD DEP BOUNDS	In: RECHARGE	In: TOTAL IN
Out: STORAGE	Out: CONSTANT HEAD	Out: WELLS	Out: RECHARGE	Out: TOTAL OUT	IN - OUT	Percent Discrepancy	Out: RIVER LEAKAGE	Out:	Out:
1	1	31.000	585455936.0000	0.0000	3570000.0000	1643596.1250	0.0000	0.0000	0.0000
3118502.7500	2755418.0000	596543424.0000	531124000.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
65092248.0000	161309.9531	0.0000	596377536.0000	165888.0000	0.03	0.0000	0.0000	0.0000	
2	1	59.000	712360384.0000	0.0000	7260000.0000	2937285.0000	0.0000	0.0000	
5323233.5000	8797067.0000	736677952.0000	615937728.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
120404336.0000	179968.6406	0.0000	736522048.0000	155904.0000	0.02	0.0000	0.0000	0.0000	
3	1	90.000	797548864.0000	0.0000	10860000.0000	3620672.7500	0.0000	0.0000	
7428493.0000	108638760.0000	928096768.0000	747226816.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
180517024.0000	199790.1406	0.0000	927943680.0000	153088.0000	0.02	0.0000	0.0000	0.0000	
4	1	120.000	869392896.0000	0.0000	13570000.0000	4365694.0000	0.0000	0.0000	
9163271.0000	172777424.0000	1069269248.0000	833627776.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
235171872.0000	315290.2812	0.0000	1069114880.0000	154368.0000	0.01	0.0000	0.0000	0.0000	
5	1	151.000	940356736.0000	0.0000	17800000.0000	5088768.0000	0.0000	0.0000	
10339235.0000	209390352.0000	1182975104.0000	893481600.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
288868704.0000	468949.0000	0.0000	1182819328.0000	155776.0000	0.01	0.0000	0.0000	0.0000	
6	1	181.000	1017706496.0000	0.0000	22340000.0000	5849598.0000	0.0000	0.0000	
11326266.0000	226382864.0000	1283605248.0000	936124800.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
337686528.0000	562827.7500	0.0000	1274374144.0000	9231104.0000	0.72	0.0000	0.0000	0.0000	
7	1	212.000	1088299904.0000	0.0000	24890000.0000	6657246.0000	0.0000	0.0000	
12351918.0000	228984320.0000	1361183360.0000	966130048.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
385220416.0000	613168.0000	0.0000	1351963648.0000	9219712.0000	0.68	0.0000	0.0000	0.0000	
8	1	243.000	1157740800.0000	0.0000	25620000.0000	7473376.5000	0.0000	0.0000	
13429477.0000	234016992.0000	1438280704.0000	995897728.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
430100928.0000	642015.0625	0.0000	1426640640.0000	11640064.0000	0.81	0.0000	0.0000	0.0000	
9	1	273.000	1217466240.0000	0.0000	26650000.0000	8267569.5000	0.0000	0.0000	

Post-procesado

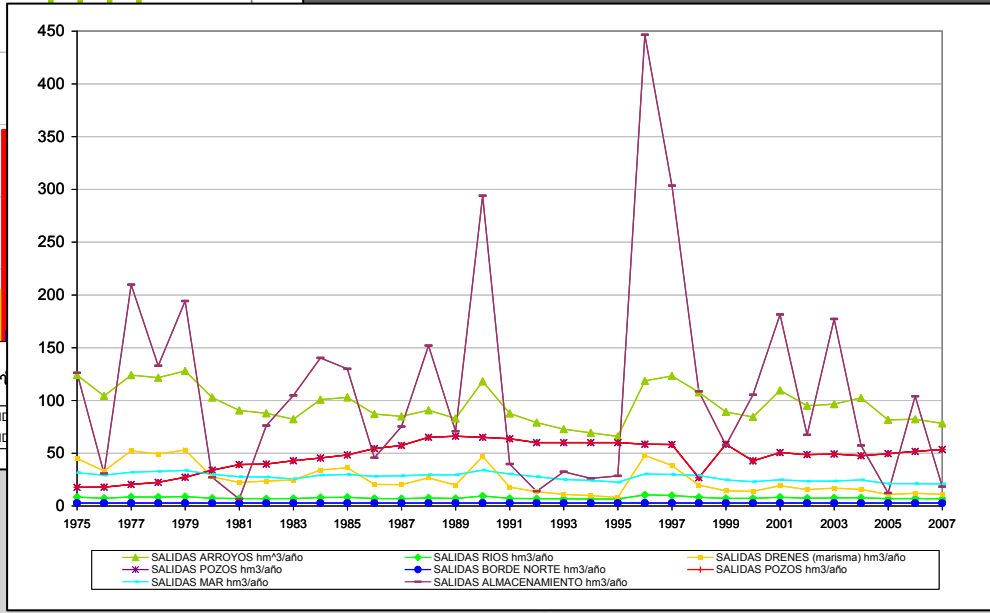
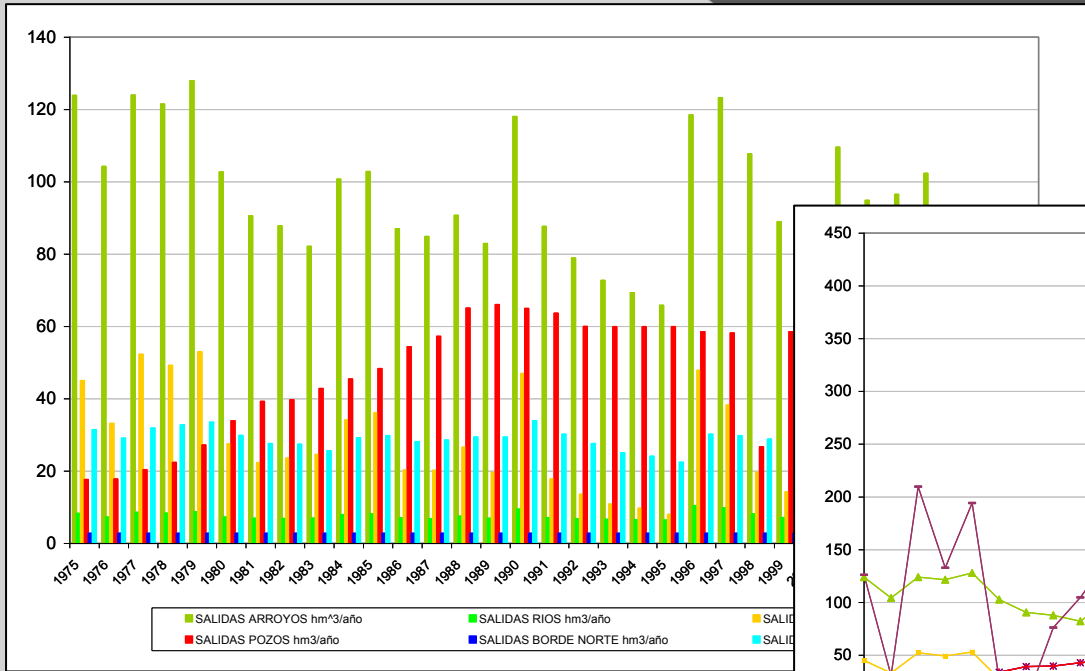
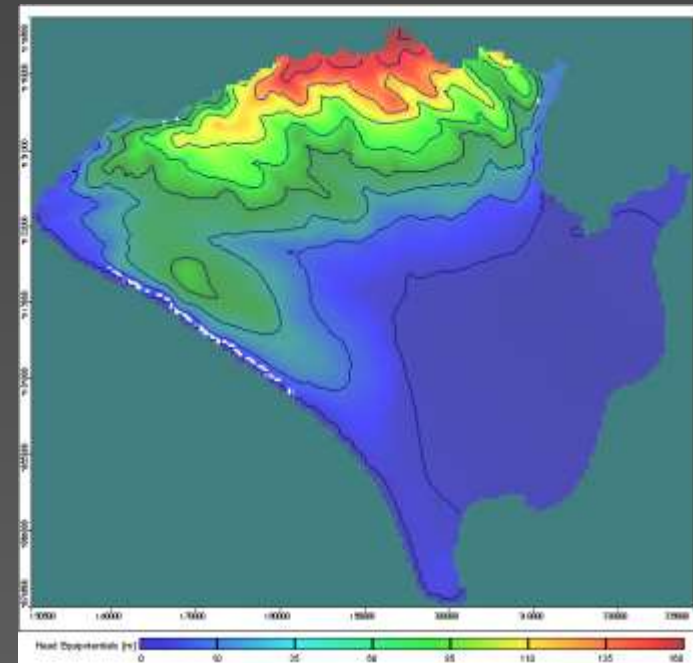
Laborioso



Año	Mes	Stress Period	Time Step	Time	In: STORAGE	In: CONSTANT HEAD	In: WELLS	In: RIVER LEAKAGE	In: HEAD DEP BOUNDS	In: RECHARGE	In: TOTAL IN	Out: STORAGE	Out: CONSTANT HEAD	Out: WELLS	Out: RIVER LEAKAGE	Out: HEAD DEP BOUNDS	Out: RECHARGE	Out: TOTAL OUT	IN - OUT	Percent Discrepancy	
1975	ENE	1	1	31	18885676	0	115161	0	0	0	18885676	0	0	0	0	0	0	0	18885676	0	0.00
	FEB	2	1	59	4532302.5	0	131785	0	0	0	4532302.5	0	0	0	0	0	0	0	4532302.5	0	0.00
	MAR	3	1	90	2748015.5	0	116129	0	0	0	2748015.5	0	0	0	0	0	0	0	2748015.5	0	0.00
	ABR	4	1	120	2394801.5	0	90333	0	0	0	2394801.5	0	0	0	0	0	0	0	2394801.5	0	0.00
	MAY	5	1	151	2289157.25	0	136451	0	0	0	2289157.25	0	0	0	0	0	0	0	2289157.25	0	0.00
	JUN	6	1	181	2578324.75	0	151333	0	0	0	2578324.75	0	0	0	0	0	0	0	2578324.75	0	0.00
	JUL	7	1	212	2277206.5	0	82258	0	0	0	2277206.5	0	0	0	0	0	0	0	2277206.5	0	0.00
	AGO	8	1	243	2240030	0	23548	0	0	0	2240030	0	0	0	0	0	0	0	2240030	0	0.00
	SEPT	9	1	273	1990849.25	0	3433	0	0	0	1990849.25	0	0	0	0	0	0	0	1990849.25	0	0.00
	OCT	10	1	304	1924748.875	0	29677	0	0	0	1924748.875	0	0	0	0	0	0	0	1924748.875	0	0.00
	NOV	11	1	334	1742416.375	0	107333	0	0	0	1742416.375	0	0	0	0	0	0	0	1742416.375	0	0.00
	DIC	12	1	365	1287643.875	0	7125	0	0	0	1287643.875	0	0	0	0	0	0	0	1287643.875	0	0.00
1976	ENE	13	1	396	1640764.625	0	116451	0	0	0	1640764.625	0	0	0	0	0	0	0	1640764.625	0	0.00
	FEB	14	1	425	1272667.5	0	128620	0	0	0	1272667.5	0	0	0	0	0	0	0	1272667.5	0	0.00
	MAR	15	1	456	1463824.5	0	117419	0	0	0	1463824.5	0	0	0	0	0	0	0	1463824.5	0	0.00
	ABR	16	1	486	1077986	0	91333	0	0	0	1077986	0	0	0	0	0	0	0	1077986	0	0.00
	MAY	17	1	517	1054108.75	0	137741	0	0	0	1054108.75	0	0	0	0	0	0	0	1054108.75	0	0.00
	JUN	18	1	547	1267852.75	0	151333	0	0	0	1267852.75	0	0	0	0	0	0	0	1267852.75	0	0.00
	JUL	19	1	578	1121532	0	83225	0	0	0	1121532	0	0	0	0	0	0	0	1121532	0	0.00
	AGO	20	1	609	1070461	0	23870	0	0	0	1070461	0	0	0	0	0	0	0	1070461	0	0.00
	SEPT	21	1	639	1204061.5	0	151333	0	0	0	1204061.5	0	0	0	0	0	0	0	1204061.5	0	0.00
	OCT	22	1	670	961315.5625	0	131785	0	0	0	961315.5625	0	0	0	0	0	0	0	961315.5625	0	0.00
	NOV	23	1	700	1066756.875	0	116451	0	0	0	1066756.875	0	0	0	0	0	0	0	1066756.875	0	0.00
	DIC	24	1	731	649438.1875	0	71290	0	0	0	649438.1875	0	0	0	0	0	0	0	649438.1875	0	0.00
1977	ENE	25	1	762	515636.125	0	118387	0	0	0	515636.125	0	0	0	0	0	0	0	515636.125	0	0.00
	FEB	26	1	790	721922.625	0	135357	0	0	0	721922.625	0	0	0	0	0	0	0	721922.625	0	0.00
	MAR	27	1	821	860441.625	0	119354	0	0	0	860441.625	0	0	0	0	0	0	0	860441.625	0	0.00
	ABR	28	1	851	893396.75	0	131785	0	0	0	893396.75	0	0	0	0	0	0	0	893396.75	0	0.00
	MAY	29	1	882	572846.6875	0	14988	0	0	0	572846.6875	0	0	0	0	0	0	0	572846.6875	0	0.00

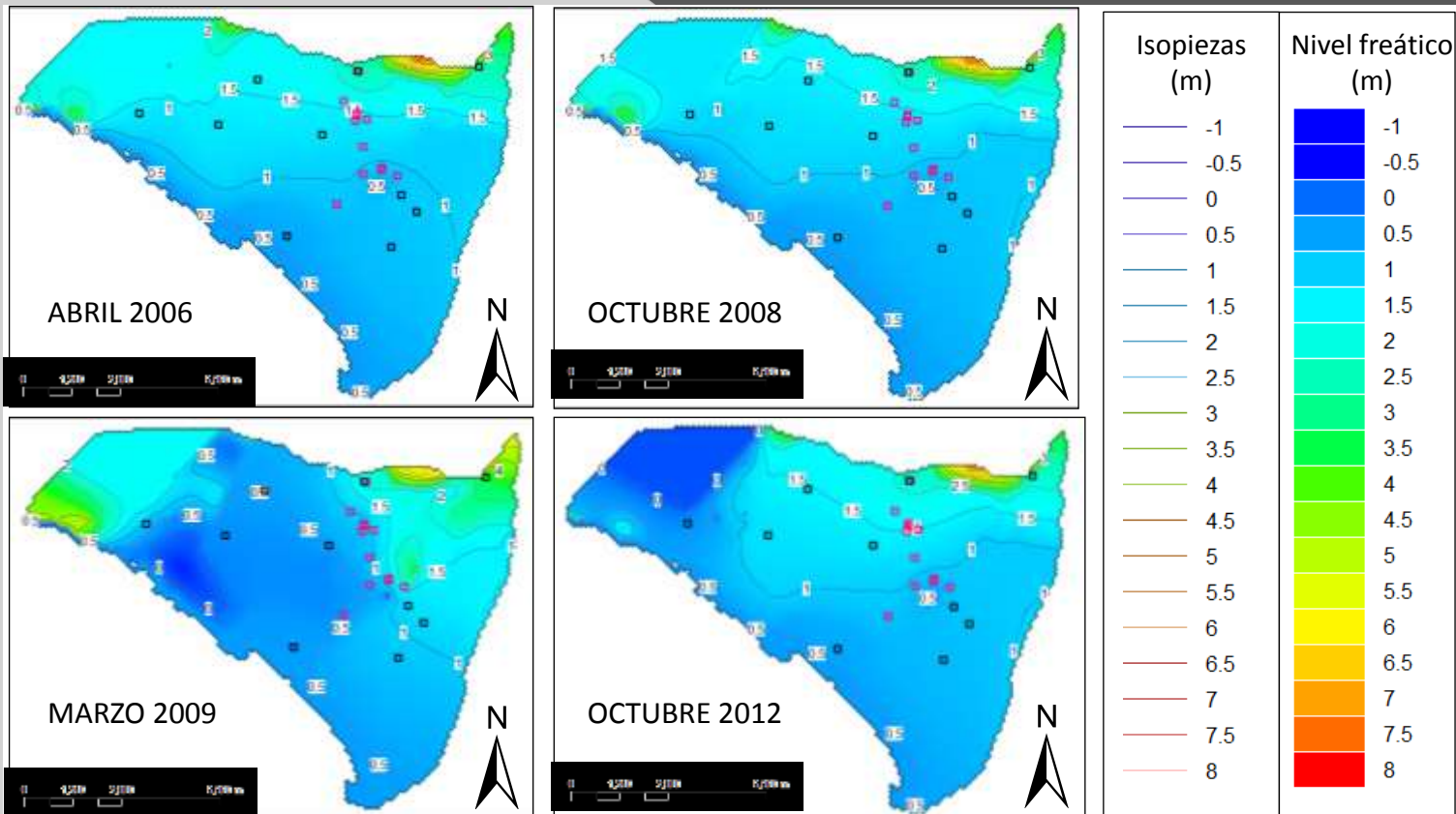
Post-procesado

○ Laborioso



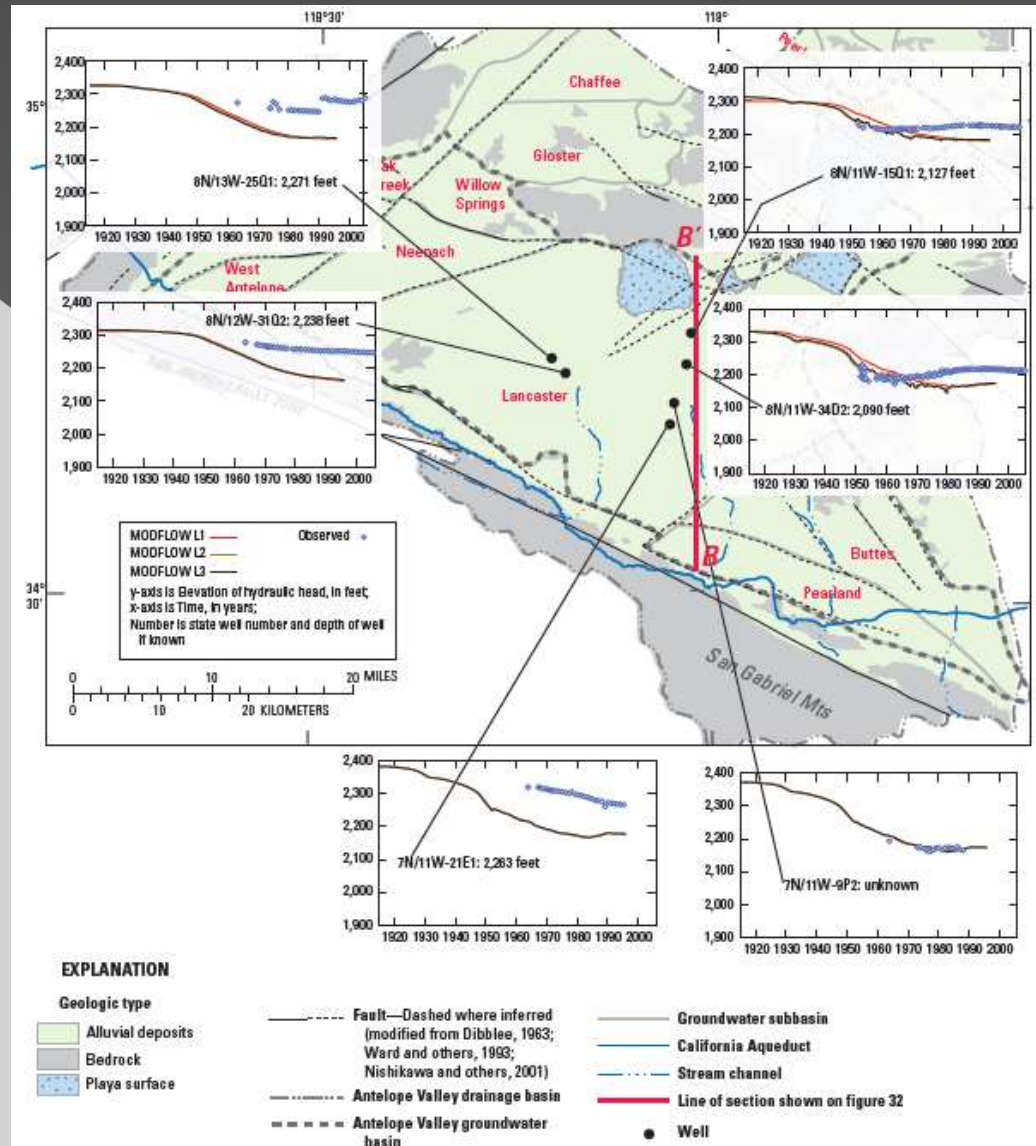
Piezometría

Mapas, diferencias



Piezometría

● Evolución temporal



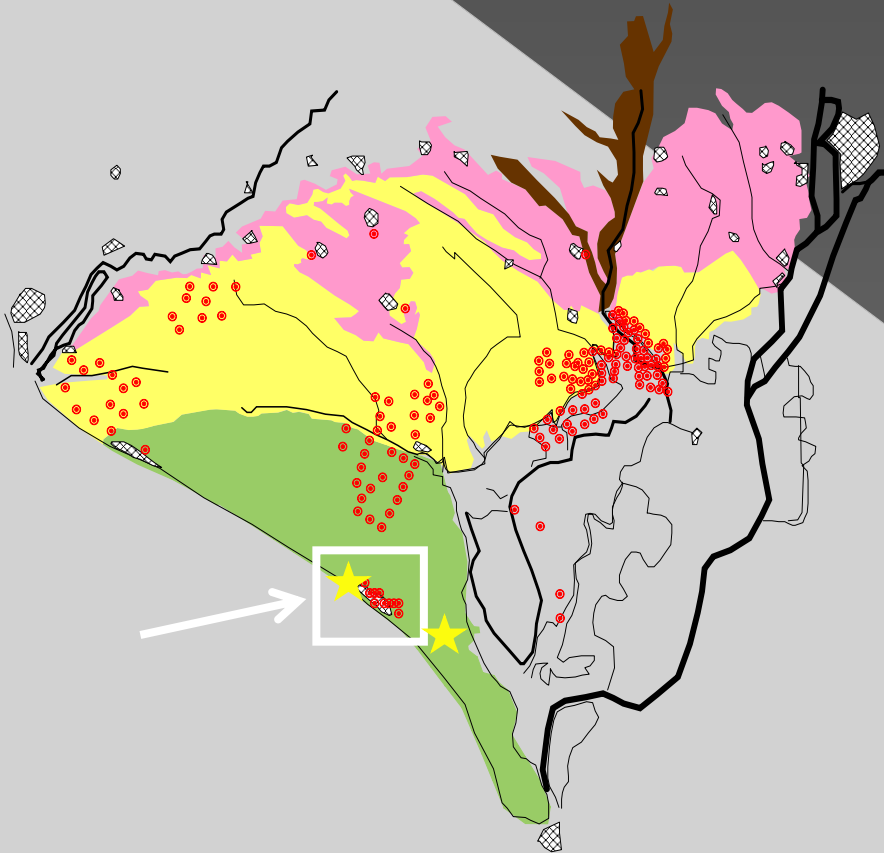
Piezometría

- Estudio del impacto de un nuevo pozo

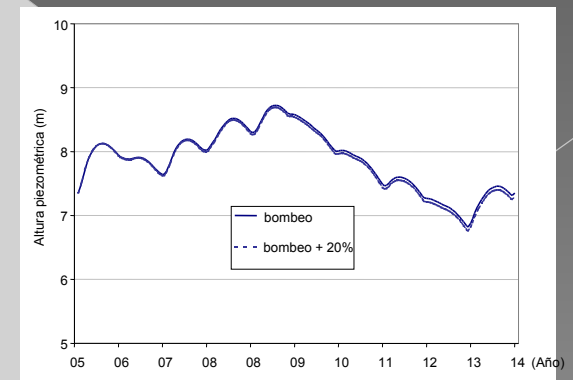
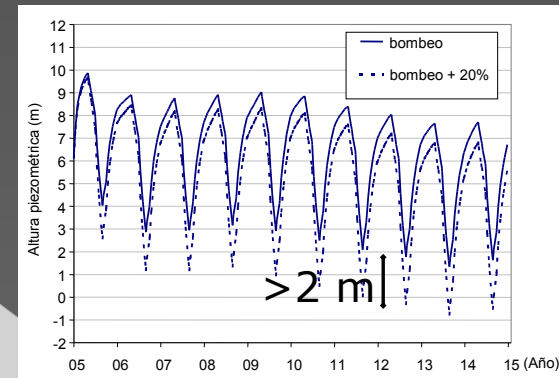
Impacto de las solicitudes de nuevos pozos

Piezometría

Estudio del impacto aumento bombeos

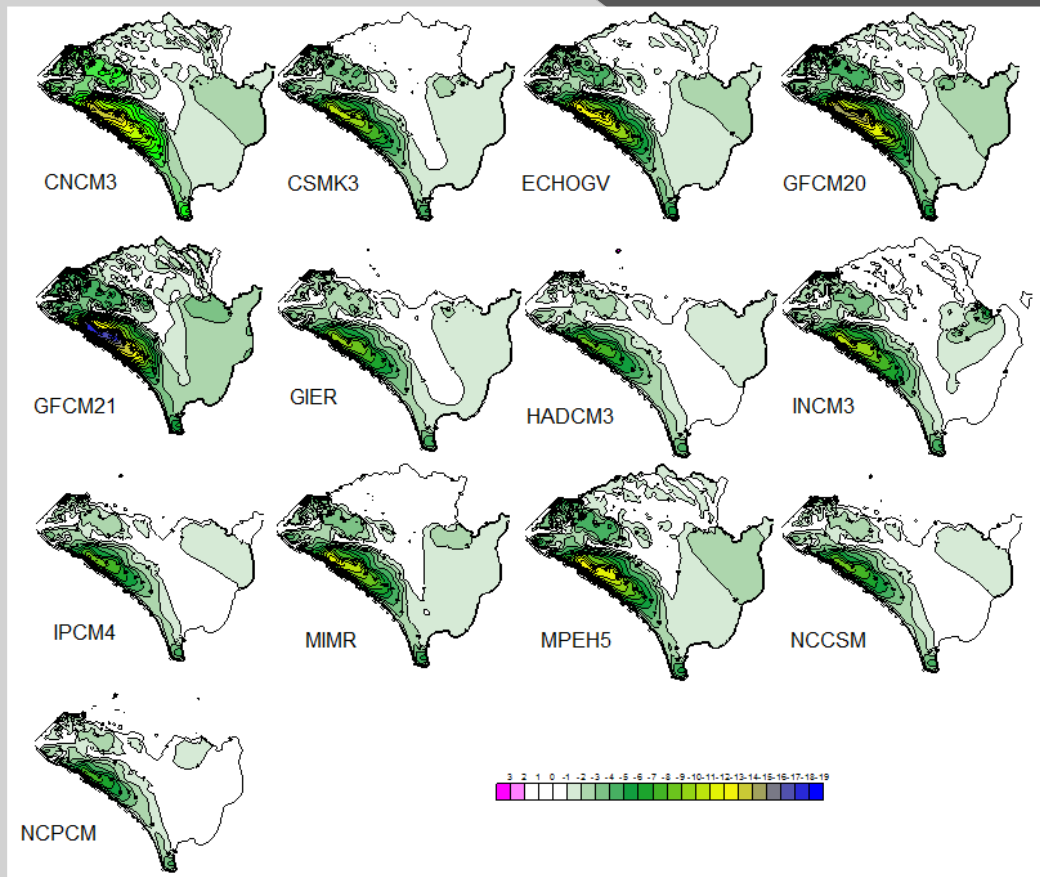


20% de extracción



Piezometría

Estudio del impacto del cambio climático



Distinta piezometría para distintos escenarios climáticos

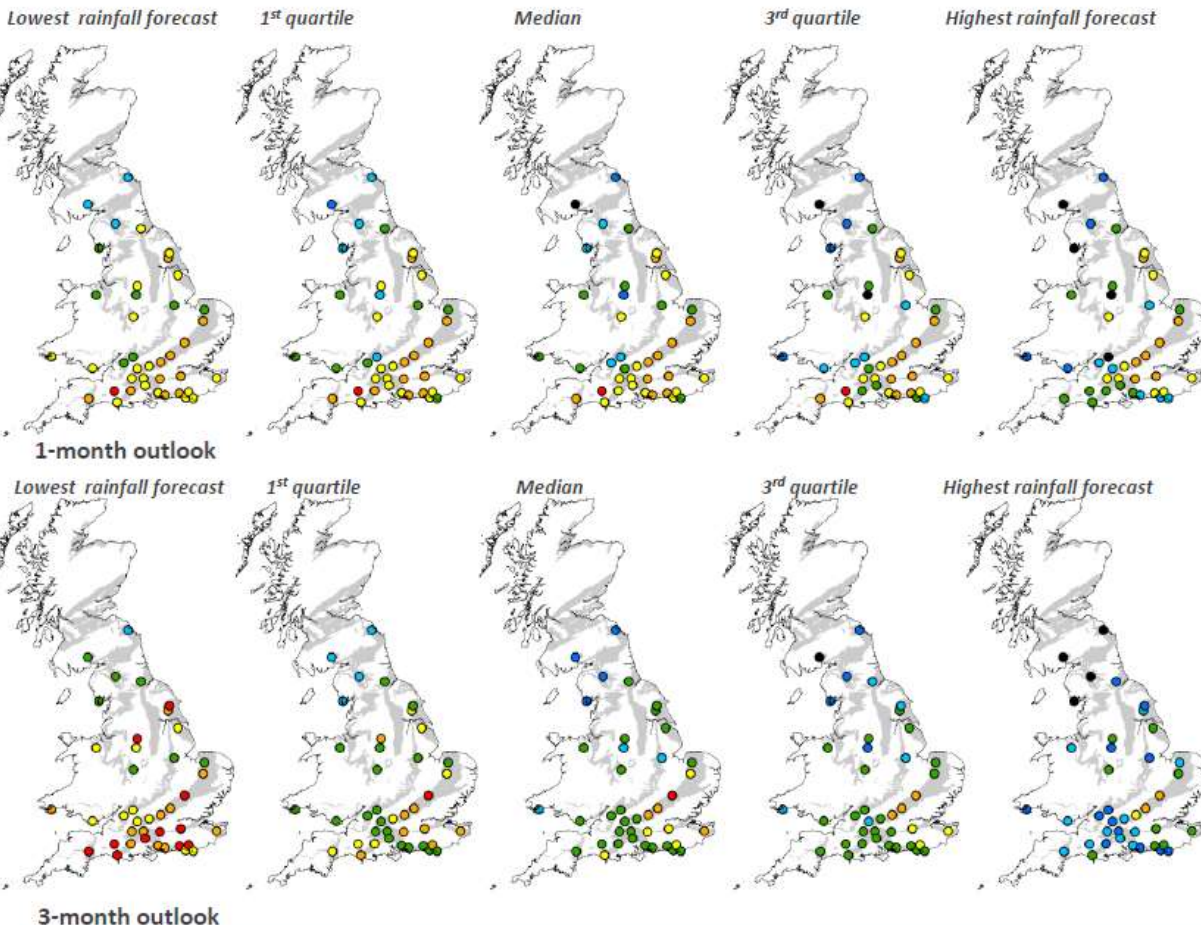
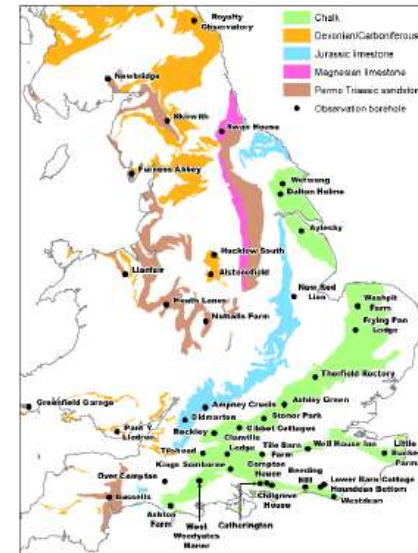
Evaluación del estado según las predicciones futuras de cambio climático

<http://www.hydoutuk.net/latest-outlook>

duced by running five members of the climate forecast through groundwater borehole hydrographs at 42 sites across are distributed across the principal

Based on the distribution of observed historical groundwater levels in a given month, seven categories have been derived for each site: very low, low, below normal, normal, above normal, high, and very high. The forecast groundwater level is assigned to one of these seven categories depending on where it falls within the distribution of the historically observed values.

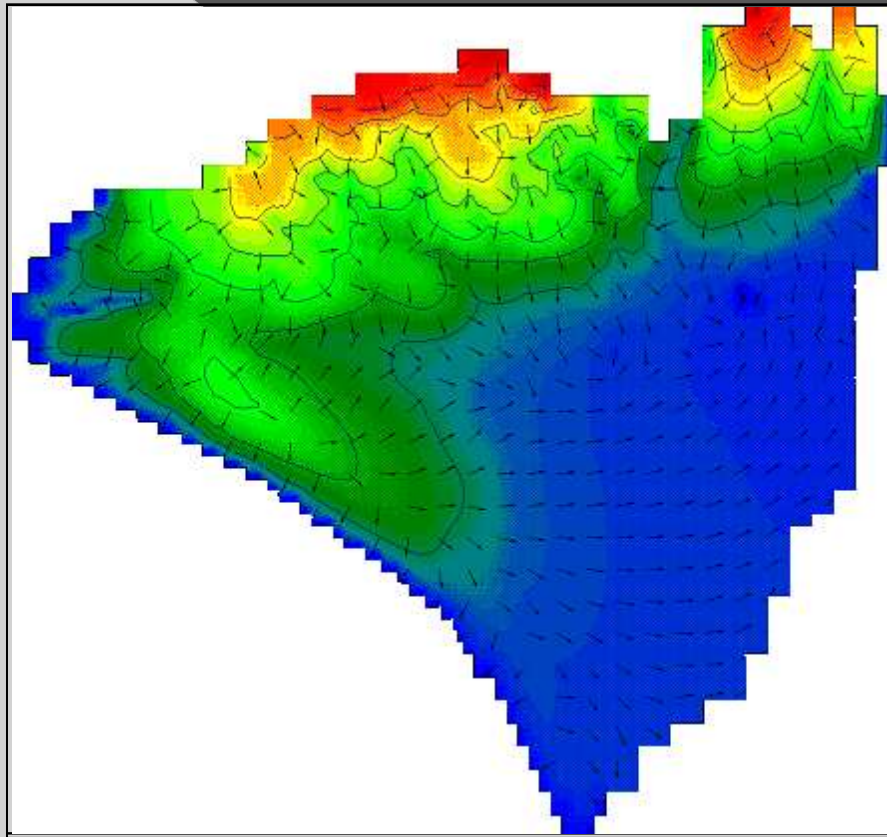
Key	Percentile range of historic observed values for relevant month
Black	Exceptionally high levels > 95
Dark Blue	Notably high levels 87-95
Light Blue	Above normal 72-87
Green	Normal 28-72
Yellow	Below normal 13-28
Orange	Notably low levels 5-13
Red	Exceptionally low levels < 5



The Hydrological Outlook UK provides an outlook for the water situation for the UK over the next three months and beyond. For guidance on how to interpret the outlook, a wider range of information, and a full description of underpinning methods, please visit the website: www.hydoutuk.net

Líneas de flujo

- ◉ Dirección de movimiento del agua

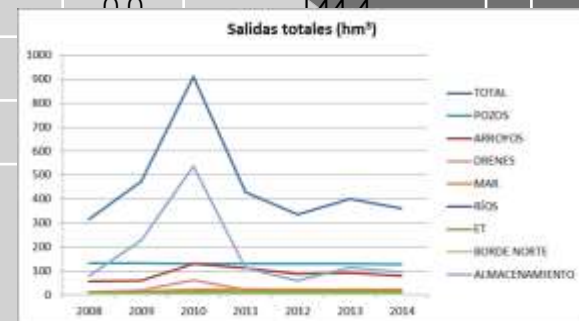
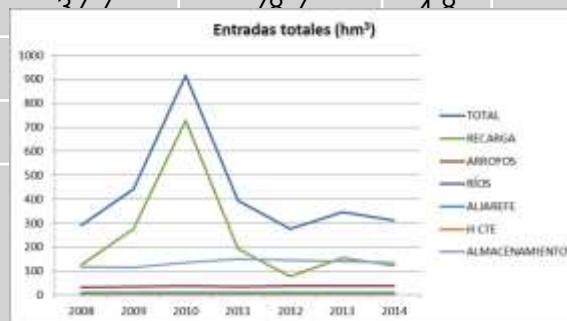


Balances

○ Balances totales del acuífero

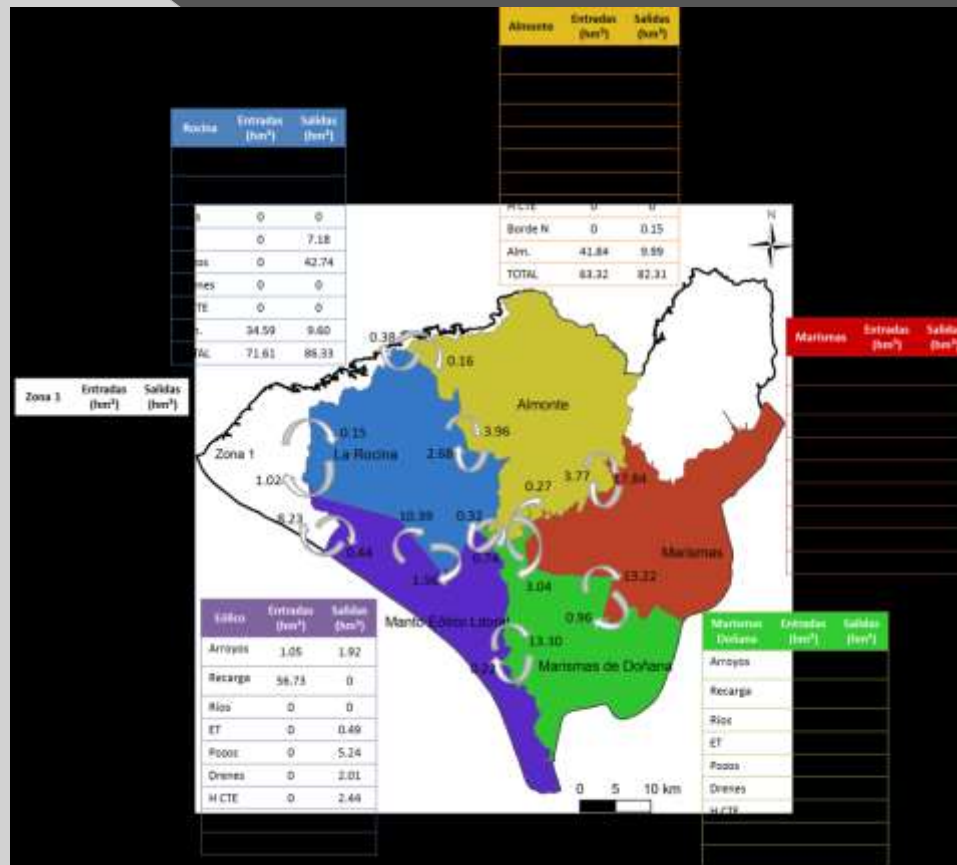
Balance anual de **entradas** (o **salidas**)

Entradas/ Salidas (hm ³ /año)	TOTAL	ARROYOS	RECARGA	RÍOS	FLUJO LATERAL	MAR	ALMACENAMIENTO	BOMBEO
2008	290.4	33.4	124.6	4.9	10.4	0.0	117.1	133.3
2009	440.7	35.0	274.8	5.0	10.4	0.0	115.5	132.2
2010	916.0	37.5	728.4	3.9	10.4	0.0	135.8	131.0
2011	392.8	35.8	192.5	4.3	10.4	0.0	149.9	131.1
2012	276.1	37.7	79.7	4.8	10.6	0.0	144.4	130.6
2013	346.5				10.4			129.2
2014	310.9				10.4			128.9



Balances

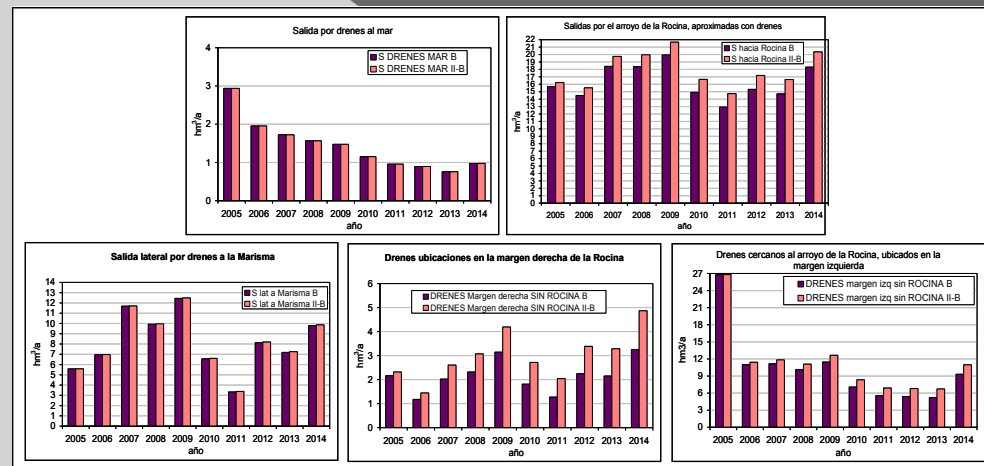
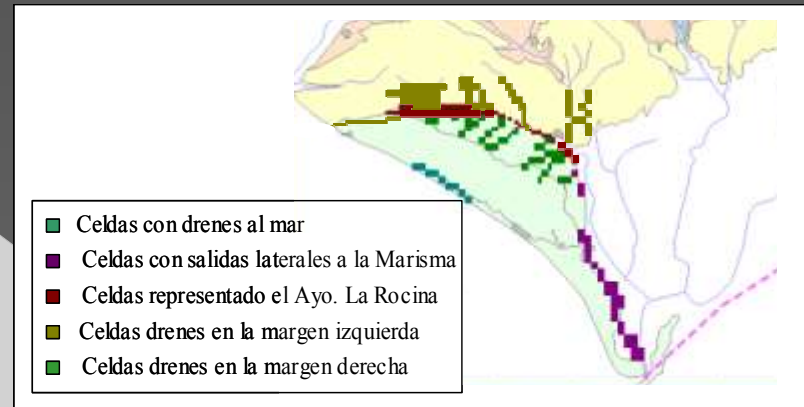
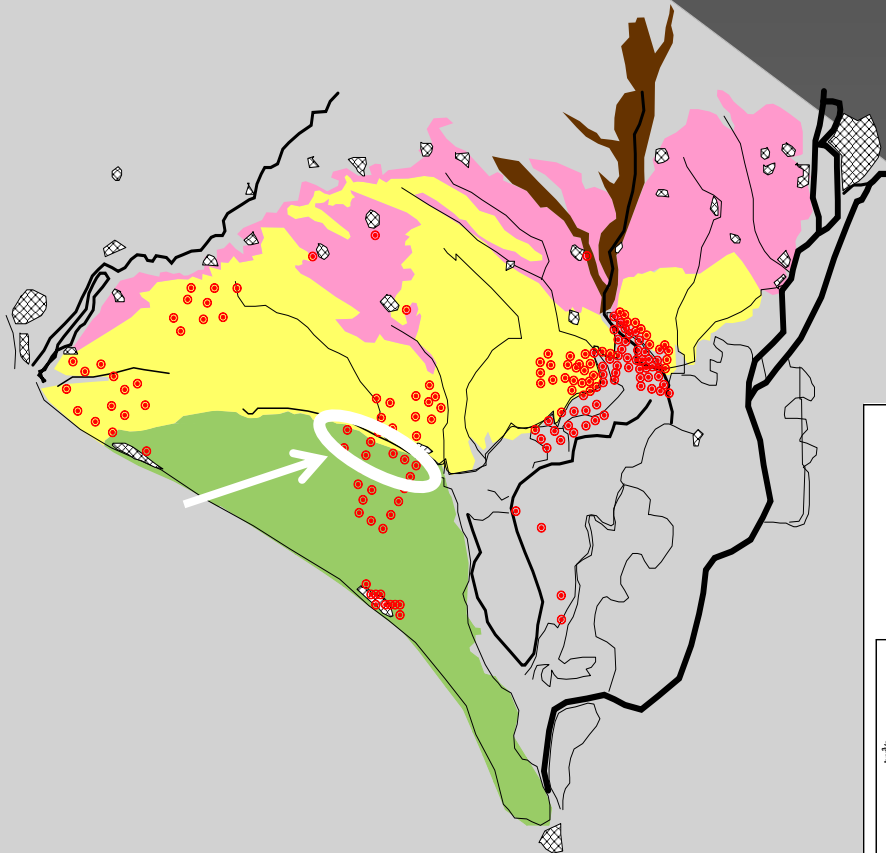
Flujos laterales



Balances

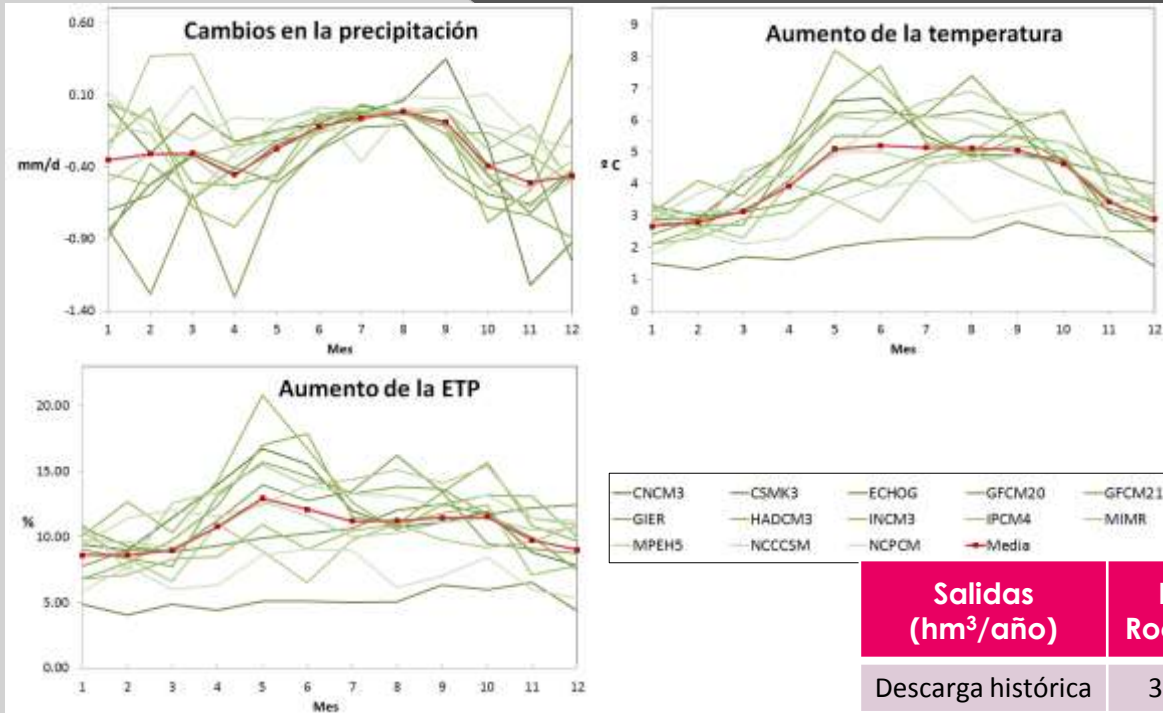
○ Estudio impacto cese bombeos

9 hm³/año menos de extracción



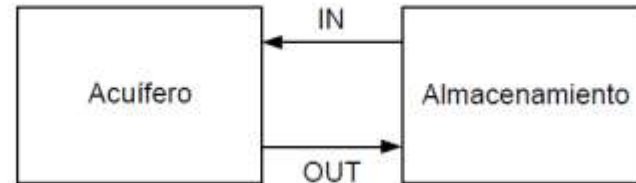
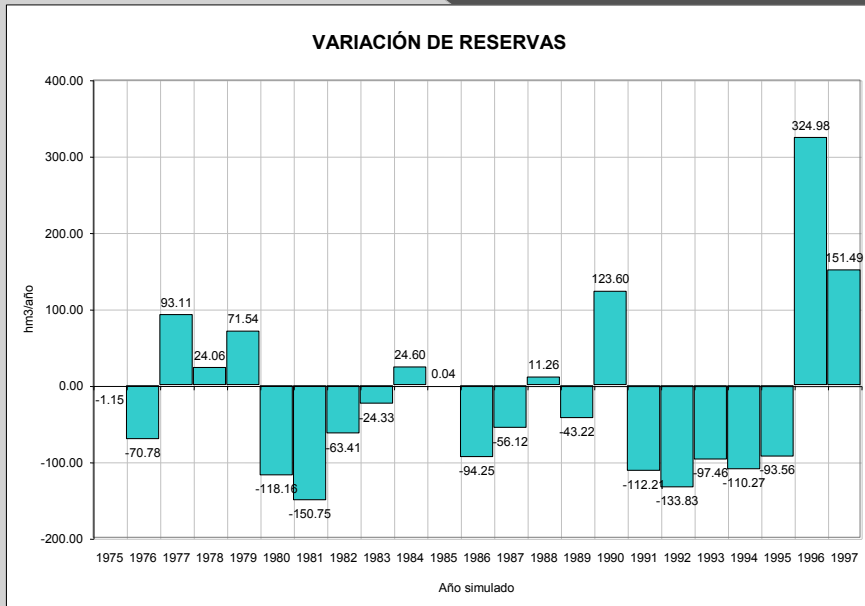
Balances

Estudio impacto del cambio climático



Salidas (hm ³ /año)		La Rocina	El Partido	Las Marismas	Guadamar
Descarga histórica		33.8	11.3	39.4	8.4
Riego histórico		7.8	0.3	18.4	0.1
Abastecimiento histórico		0.2	0	0.4	0
Cambio simulado 2080s	Max	-18.7	-8.3	-26.7	-1.8
	Med	-12.2	-1.7	-20.7	-0.6
	Min	-8.4	0.4	-16.9	0.4

Variación del almacenamiento

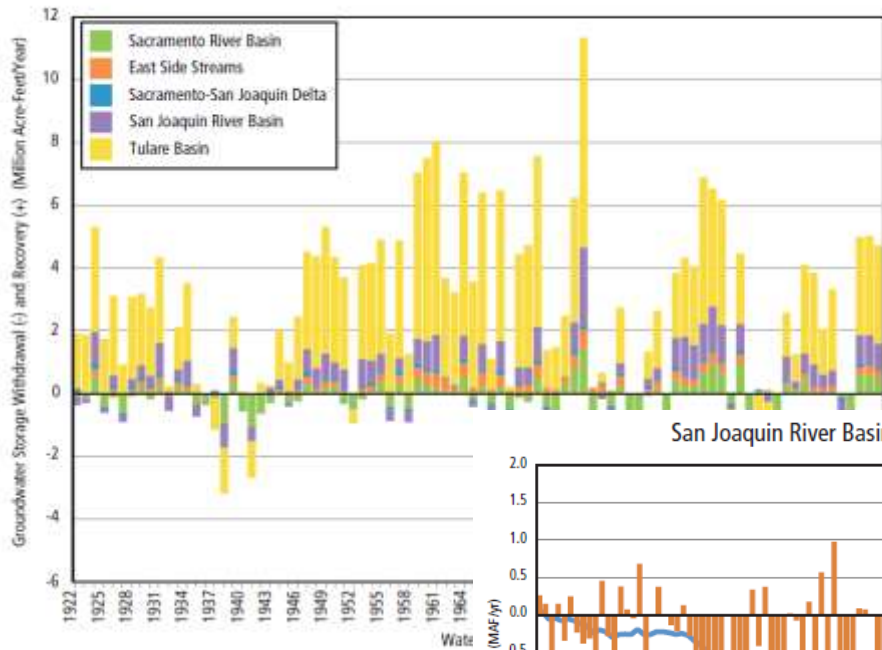


El cambio de almacenamiento resulta:

$$\Delta S = STORAGE\ OUT - STORAGE\ IN \begin{cases} < 0 \implies \text{El acuífero se está vaciando} \\ = 0 \implies \text{No hay cambio} \\ > 0 \implies \text{El acuífero se está recargando} \end{cases}$$

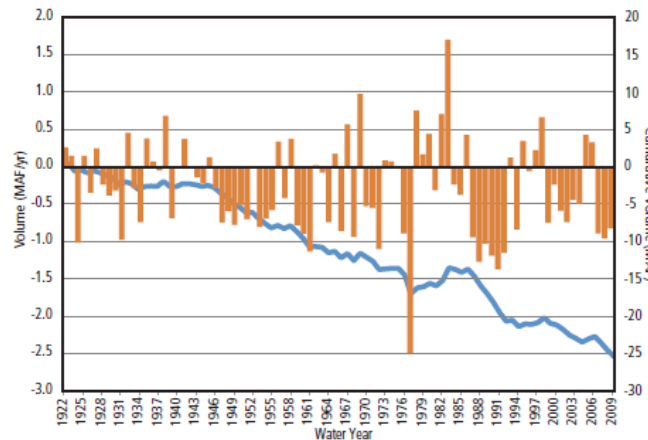
Variación del almacenamiento

Figure 82. Simulated annual change in Central Valley groundwater storage, 1922-2009.

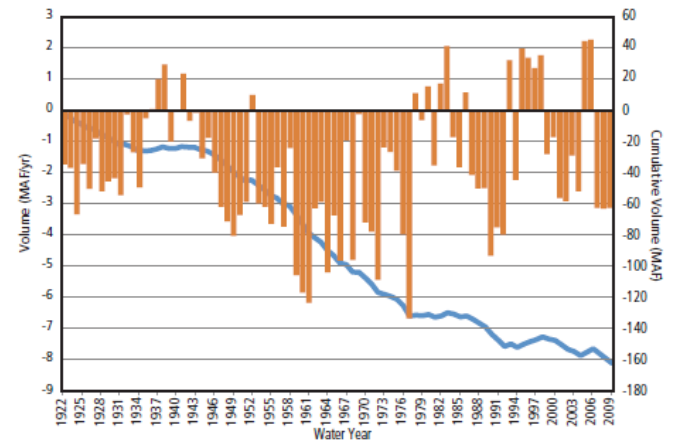


<https://ca.water.usgs.gov/projects/central-valley/tulare-basin.html>

San Joaquin River Basin



Tulare Basin

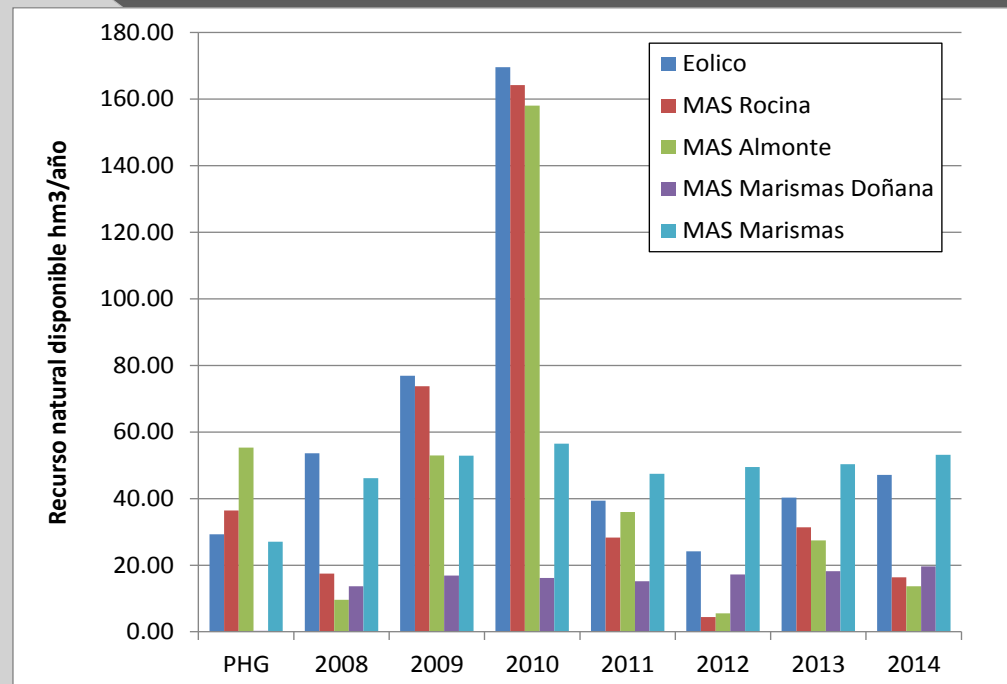


Annual Cumulative

Recursos subterráneos

○ El **recurso natural disponible**, según se define en el PH: **balance general de agua** con

- infiltración lluvia
- recargas laterales otras masas
- recarga desde humedales conectados
- retornos de riego
- drenajes a ríos
- manantiales
- entradas/salidas mar



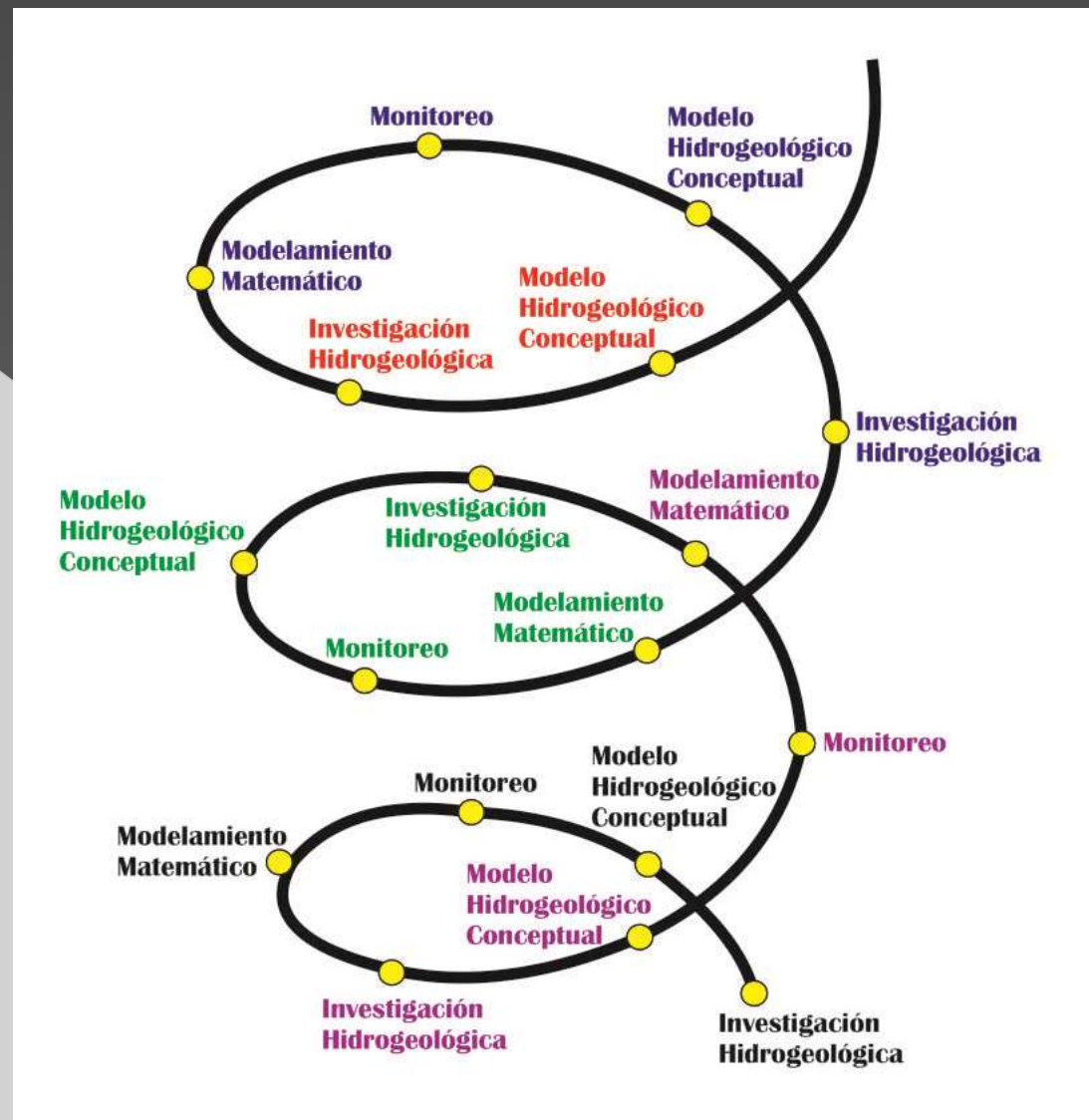
Reflexiones



**Tarea dinámica,
continua**

No debe verse
como cuando
se resuelve un
problema
puntual.

**Es un trabajo
complejo que
debe
mantenerse en
el tiempo si
queremos
preservar
nuestros
acuíferos y
ecosistemas**



=> Medios económicos y humanos

Equipo multidisciplinar

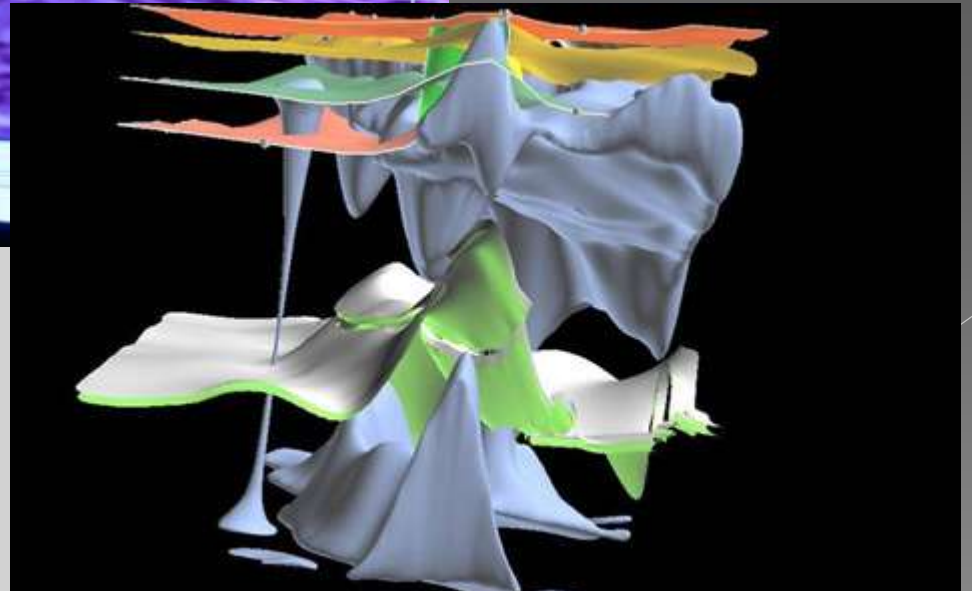
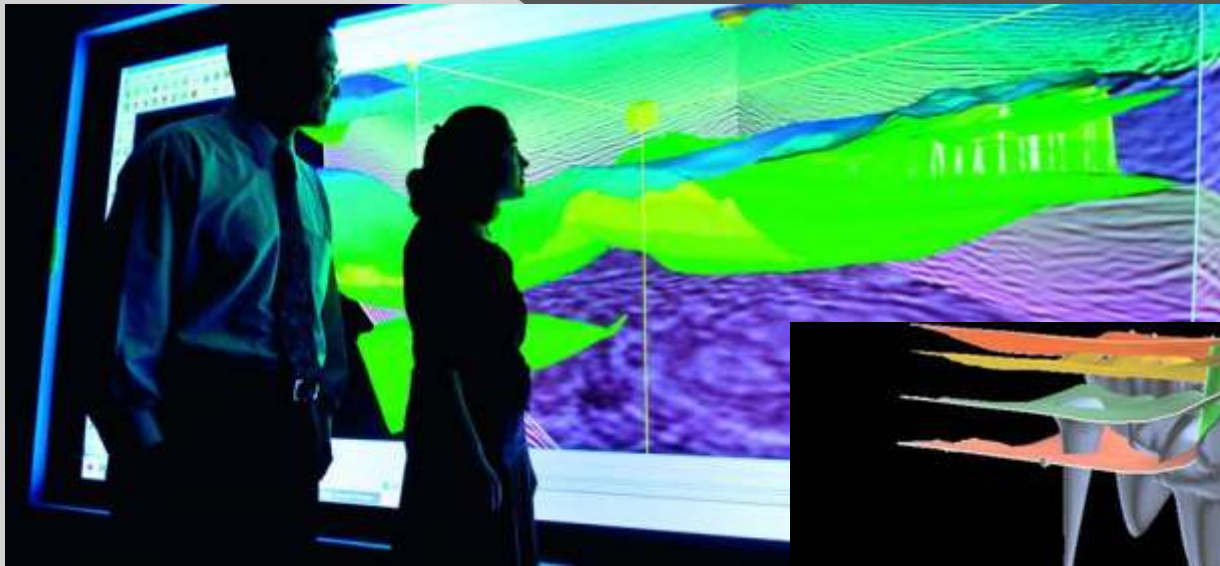
- Técnicos de laboratorio
- Gestores
- Geólogos
- Hidrogeólogos
- Técnicos de campo (mantenimiento y monitorización)
- Expertos en bases de datos
- Modelistas de recarga
- Modelistas de flujo subterráneo
- Desarrolladores de los modelos numéricos
- Expertos en sistemas de información geográfica



Preparado & Coordinado => Medios económicos y humanos

COORDINACIÓN/UNIFICACIÓN DATOS Y MODELACIÓN

¿Cuántos medios económicos/humanos?



Compararnos con las petroleras....

¿es mucho?

Hay mucho en juego como para no invertir en ello

13-11-2019 22:24

Región de Murcia

El 80% de las aguas del Mar Menor se quedaron sin oxígeno tras la DANA



ANTES

AHORA

El pueblo de Lucena del Puerto se vuelca para impedir la clausura de las prospecciones con las que se riegan más de 200 hectáreas de cultivo. Los agricultores denuncian que hay entre 4.000 y 5.000 puestos de trabajo en juego



Muchas gracias

Hay mucho en juego como
para no invertir en ello