UNIVERSIDAD AUTONOMA DE CIUDAD JUAREZ

DEPARTAMENTO DE INGENIERIA CIVIL Y AMBIENTAL

Sustainable Water Resources for Irrigated Agriculture in a Desert River Basin Facing Drought and Competing Demands: From Characterization to Solutions

Reporte Técnico Final

Proyecto USDA

For

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Listado de reportes técnicos presentados por el Dr. Luis Carlos Alatorre Cejudo, número de empleado 7484, adscrito a la Licenciatura en Geoinformática, responsable del área de análisis geoespacial y cartografía, así como los estudiantes del programa y de posgrado de la UACJ.

REPORTE DE ACTIVIDADES MODELACION GEOESPACIAL

Y CAMBIOS EN E USO DEL SUELO

10/04/2020

Dr. Luis Carlos Alatorre Cejudo

Se han realizado un sin número de actividades, como responsable del área geoespacial y de cartografía, se generaron los insumos necesarios para poder caracterizar la geografía física de la parte media del Rio Bravo/Rio Grande, entre México y los Estados Unidos. También se han realizado actividades de representación institucional y otras de índole académico-científicas, como la obtención del Título de Pregrado de la estudiante/becaria Gabriela Veleta Jáquez, con su proyecto “Determinación de la Cobertura y Uso de Suelo del Rio Bravo (1994-2015). Proceso de Cambios y Evolución del NDVI”. También se está por concluir un artículo científico para enviarlo a la revista de Tecnociencia de la Universidad Autónoma de Chihuahua, el cual tiene como título “Analysis of the Temporal and Spatial Evolution of Recovery and Degradation Processes in Vegetated Areas Using a Time Series of Landsat TM Images (1994-2015): Río Grande”. Por otra parte, se ha consolidado la plataforma SIG que administra los datos geoespaciales, suministrando los datos necesarios para los modeladores de SWAT/MODFLOW.

Propuesta para la segunda fase del Proyecto Restructure water pricing

Se propone el análisis de evaluar el potencial del precio que se paga como instrumento para la gestión y manejo sustentable de la demanda del agua en zonas urbanas. Para ello, en primera instancia se analizarán los datos provenientes de cientos de organismos operadores de agua potable en el país, para buscar la correlación entre el precio y la demanda de agua (sensibilidad), así como la caracterización de las condiciones socioeconómicas de la población que pudiera incidir en tarifas más justas, que puedan incluir impuestos a la conservación y restauración ambiental del medio geográfico. En general, creemos que la información que se genere, debería incidir en la forma de administrar los organismos operadores, dado que los costos del agua están más que nada en función de sus ineficiencias técnicas y financieras, por lo que, para un manejo efectivo, eficiente y sustentable del uso urbano del agua, es imprescindible un cambio de fondo en la manera en que se operan los sistemas urbanos del agua.

Propuesta para la segunda fase del proyecto Direct potable reuse

Se sabe que el reúso de aguas residuales ha tenido un gran impacto en las actividades industriales, agrícolas, regado de áreas verdes urbanas, entre otros más. Antes de hablar de cambio climático ya se hablaba del reúso del agua, ya que la cantidad de agua es la misma, pero cada vez somos más gente. Por ello se generar una base de datos geoespacial, que permita contrastar la producción de aguas residuales, la capacidad instalada para el tratamiento y las características de calidad, contra un padrón de todas las actividades urbanas, industriales, domésticas, recreación, etc. que podrían ser susceptibles de cambiar el consumo de agua potable por agua de reúso urbano. Con esta información de partida, se conocerá el grado de presión que se le puede quitar al acuífero, la viabilidad técnico financiera de la mejora en el tratamiento de aguas residuales, la mejora la red morada para distintas actividades, así como la disponibilidad para incrementar la recarga del acuífero, incluso una valoración del incremento del precio de agua potable para fortalecer la infraestructura encaminada al reúso del agua en el área urbana.

RESUMEN/REPORTE DE ACTIVIDADES 27/06/2019

Dr. Luis Carlos Alatorre Cejudo

PROYECTO USDA: “SUSTAINABLE WATER RESOURCES FOR IRRIGATED AGRICULTURE IN A DESERT RIVER BASIN FACING CLIMATE CHANGE AND COMPETING DEMANDS: FROM CHARACTERIZATION TO SOLUTIONS”

Dr. Luis Carlos Alatorre Cejudo (LCAC)

Profesor Investigador de Tiempo Completo “PTC”, División Multidisciplinaria de la UACJ en Cuauhtémoc, Chihuahua, México.

El Dr. LCAC actualmente es miembro del equipo de investigadores que colaboran en el citado proyecto, ha estado bajo la dirección y liderazgo del Dr. Alfredo Granados Olivas, responsable del proyecto, durante el periodo 2018-2019 ha realizado un sin número de actividades, como responsable del área geoespacial y de cartografía, y ha generado los insumos necesarios para poder caracterizar la geografía física de la parte media del Rio Bravo/Rio Grande, entre México y los Estados Unidos.

El proyecto tiene como principales objetivos:

i) El modelado de sistemas hidrológicos e hidrogeológicos, y en particular la interacción agua-suelo, entre otras variables; ii) el desarrollo de un modelo de hidrología superficial y otro de agua subterránea utilizando diversas plataformas de modelado, principalmente el modelo Soil Water Assessment Tool (SWAT); iii) el modelado matemático de agua subterránea se realiza con la plataforma computacional de ModFlow, la cual permite visualizar los flujos de agua subterránea en relación a los bombeos que se realizan en el acuífero del Bolsón del Hueco.

Además de esto, el Dr. LCAC ha realizado durante el periodo de tiempo 2018-2019 una serie de actividades de representación institucional y otras de índole académico-científicas las cuales se enlistan a continuación, y se destacan las siguientes:

Dirección de Tesis de Licenciatura en Geoinformática la UACJ-Cuauhtémoc:

Estudiante: Gabriela Veleta Jáquez (2019- en proceso)

Título: "Determinación de la Cobertura y Uso de Suelo del Rio Bravo (1994-2015). Proceso de Cambios y Evolución del NDVI".

Estudiante: Perla Yesenia Borja Domínguez (2018)

Título: "Modelización de la erosión potencial mediante la RUSLE: comparación con las tasas de erosión determinadas con Cs 137".

Tesis dirigidas en el Doctorado en Estudios Urbanos:

Estudiante: Víctor Hugo Esquivel Ceballos (2016-en proceso)

Título:" Crecimiento urbano de Ciudad Juárez y disponibilidad hídrica ante los efectos del cambio climático, por efectos de la atenuación solar como retos para una ciudad sustentable "

Tesis dirigidas en el New Mexico State University:

Estudiante: Hugo Luis Rojas Villalobos (en proceso)

Título:" Physical-geospatial analysis of the water balance in the basin of Cuauhtemoc, Chihuahua, México "

Participación en Proyectos:

Patrones espacio-temporales de la calidad de agua en la red hídrica de la cuenca Laguna de Bustillos, Chihuahua.

Entidad Financiadora: PRODEP.

Vigencia: 01/08/2018-31/07/2019

Investigador principal: Dr. Víctor Manuel Salas Aguilar

Investigador corresponsable: Dr. Luis Carlos Alatorre Cejudo.

Modelado predictivo de la deforestación en el Oeste y Suroeste de Chihuahua.

Entidad Financiadora: Universidad Autónoma de Ciudad Juárez.

Vigencia: 01/03/2017-31/08/2018

Investigador principal: Dr. Luis Carlos Bravo Peña.

Investigador corresponsable: Dr. Luis Carlos Alatorre Cejudo.

Aproximación biogeográfica del Jabalí Europeo (Sus scrofa) en Chihuahua México para el año 2075.

Entidad Financiadora: Universidad Autónoma de Ciudad Juárez.

Vigencia: 01/10/2017-01/10/2018.

Investigador principal: Dra. María Elena Torres Olave

Investigador corresponsable: Dr. Luis Carlos Alatorre Cejudo.

Artículos en revistas Internacionales habla hispana, indexadas (ISSN)

1. Maldonado-Marín, J.D., Alatorre-Cejudo, L.C., Sánchez-Flores, E. (2019). IDENTIFICACIÓN DE CONFLICTOS DE USO DE SUELO PARA LA PLANIFICACIÓN DEL CRECIMIENTO URBANO: CIUDAD CUAUHTÉMOC, CHIHUAHUA (MÉXICO). Cuadernos de Investigación Geográfica, 45 (1), X-X. ISSN 0211-6820; EISSN 1697-9540

2. Amado-Álvarez, J.P.; Pérez-Cutillas, P.; Alatorre-Cejudo, L.C.; Ramírez-Valle, O.; (2019). Multispectral analysis to estimate the turbidity as an indicator of the quality of water in reservoirs in Chihuahua State, Mexico. Revista Geográfica de América Central, 62(1), 49-77. ISSN: 1011-484X

3. María E. Torres, Luis C. Bravo, Luis C. Alatorre, Mario I. Uc, Manuel O. González (2018). Factores biogeográficos y cambios de usos de suelo (2009-2013) en el nicho del Trogon Elegans Amiguus y Euptilitis Neoxenus en Chihuahua, México. Cuadernos de Investigación Geográfica, 44 (2): 763-779. ISSN: 0211-6820; eISSN: 1697-9540

Artículos en revistas de México, indexadas (ISSN)

1. Luis C. Alatorre, Alfredo Granados, Luis C. Bravo, María E. Torres, Lara C. Wiebe, Mario I. Uc, Manuel O. González, Erick Sánchez, Hugo L. Rojas, Víctor Salas, (2019). Agricultural furrow irrigation inefficiency in the basin of the Laguna de Bustillos, Chihuahua, Mexico: geometric characteristics of agricultural plots and aquifer depletion.

Tecnologías y Ciencias del Agua, ISSN electrónico: 2007-2422; ISSN impreso: 0187-8336; DOI: 10.24850/j-tyca-2019-05-10

2. Rojas-Villalobos, H.L.; Alatorre-Cejudo, L.C.; Stringam, B.; Samani, Z; Brown, C.; (2018). Topobathymetric 3D model reconstruction of shallow water bodies through remote sensing, GPS, and bathymetry. TECNOCIENCA Chihuahua, 12(1), 42-54. ISSN: 1870-6606.

3. Ramón Leopoldo Moreno Murrieta, Luis Carlos Bravo Peña, Luis Carlos Alatorre Cejudo, (2018). Entre fronteras: vivir, pensar y experimentar. Ciudades, 118(1), 12-24. ISSN: 0187-8611.

Capítulos de libros

1. Moreno, R.L., Bravo, L.C., Alatorre, L.C. (2018). Habitar, imaginarios y territorios en Cuauhtémoc y Ciudad Juárez: la ciudad como un espacio pluriétnico y pluricultural. En: Hacia una EVALUACIÓN de las ciudades CONTEMPORÁNEASDIAGNÓSTICO Y ESTRATEGIAS PARA LA HABITABILIDAD SOSTENIBLE Y CALIDAD DE VIDA. Eds. María Elena Torres Pérez. Red Nacional de Investigación Urbana, Universidad Autónoma de Yucatán, Facultad de Arquitectura, 912 pp. ISBN: 978-607-8527-75-5

Libros (ISBN)

1. Mosiváis-Hurtero A.; Villalón-Turrubiates I.E.; Alatorre-Cejudo L.C.; Romo C.; Álvaro-Moltalvo M.; Soria-Ruíz, J.; et al.; (2017). 2016 IEEE 1er Congreso Nacional de Ciencias Geoespaciales (CNCG). IEEE-Explore, 71 pp. ISBN: 978-1-5386-1863-9 Online: IEEE Xplore digital library effective 2017-07-20, http://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=7985009

Participación en eventos académicos e investigación

1. Título del trabajo: Modelización de la erosión potencial con la RUSLE: comparación con las tasas de sedimentos real con Cs137.

Autores: Perla Yesenia Borja Dominguéz, Luis Carlos Alatorre Cejudo.

Evento: XVIII Simposio Internacional SELPER Cuba 2018

Tipo de participación: Oral

Lugar y fecha: Habana, Cuba, del 6 al 9 de Noviembre de 2018.

2. Título del trabajo: Aproximación espacio-temporal de Triatoma recurva en Chihuahua, México.

Autores: Maria Elena Torres Olave, Gina Isabel Zesati Pereyra, Luis Carlos Alatorre, Luis Carlos Bravo, Mario Uc, Manuel González León, Salvador Vargas García, Alfredo Granados Olivas.

Evento: XVIII Simposio Internacional SELPER Cuba 2018

Tipo de participación: Poster

Lugar y fecha: Habana, Cuba, del 6 al 9 de Noviembre de 2018.

3. Título del trabajo: Proceso Biogeográficos enfocados a la vigilancia epidemiológica de Triatoma recurva en Chihuahua.

Autores: María Elena Torres-Olave, Gina Isabel Zesati Pereyra, Luis Carlos Alatorre-Cejudo, Luis Carlos Bravo-Peña, Mario Iván Uc-Campos, Manuel Octavio González-León, Lara Cecilia Wiebe-Quintana, Alfredo Granados-Olivas.

Evento: XVII Congreso Internacional & XXVIII Congreso Nacional de ANCA

Tipo de participación: Oral

Lugar y fecha: Zacatecas, Zacatecaz, México, del 11 al 15 de Julio de 2018.

Technical report, 26/12/2018

Participants in this part of the Project are:

PhD. Luis Carlos Alatorre Cejudo (7484)

Undergraduate students:

Gabriela Veleta Jáquez (145410)

Doctoral student:

Víctor Hugo Esquivel Ceballos. (150571)

The following describes the databases and methodological processes to be able to generate the geographic information of the territory included in the study area (figure 1). In general, most of the information has been obtained from institutions such as the National Institute of Statistics and Geography (INEGI), National Commission for the Knowledge and Use of Biodiversity (CONABIO), National Water Commission (CONAGUA), United States Geological Survey (USGS-USA), among others.

A continuación se describen las bases de datos y los procesos metodológicos para poder generar la información geográfica del territorio incluido en el área de estudio (figura 1). En general, la mayor parte de la información se ha obtenido de instituciones como el Instituto Nacional de Estadística y Geografía (INEGI), Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO), Comisión Nacional del Agua (CONAGUA), Servicio Geológico de Estados Unidos (USGS-USA), entre otros.

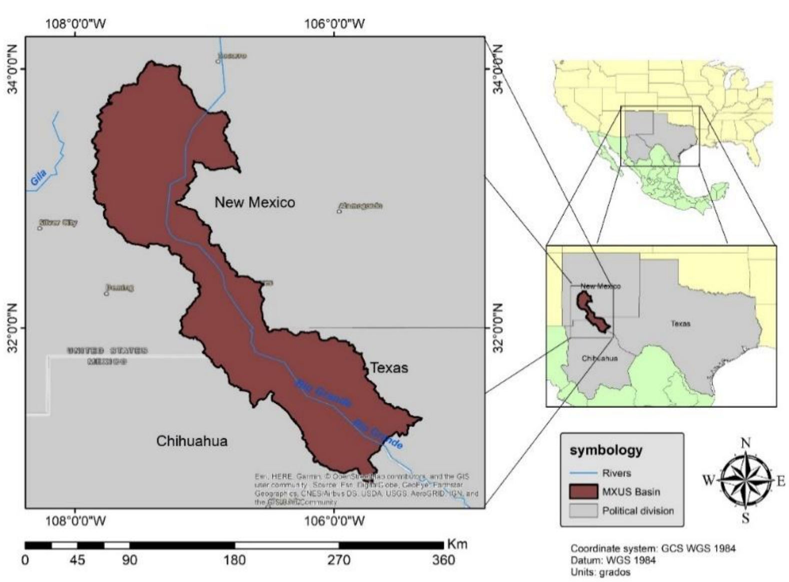

Figure 1. Study area: Rio Bravo hydrological basin; A) United State of America, México; B) New Mexico, Texas, Chihuahua.

In general, it shows preliminary results of the analysis of the temporal and spatial evolution of vegetation dynamics in various land covers in the basin of the Middle Rio Bravo/Grande (USA and México). The methodology developed was based on: 1)- construction of the annual time series of satellite images from Landsat TM and Landsat 8OLI (1994-2015); 2)- definition of thematic categories and training areas; 3)- the classification of the images using the maximum likelihood method; and, 4)- use of the NDVI as a measure of recovery and degradation processes of vegetated categories (figure 2).

En general, se muestran los resultados preliminares del análisis de la evolución temporal y espacial de la dinámica de la vegetación en diversas coberturas terrestres en la cuenca del Río Bravo Medio / Grande (Estados Unidos y México). La metodología desarrollada se basó en: 1) - construcción de la serie temporal anual de imágenes de satélite de Landsat TM y Landsat 8OLI (1994-2015); 2) - definición de categorías temáticas y áreas de formación; 3) - la clasificación de las imágenes utilizando el método de máxima verosimilitud; y, 4) - uso del NDVI como medida de procesos de recuperación y degradación de categorías vegetadas (figura 2).

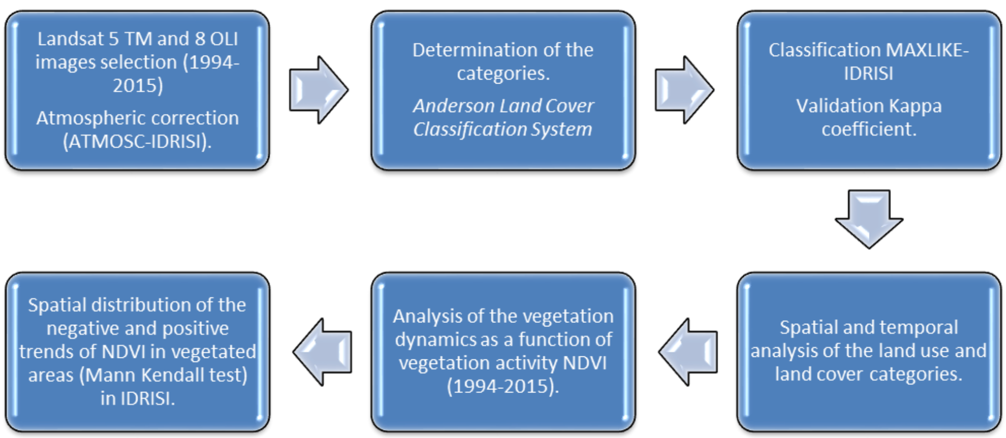

Figure 2. Methodological steps for the supervised classification process and analysis of the temporal and spatial evolution of vegetation dynamics in various land covers

Main results

In figure 3 you can see the result of the Maxlike classification process, to determine the 8 selected categories. The preliminary results show spatial distribution of the area occupied by each category in which the category that occupies the largest area is the scrubland, followed in descending order by grassland, forest, bare soil, urban, agriculture, wetlands and water bodies.

Resultados principales

En la figura 3 se puede ver el resultado del proceso de clasificación de Maxlike, para determinar las 8 categorías seleccionadas. Los resultados preliminares muestran la distribución espacial del área ocupada por cada categoría en la que la categoría que ocupa la mayor superficie es el matorral, seguida en orden descendente por pastizales, bosques, suelo desnudo, urbano, agricultura, humedales y cuerpos de agua.

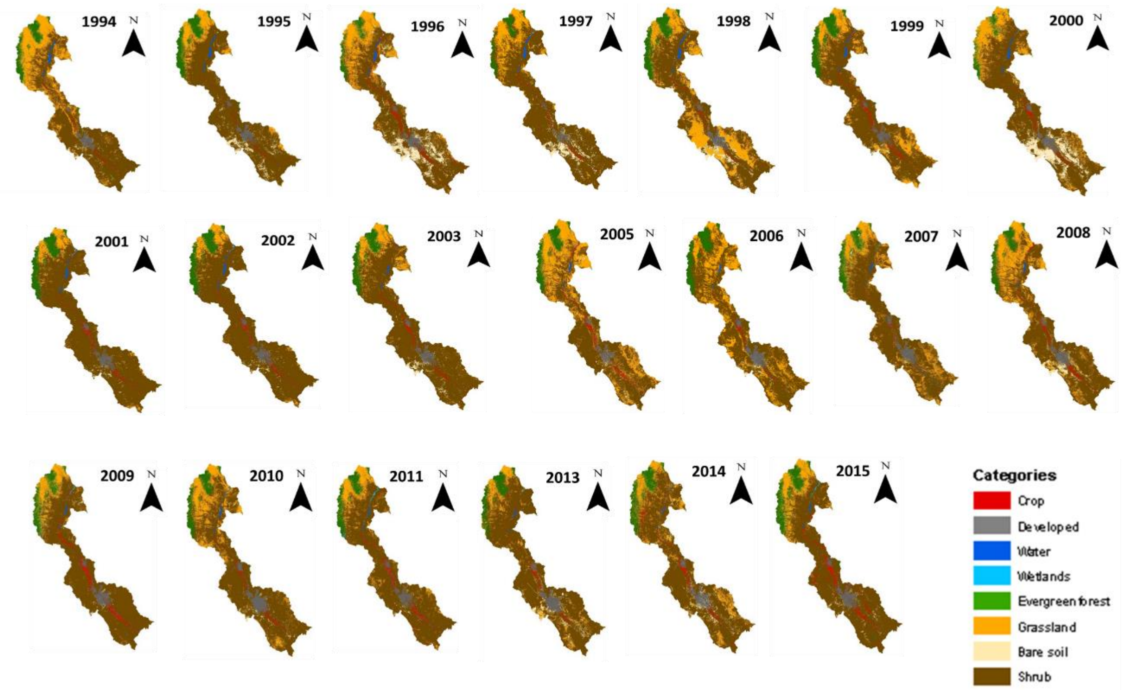

Figure 3. Result of the Maxlike classification process (1995-2015).

The use of an independent set of randomly selected pixels allowed for validating the classification model, which was very good (87.67% overall accuracy) (Table 1). The biggest confusion occurred with the category of bare soil and shrub, with an error of commission of 12.5% and 14%, and an error of omission of 11.06% and 1.9%, respectively.

El uso de un conjunto independiente de píxeles seleccionados aleatoriamente permitió validar el modelo de clasificación, el cual fue muy bueno (87,67% de precisión general) (Tabla 1). La mayor confusión ocurrió con la categoría de suelo desnudo y arbusto, con un error de comisión del 12,5% y 14%, y un error de omisión del 11,06% y 1,9%, respectivamente.

	1	2	3	4	5	6	7	8	ErrorC
1	1	0	0	0	0	0	0	0.002212389	0.0244
2	0	1	0	0	0	0	0	0	0.0294
3	0	0	0.928571	0	0	0	0	0	0
4	0	0	0	1	0	0	0	0	0
5	0	0	0	0	0.958333	0	0	0.006637168	0.0612
6	0	0	0	0	0	0.989691	0.035714	0.084070796	0.2941
7	0	0	0	0	0	0	0.875	0.017699115	0.1404
8	0	0	0.071429	0	0.041667	0.010309	0.071429	0.889380531	0.0195
Total	40	33	14	26	48	97	56	452	
ErrorO	0	0	0.0714	0	0.0417	0.0103	0.125	0.1106	0.0796
								Kappa coefficient	0.8767

Table 1. Confusion matrix between thematic categories (proportion of total pixels) and kappa coefficient. Categories: (1) Crop; (2) Developed; (3) Water; (4) Wetland; (5) Evergreenforest; (6) Grassland; (7) Bare soil; (8) Shrub

The temporal analysis was carried out. In Figure 4 you can see the behavior over time, which highlights the following: i) The largest area is occupied by the categories of scrub and grassland, it is also observed that there is a significant relationship between these two categories, that is, when the shrubs increase the area of the grassland it falls in the same order of magnitude; ii) in second order of importance appear the categories grassland, bare soil and evergreenforest; and, iii) the categories that occupy the least area are the water and developed areas.

Se realizó el análisis temporal. En la Figura 4 se puede observar el comportamiento a lo largo del tiempo, donde se destaca lo siguiente: i) La mayor superficie la ocupan las categorías de matorral y pastizal, también se observa que existe una relación significativa entre estas dos categorías, es decir, cuando los arbustos aumentan el área de la pradera cae en el mismo orden de magnitud; ii) en segundo orden de importancia aparecen las categorías pastizal, suelo desnudo y bosque siempreverde; y, iii) las categorías que ocupan menor área son el agua y las áreas desarrolladas.

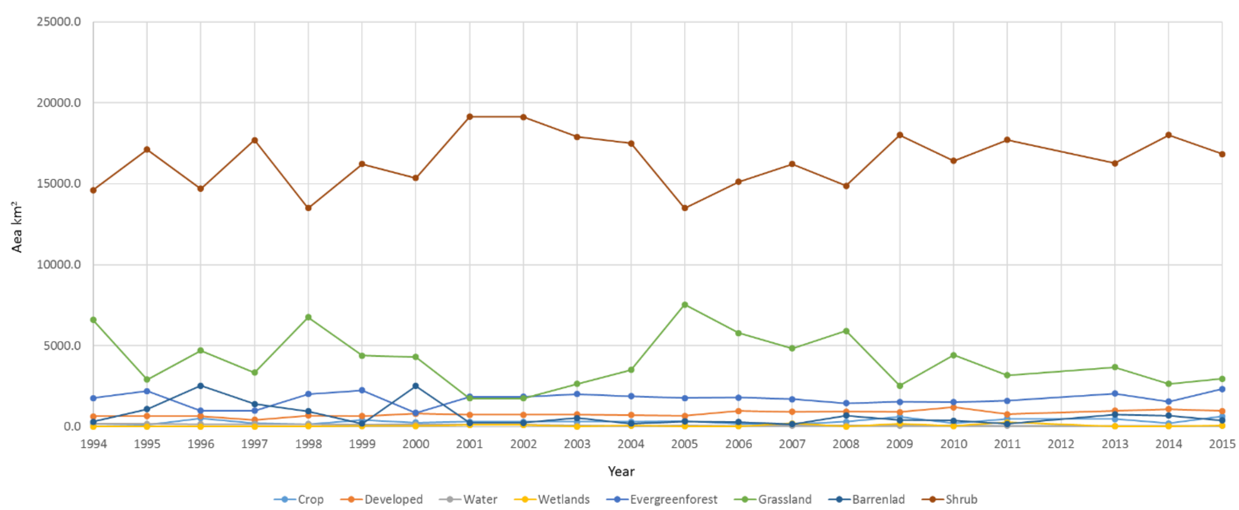

Figure 4. Temporal and spatial evolution of the 8 cagtegories in the study área.

The time series of the mean NDVI values showed a clear difference between the different vegetated areas, the evergreenforest areas show the highest mean values of the NDVI, followed by the categories of grassland, scrubs, and, finally, the bare soil category with the lowest mean values. Preliminary visual inspection revealed remarkable differences in NDVI trends (Figure 5) related to the different land cover and use categories. In general, it appears that the NDVI values of the some areas show a negative trend, which is more evident for the category of evergreen forest.

La serie de tiempo de los valores medios del NDVI mostró una clara diferencia entre las diferentes áreas vegetadas, las áreas de bosque siempreverde muestran los valores medios más altos del NDVI, seguidas de las categorías de pastizal, matorral y, finalmente, la categoría de suelo desnudo con menor valores medios. La inspección visual preliminar reveló diferencias notables en las tendencias del NDVI (Figura 5) relacionadas con las diferentes categorías de uso y cobertura del suelo. En general, parece que los valores del NDVI de algunas áreas muestran una tendencia negativa, que es más evidente para la categoría de bosque siempre verde.

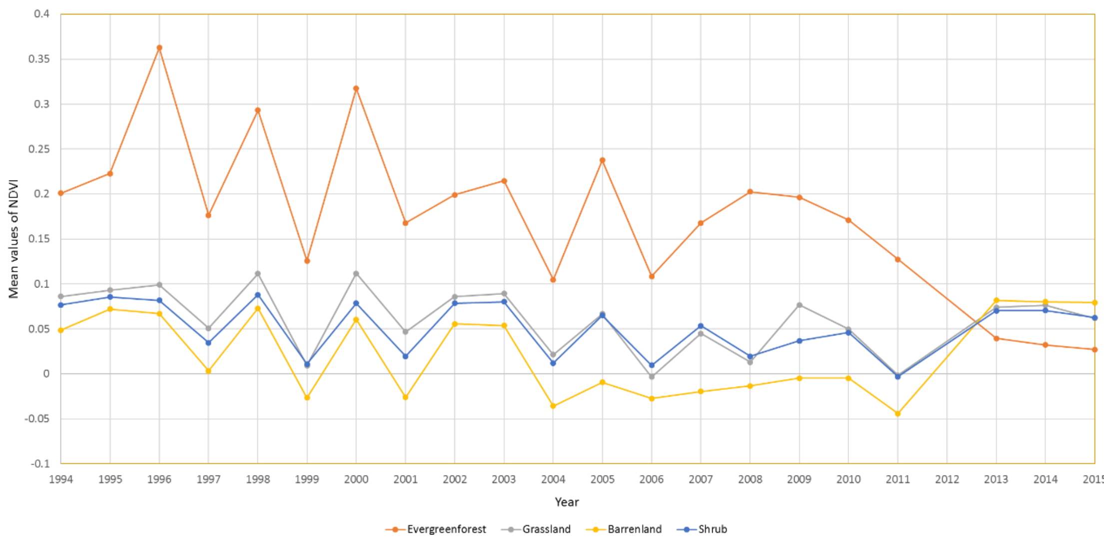

Figure 5. Temporal and spatial evaluation of the NDVI.

Figure 6 shows the spatial distribution of the negative trends of NDVI in vegetated areas, using the non-parametric measure of Mann Kendall (MK) test. There are large areas with negative temporal trends, which, in a forthcoming work, will try to explain with the temporal variation of climatic variables, such as: minimum and maximum temperature, precipitation, etc. However, it is also possible to see areas with negative trends, which can be associated with degradation processes of the vegetation cover (Next results to develop.).

La Figura 6 muestra la distribución espacial de las tendencias negativas de NDVI en áreas con vegetación, utilizando la medida no paramétrica de la prueba de Mann

Kendall (MK). Existen grandes áreas con tendencias temporales negativas, que en un próximo trabajo se intentará explicar con la variación temporal de variables climáticas, tales como: temperatura mínima y máxima, precipitación, etc. Sin embargo, también es posible ver áreas con tendencias negativas, que pueden estar asociadas con procesos de degradación de la cubierta vegetal (próximos resultados a desarrollar).

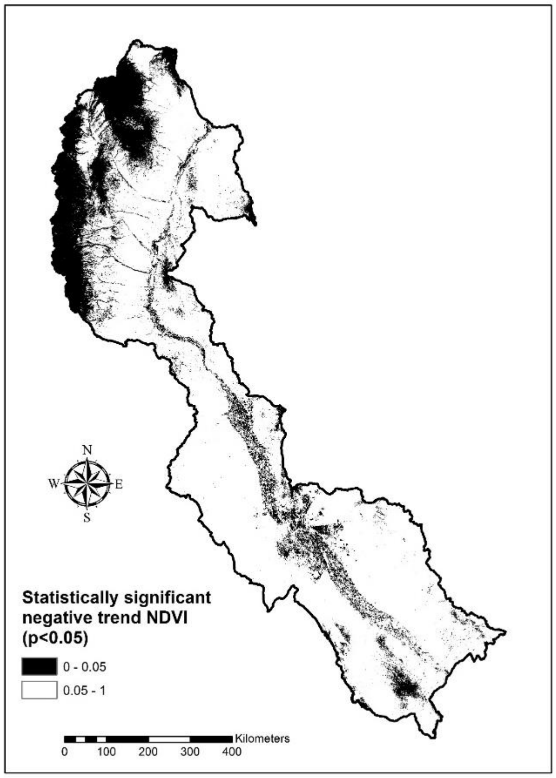

Figure 6. Spatial distribution of NDVI temporal trends (1994-2015) in vegetated areas.

Preliminary conclusions

The present work shows the usefulness of remote sensing and GIS techniques in basin and regional scales (study areas between 10 and 10,000 km2). The use of supervised classification techniques using the maximum likelihood method from an a priori set of categories (land use and land cover), has allowed to obtain a cartography of the different selected categories (1994-2015). Without forgetting that the correct selection of training areas has allowed to locate areas for each of the categories (replicas), resulting in maximum possible variability of the spectral signatures between them. In general, shown that the most important categories in the region are the Shrub, Grassland, Bare soil and Evergreenforest, and the temporal variability shown may be due to climatic conditions (drought, wet periods, etc.) that alter the spectral response, mainly the vegetation greenness. The homogenized series of NDVI for the months of March-April (early spring) allowed us to analyze the spatial and temporal dynamics of vegetation activity in vegetated areas (evergreenforest, shrub and grassland) and bare soil with sparse vegetation. The methodology and the results obtained in this research are a powerful tool for institutions that have responsibility for implementing environmental and land use management plans for mitigating the degradation processes of the areas vegetated, principally forests, allowing prevention efforts to be concentrated in places where the benefit will be greatest.

Conclusiones preliminares

El presente trabajo muestra la utilidad de las técnicas de teledetección y SIG a escala de cuenca y regional (áreas de estudio entre 10 y 10,000 km2). El uso de técnicas de clasificación supervisada utilizando el método de máxima verosimilitud a partir de un conjunto de categorías a priori (uso del suelo y cobertura del suelo), ha permitido obtener una cartografía de las diferentes categorías seleccionadas (1994-2015). Sin olvidar que la correcta selección de áreas de entrenamiento ha permitido ubicar áreas para cada una de las categorías (réplicas), resultando en la máxima variabilidad posible de las firmas espectrales entre ellas. En general, se muestra que las categorías más importantes de la región son Arbusto, Pastizal, Suelo desnudo y Bosque siempreverde, y la variabilidad temporal mostrada puede deberse a condiciones climáticas (sequía, períodos húmedos, etc.) que alteran la respuesta espectral, principalmente el verdor de la vegetación. La serie homogeneizada de NDVI para los meses de marzo-abril (principios de primavera) permitió analizar la dinámica espacial y temporal de la actividad de la vegetación en áreas con vegetación (bosque siempre verde, arbusto y pastizal) y suelo desnudo con escasa vegetación. La metodología y los resultados obtenidos en esta investigación son una poderosa herramienta para las instituciones que tienen la responsabilidad de implementar planes de manejo ambiental y de ordenamiento territorial para mitigar los procesos de degradación de las áreas vegetadas, principalmente bosques, permitiendo concentrar los esfuerzos de prevención en los lugares donde el beneficio será más grande.

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Technical report 24/12/2016

Participants in this part of the Project are:

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Obed Alejandro Márquez Barraza}

Doctoral student:

Víctor Hugo Esquivel Ceballos.

Technical report

The following describes the databases and methodological processes to be able to generate the geographic information of the territory included in the study area. In general, most of the information has been obtained from institutions such as the National Institute of Statistics and Geography (INEGI), National Commission for the Knowledge and Use of Biodiversity (CONABIO), National Water Commission (CONAGUA), United States Geological Survey (USGS-USA), among others.

Reporte técnico

A continuación, se describen las bases de datos y procesos metodológicos para poder generar la información geográfica del territorio comprendido por el área de estudio. En general, la mayor parte de la información se ha obtenido de instituciones como el Instituto Nacional de Estadística y Geografía (INEGI), Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO), Comisión Nacional del Agua (CONAGUA), United States Geological Survey (USGS-USA), entre otros.

The delimitation of the study area required several meetings to define the geographical limits of the watershed and sub-basins, this was necessary to guarantee compatibility with the database generated by our colleagues in the USA. The database of the hydrographic basin was obtained from INEGI, Red hidrográfica, subcuencas hidrográficas de México', escala: 1:50000. Edición: 2. The study area is comprised of 6 hydrographic sub-basins, which together have an area of approximately 4697 km2.

La delimitación del área de estudio requirió de varias reuniones para definir los límites geográficos de la cuenca hidrográfica y de las sub-cuencas, para así garantizar la compatibilidad con la base de datos generada por nuestros colegas en USA. La base de datos de la cuenca hidrográficas fue obtenida del INEGI, 'Red hidrográfica, subcuencas hidrográficas de México', escala: 1:50000. Edición: 2. El área de estudio está comprendida por 6 subcuencas hidrográficas, la cuales en su conjunto tienen un área aproximada de 4697 km2.

One of the most important aspects for the correct modeling with SWAT, among others, is to have a Digital Terrain Model (DTM) with good precision. Therefore, it was decided to use the Mexican Elevation Continuous 3.0 (CEM 3.0), with a spatial resolution of 15 m, has a coverage for the entire continental territory of the United Mexican States, and has a mean square error of 4.8 m, INEGI. The altitudinal range shows elevations ranging from 997 to 2199 masl, and the average altitude for the entire area is of the order of 1321 masl.

Uno de los aspectos más importantes para la correcta modelización con SWAT, entre otros, es contar con un Modelo Digital del Terreno (MDT) con una buena precisión. Por ello, se optó por utilizar el Continuo de Elevaciones Mexicano 3.0 (CEM 3.0), con una resolución espacial de 15 m, tiene una cobertura para todo el Territorio continental de los Estados Unidos Mexicanos, y tiene un error medio cuadrático de 4.8 m, INEGI. El rango altitudinal muestra tener elevaciones que van desde los 997 msnm a los 2199 msnm, y la altitud media para toda el área es del orden de 1321 msnm.

For the land use and land cover (LULC) present in the study area, several sources have been chosen, since the time scale of analysis includes from 1985 to 2015. Our map of reference is the cartography of land use and vegetation of the state of Chihuahua (1: 50,000), generated by the Government of the State of Chihuahua (local), and the valid period of this map is the year 2013. For others years we used the set of vector data of Datos Vectoriales de Uso de Suelo y Vegetación, scale 1:250 000, series I-V of INEGI, which correspond to the years 1985, 1995, 2000, 2007, 2013. Although we have a good data base, we chose to implement remote sensors to be able to generate information through LANDSAT satellite, for the years 1985 to 2015, it was necessary to perform classification processes using LANDSAR 5 TM and LANDSAT 8 OLI images (Table 1; Glovis USGS). In general, the study area consists mainly of irrigation agriculture, temporary agriculture, human settlements (urban areas), induced pasture, natural grassland and mixed vegetation.

Para las coberturas y uso de suelos presentes en el área de estudio se han optado por varias fuentes, ya que se la escala temporal de análisis comprende desde el año 1985-2015. Nuestra cartografía base y de referencia es la Cartografía de uso de suelo y vegetación del estado de Chihuahua (1:50,000), generada por el Gobierno del Estado de Chihuahua (local), y el periodo valido de esta cartografía es el año 2013. Para los demás años utilizamos el conjunto de datos vectoriales de uso de suelo y vegetación escala 1:250 000, series I-V de INEGI, las cueles corresponden a los años 1985, 1995, 2000, 2007, 2013. A pesar de que contamos con estas bases de datos, optamos por implementar sensores remotos para poder generar información a través del satélite LANDSAT, para los año 1985 al 2015 fue necesario realizar procesos de clasificación mediante imágenes LANDSAR 5 TM y LANDSAT 8 OLI (tabla 1; Glovis USGS). En general el área de estudio está constituida principalmente por agricultura de riego, agricultura de temporal, asentamientos humanos (áreas urbanas), pastizal inducido, pastizal natural y vegetación mixta.

Table 1. LANDSAT scenes for the construction of the mosaic of each year of study.

Tabla 1. Escenas LANDSAT para la construcción del mosaico de cada año de estudio.

Images	Date	Sensor
LT50320381985185AAA02	04/07/1985	Landsat 5 TM
LT50320391985185AAA02	05/07/1985	Landsat 5 TM
LT50330381985144AAA07	24/05/1985	Landsat 5 TM
LT50320381995165XXX01	14/06/1995	Landsat 5 TM
LT50320391995165XXX01	14/06/1995	Landsat 5 TM
LT50330381995204XXX00	23/07/1995	Landsat 5 TM
LT50320382005176PAC01	25/06/2005	Landsat 5 TM
LT50320392005192EDC00	11/07/2005	Landsat 5 TM
LT50330382005215EDC00	03/08/2005	Landsat 5 TM
LT50320382008153PAC01	01/06/2008	Landsat 5 TM
LT50320392008153EDC00	01/06/2008	Landsat 5 TM
LT50330382008160PAC01	08/06/2008	Landsat 5 TM
LC80320392013214LGN00	02/08/2013	Landsat 8 OLI
LC80330382013173LGN00	22/06/2013	Landsat 8 OLI
LC80320392015204LGN00	23/07/2015	Landsat 8 OLI
LC80330382015163LGN00	12/06/2015	Landsat 8 OLI

To determine the spatial distribution of the average evapotranspiration we chose to use the MODIS Evapotranspiration Data Set database, MOD16 ET, we obtained the mean values for the month of September, the month in which the evapotranspiration is more critical. The MOD16 ET datasets are estimated using Mu et al.'s improved ET algorithm (2011) over previous Mu et al.'s paper (2007a). The ET algorithm is based on the

Penman-Monteith equation (Monteith, 1965). Surface resistance is an effective resistance to evaporation from land surface and transpiration from the plant canopy.

Para determinar la distribución espacial de la evapotranspiración media se optó por utilizar la base de datos de MODIS Evapotranspiration Data Set, MOD16 ET, se obtuvieron los valores medios para el mes de septiembre, mes en que la evapotranspiración es más crítica. The MOD16 ET datasets are estimated using Mu et al.'s improved ET algorithm (2011) over previous Mu et al.'s paper (2007a). The ET algorithm is based on the Penman-Monteith equation (Monteith, 1965). Surface resistance is an effective resistance to evaporation from land surface and transpiration from the plant canopy.

In order to determine the spatial distribution of the different soil units, we used the vector dataset of Conjunto de datos vectoriales edafológico, escala 1:250000 Serie II. (Continuo Nacional-INEGI).

Para determinar la distribución espacial de las distintas unidades de suelos, se utilizó la base del Conjunto de datos vectoriales edafológico, escala 1:250000 Serie II. (Continuo Nacional-INEGI).

Finally, mentioning that within this project three theses are being developed, two of them are developed in the Degree in Geoinformatics and one more in the Doctorate of Urban Studies, both of the Autonomous University of Ciudad Juárez. The titles of these works are: 1) MODELING GROUNDWATER FLOWS IN THE AQUIFER OF CUAUHTÉMOC, CHIHUAHUA, MÉXICO: VISUAL MODFLOW; 2) URBAN GROWTH IN CIUDAD JUÁREZ (1995-2015): IMPACT ON URBAN LULC AND LULC OF THE TERRITORY; y, 3) ANALYSIS OF URBAN GROWTH IN JUAREZ CITY: SPATIAL AND TEMPORAL REPERCUSSIONS ON DEMAND AND WATER AVAILABILITY, AND THE STATIC WATER LEVEL OF THE AQUIFER (1985-2015).

Finalmente mencionar que dentro de este proyecto se están desarrollando tres tesis, dos de ellas se desarrollan en la Licenciatura en Geoinformática y una más en el Doctorado de Estudios Urbanos, ambas de la Universidad Autónoma de Ciudad Juárez. Los títulos de estos trabajos son: 1) CONCEPTUAL MODELING OF FLOW NETWORKS IN CUAUHTÉMOC AQUIFER, CHIHUAHUA, MEXICO BY VISUAL MODFLOW; 2) ANALYSIS OF URBAN GROWTH IN JUAREZ CITY AND ITS IMPACT ON THE COVERAGE AND USES OF URBAN LAND AND TERRITORY 1995-2005, 2005-2015; y, 3) ANALYSIS OF URBAN GROWTH IN JUAREZ CITY: SPATIAL AND TEMPORAL REPERCUSSIONS ON DEMAND AND WATER AVAILABILITY, AND THE STATIC WATER LEVEL OF THE AQUIFER (1985-2015).

Galeria de fotos:

La Universidad Autónoma de Ciudad Juárez

a través de la

Coordinación de Investigación y Posgrado y el Cuerpo Académico de Geoinformática Aplicada a Procesos Geoambientales UACJ-CA-94

Otorgan:

CERTIFICADO DE COORDINADOR GENERAL DE EVENTO INTERNACIONAL

Luis Carlos Alatorre Cejudo

V Foro de Capacitación

de la plataforma Sustainable Water Through Integrated Modeling-SWIM

Llevado a cabo en Centro Cultural de las Fronteras - UACJ

22 de noviembre de 2019

Ciudad Juárez, Chihuahua

Dra. Beatriz A. Díaz Torres
COORDINADORA GENERAL DE INVESTIGACIÓN Y POSGRADO UACJ

Dr. Joseph M. Heyman
DIRECTOR DEL CENTRO DE ESTUDIOS FRONTERIZOS E INTERAMERICANOS-UTEP

Dr. William L. Hargrove
DIRECTOR DEL CENTRO DE INVESTIGACIÓN Y ADMINISTRACIÓN AMBIENTAL-UTEP

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SUSTAINABLE WATER RESOURCES SYMPOSIUM

January 8, 2019

The University of Texas at El Paso
Center for Environmental Resource Management
(CERM)

Sponsored in part by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under award number 2015-68007-23130

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UTEP

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CERTIFICATE OF PARTICIPATION BY:

Dr. Luis Carlos Alatorre

W. L. Hargrove, Director
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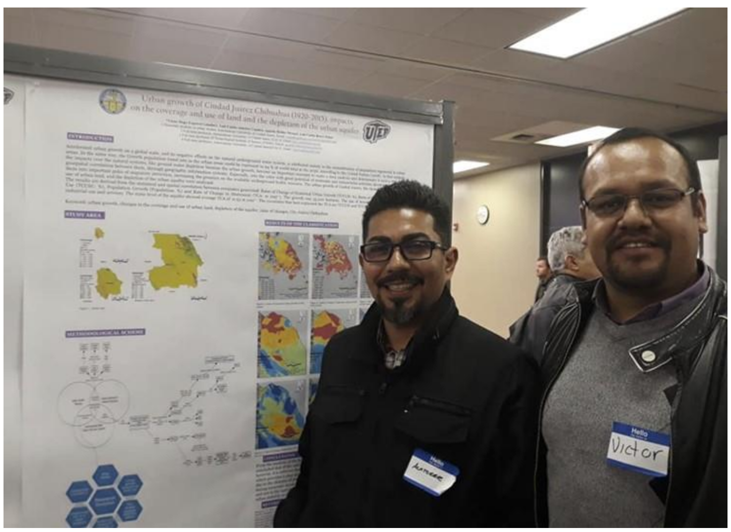

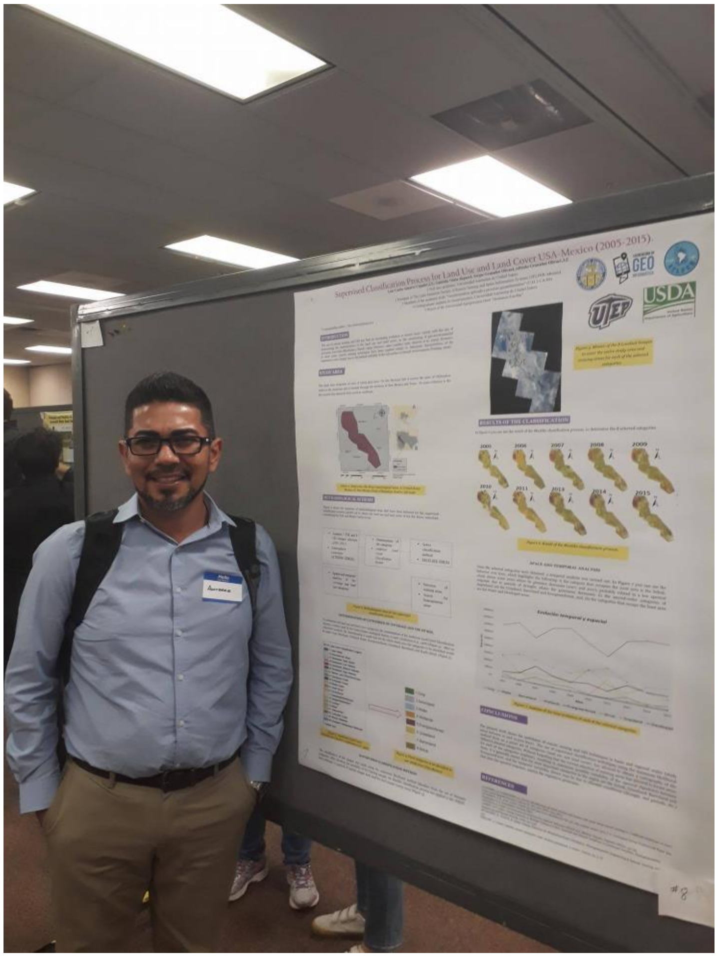
Supervised Classification Process for Land Use and Land Cover USA-Mexico (2005-2015).
GEO
UTEP
USDA


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PROYECTO DE INVESTIGACION CON FINANCIAMIENTO EXTERNO:

Sustainable Water Resources for Irrigated Agriculture in a Desert River Basin Facing Drought and Competing Demands: From Characterization to Solutions

Resumen de Actividades
Equipo de modelación de balance hídrico (SWAT)
Periodo 2016-2020

Coordinador: Dr. Sergio Saúl Solís

Colaboradores:

Estudiantes	Matricula	Investigadores
Holman Quintero Salazar	164626	Dr. Hugo Rojas Villalobos
Katya Esquivel Herrera	132138	Dr. Arturo Soto Ontiveros
Carolina Salazar González	148236	Dr. Luis Alatorre Cejudo
Miguel Durán Rangel	183310	Dra. Sora Ahn (TAMU)
Alexis Rodríguez Sánchez	122010	Dr. Zhuping Sheng (TAMU)
Alida Lizeth Castillo Castro	171918	Dr. Alfredo Granados
Victor Esquivel Ceballos	150571	

Cd. Juárez, Chihuahua. 20 de agosto, 2020.

I. Relación de actividades relacionadas con el desarrollo general del proyecto.

A continuación, se describen de manera resumida, las actividades desarrolladas más relevantes por el equipo de modelación, en el marco del proyecto de investigación, para el periodo que se señala.

2016

- 6 enero, 2016. Reunión binacional de seguimiento al proyecto, definición de componentes hidrológicos de interés para modelación, presentación de avances del simulador “Bucket Model”, revisión y evaluación de las opciones de paquetes computacionales para el desarrollo de modelos hidrológicos e hidrogeológicos.
- Enero – Junio, 2016. Definición de la delimitación geográfica de la cuenca y subcuencas binacionales del área de estudio, con base en las clasificaciones hidrológicas de cada país, generación digital de mapas y bases de datos, procesamiento de imágenes de satélite para generación de mapas de usos de suelo.
- Julio – Diciembre, 2016. Capacitación para el desarrollo del modelo de SWAT, trabajos para la generación de los mapas y bases de datos en Sistemas de Información Geográficas y aplicaciones para el manejo de Sensores Remotos para mapas de usos de suelo, tipos de suelo, series de tiempo de información climatológica, y modelos digitales e elevación de terreno.

2017

- 3 enero, 2017. Participación en reunión binacional de seguimiento al proyecto, presentación de avances mediante ponencias y posters, redacción de reporte en ingles de actividades de modelación SWAT (2016-17).
- 16 febrero, 2017. Participación en Pre congreso de la Sección Frontera Norte de la Asociación Mexicana de Hidráulica (AMH), Ciudad Juárez, Chihuahua. *“Mecanismos de Cooperación en Cuencas Transfronterizas entre México y Estados Unidos*”. Ponencia: Construcción del Modelo Soil Water Assessment Tool (SWAT) para la Cuenca Hidrológica de Ciudad Juárez, Retos y Aspectos Técnicos. Dr. Sergio Saúl Solís.
- Diciembre, 2017. Participación en talleres de participación y retroalimentación con los usuarios sociales (stakeholders), de los modelos del proyecto (agrícola, academia, organismos operadores). Presentación de avances sobre la integración del modelo SWAT, así como la plataforma de simulación del modelo Bucket Model. 30 de noviembre.

2018

- 8 enero, 2018, Participación en reunión binacional de seguimiento al proyecto, y presentación de avances mediante ponencias, posters y redacción de un White Paper: *Modeling of hydrological variables of the Hueco Bolson - Valle de Juárez Basin, Using the Soil Water Assessment Tool (SWAT) Program*.
- 23 marzo, 2018. Participación en taller binacional de seguimiento al proyecto, presentación de avances mediante ponencias.
- Octubre, 2018. Revisión de funcionalidad a la versión beta del modelo SWIM, en la página web http://water.cybershare.utep.edu.
- 25 octubre, 2018. Participación en el III Taller binacional de seguimiento al proyecto, y presentación de avances mediante ponencias, redacción de un White Paper: *Modelación de Variables Hidrológicas de la Cuenca Hidrográfica RH24I "Río Bravo – Ciudad Juárez", Mediante Aproximación de Balance Hídrico*.

2019

- 7 enero, 2019. Participación en reunión binacional de seguimiento al proyecto, y presentación de avances mediante ponencias, posters (2), reunión de trabajo y planeación con líderes de áreas.
- Abril, 2019. Participación en IV Taller de Capacitación de la Plataforma Sustainable Water through Integrated Modeling-SWIM, en las instalaciones de la UACJ. Presentación de plataforma en centro de cómputo.
- 5-6 agosto, 2019. Reunión de trabajo de los equipos de modelación del proyecto, realizado en las instalaciones de la Universidad de Texas en El Paso.
- 21-22 octubre, 2019. Participación en la convocatoria Encuentro de Jóvenes Investigadores del Estado de Chihuahua Jóvenes Investigadores 2019, por parte de tres estudiantes colaboradores del equipo de modelación SWAT.
- 20 noviembre, 2019. Participación en el V Foro de Trabajo Participativo con Usuarios, el cual consistió en una reunión plenaria de participación y retroalimentación con los usuarios sociales (stakeholders), de los modelos del proyecto. Presentación de avances sobre la integración del modelo SWAT, informes técnicos y posters.

2020

- Enero, 2020. Participación en reunión binacional de seguimiento al proyecto, y presentación de avances mediante ponencias, posters (2), reunión de trabajo y planeación con líderes de áreas.
- Desarrollo de investigación enfocada en el análisis de los impactos en la recarga y balance hídrico, mediante la modelación de eficiencias de riego y cambios de cultivos,

para el distrito de riego 09 del Valle de Juárez. Generación de reporte técnico. Agosto, 2020.

II. Relación de actividades relacionadas con el desarrollo de modelos en SWAT (Soil Water Assessment Tool).

A continuación, se describen de manera resumida, las principales actividades desarrolladas relacionadas con los procesos de construcción de los modelos en la plataforma computacional SWAT, para el periodo que se señala.

Enero – Junio, 2016

- Delimitación geográfica de la cuenca y subcuencas binacionales del área de estudio, procesamiento de imágenes de satélite para generación de mapas de usos de suelo, generación digital de mapas y bases de datos.

Julio – Diciembre, 2016

- Capacitación para el desarrollo del modelo de SWAT, compilación y revisión de bases de datos y mapas de usos de suelo, tipos de suelo, series de tiempo de información climatológica, y modelos digitales de elevación de terreno.

Enero – Junio, 2017

- Desarrollo de los primeros modelos de prueba de la plataforma SWAT en ArcMAP

Marzo 2018

- Modelación de balance hídrico por sub-cuencas RH24 (IG, IF, IE, ID), utilizando las primeras coberturas desarrolladas de usos y tipo de suelo, periodo (1995-2005).

Mayo 2018

- Integración de fuentes puntuales americanas de aportación de agua (point sources) para la modelación, incorporando mapas digitales de usos y tipos de suelo, información de datos climáticos de estaciones de monitoreo y algoritmo generador de clima, para los periodos (1995-2005).
- Reunión con investigadores de Texas A&M University, para intercambio de bases de datos.

Junio 2018

- Reunión de trabajo de los equipos de modelación, revisión de avances y establecimiento de objetivos de trabajo a desarrollar, instalaciones de la UACJ.

- Desarrollo y entrega de coberturas digitales actualizados de usos y tipos de suelo, para el periodo (1995-2015).

Octubre 2018:

- Reunión de trabajo con investigadores de Texas A&M University, para intercambio y revisión de bases de datos de aportaciones hidrológicas del lado estadounidense.
- Actualización de datos hidrométricos de las entradas puntuales (point sources), provenientes de la cuenca estadounidense.

Diciembre 2018

- Entrega de evidencia de publicaciones RAUGM 2018.

Enero 2019

- Revisión de los parámetros de simulación de agricultura, para mejorar el refinamiento de los modelos desarrollados.
- Participación en el taller: One Water en las instalaciones de la Universidad de Texas en El Paso (UTEP), presentación de resultados de modelación SWAT.

Marzo 2019

- Pruebas de modelación en la cuenca mexicana, integrando parámetros de agricultura, ajuste y revisión de entradas puntuales americanas (point sources).

Marzo – Mayo 2019

- Modelación de la sección de la cuenca mexicana con una serie de cuatro escenarios hipotéticos de administración hídrica en quinquenios para cuantificar posibles efectos que tendrían en la recarga, incluyendo opciones de reinyección de agua tratada al acuífero.

Abril 2019

- Asistencia al taller IV Taller de Capacitación de la Plataforma Sustainable Water through Integrated Modeling-SWIM dentro de las instalaciones de la UACJ.
- Presentación de resultados preliminares de modelación SWAT, sobre escenarios (4) hipotéticos de administración de agua en la cuenca.

Mayo 2019

- Integración de nuevo escenario de modelación SWAT, incorporando la simulación de un reservorio de captación y retención de agua, y su efecto en los procesos de recarga.

Junio – Julio 2019

- Modelación de toda la sección mexicana de la cuenca, incluyendo todas las propuestas de escenarios hipotéticos de administración de agua para el periodo de 1995 al 2015.
- Procesamiento de estadística de datos de población, demandas de agua, generación de agua residual, datos climatológicos con escenarios de trayectorias de concentración representativas (RCP) para el cambio climático (RCP 8.5 y RCP 4.5), para modelación futura.
- Desarrollo de las proyecciones futuras de las variables climatológicas, crecimiento poblacional, requerimientos de abastecimiento de agua, generación de agua residual tratada, para la modelación del balance hídrico del periodo por quinquenios de 2015 – 2040, por medio del paquete computacional SWAT.

Agosto – Diciembre 2019

- Entrega de flujos modelados de la sección de cuenca estadounidense por el equipo de modelación de Texas A&M University, así como proyecciones de datos climatológicos RCP.
- Aplicación de variables generadas de estadística para datos de población, demandas de agua, generación de agua residual, datos climatológicos con escenarios de trayectorias de concentración representativas (RCP) considerando escenarios de cambio climático (RCP 8.5 y RCP 4.5), para modelación futura SWAT del balance hídrico, periodo 2016 – 2040.
- Desarrollo de proyectos para la participación en el evento " Encuentro de Jóvenes investigadores", sede Chihuahua, presentación de los siguientes trabajos en extenso desarrollados por los estudiantes colaboradores del proyecto:
    - "*Evaluación de la recarga del acuífero en base a la administración de las plantas de tratamiento de Ciudad Juárez*"
    - "*Variación de la recarga al acuífero Valle de Juárez de 1995 a 2040 considerando un modelo de cambio climático RCP 4.5*"
    - *"Desarrollo del modelo de recarga hídrica superficial del acuífero Bolsón del Hueco, respecto a la administración del recurso hídrico de agua residual y agua del tratado internacional en Ciudad Juárez, Chihuahua*".

- Generación de datos anuales complementarios a los polígonos de recarga, de las variables generadas por la aplicación SWAT Check incluida en SWAT, para el periodo 1995 - 2015 tabulando las ponderaciones anuales, para la construcción de un modelo geo hidrológico con el paquete computacional Visual ModFlow, procesos liderado por el Dr. Adal Pinales.

Febrero – Mayo 2020

- Redacción de dos borradores de artículos generados por los modelos desarrollados, los cuales tiene contemplado someter en las revistas indexadas Tecno Ciencia (UACH), Ciencia y Tecnología del Agua del IMTA, y/o en Cultura Científica y Tecnológica (UACJ).

Abril – Agosto 2020

- Desarrollo de ejercicio de simulación SWAT, sobre procesos de eficiencia de riego y cambio de cultivos, para el área agrícola de la cuenca, con el fin de cuantificar los efectos potenciales en la recarga del acuífero, mediante la implantación de estas variables. Redacción de reporte técnico.

REPORTE DE ACTIVIDADES REALIZADAS DURANTE EL

PERIODO 2018-2020

MODELACION AGUA SUBTERRANEA (MODFLOW)

DR. ADÁN PINALES MUNGUÍA

DR. ARTURO SOTO ONTIVEROS

PROYECTO

Sustainable water resources for irrigated agriculture in a desert river basin facing climate change and urban growth: from characterization to solutions.

Financiamiento externo:

Departamento de Agricultura de los Estados Unidos (UACJ)

agosto de 2020

C O N T E N I D O

ÍNDICE DE FIGURAS

1. Introducción

Durante el periodo comprendido entre los años 2018 y 2020, se realizaron las siguientes actividades académicas-científicas relacionadas con el proyecto denominado: "Sustainable water resources for irrigated agriculture in a desert river basin facing climate change and competing demands: From characterization to solutions". Este proyecto tiene como área de estudio las principales cuencas de la parte media del Rio Bravo/Rio Grande, entre México y los Estados Unidos. El área de estudio que cubre este reporte es la porción norte del acuífero Valle de Juárez, desarrollado en una primera etapa y en una segunda etapa el área de estudio se incrementó para cubrir todo el acuífero.

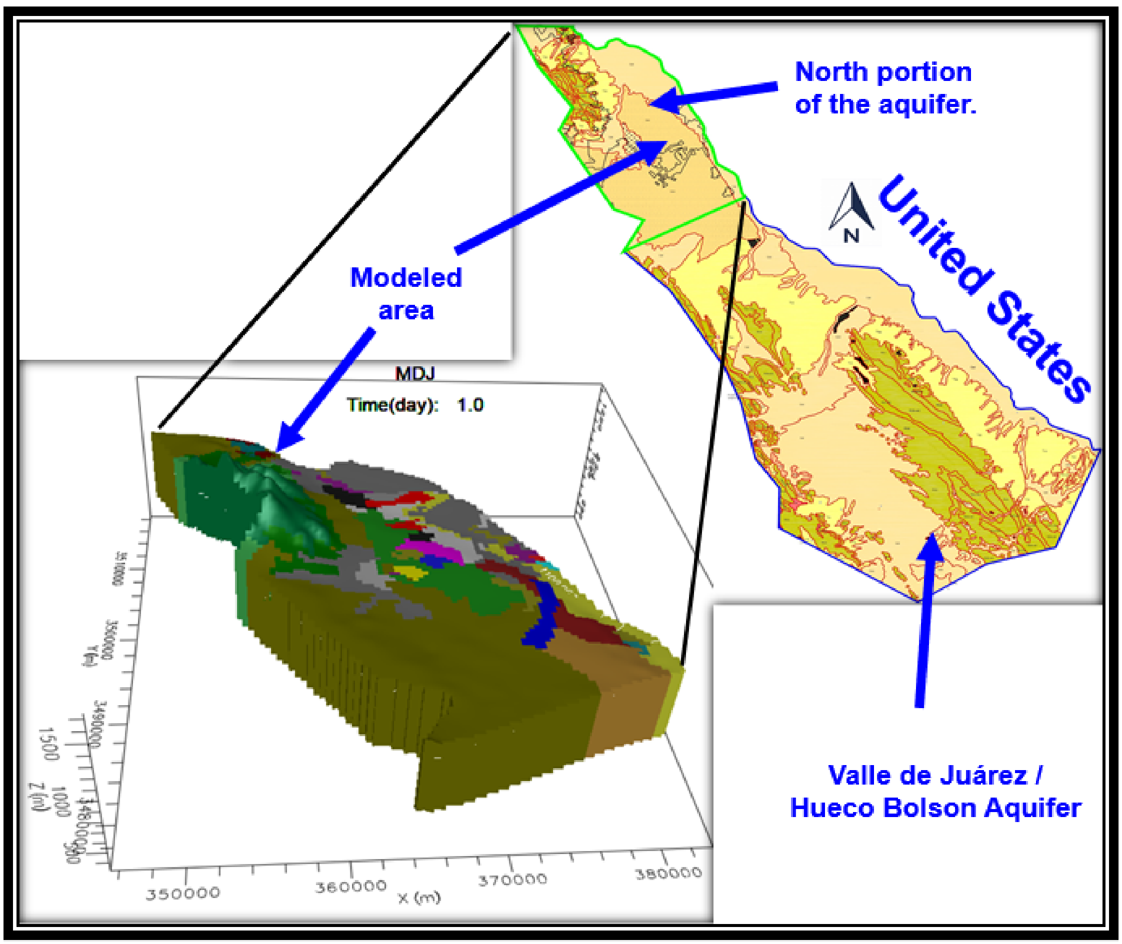


Figura 1. Localización del área de estudio

2. MODELACIÓN DE LA ZONA URBANA DE CIUDAD JUÁREZ

El acuífero del Valle de Juárez o Bolsón del Hueco en el lado mexicano abarca la ciudad de Ciudad Juárez, localizada principalmente en la porción centro y centro noroeste del acuífero, así como también las zonas agrícolas localizadas al centro y centro sureste del acuífero. Por lo que respecta a modelo, éste abarca principalmente el área urbana de Ciudad Juárez, es decir, se modeló una porción del acuífero (Figura 2).

El modelo se construyó en estado transitorio, iniciando e 31 de octubre de 2008 (t=1 día) y terminando el 15 de julio de 2014 (t= 2085 días). Para el inicio de la calibración se contó con 193 pozos de observación y al final de calibración con 177 datos. El área del modelo comprende la porción norte del acuífero Valle de Juárez.

Para la construcción del modelo de flujo del agua subterránea se utilizó el código MODFLOW integrado en el paquete Visual Modflow. La construcción del modelo implicó delimitar un área de estudio (Figura 1), así como los siguientes elementos del modelo de flujo (Anexo E1 Modelos).

a) **Diseño de la malla del modelo**. En el que se consideró información geológica, hidrogeológica, geofísica, hidráulica, entre otros (Figuras 3, 4 y 5).

b) **Periodos de esfuerzo**. Se determinaron en función de las fechas con que se cuente con información hidrométrica de las captaciones, así como la distribución espacial y temporal del agua superficial.

c) **Extracciones por bombeo**. La extracción de bombeo y su régimen de operación, fue proporcionada por la Junta Municipal de Agua y Saneamiento de Ciudad Juárez y la Comisión Nacional del Agua, los cuales fueron cargados al software VISUAL MODFLOW para simular las descargas del agua subterránea (Figura 6).

d) **Condiciones iniciales**. Las condiciones iniciales corresponden a distribución de cargas hidráulicas correspondientes al inicio de la modelación.

e) **Condiciones de frontera**. A través del desarrollo de configuraciones piezométricas de estimó el comportamiento de las fronteras, buscando que coincidieran con las fronteras hidrogeológicas del sistema.

f) **Parámetros hidráulicos**. Corresponden principalmente a la conductividad hidráulica y al almacenamiento. Para los cuales se utilizó la información geológica, hidrogeológica, geofísica, cortes litológicos, resultados de las pruebas de bombeo disponibles.

g) **Recarga difusa**. Para la zonificación de la recarga difusa en una primera estimación se empleó la zonificación de uso de suelo.

h) **Calibración del modelo de flujo**. En este apartado se usaron los pozos de observación, el modelo de flujo abarcó la porción que comprende la ciudad de Ciudad Juárez (Figura 7).

Los resultados de la calibración se muestran en las Figuras 8 y 9, donde se muestran la distribución de cargas hidráulicas simuladas, tanto e planta como en perfil.

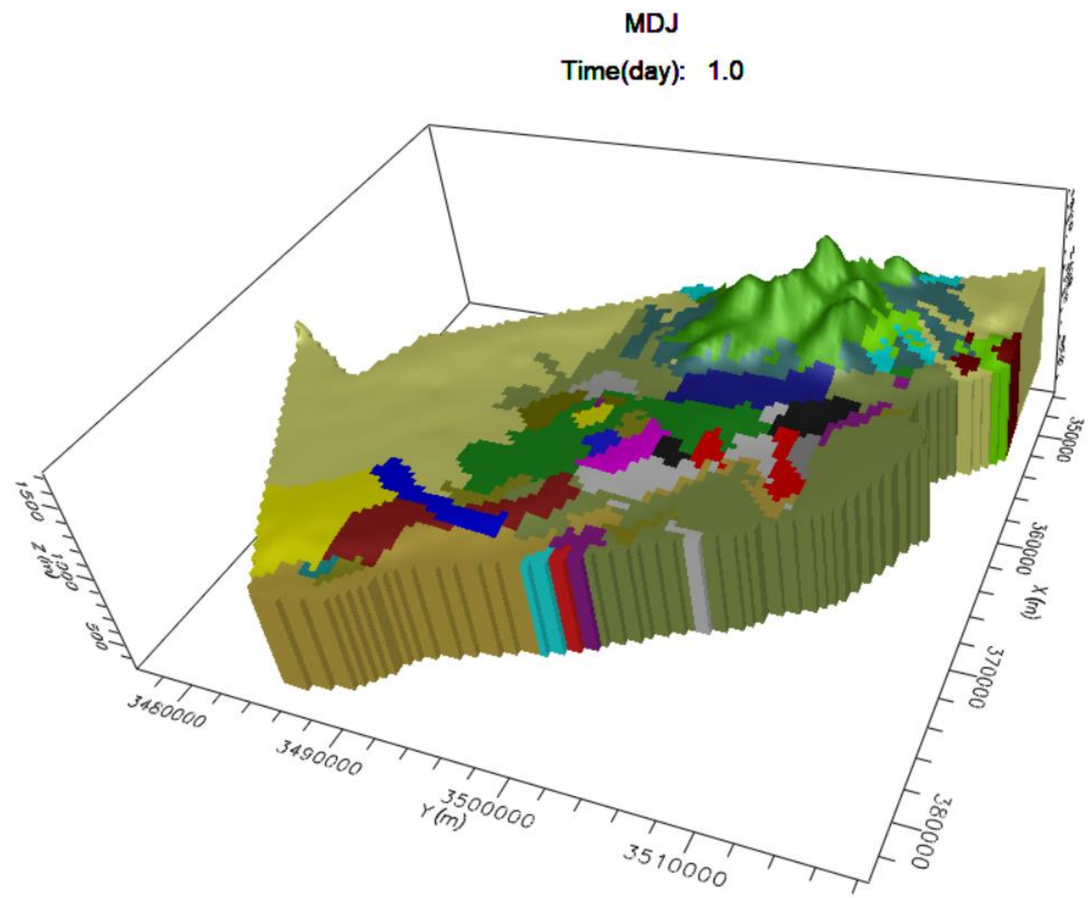


Figura 2. Modelo conceptual

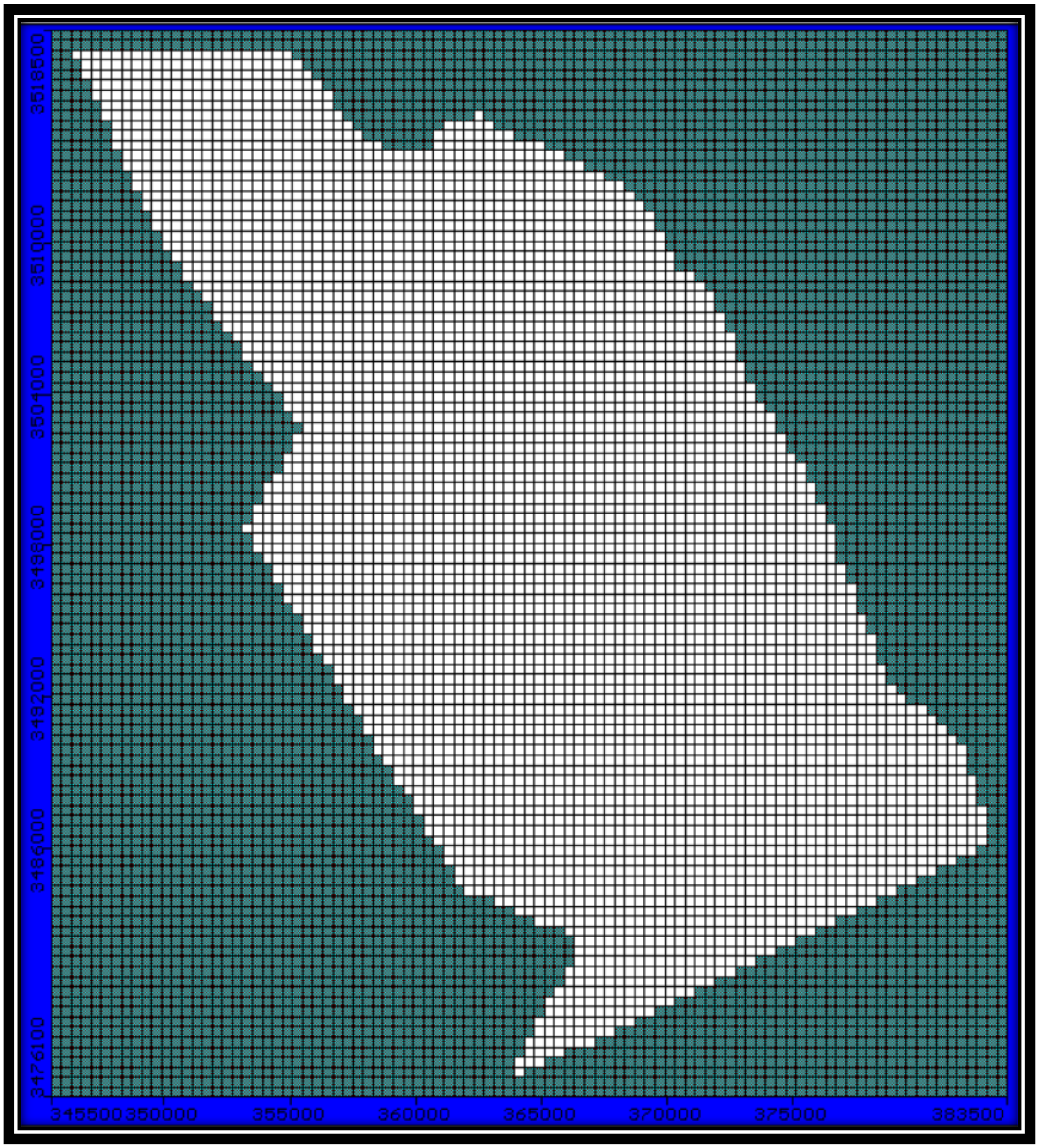


Figura 3. Malla del modelo en planta

Malla del modelo en perfil a lo largo del renglón 30 y columna 49

Renglón 30

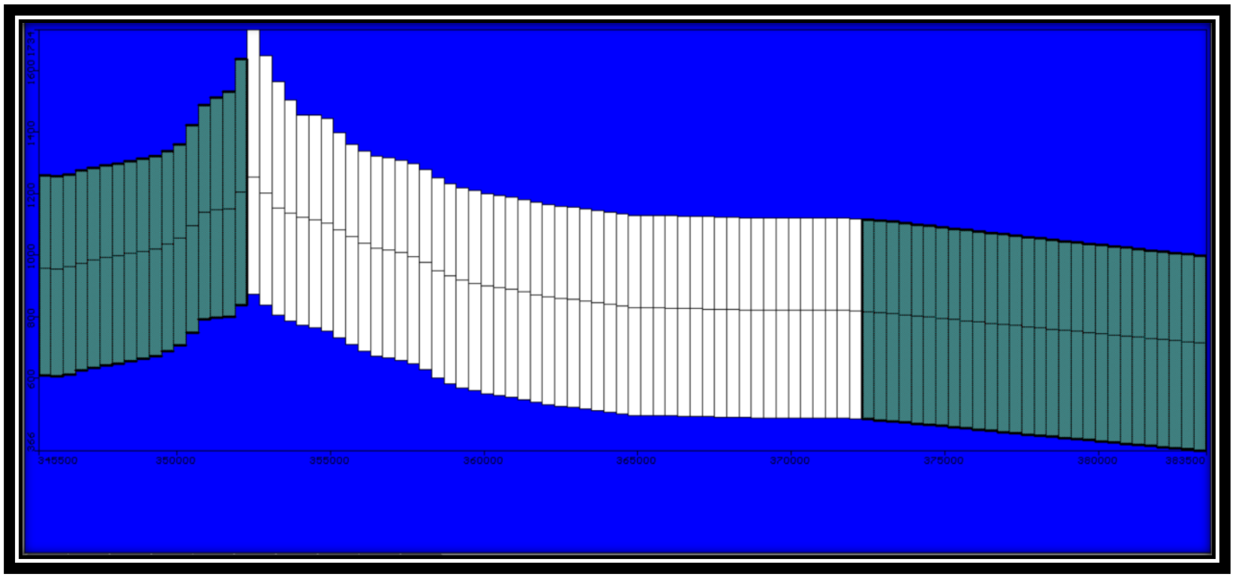


Figura 4. Malla del modelo en perfil, a lo largo del renglón 30

Columna 49

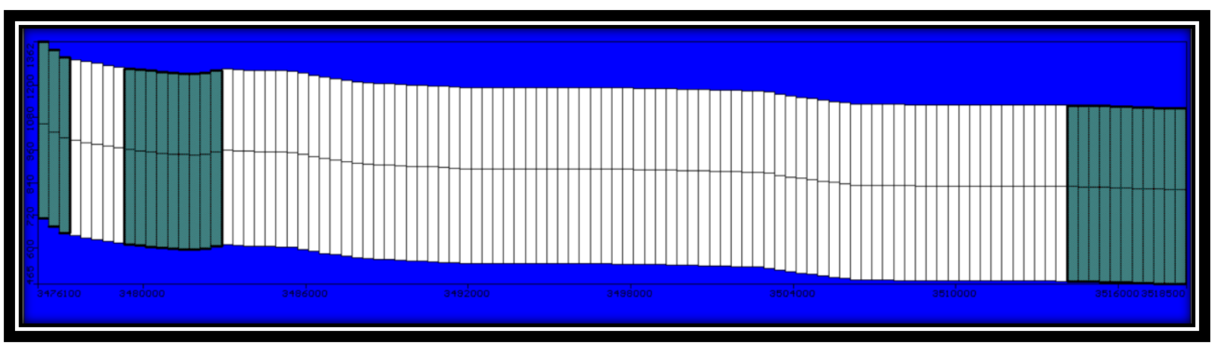


Figura 5. Malla del modelo en perfil, a lo largo de la columna 49

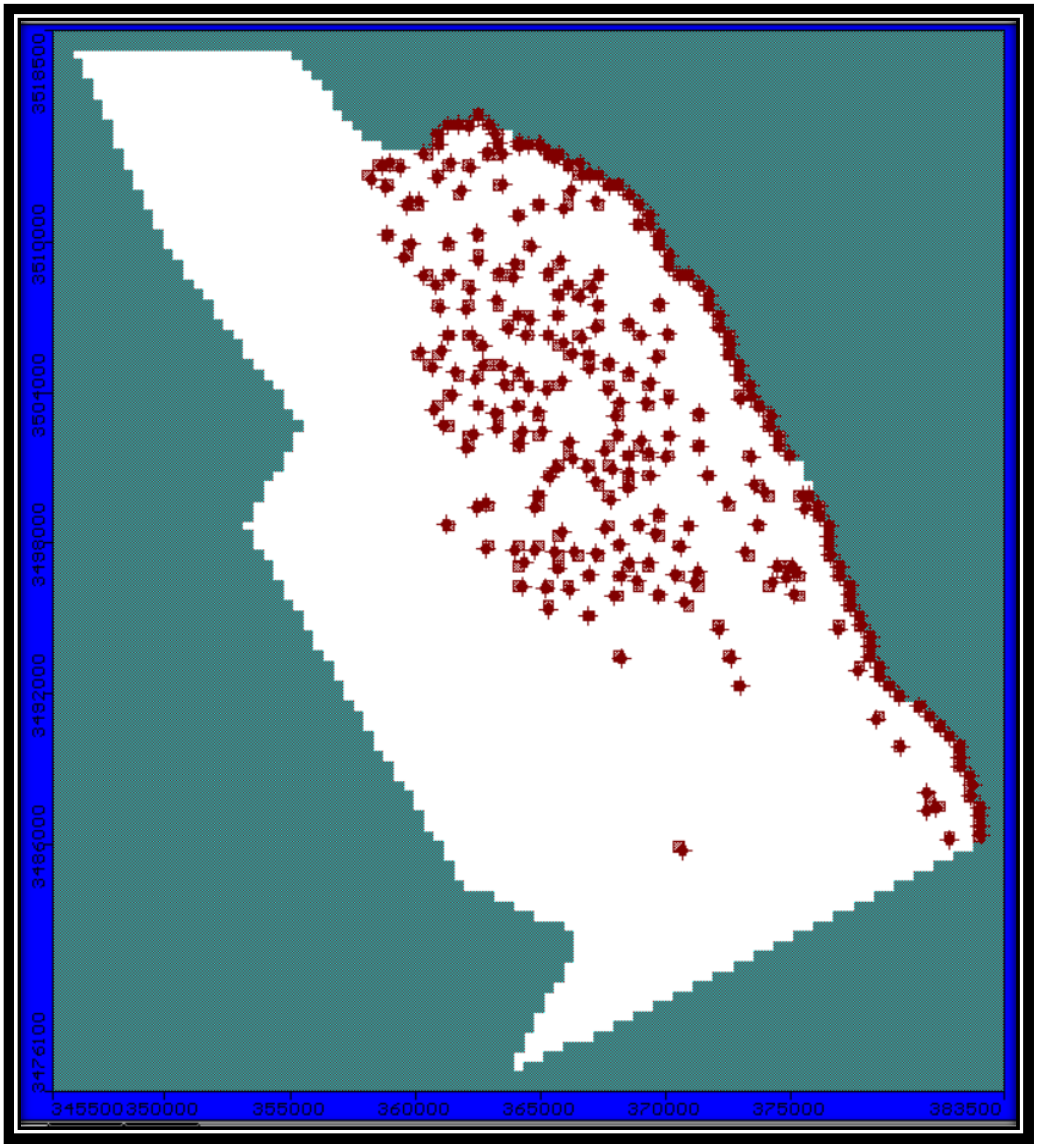


Figura 6. Distribución de los pozos de bombeo

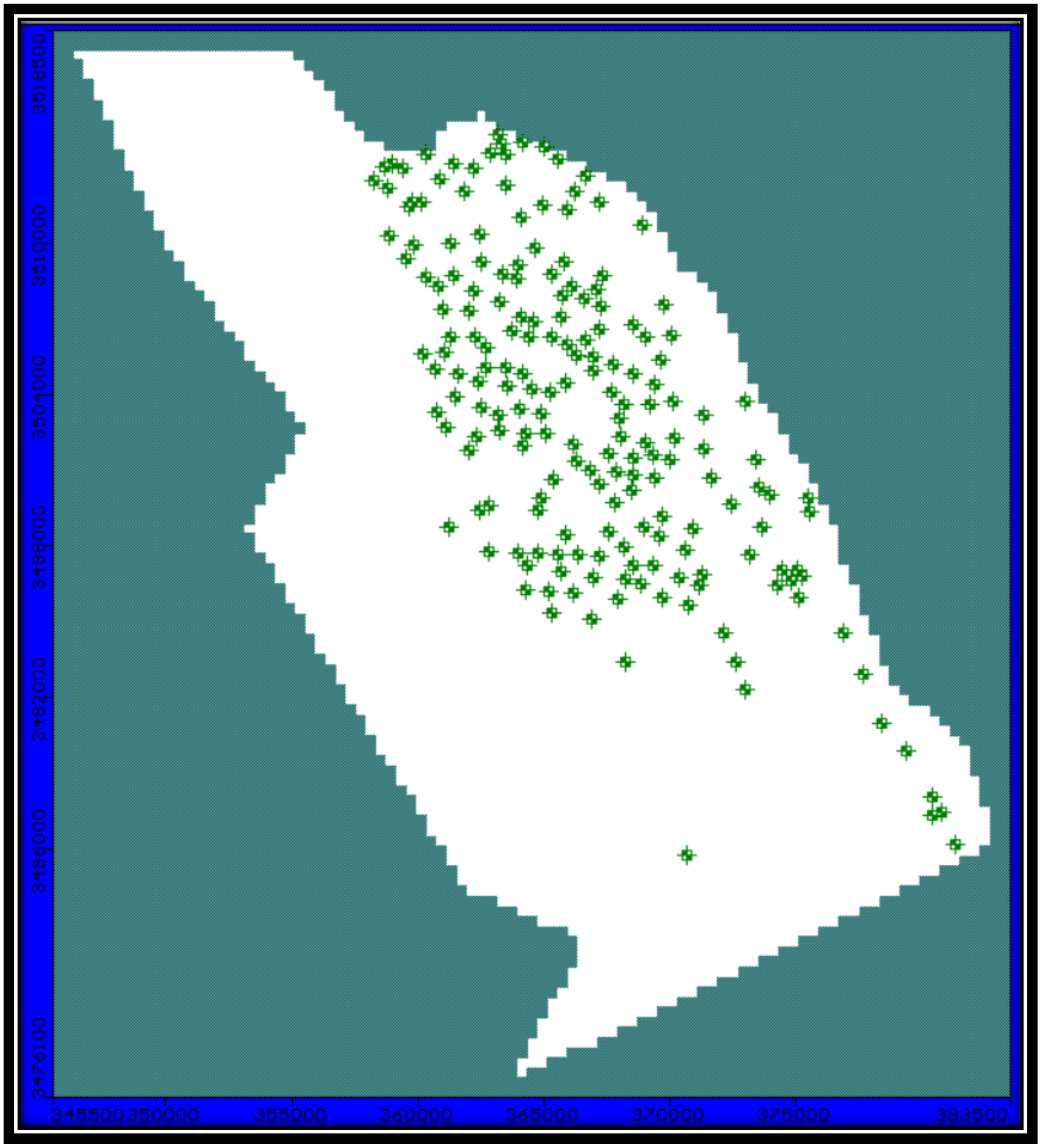


Figura 7. Distribución de los pozos de observación

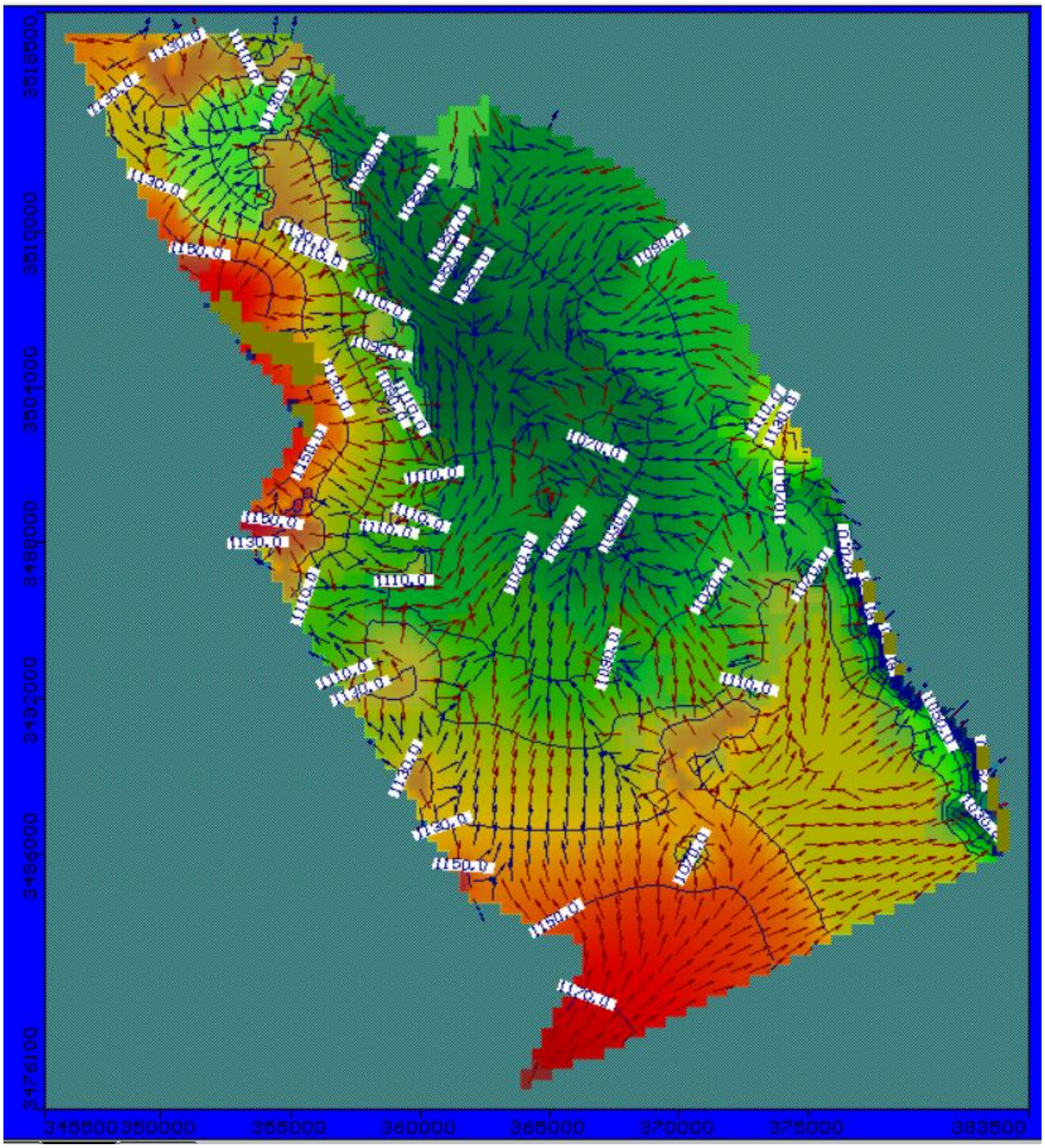


Figura 8. Elevación del nivel del agua simulada y direcciones de flujo

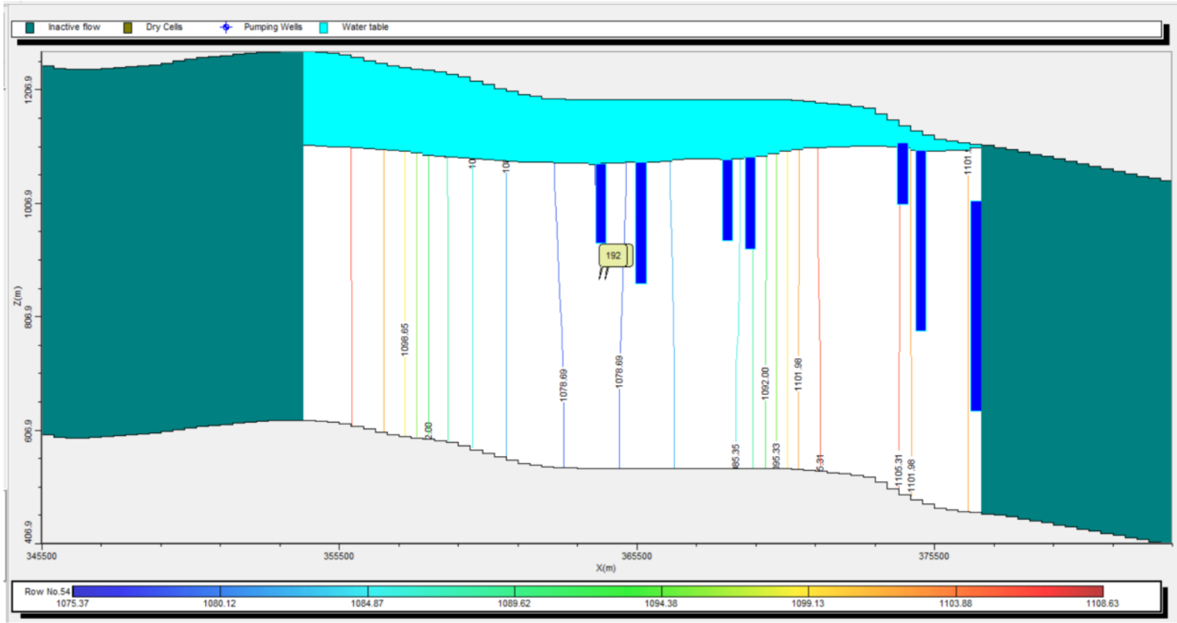


Figura 9. Elevación del nivel del agua en perfil

A continuación, se presenta los resultados de la elaboración o planteamiento de 7 escenario, donde algunos de ellos pueden tener hasta 3 variaciones.

Estos escenarios están planteados para conocer el abatimiento promedio a partir del 15 de julio de 2018 (t=3546 días) y hasta el 18 de julio de 2030 (t=7932 días). También se tomaron fechas intermedias como las del 15 de julio de 2022 (t= 5007 días) y 18 de julio de 2026 (t= 6471 días).

3. ESCENARIO ES1N

Mantener las condiciones constantes hasta 2030.

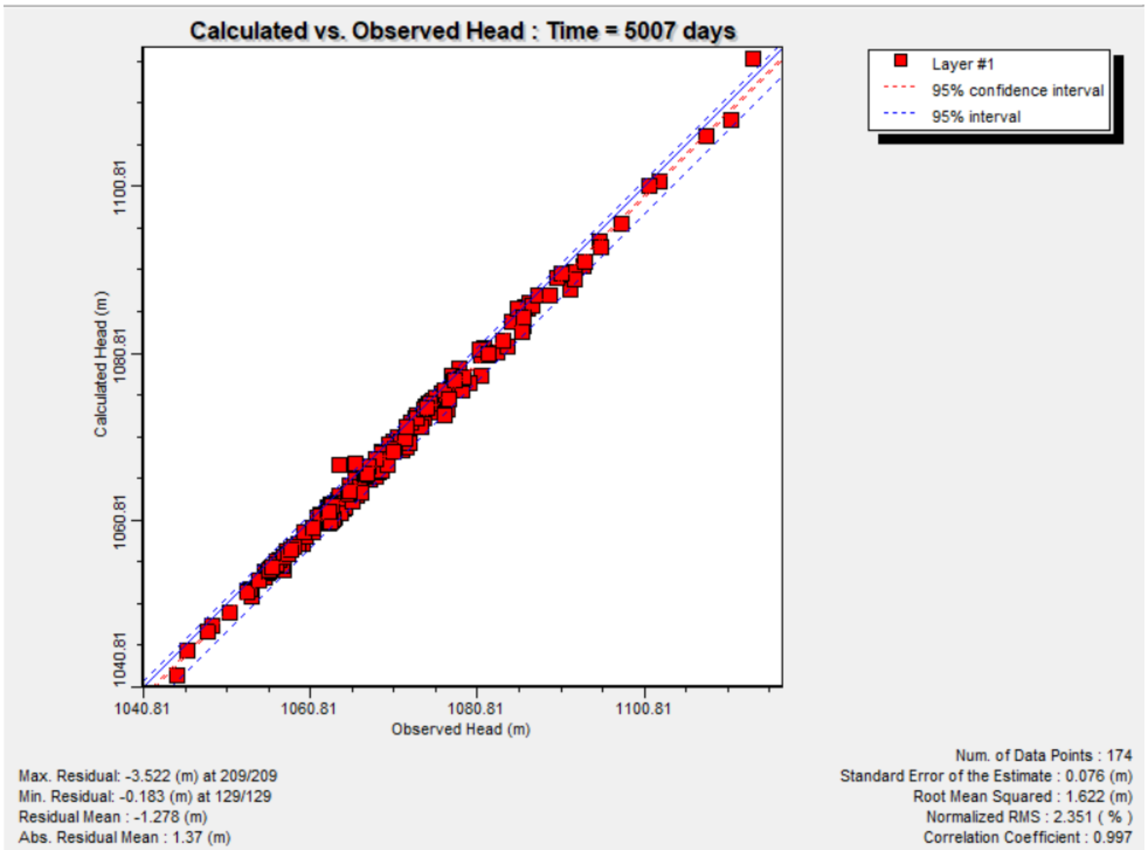


Figura 10. Recta de abatimientos correspondiente a julio de 2022 (t= 5007 días), para el ES1N.

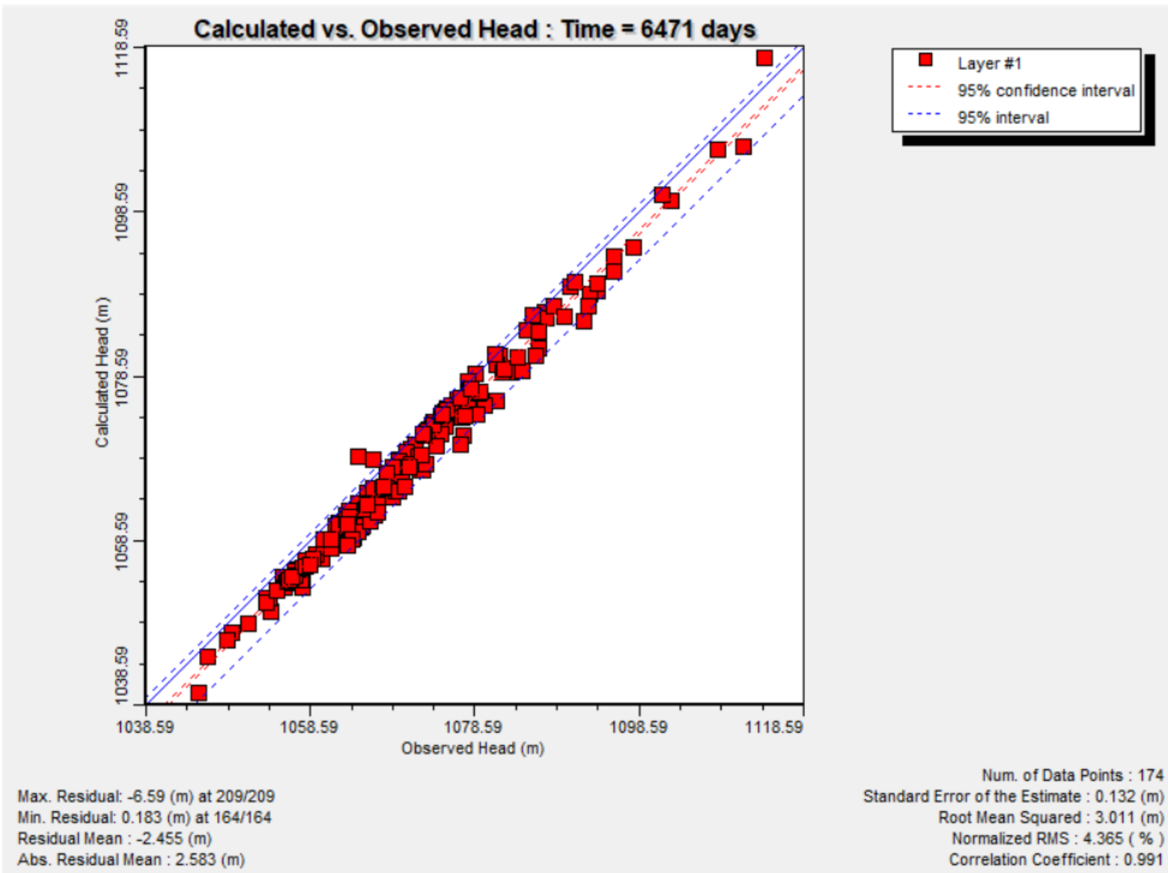


Figura 11. Recta de abatimientos correspondiente a julio de 2026 (t= 6471 días), para el ES1N.

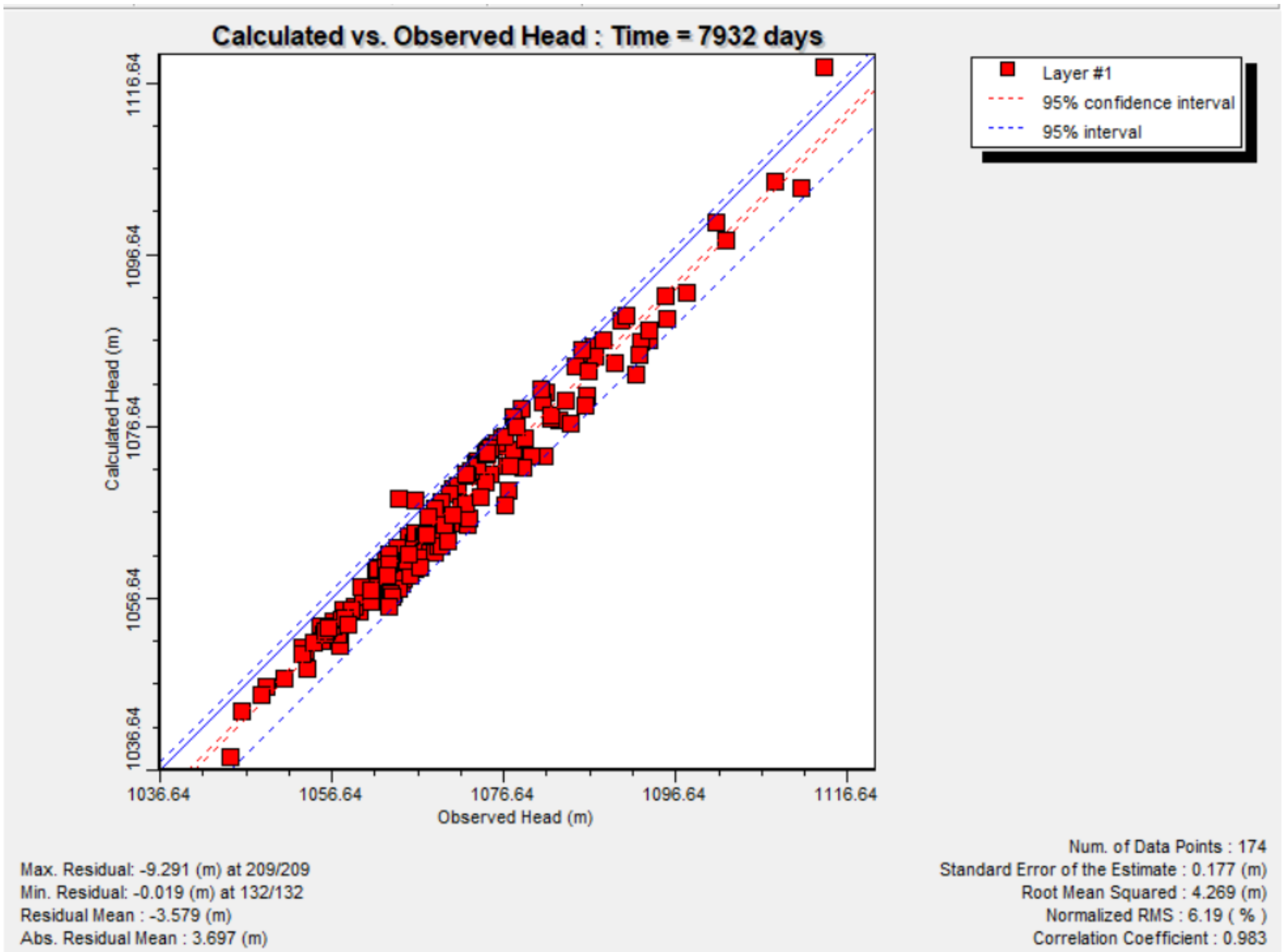


Figura 12. Recta de abatimientos correspondiente a julio de 2030 (t=7932 días), para el ES1N.

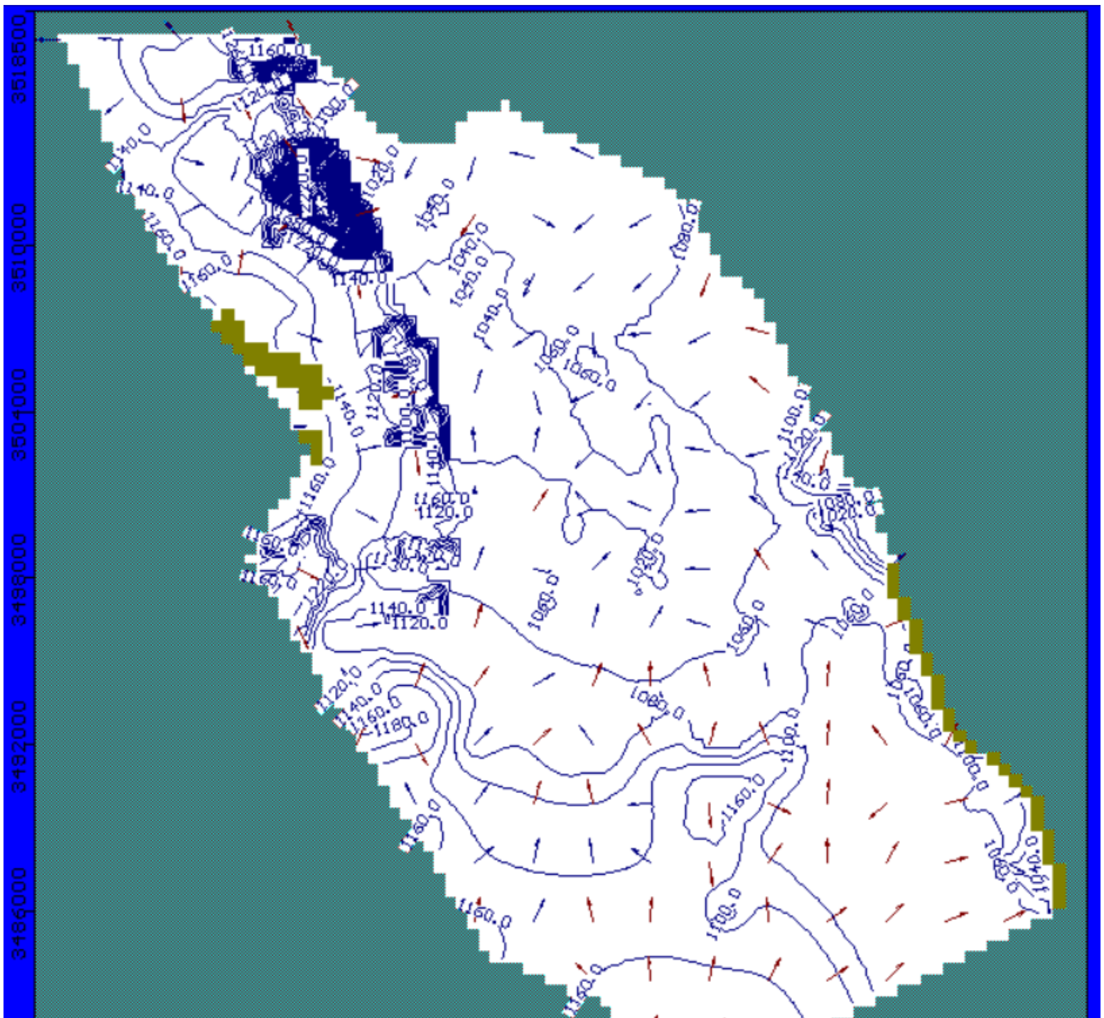


Figura 13. Cargas simuladas escenario ES1N, julio de 2030 (t=7932 días)

4. ESCENARIO ES2N

Mantener el bombo constante hasta 2030 y reducir la recarga por fugas y total en un 25%.

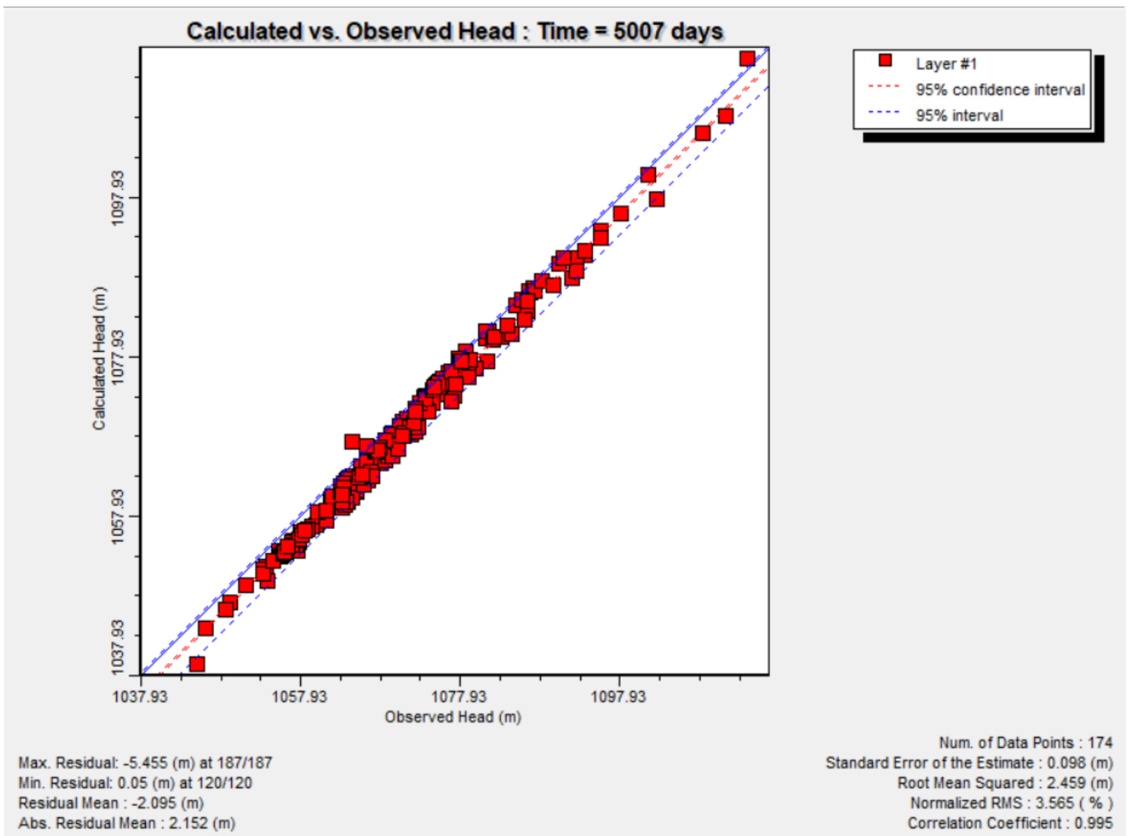


Figura 14. Recta de abatimientos correspondiente a julio de 2022 (t= 5007 días), para el ES2N.

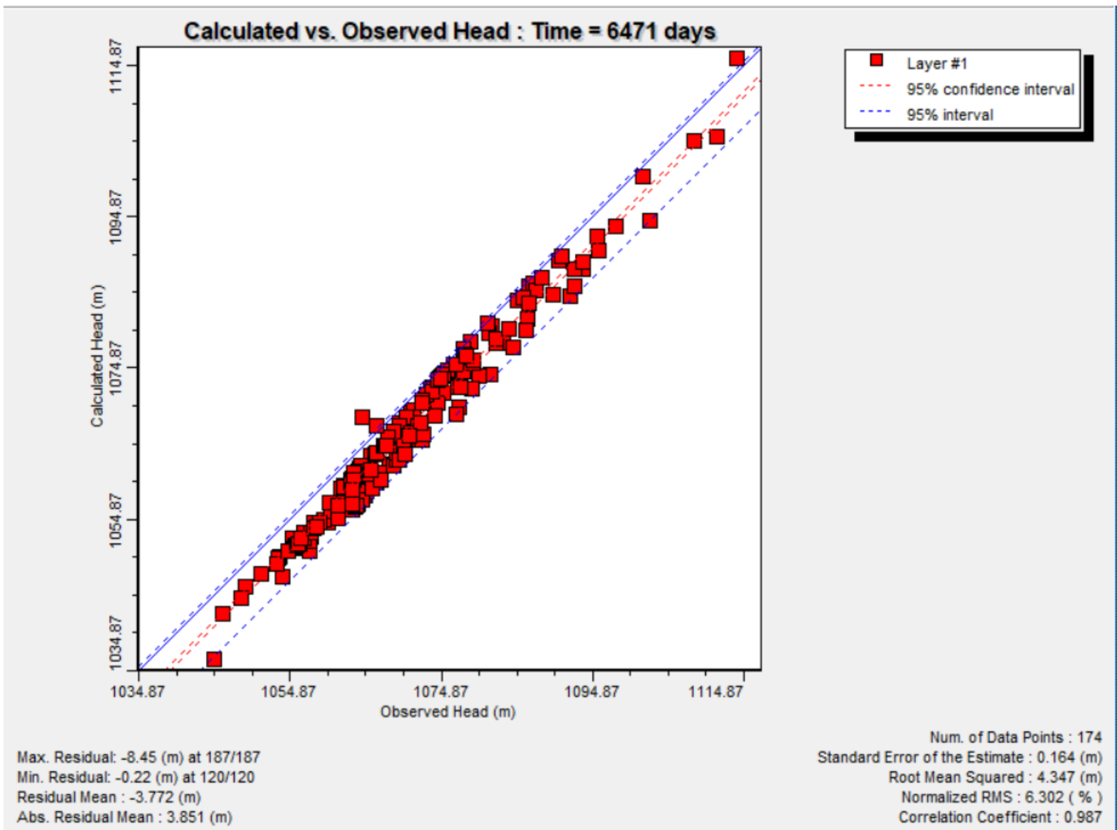


Figura 15. Recta de abatimientos correspondiente a julio de 2026 (t= 6471 días), para el ES2N

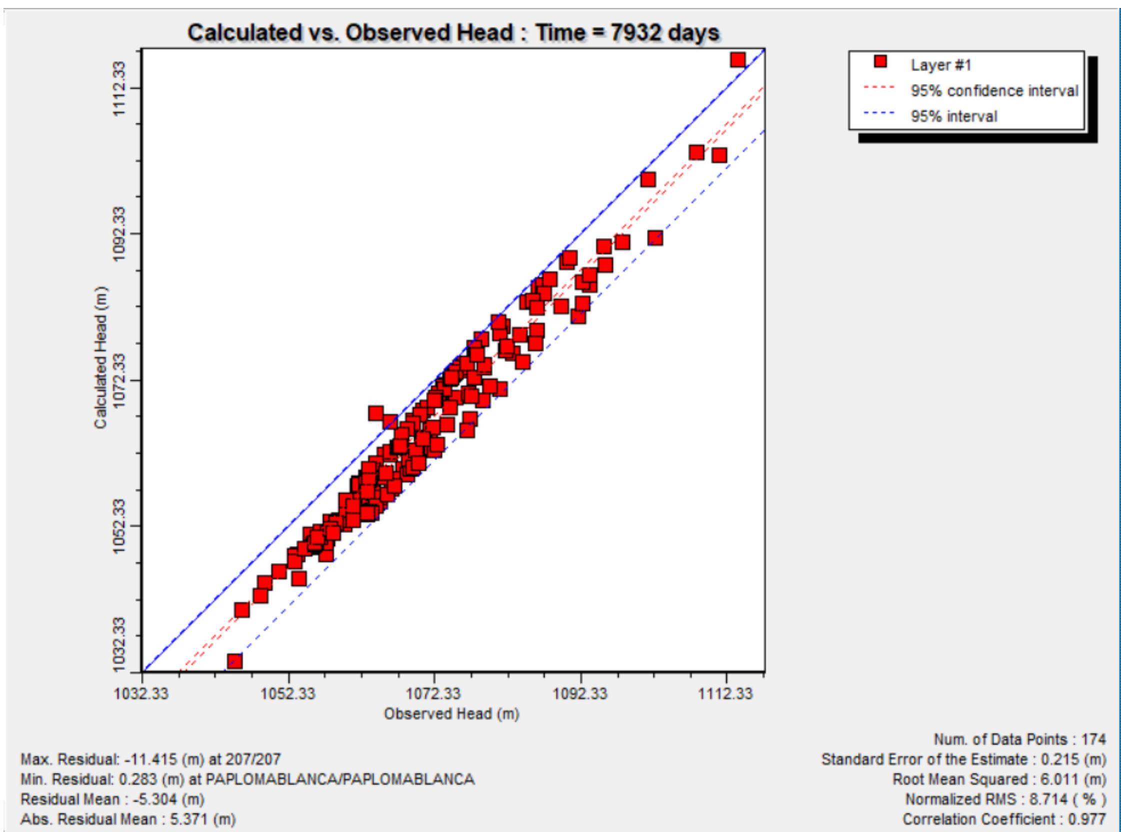


Figura 16. Recta de abatimientos correspondiente a julio de 2030 (t=7932 días), para el ES2N

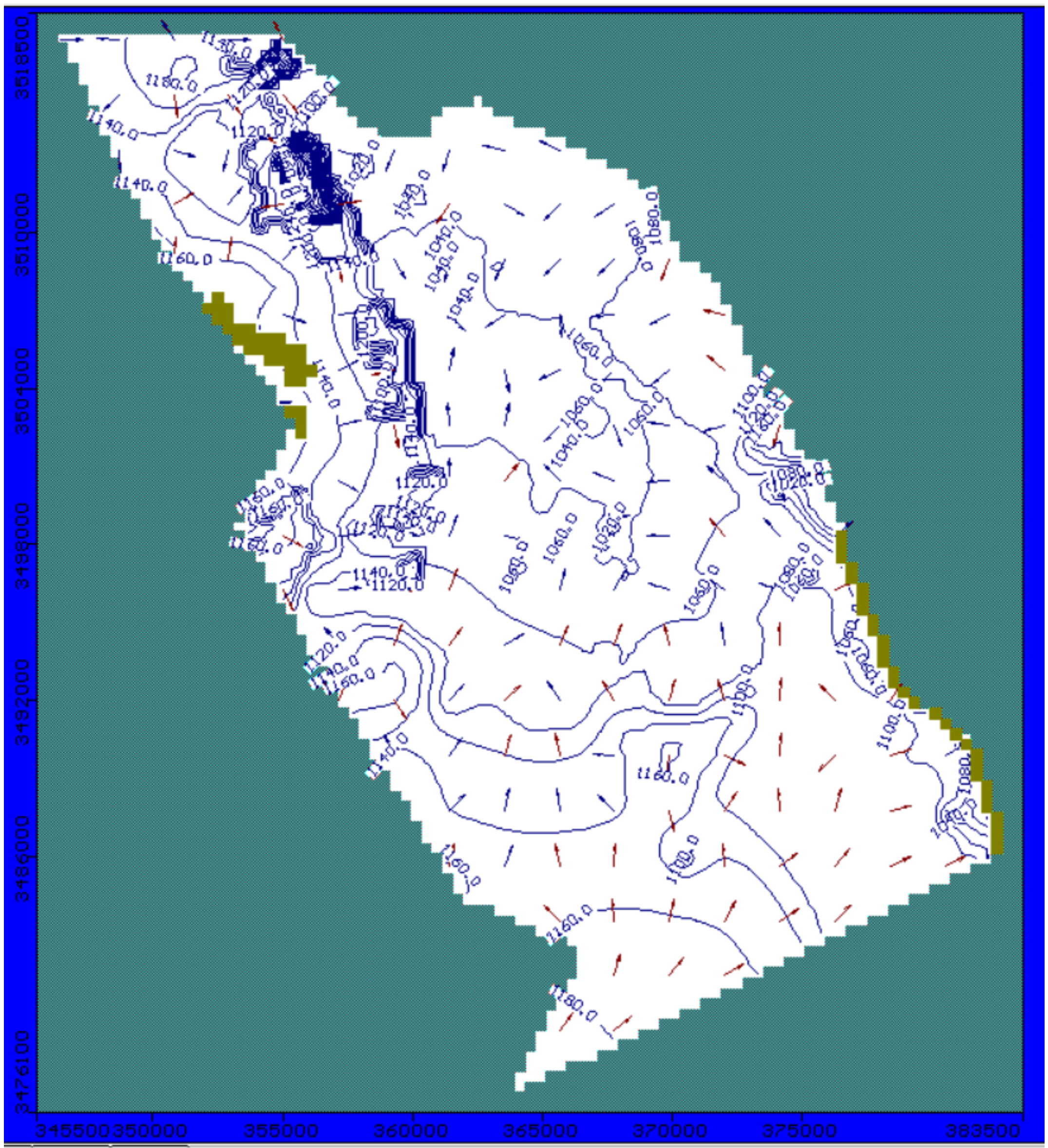


Figura 17. Cargas simuladas escenario **ES2N** julio de 2030 (t=7932 días)

5. ESCENARIO ES3N

Mantener el bombeo constante hasta 2030 y eliminar la entrega de agua del acuífero de Conejos Médanos (Bolsón de la Mesilla) a Ciudad Juárez. Esta eliminación de la entrega del agua, reduce la recarga en un 10.03%.

T= 5007 días

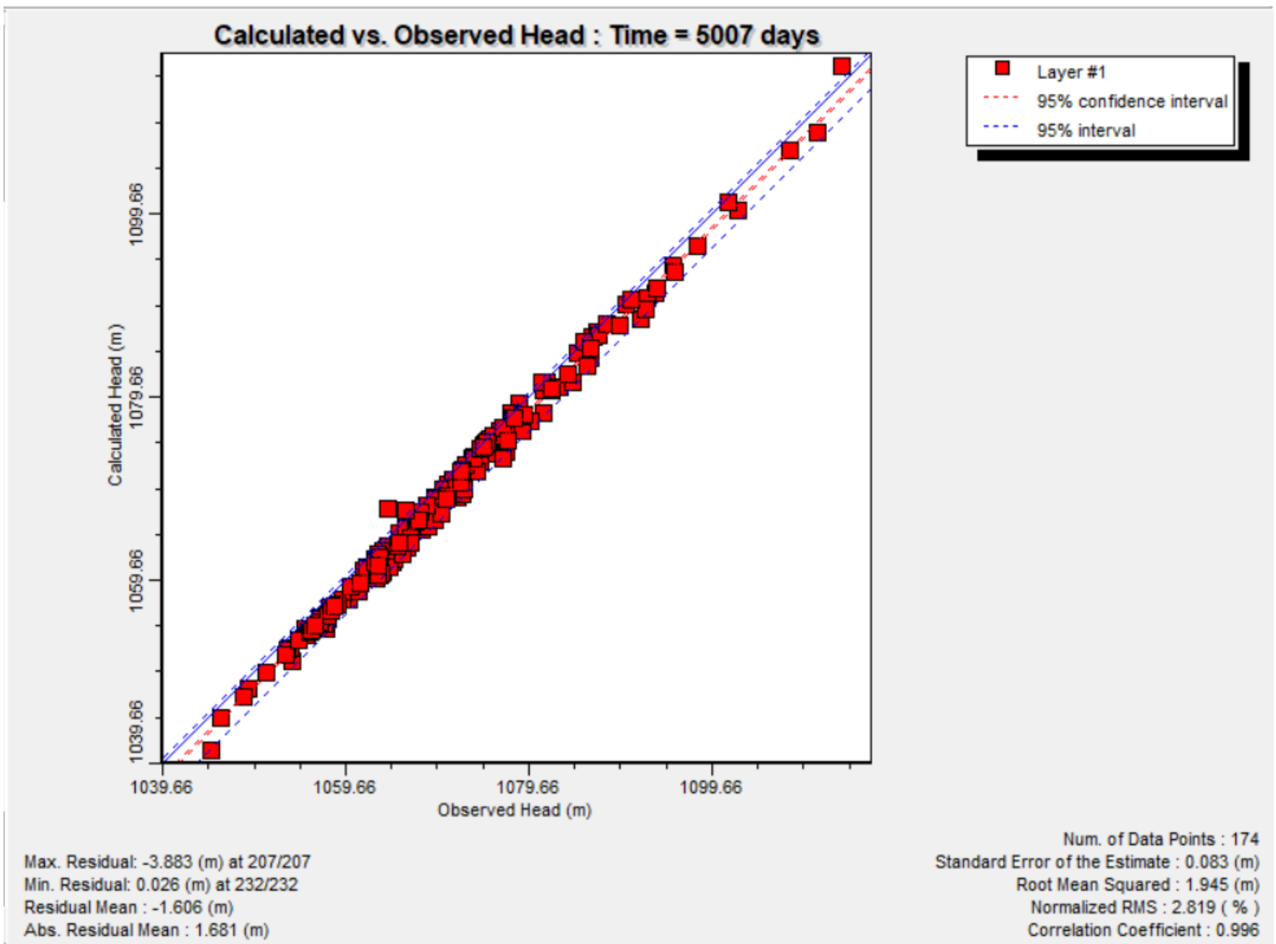


Figura 18. Recta de abatimientos correspondiente a julio de 2022 (t= 5007 días), para el ES3N.

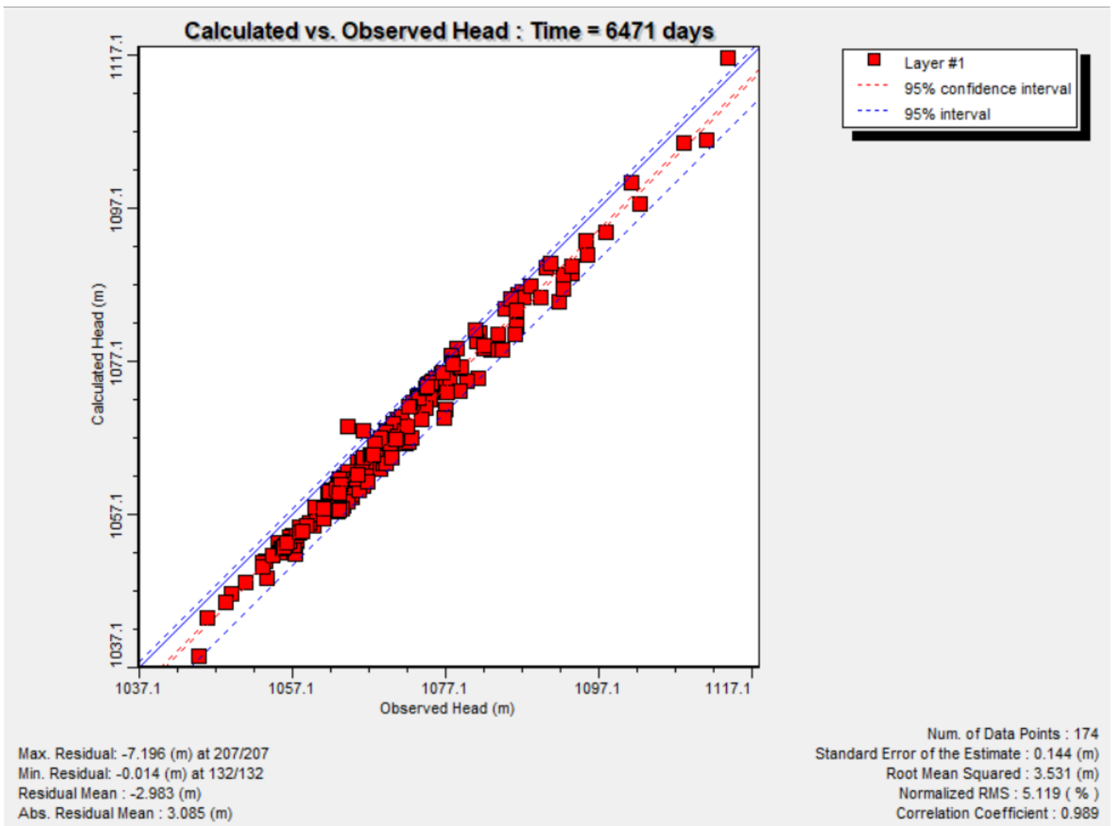


Figura 19. Recta de abatimientos correspondiente a julio de 2026 (t= 6471 días), para el ES3N.

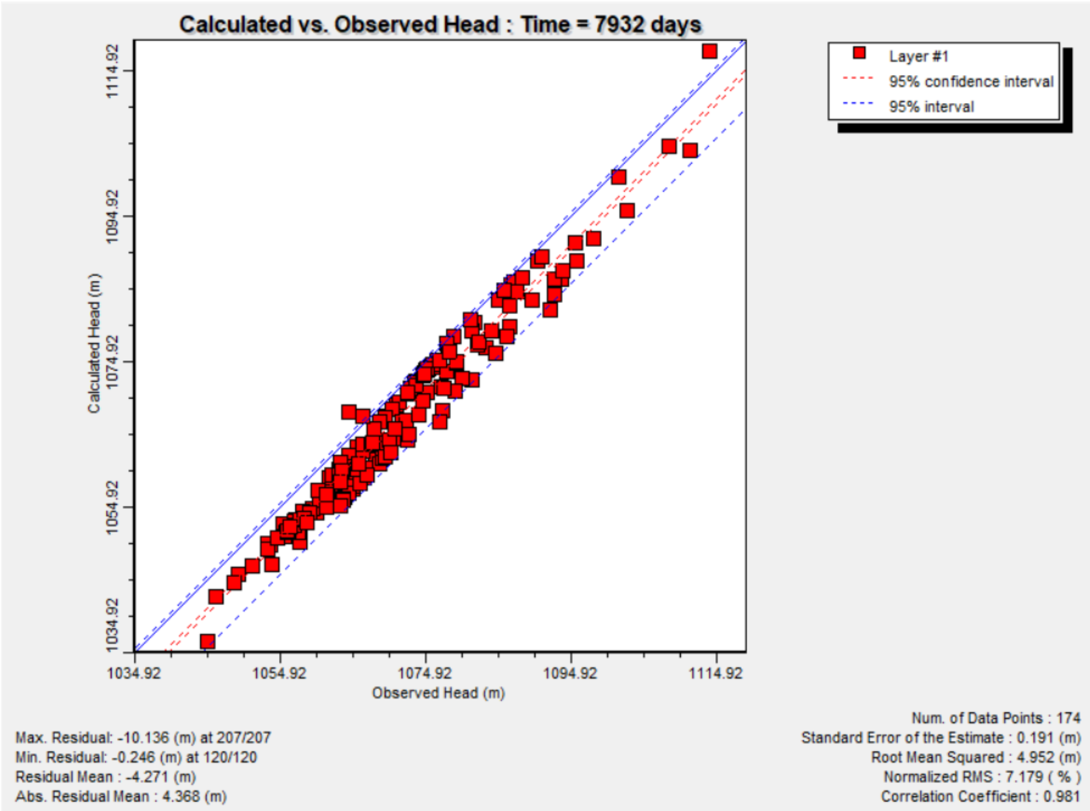


Figura 20. Recta de abatimientos correspondiente a julio de 2030 (t=7932 días), para el ES3N.

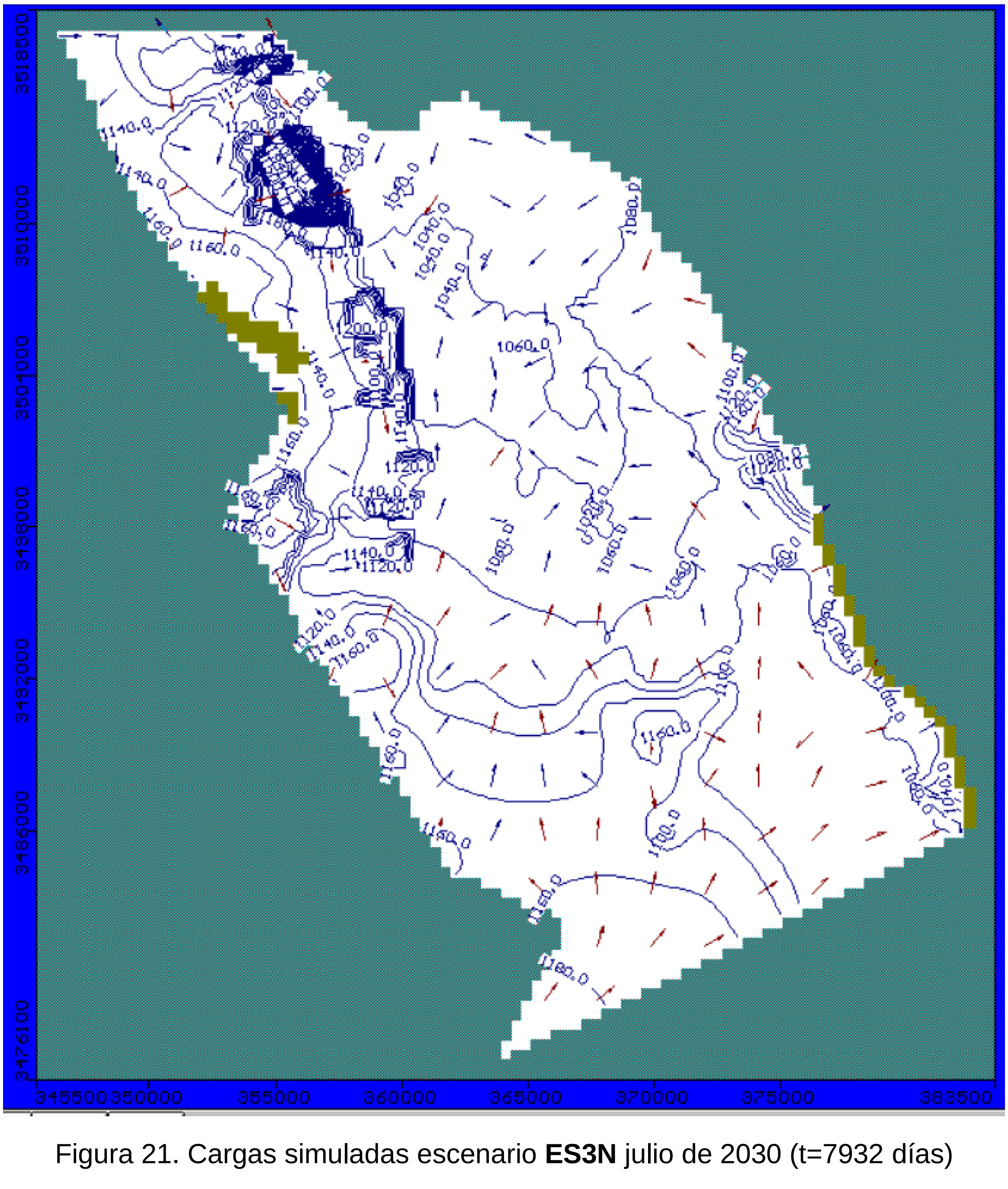


Figura 21. Cargas simuladas escenario **ES3N** julio de 2030 (t=7932 días)

6. ESCENARIO ES4NA

Reducir la dotación por habitante por día en un 25%. Lo que implica reducir la extracción del agua subterránea y la recarga a partir de 2018 y hasta 2030, también en un 25%.

T= 5007 días

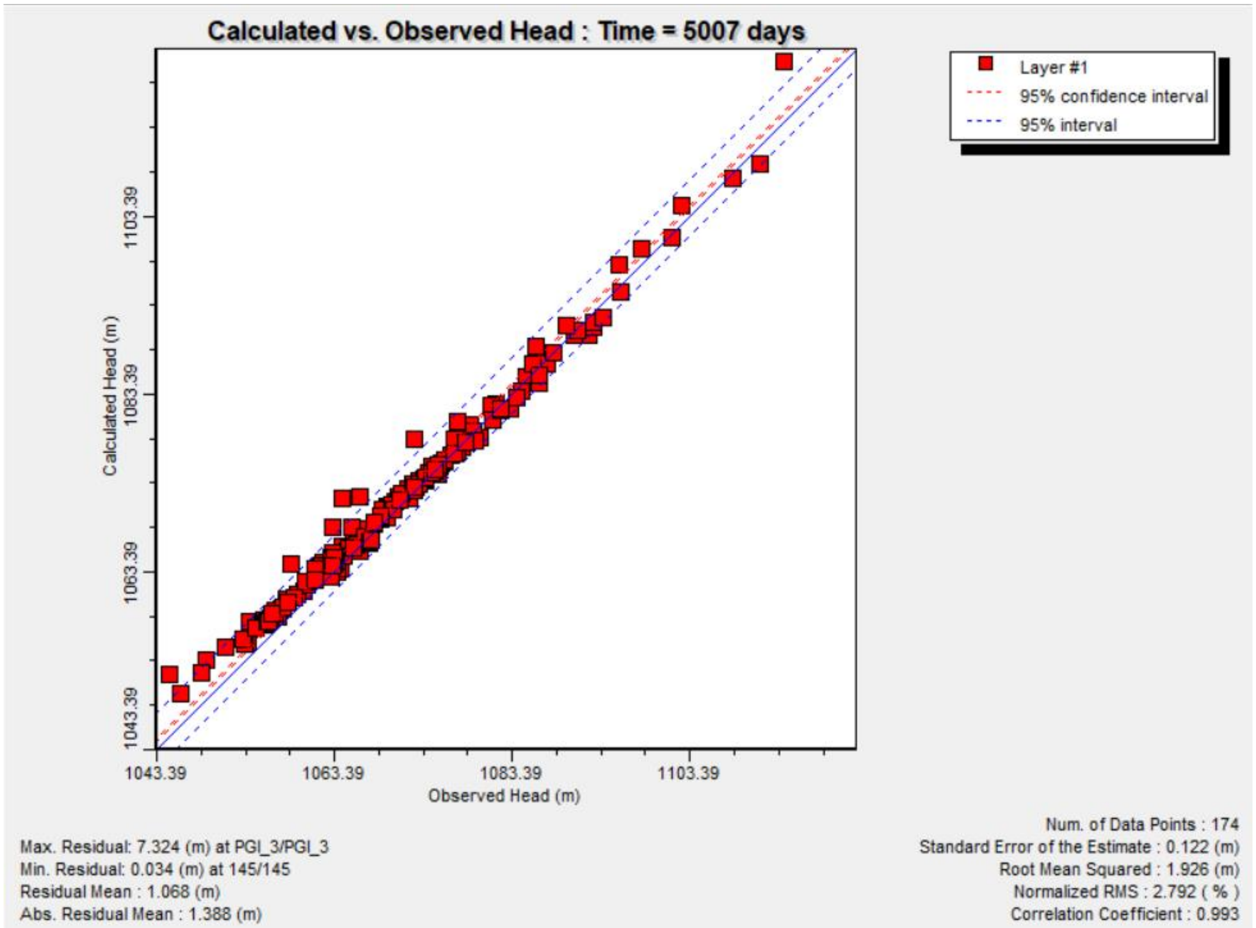


Figura 22. Recta de abatimientos correspondiente a julio de 2022 (t= 5007 días), para el ES4NA.

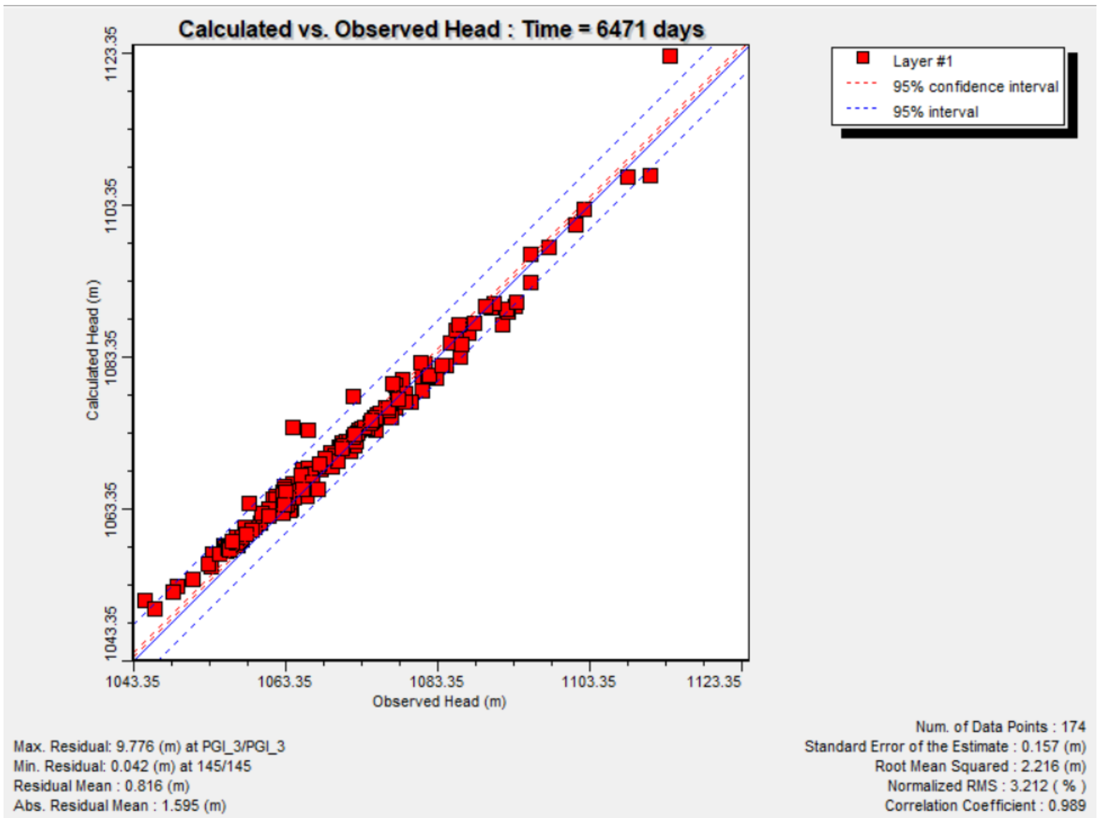


Figura 23. Recta de abatimientos correspondiente a julio de 2026 (t= 6471 días), para el ES4NA.

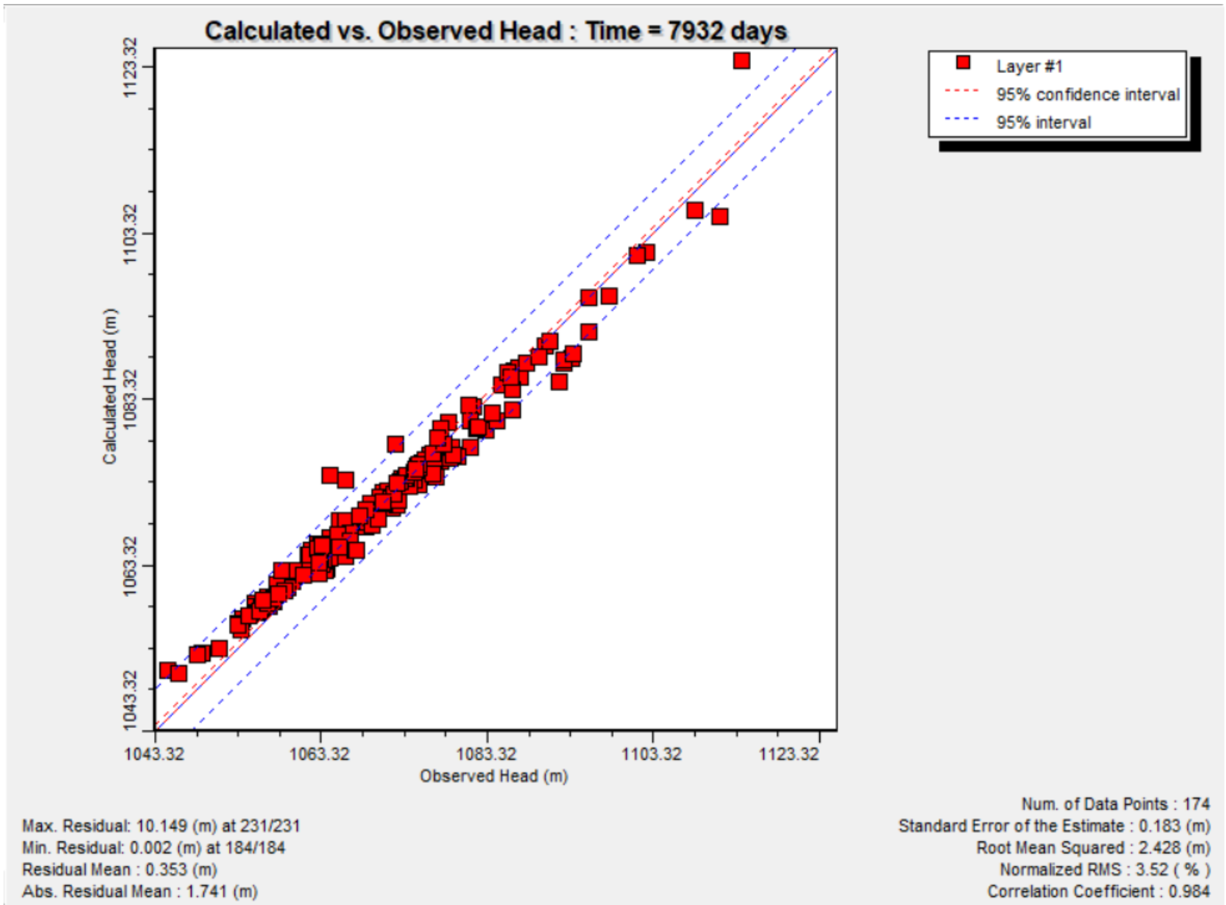


Figura 24. Recta de abatimientos correspondiente a julio de 2030 (t=7932 días), para el ES4NA.

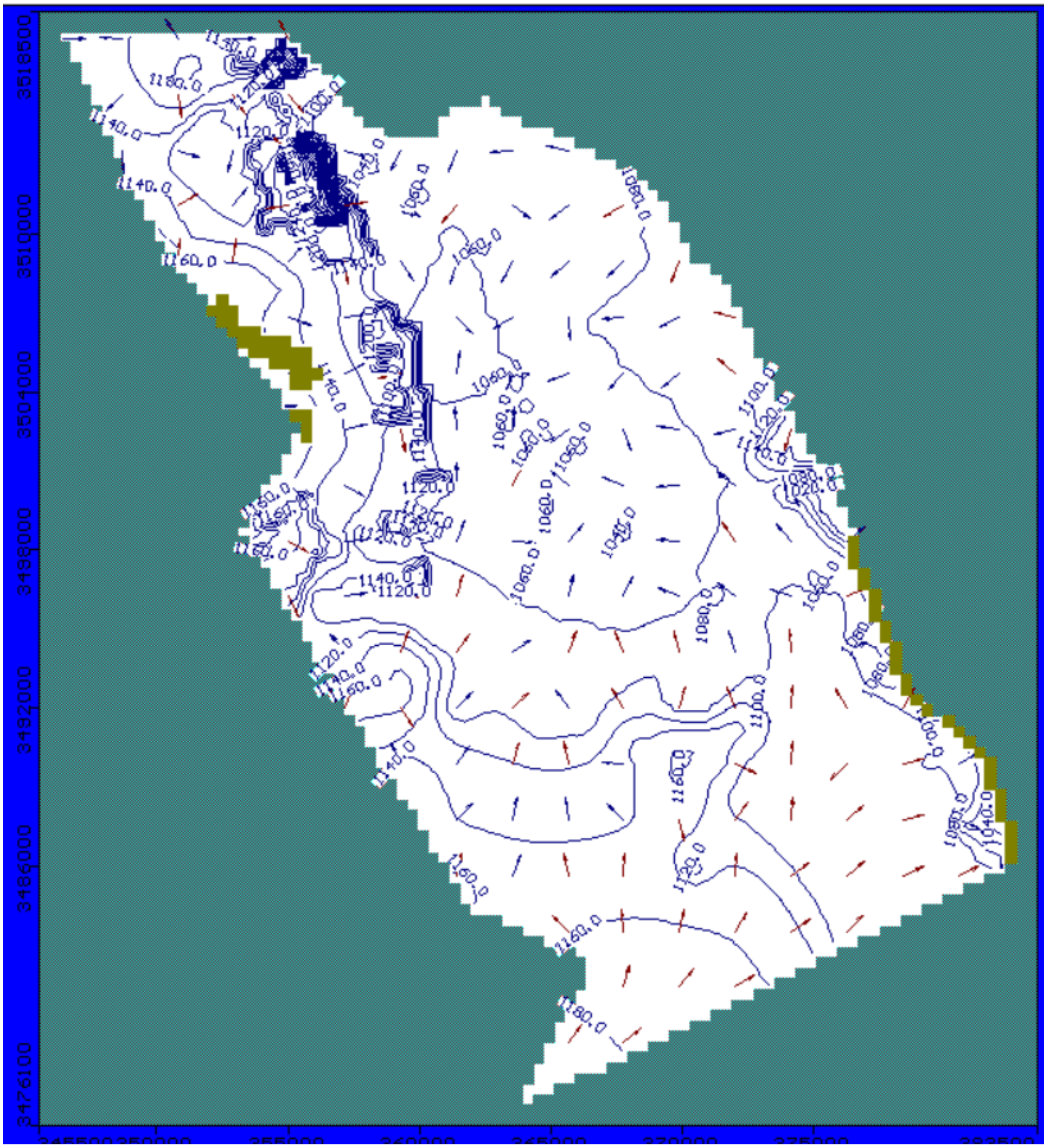


Figura 25. Cargas simuladas escenario **ES4NA** julio de 2030 (t=7932 días)

7. ESCENARIO ES4NB

Reducir la dotación por habitante por día en un 50%. Lo que implica reducir la extracción del agua subterránea y la recarga a partir de 2018 y hasta 2030, también en un 50%.

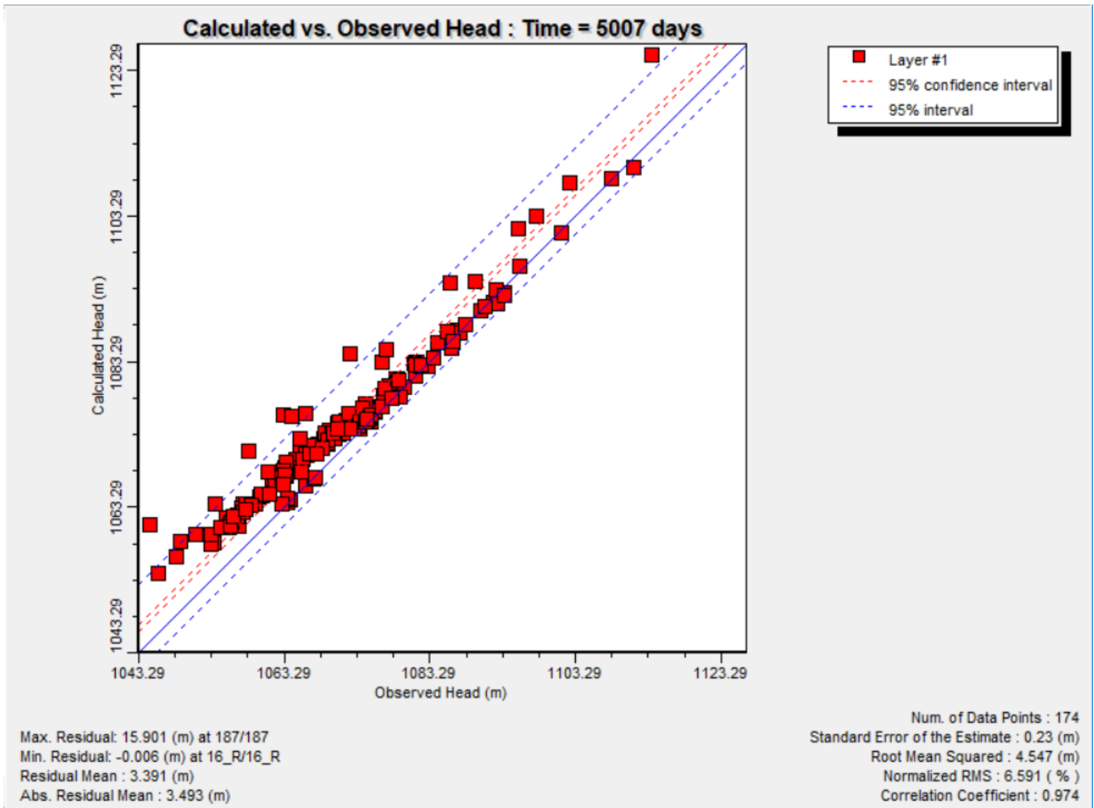


Figura 26. Recta de abatimientos correspondiente a julio de 2022 (t= 5007 días), para el ES4NB.

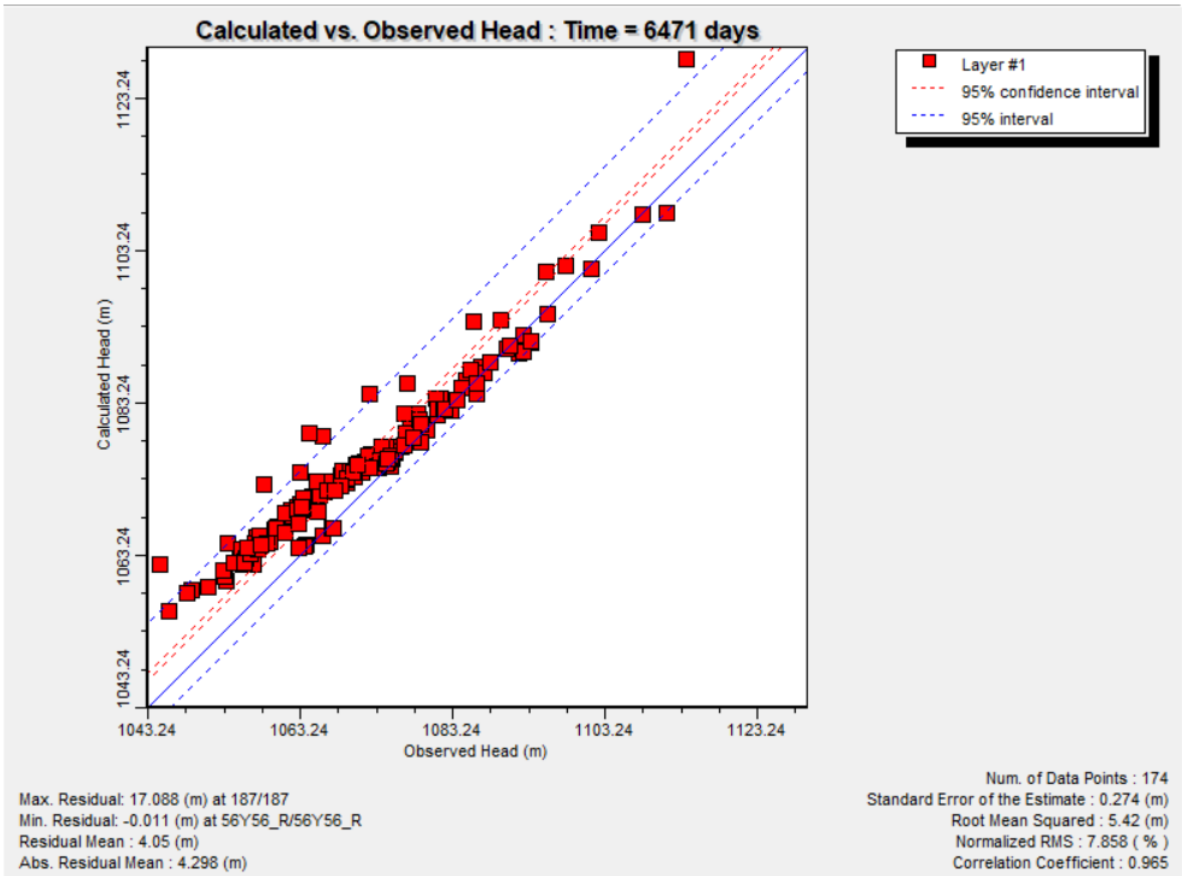


Figura 27. Recta de abatimientos correspondiente julio de 2026 (t= 6471 días), para el ES4NB.

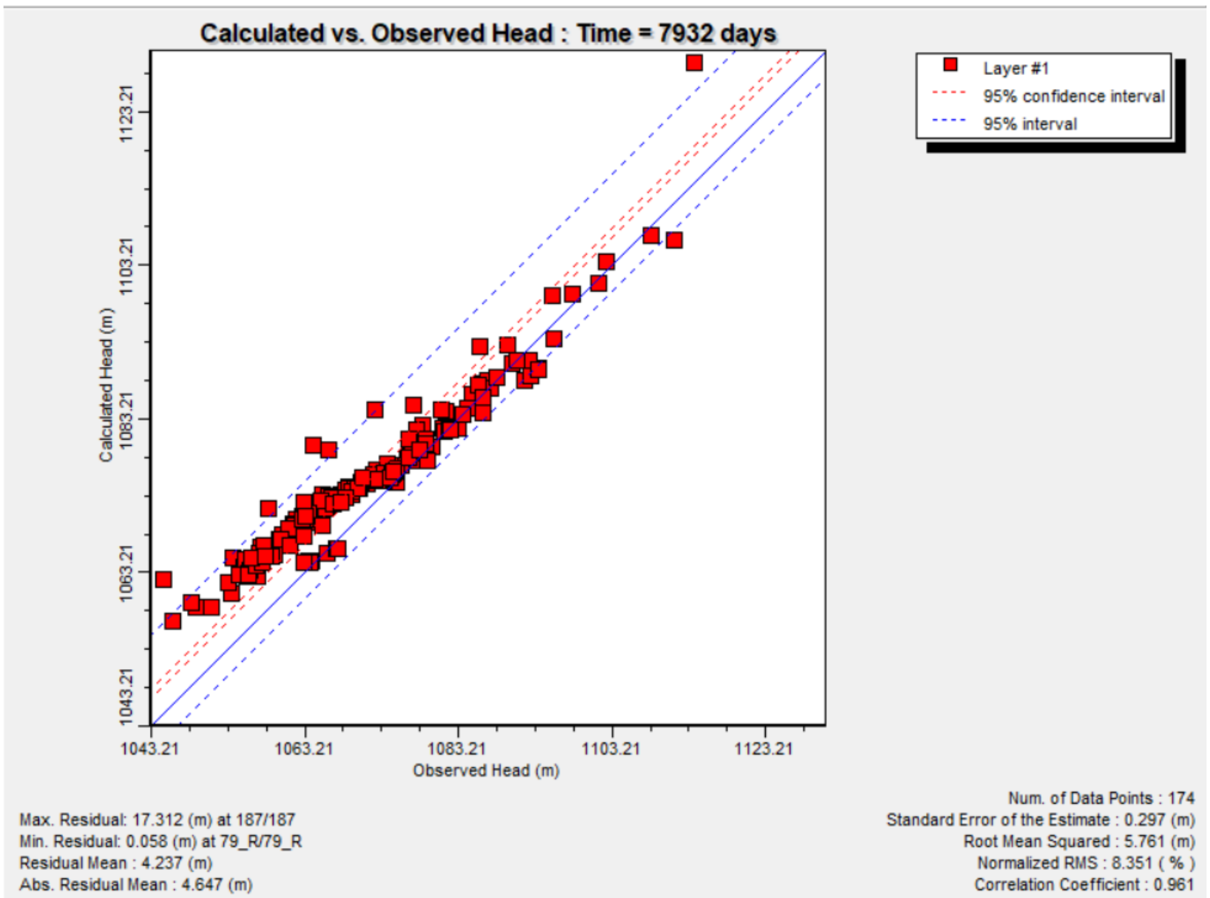


Figura 28. Recta de abatimientos correspondiente julio de 2030 (t=7932 días), para el ES4NB.

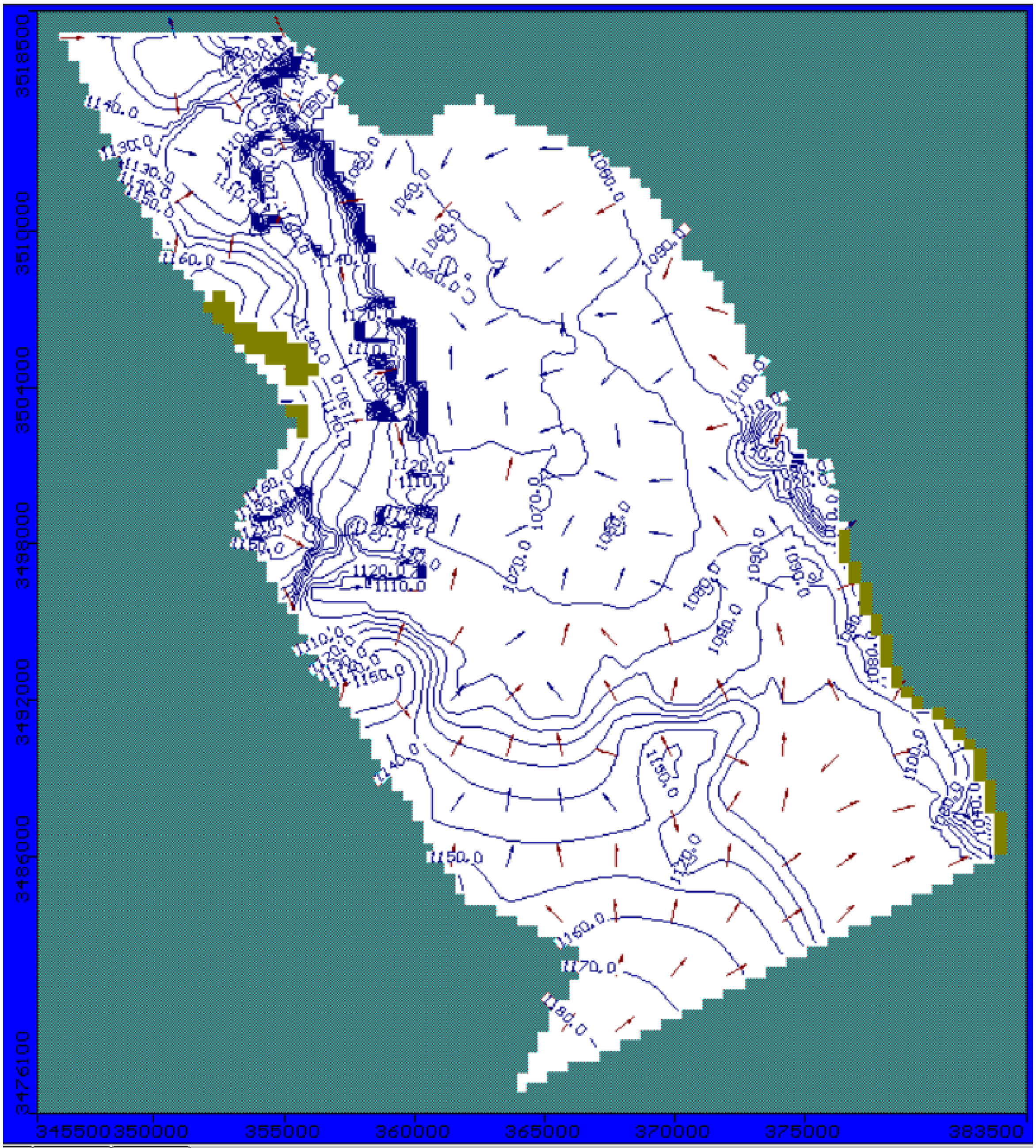


Figura 29. Cargas simuladas escenario **ES4NB** julio de 2030 (t=7932 días)

8. ESCENARIO ES5N

Entregar el doble de agua de Conejos Médano o de otro lugar y este incremento reducirlo del bombeo. Por lo que, el volumen distribuido mantendrá constante, pero se reducirá la extracción en 10.03%, equivalente a traer ese volumen de agua de otro lugar.

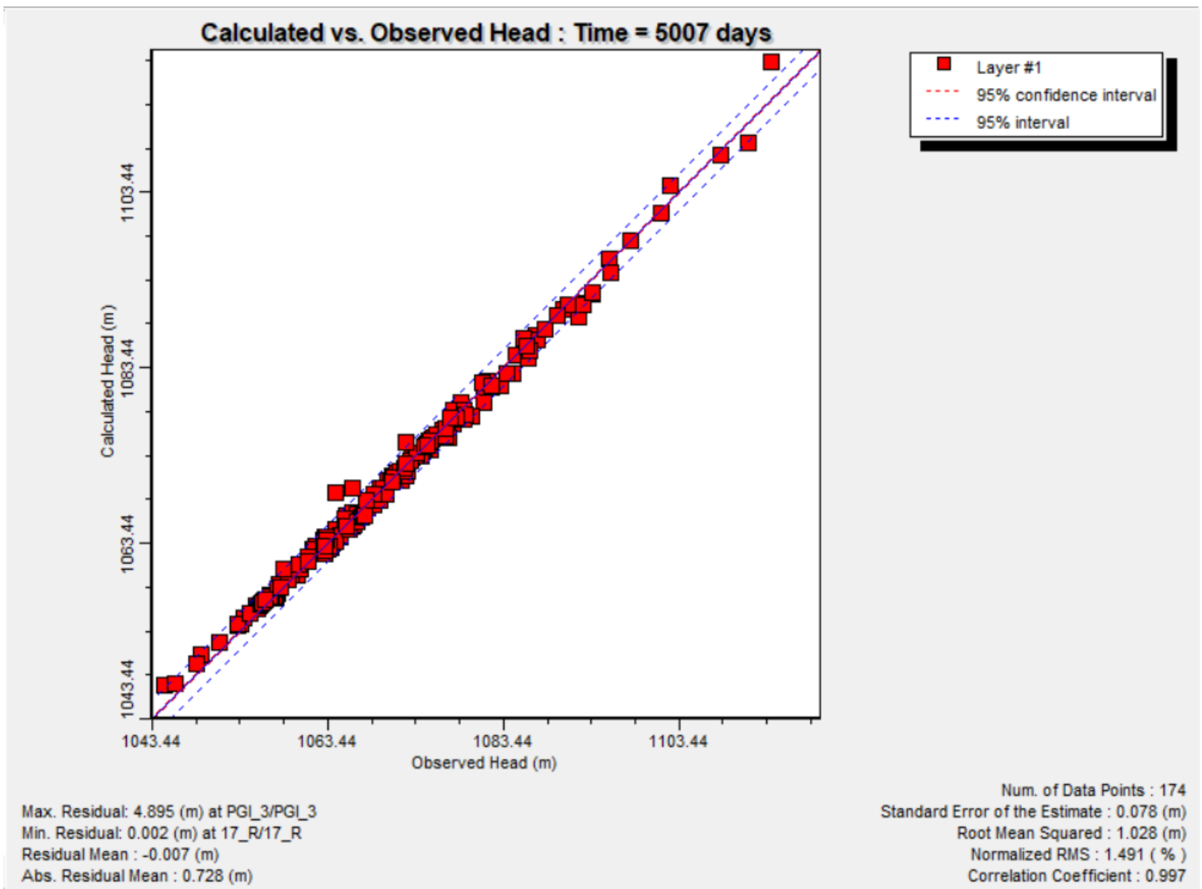


Figura 30. Recta de abatimientos correspondiente a julio de 2022 (t= 5007 días), para el ES5N.

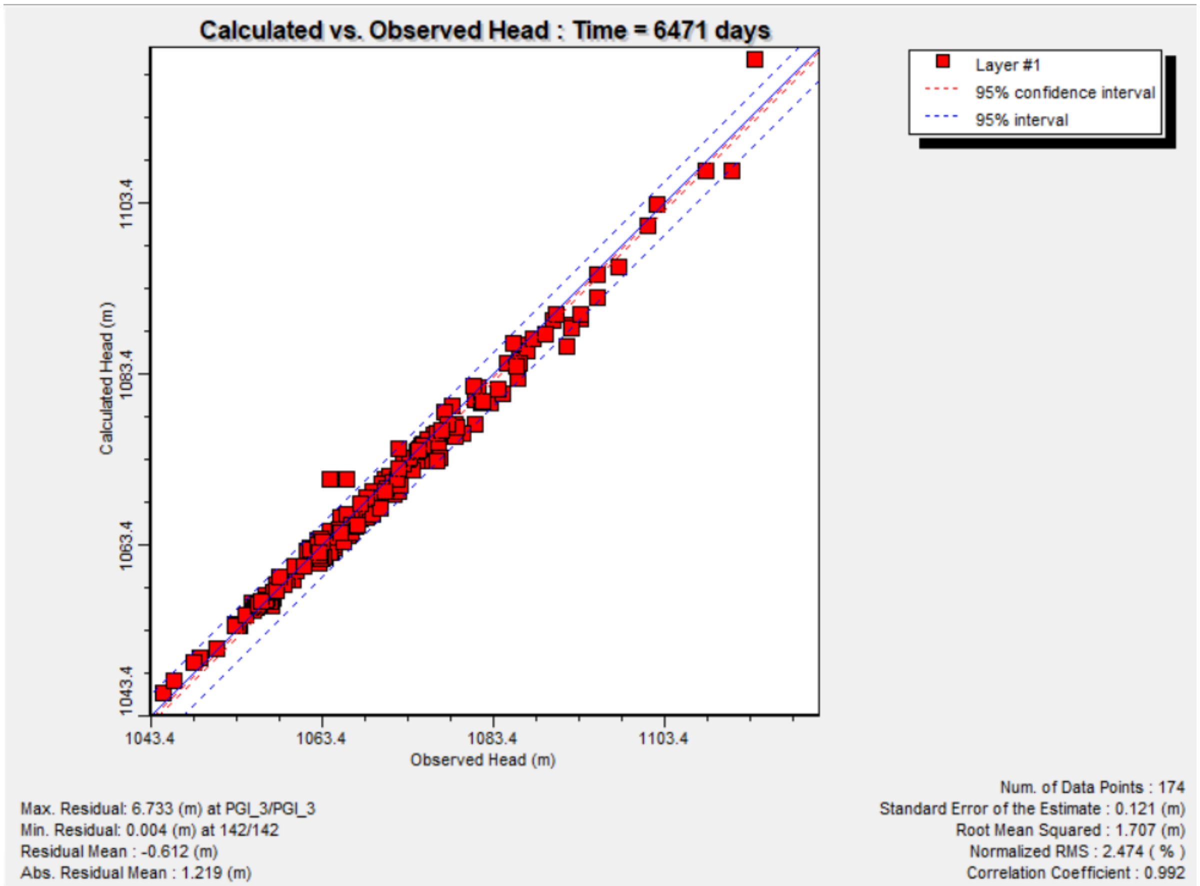


Figura 31. Recta de abatimientos correspondiente a julio de 2026 (t= 6471 días), para el ES5N.

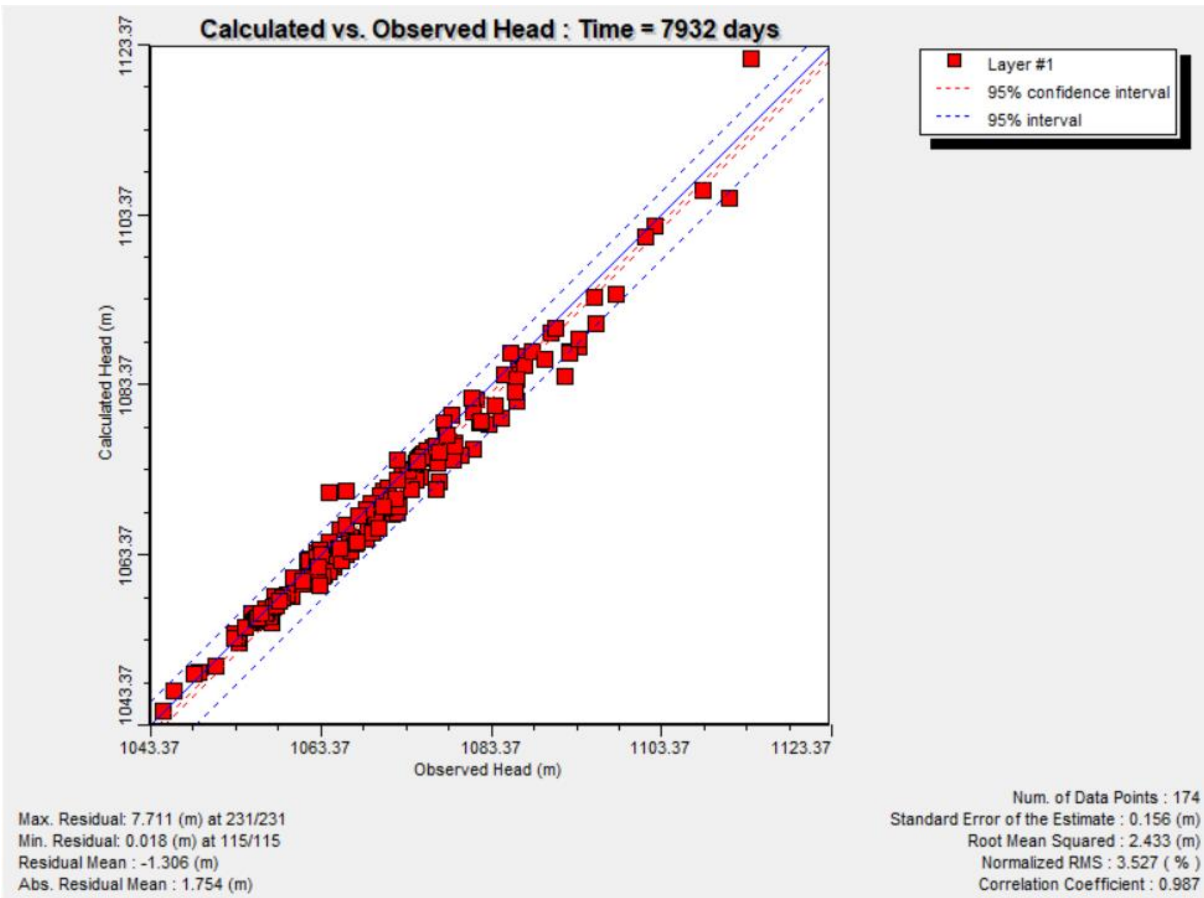


Figura 32. Recta de abatimientos correspondiente a julio de 2030 (t=7932 días), para el ES5N.

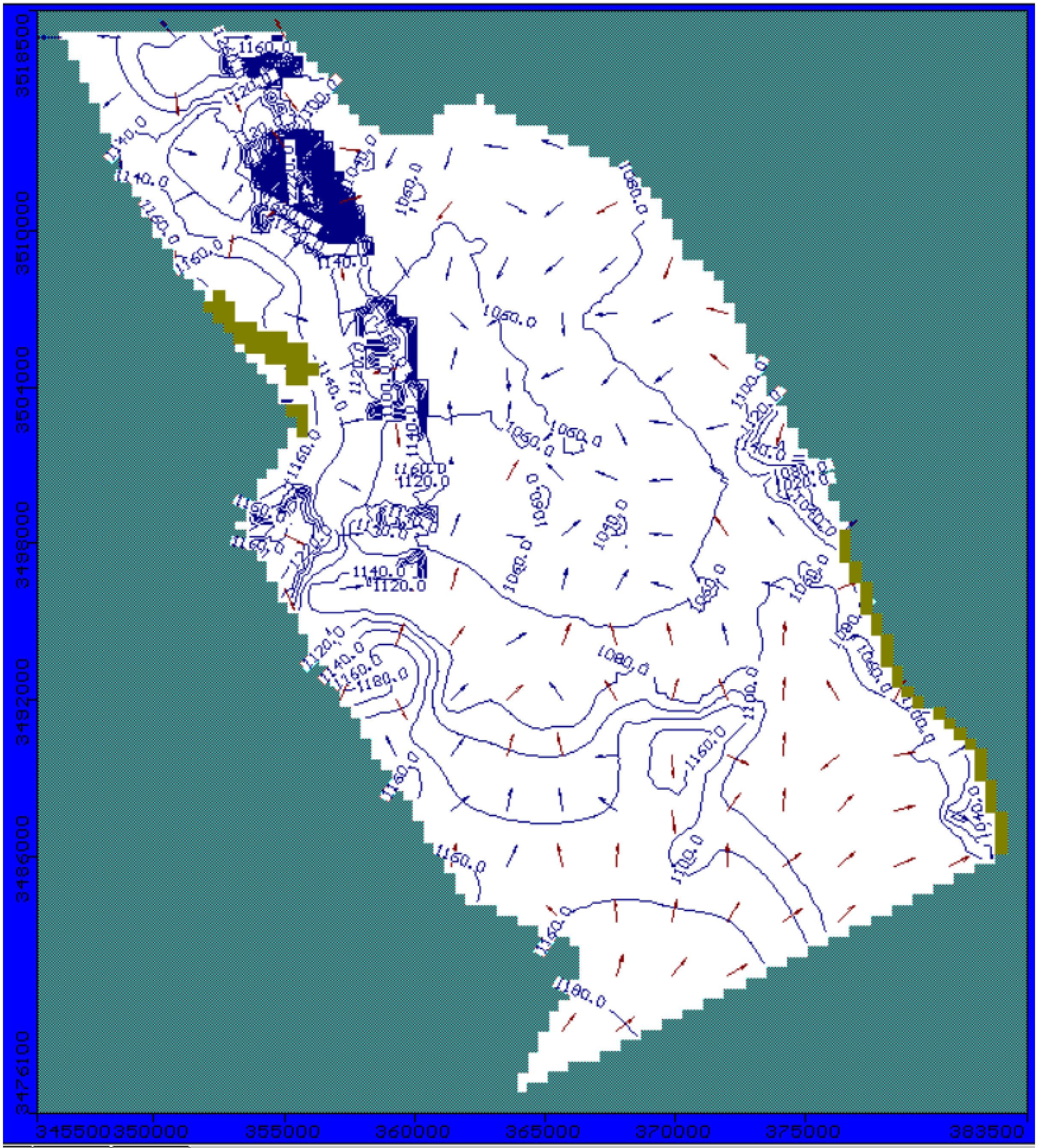


Figura 33. Cargas simuladas escenario **ES5N** julio de 2030 (t=7932 días)

9. ESCENARIO ES6NA

Tronar el modelo.

En este escenario se aumentó la extracción en un 50% y se redujo la recarga también en un 50%.

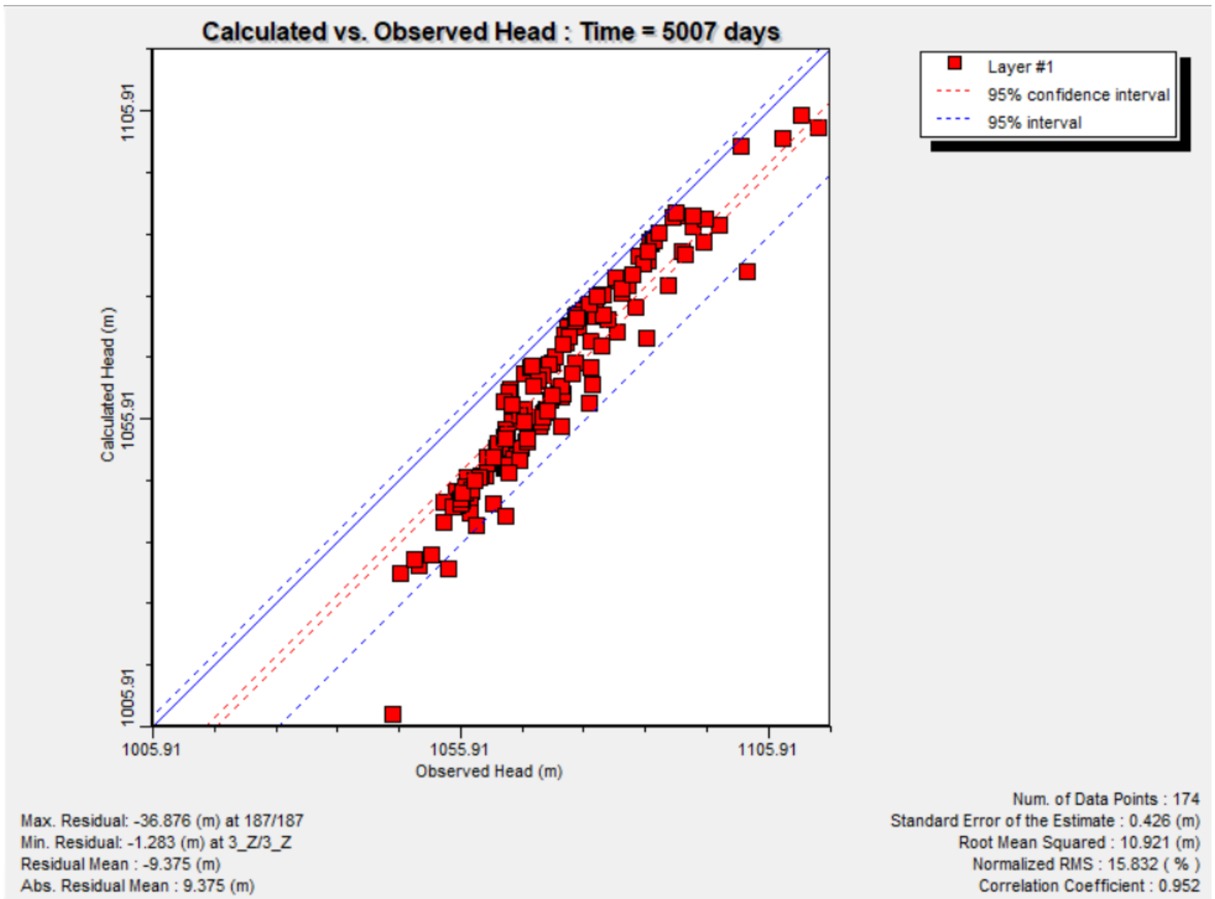


Figura 34. Recta de abatimientos correspondiente a julio de 2022 (t= 5007 días), para el ES6NA.

T = 6471 días

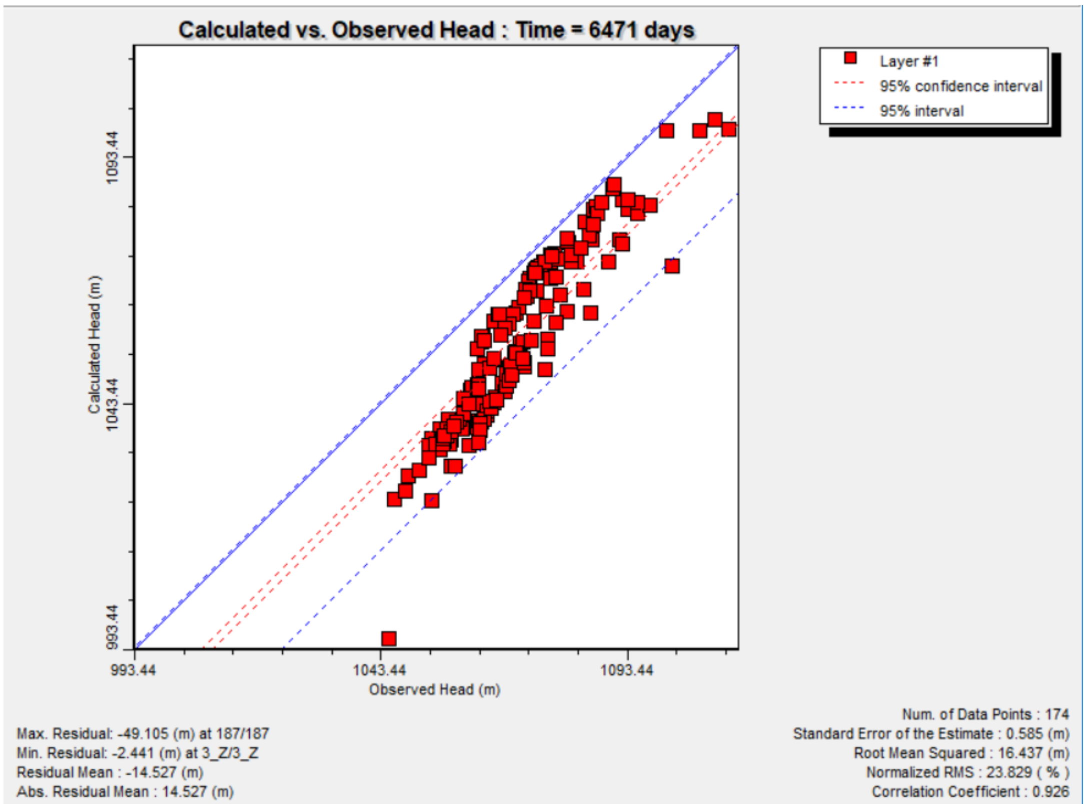


Figura 35. Recta de abatimientos correspondiente a julio de 2026 (t= 6471 días), para el ES6NA.

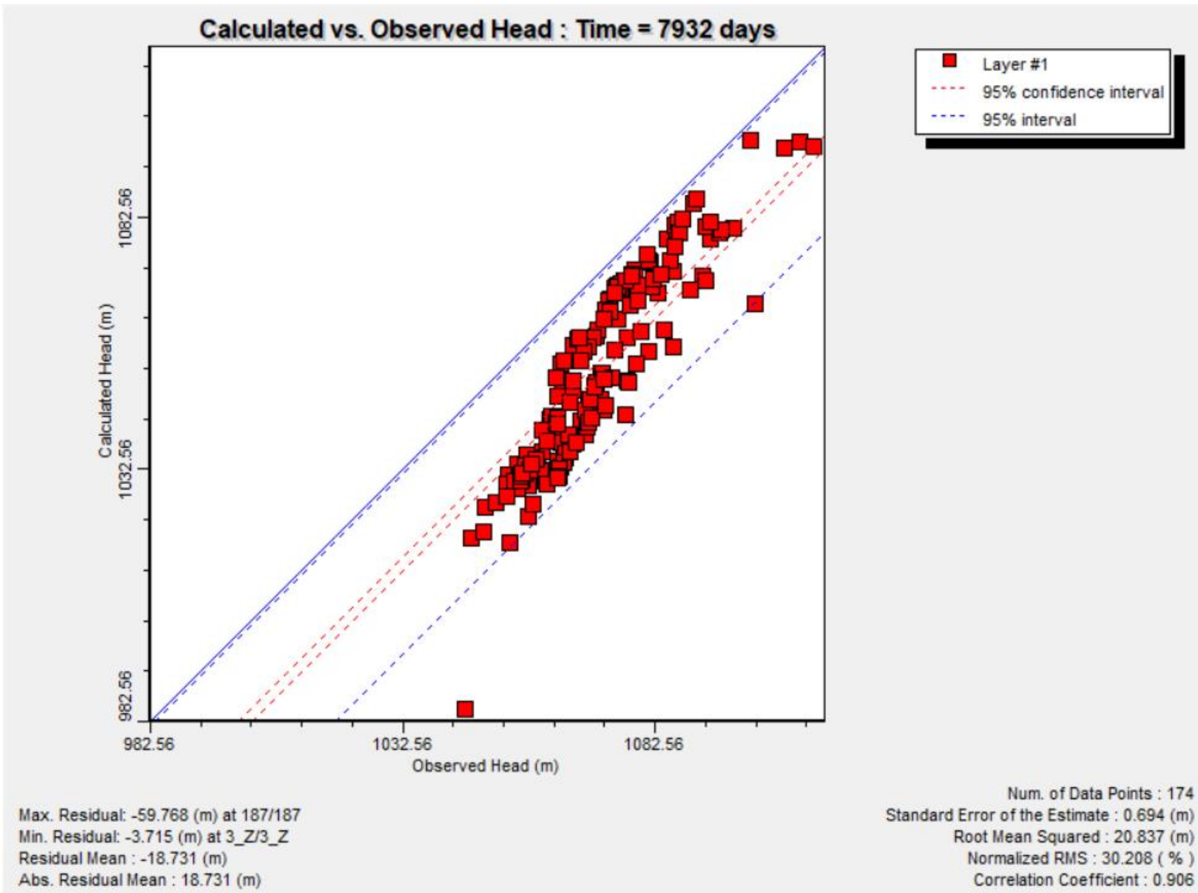


Figura 36. Recta de abatimientos correspondiente a julio de 2030 (t=7932 días), para el ES6NA.

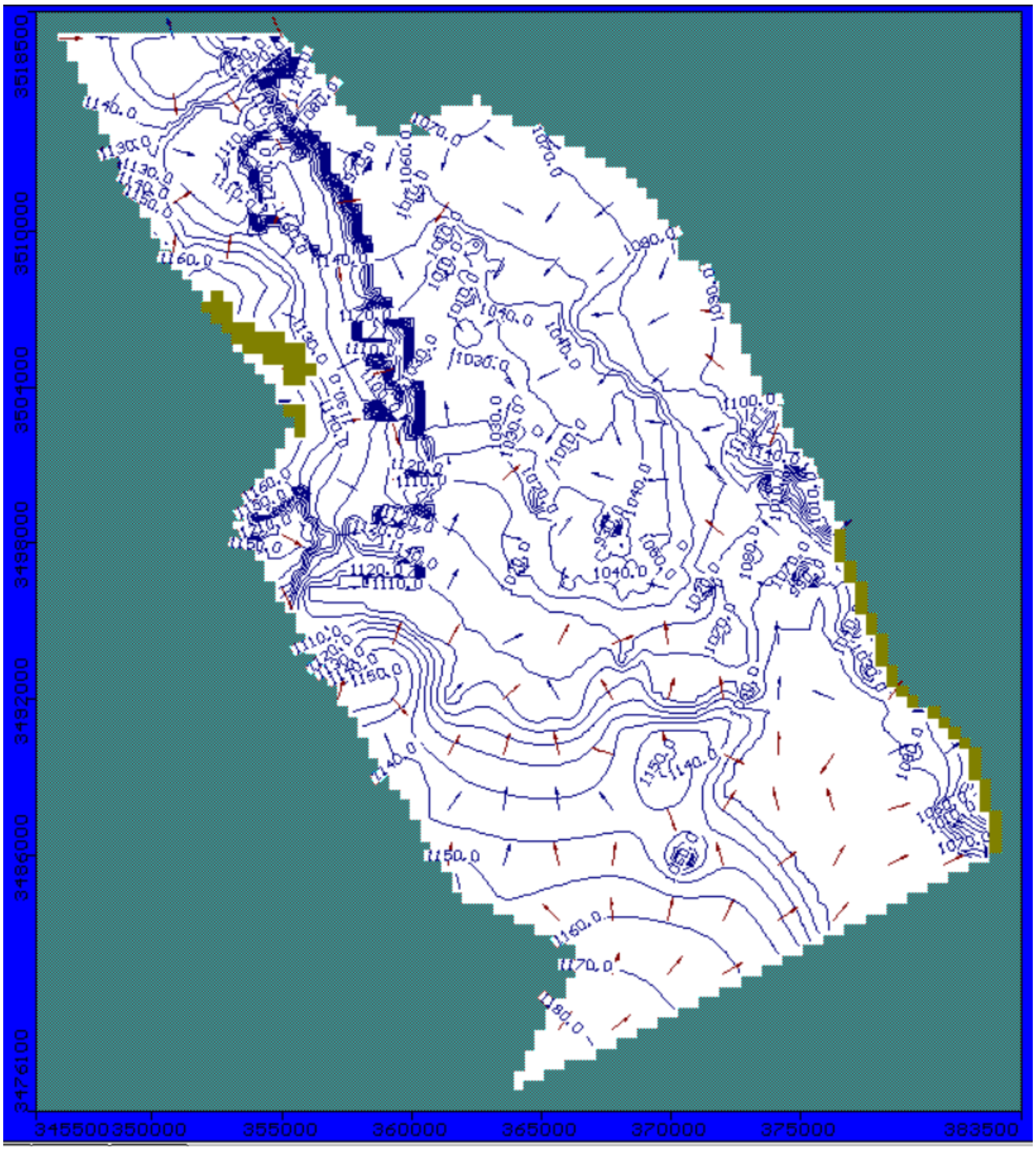
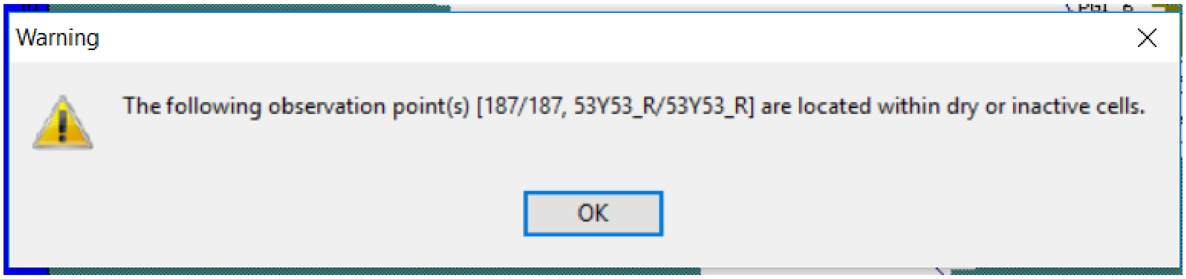


Figura 37. Cargas simuladas escenario **ES6NA** julio de 2030 (t=7932 días)

10. ESCENARIO ES6NB

En este escenario se aumentó la extracción al doble y se redujo la recarga en un 75%.



T= 5007 días

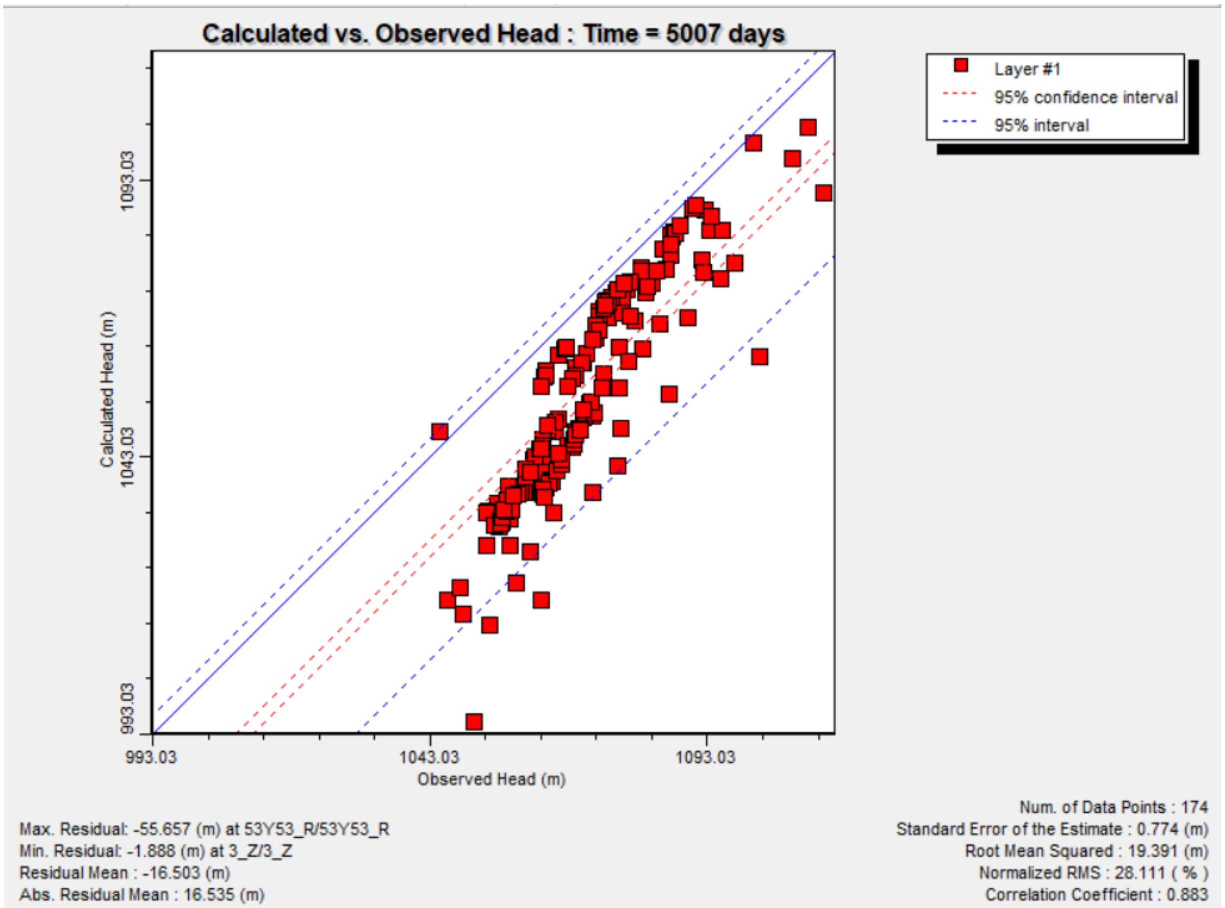


Figura 38. Recta de abatimientos correspondiente a julio de 2022 (t= 5007 días), para el ES6NB.

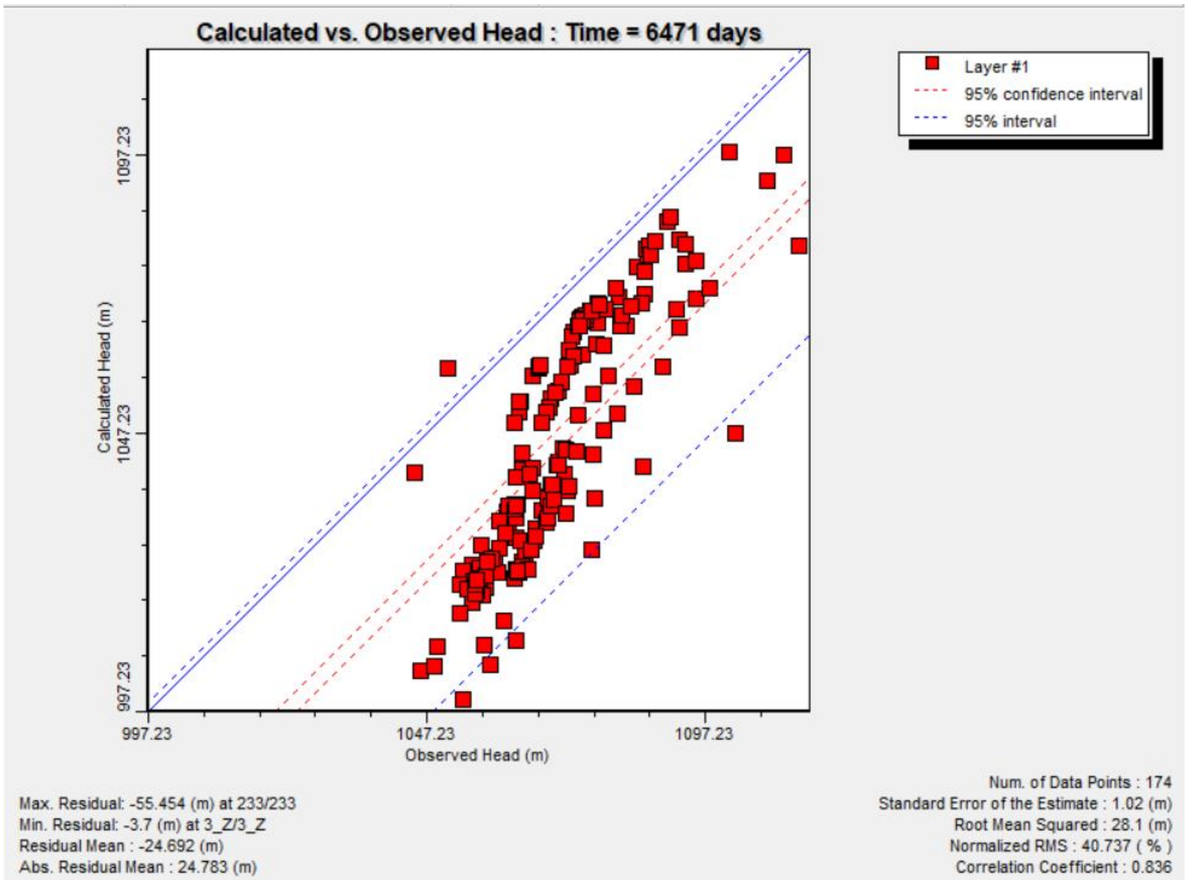


Figura 39. Recta de abatimientos correspondiente a julio de 2026 (t= 6471 días), para el ES6NB.

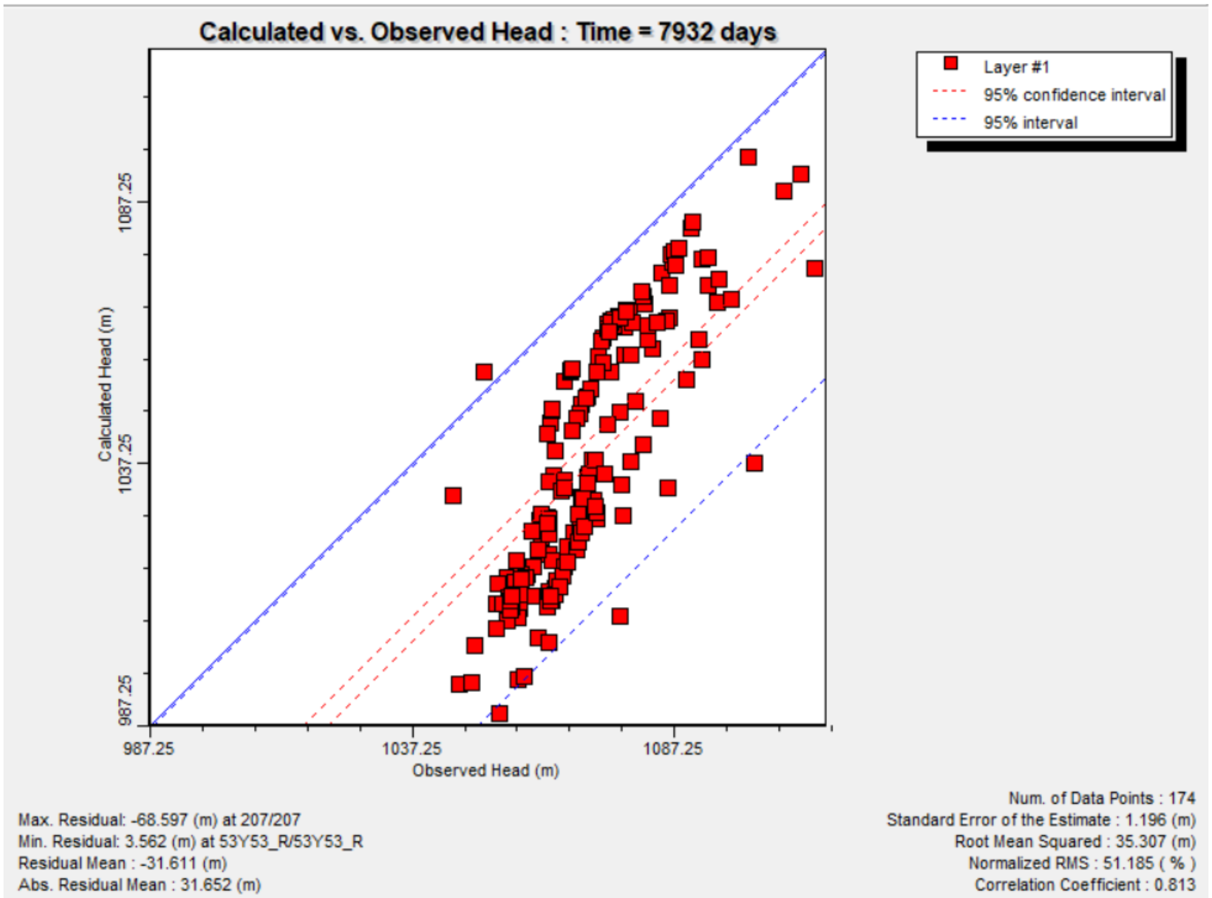


Figura 40. Recta de abatimientos correspondiente a julio de 2030 (t=7932 días), para el ES6NB.

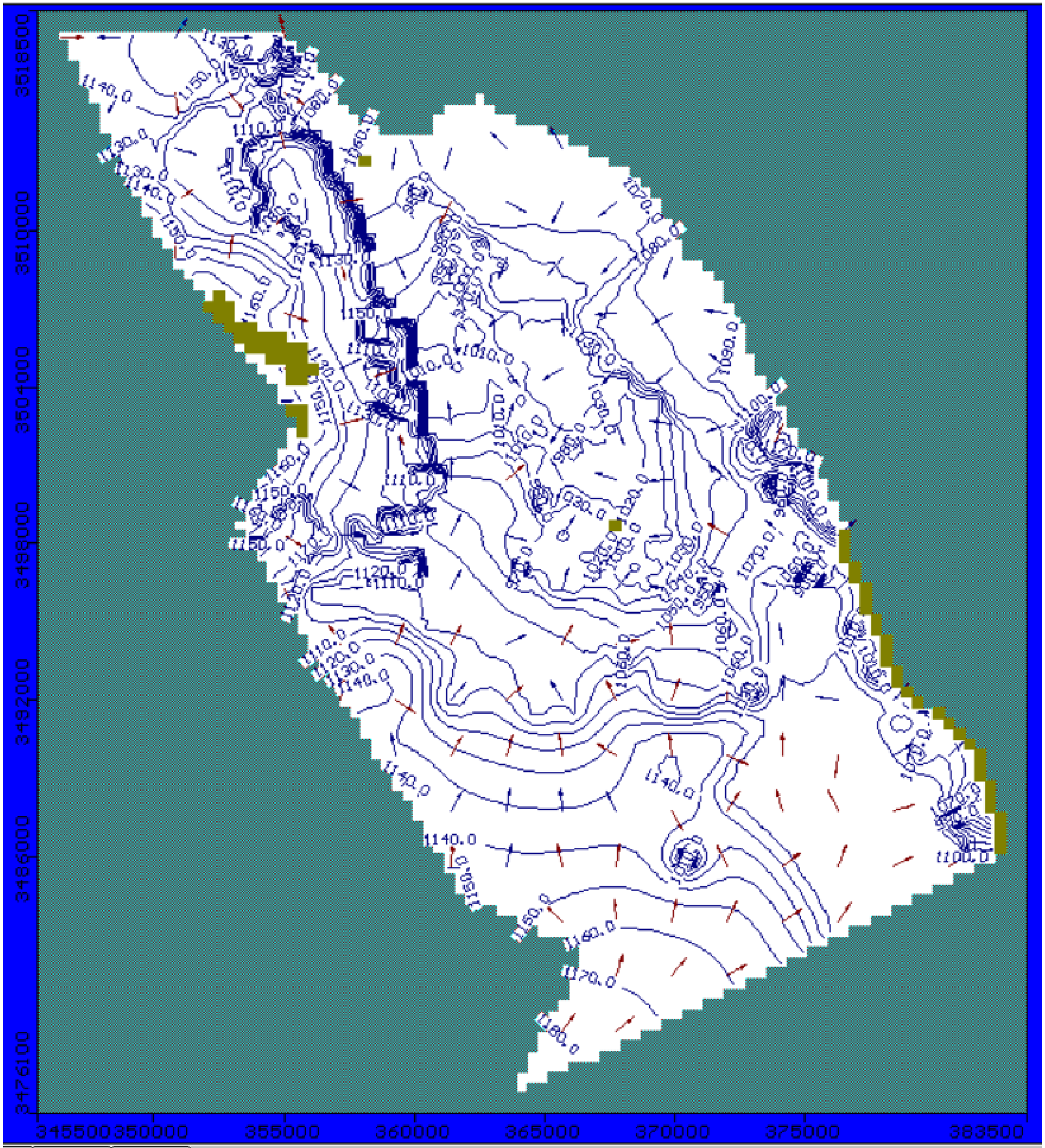
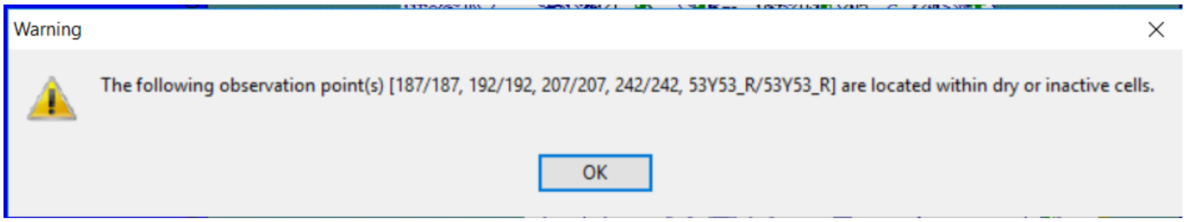


Figura 41. Cargas simuladas escenario **ES6NB** julio de 2030 (t=7932 días)

11. ESCENARIO ES6NC

En este escenario se aumentó la extracción en 2.5 veces y se redujo la recarga en un 90%.



T= 5007 días

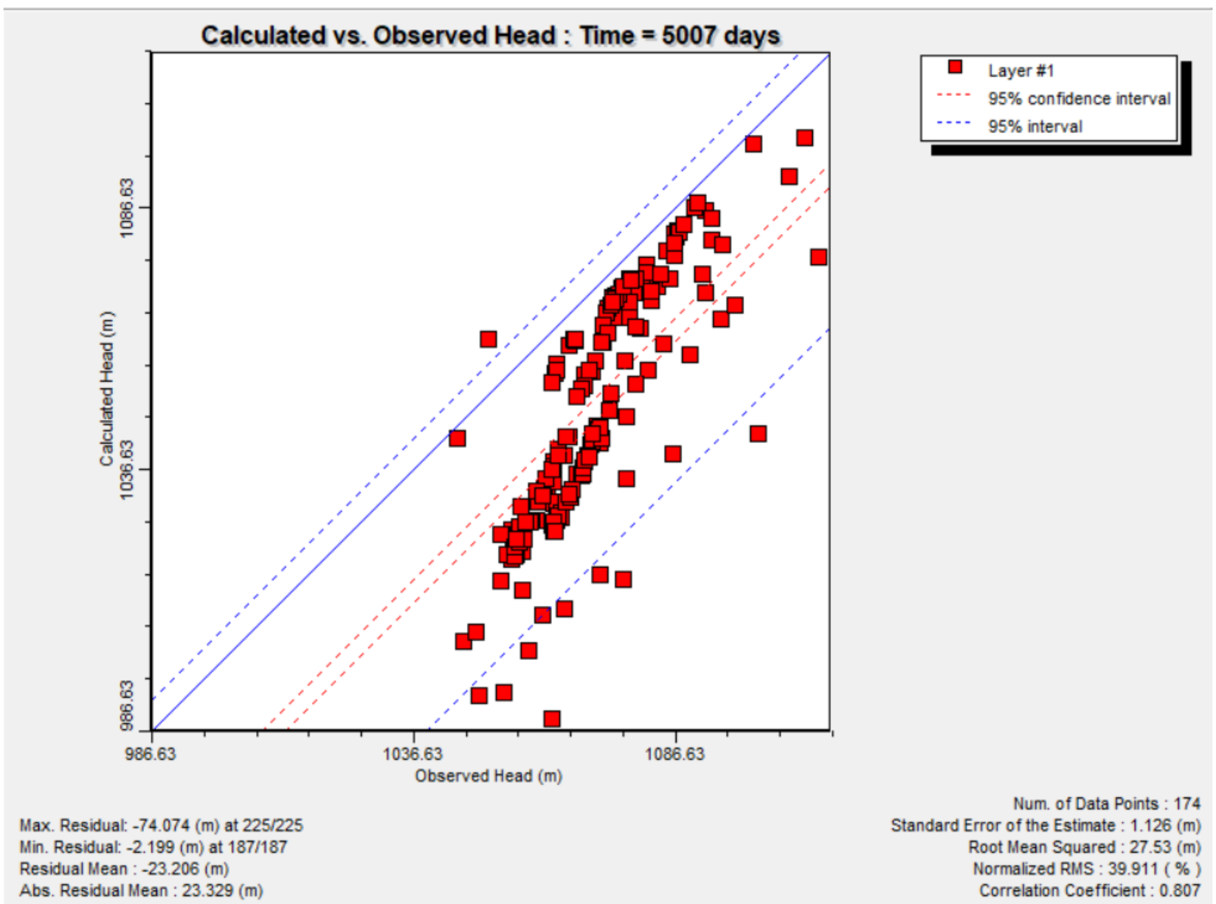


Figura 42. Recta de abatimientos correspondiente a julio de 2022 (t= 5007 días), para el ES6NC.

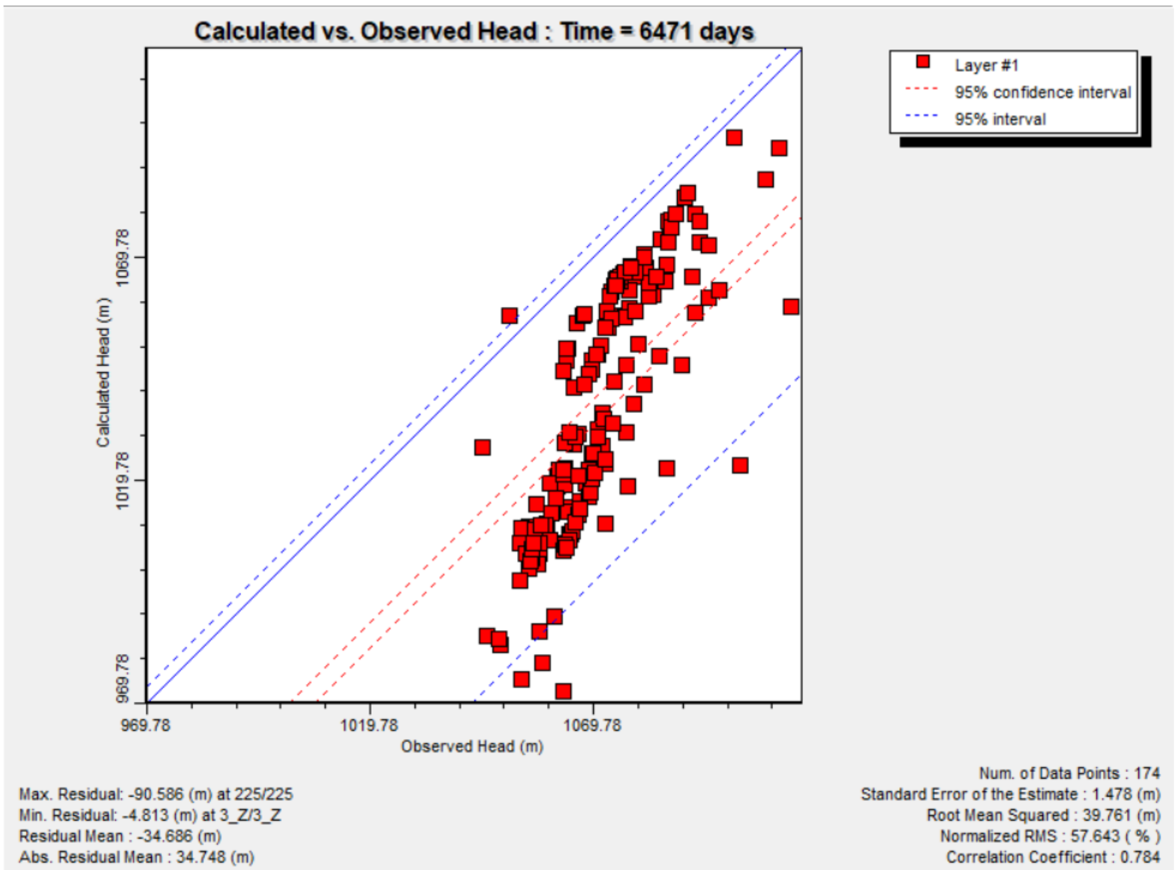


Figura 43. Recta de abatimientos correspondiente a julio de 2026 (t= 6471 días), para el ES6NC.

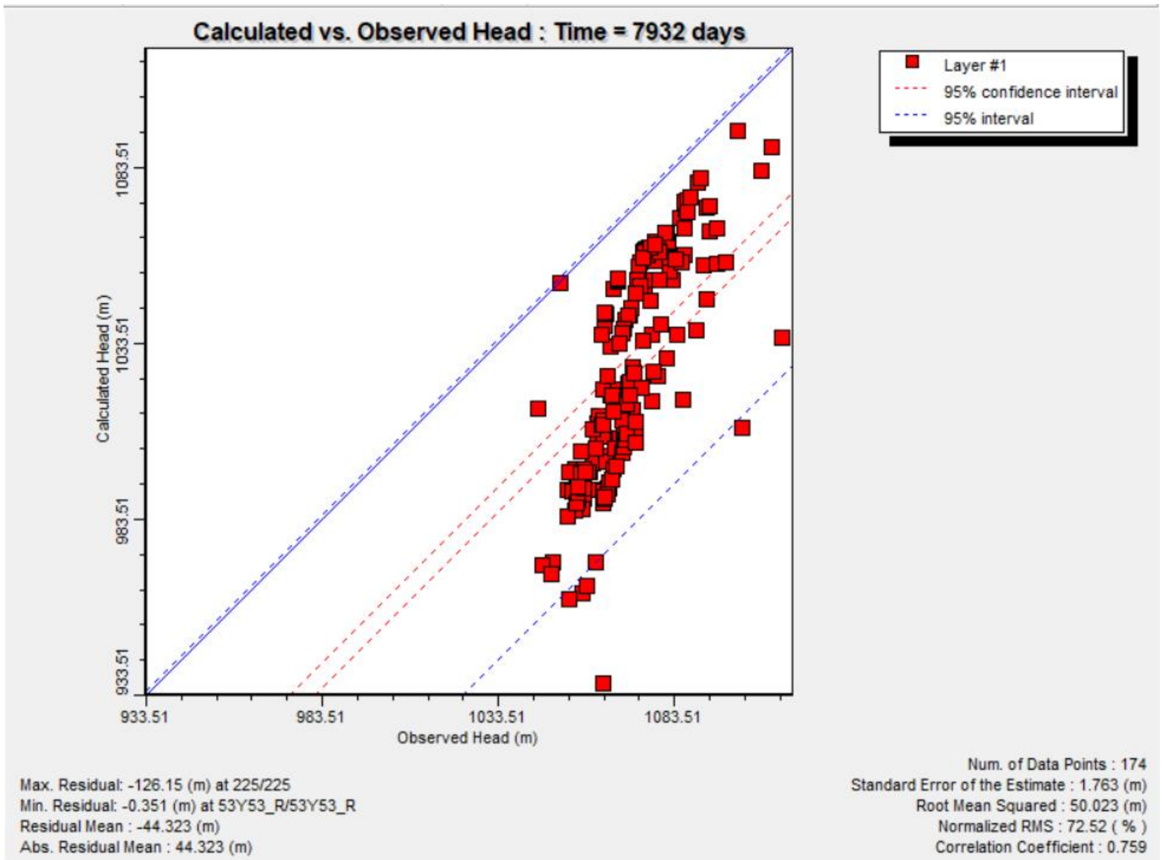


Figura 44. Recta de abatimientos correspondiente a julio de 2030 (t=7932 días), para el ES6NC.

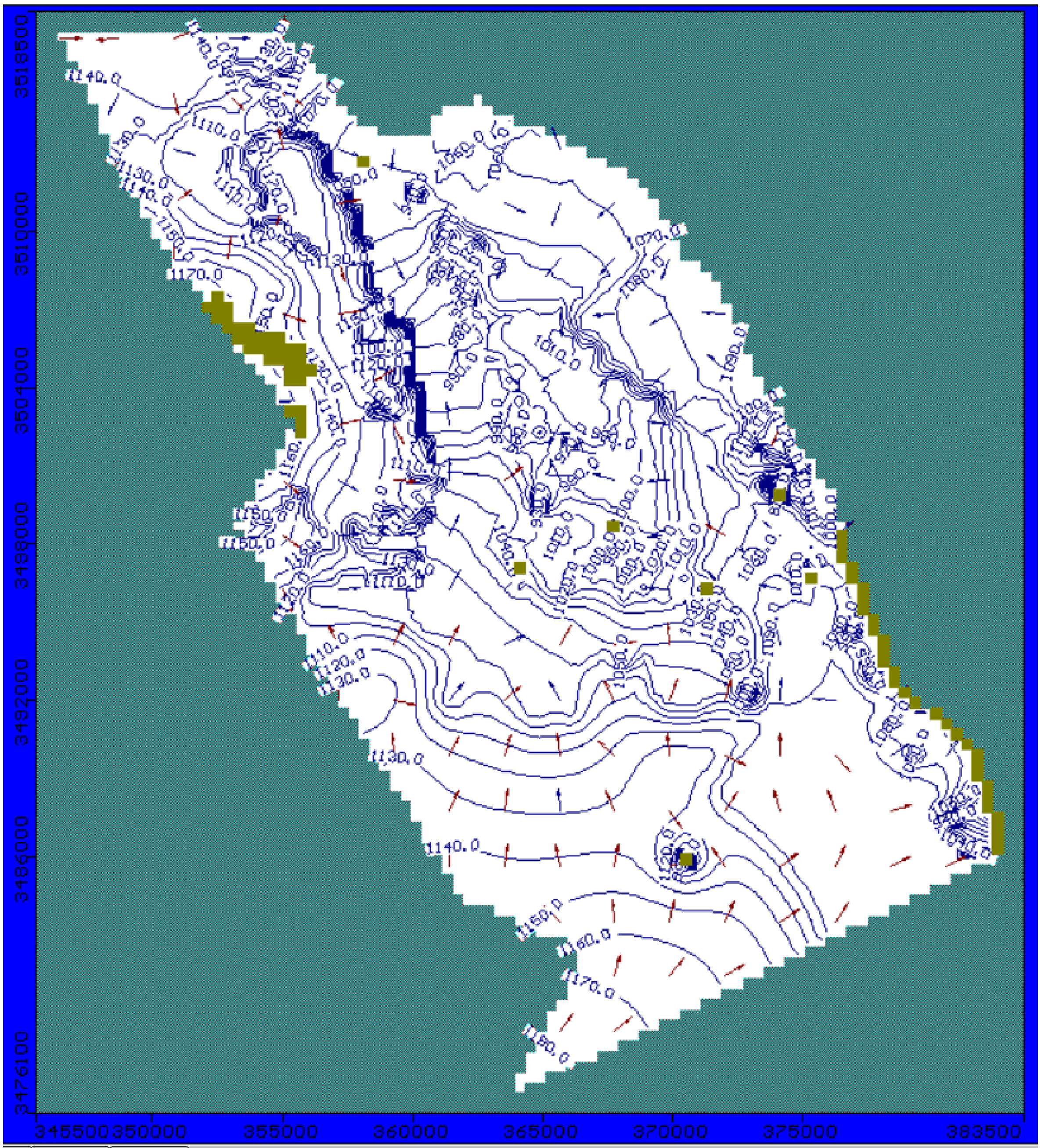


Figura 45. Cargas simuladas escenario **ES6NC** julio de 2030 (t=7932 días)

12. ESCENARIOS ES7NA

En este escenario se redujo el bombeo en un 10% y se mantuvo la recarga sin cambio.

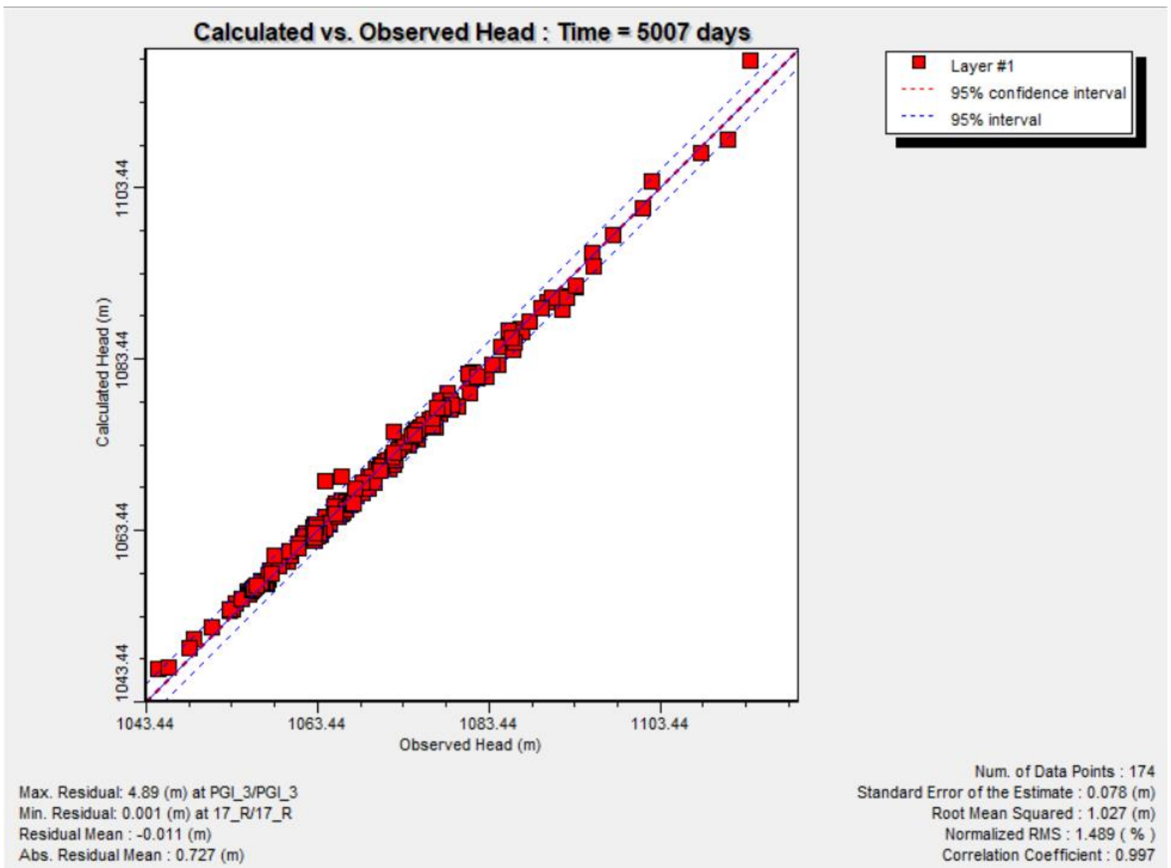


Figura 46. Recta de abatimientos correspondiente a julio de 2022 (t= 5007 días), para el ES7NA.

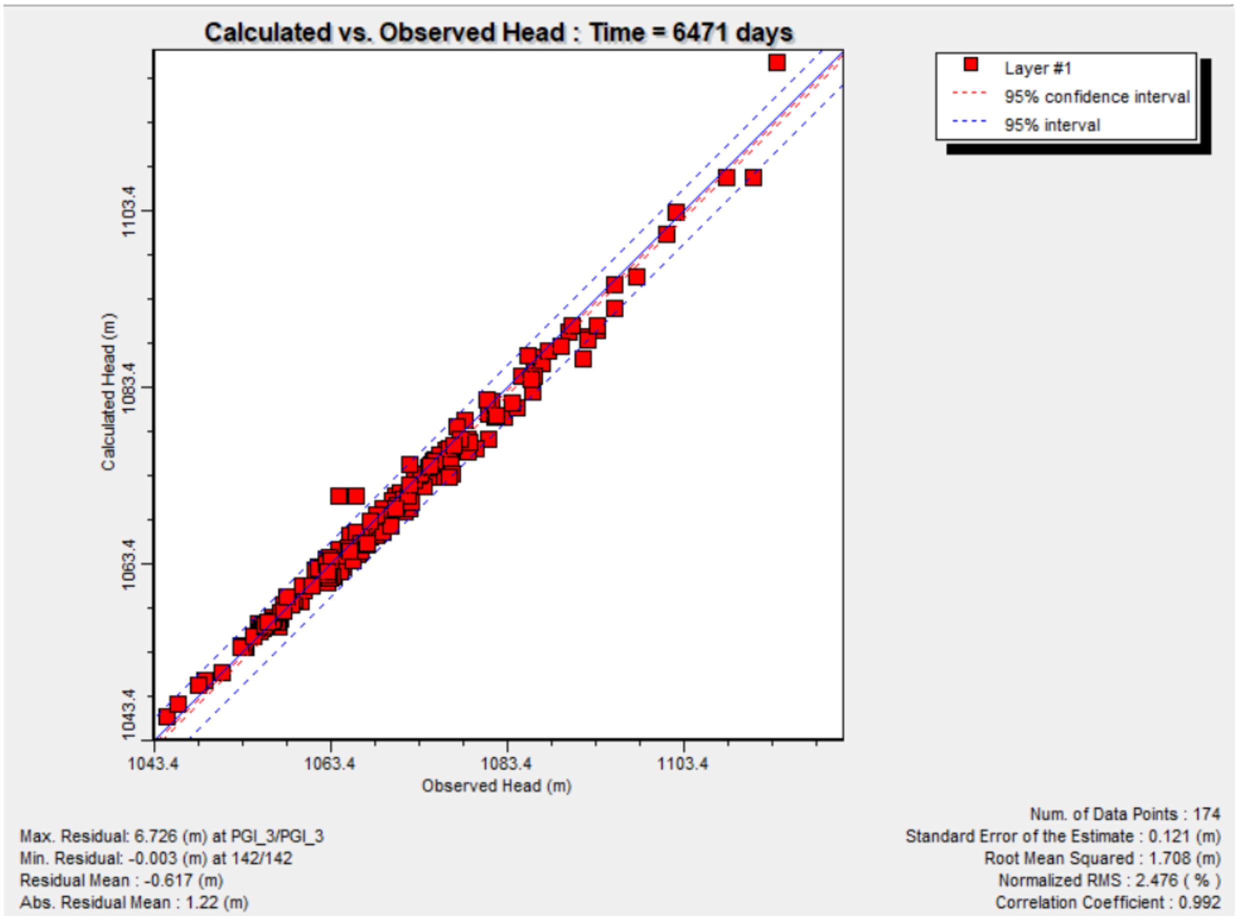


Figura 47. Recta de abatimientos correspondiente a julio de 2026 (t= 6471 días), para el ES7NA.

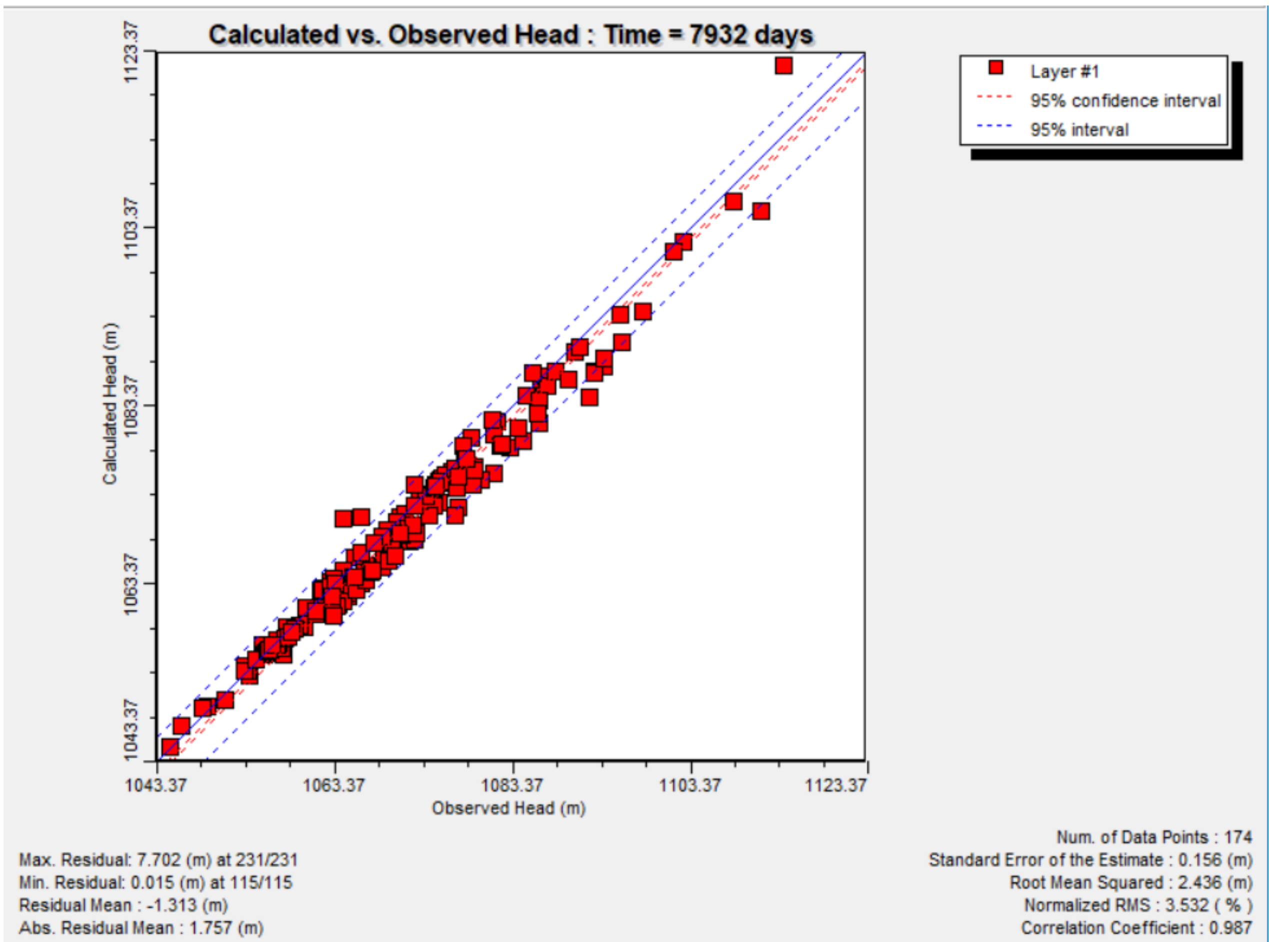


Figura 48. Recta de abatimientos correspondiente a julio de 2030 (t=7932 días), para el ES7NA.

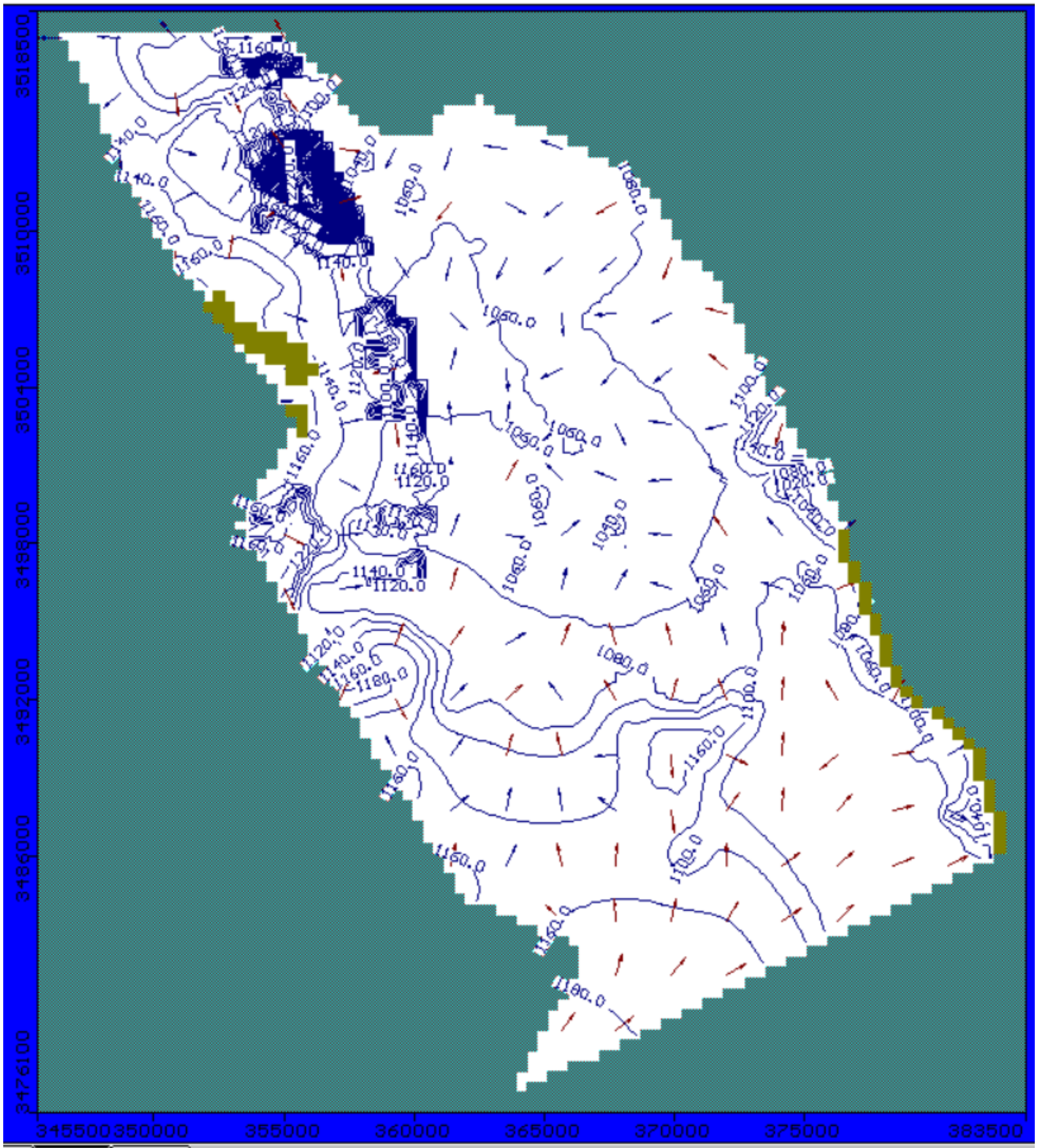


Figura 49. Cargas simuladas escenario **ES7NA** julio de 2030 (t=7932 días)

13. ESCENARIOS ES7NB

En este escenario se redujo el bombeo en un 25% y se mantuvo la recarga sin cambio.

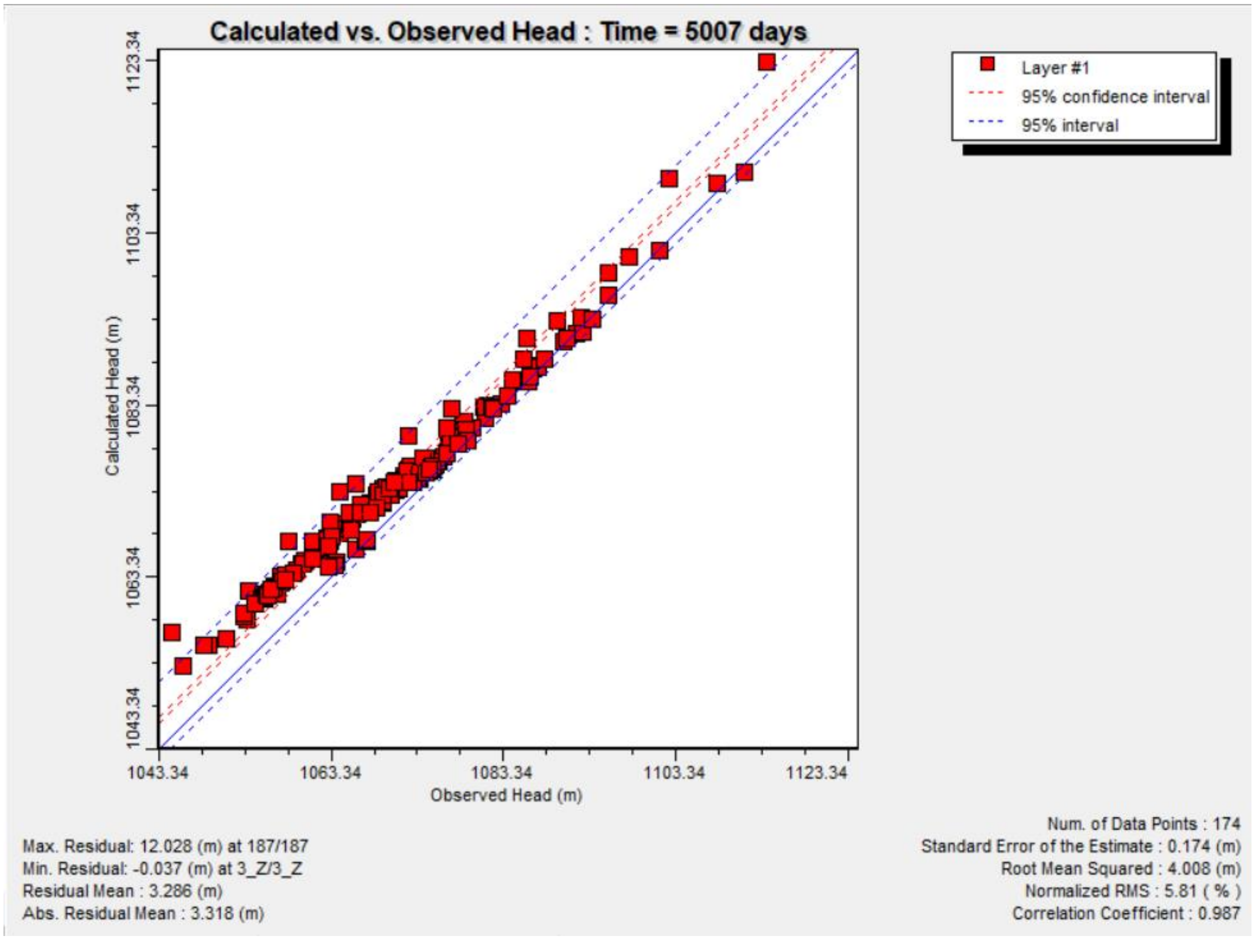


Figura 50. Recta de abatimientos correspondiente a julio de 2022 (t= 5007 días), para el ES7NB.

T = 6471 días

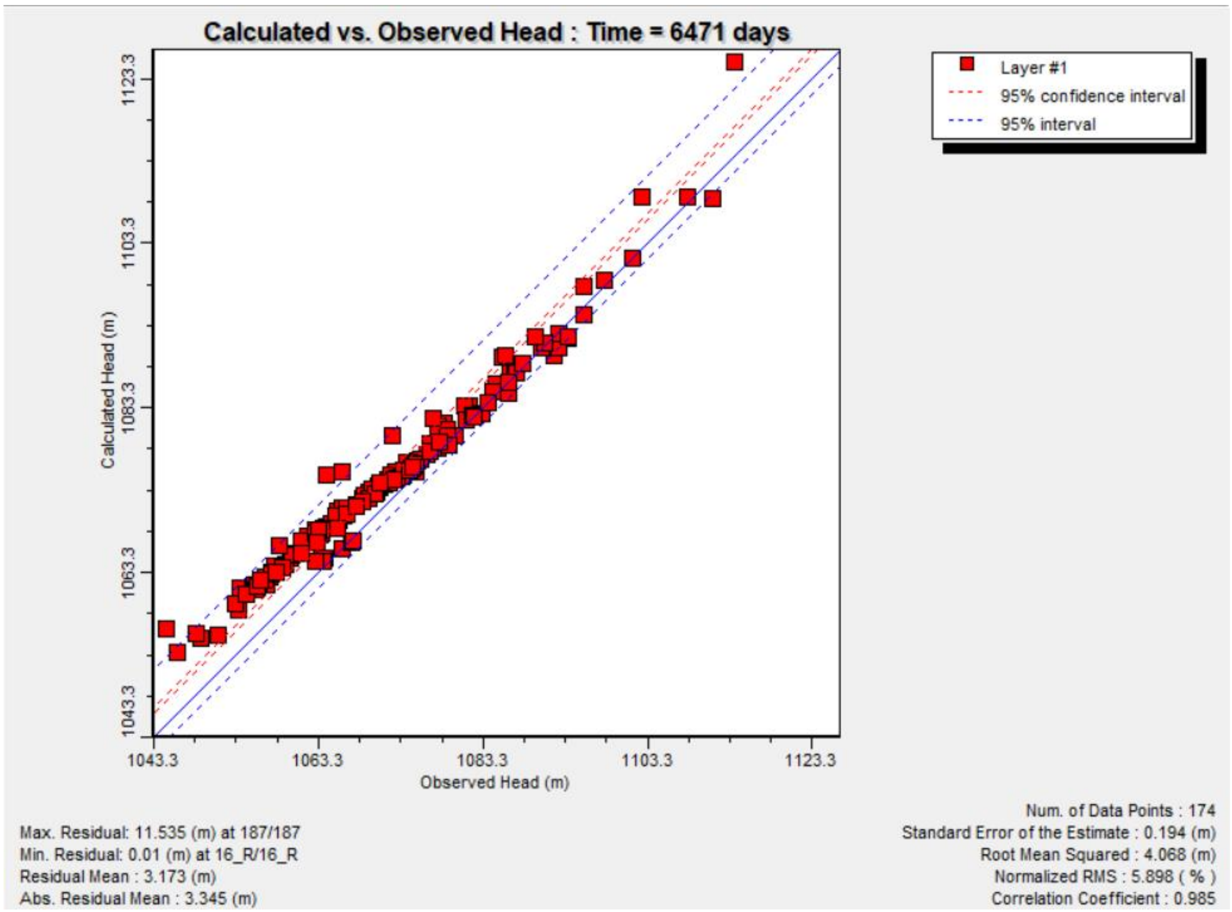


Figura 51. Recta de abatimientos correspondiente a julio de 2026 (t= 6471 días), para el ES7NB.

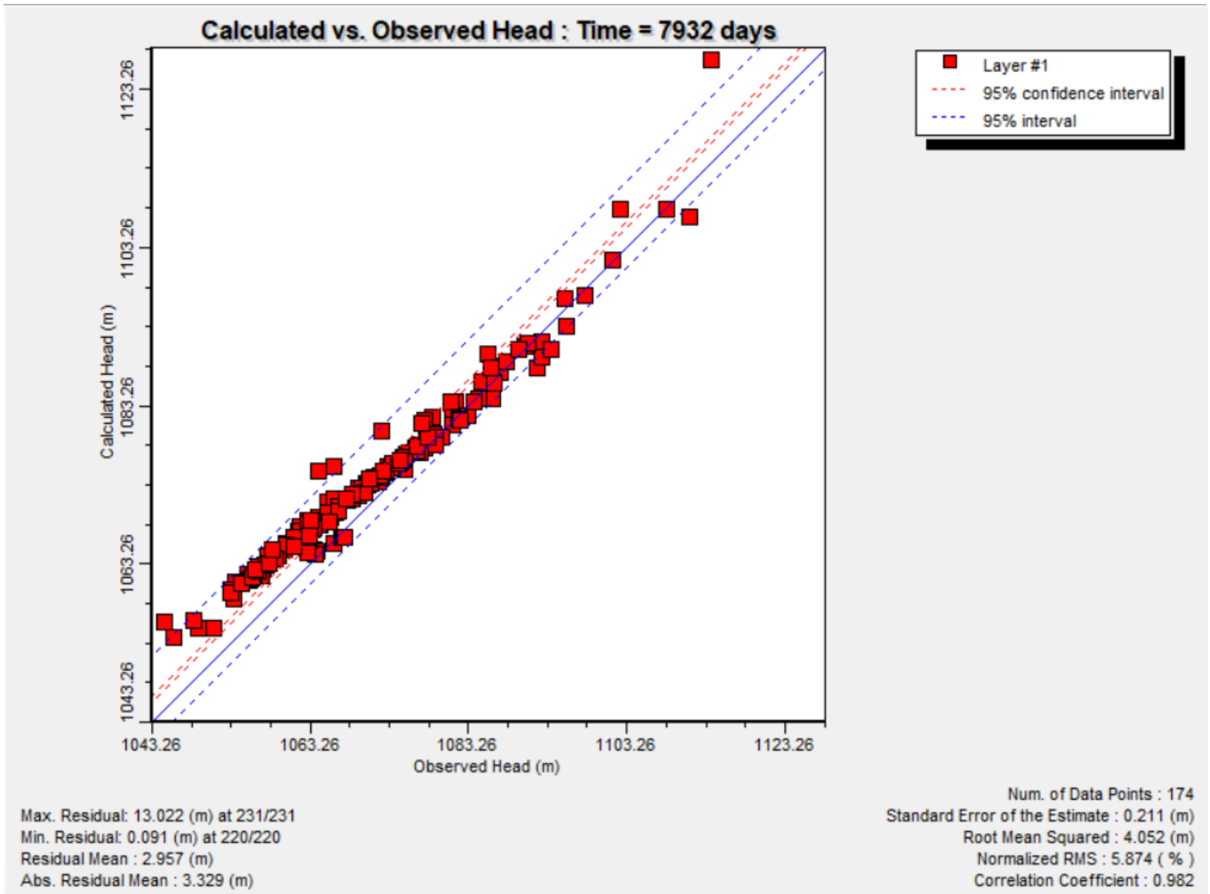


Figura 52. Recta de abatimientos correspondiente a julio de 2030 (t=7932 días), para el ES7NB.

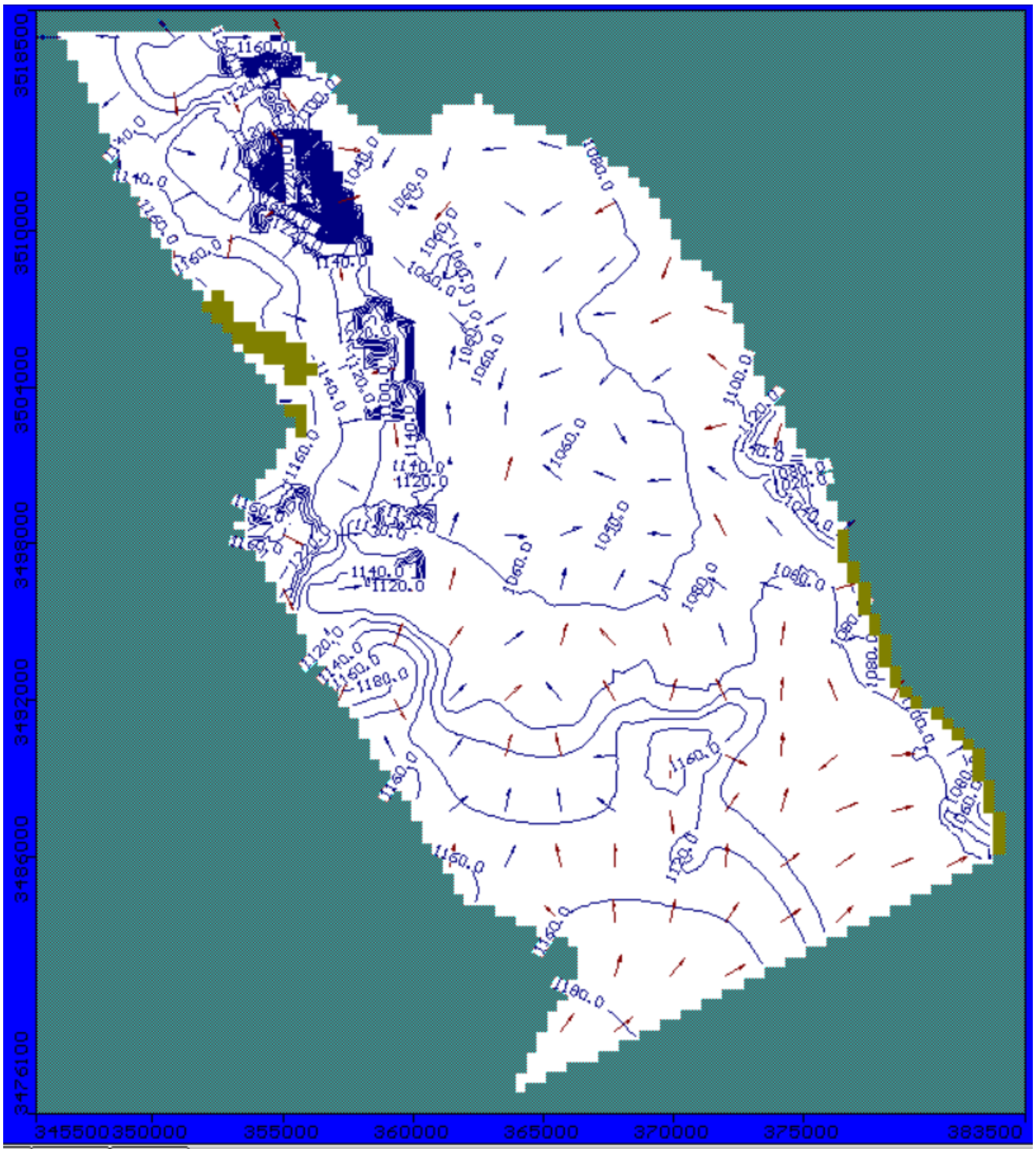


Figura 53. Cargas simuladas escenario **ES7NB** julio de 2030 (t=7932 días)

14. ESCENARIOS ES7NC

En este escenario se redujo el bombeo en un 50% y se mantuvo la recarga sin cambio.

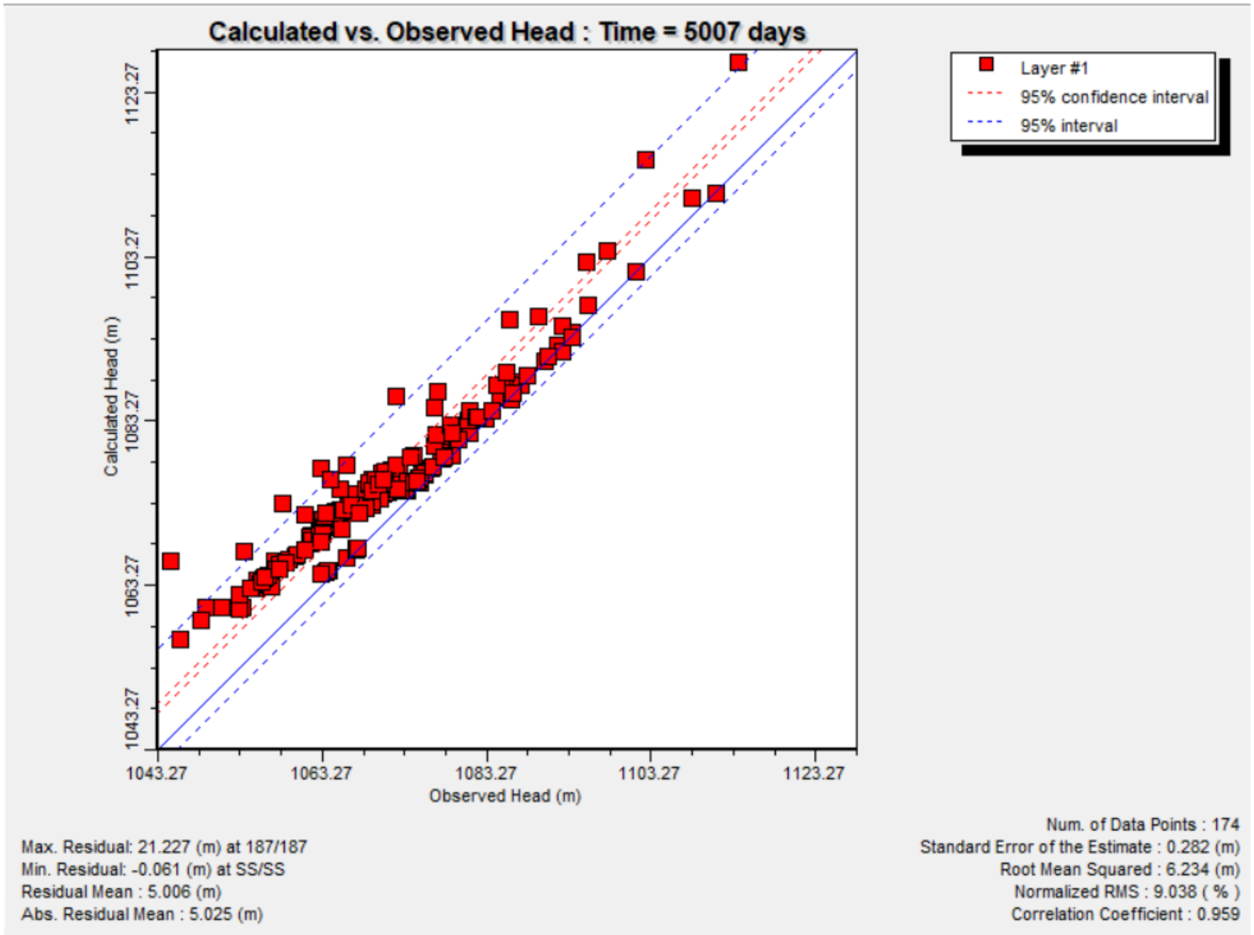


Figura 54. Recta de abatimientos correspondiente a julio de 2022 (t= 5007 días), para el ES7NC.

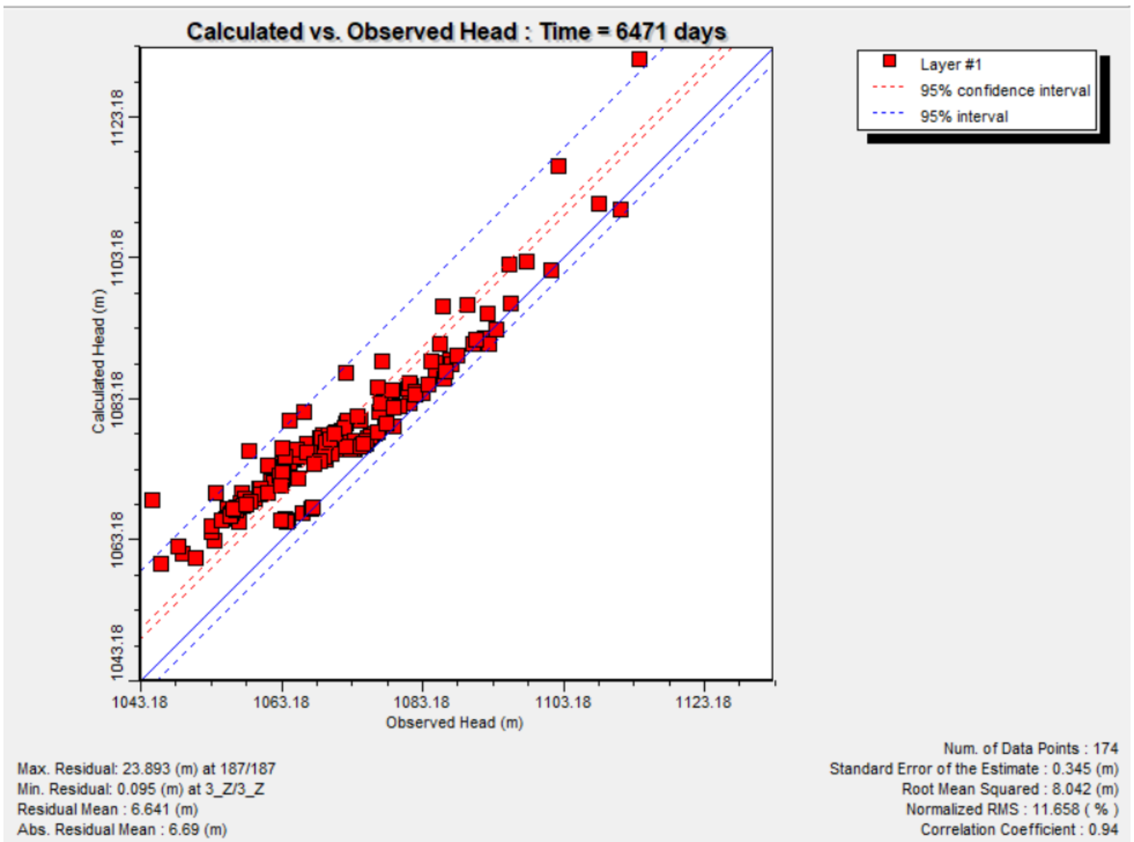


Figura 55. Recta de abatimientos correspondiente a julio de 2026 (t= 6471 días), para el ES7NC.

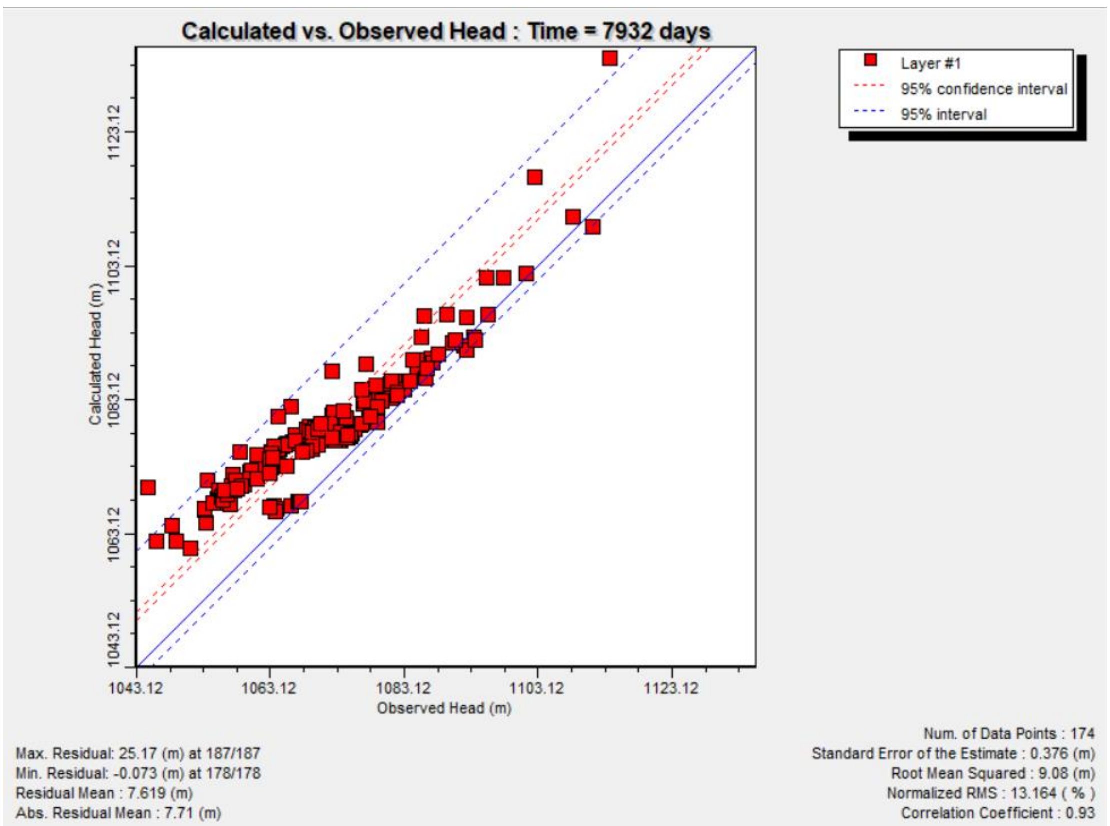


Figura 56. Recta de abatimientos correspondiente julio de 2030 (t=7932 días), para el ES7NC.

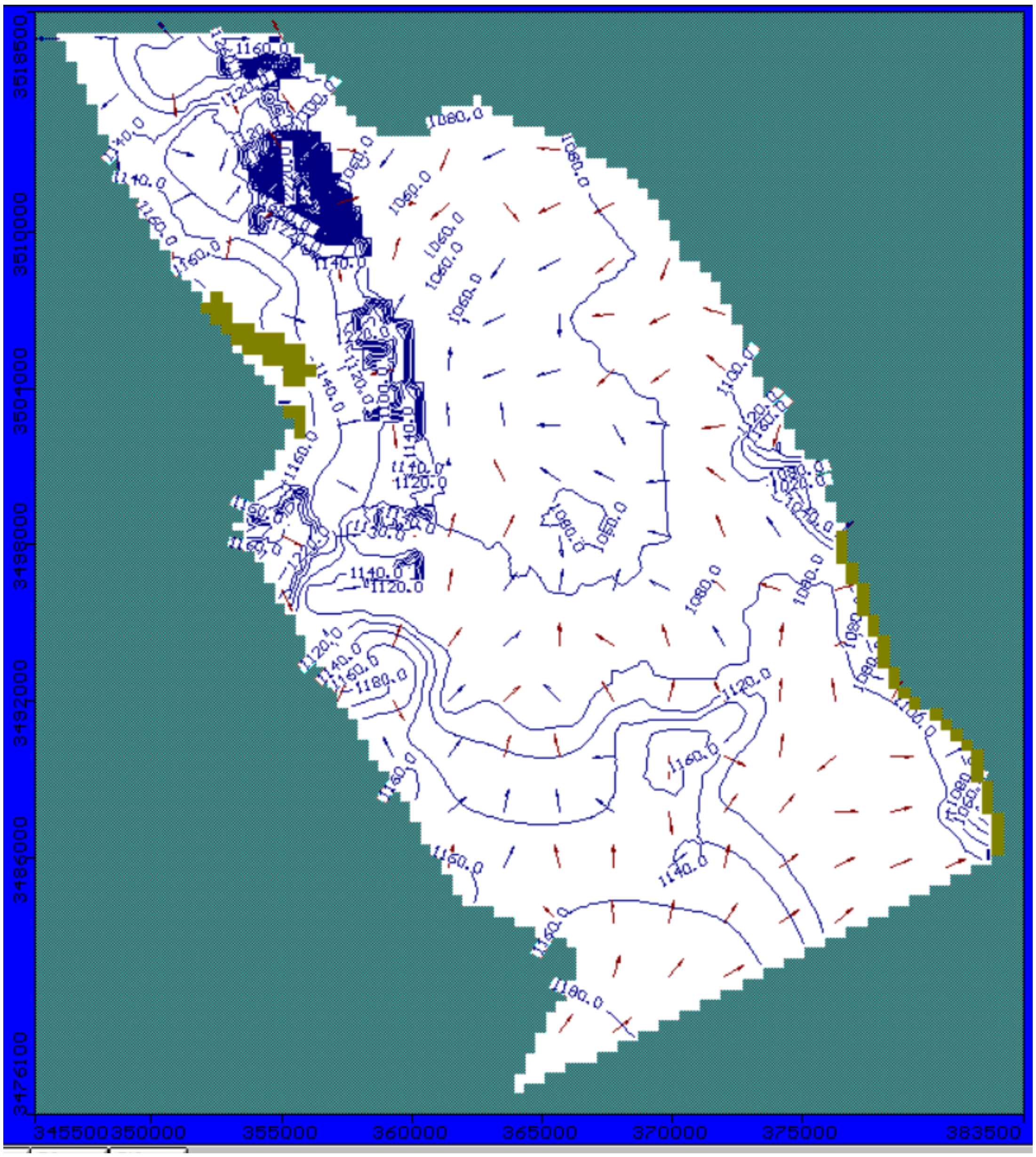


Figura 57. Cargas simuladas escenario **ES7NC** julio de 2030 (t=7932 días)

15. RESUMEN DE RESULTADOS DE CADA UNO DE LOS ESCENARIOS.

Escenarios	Tiempo (días)	Máx. Residual (m)	Residual Medio (m)	RECMN (%)	Observaciones
ES1N	3546	0	0	0	
ES1N	5007	-3.522	-1.278	2.351	
ES1N	6471	-6.59	-2.455	4.365	
ES1N	7932	-9.291	-3579	6.19	
ES2N	5007	-5.455	-2.095	3.565	
ES2N	6471	-8.45	-3.772	6.302	
ES2N	7932	-11.415	-5.304	8.714	
ES3N	5007	-3.883	-1.606	2.819	
ES3N	6471	-7.196	-2.983	5.119	
ES3N	7932	-10.136	-4.271	7.179	
ES4NA	5007	7.324	1.068	2.792	
ES4NA	6471	9.776	0.816	3.212	
ES4NA	7932	10.149	0.353	3.52	
ES4NB	5007	15.901	3.391	6.591	
ES4NB	6471	17.088	4.05	7.858	
ES4NB	7932	17.312	4.237	8.351	
ES5N	5007	4.895	-0.007	1.491	
ES5N	6471	6.733	-0.612	2.474	
ES5N	7932	7.711	-1.306	3.527	
ES6NA	5007	-36.876	-9.375	15.832	
ES6NA	6471	-49.105	-14.527	23.829	
ES6NA	7932	-59.768	-18.731	30.208	
ES6NB	5007	-55.657	-16.503	28.111	SE SECAN LOS POZOS DE OBSERVACIÓN: 187, 53Y53_R
ES6NB	6471	-55.454	-24.692	40.737	
ES6NB	7932	-68.597	-31.611	51.185	
ES6NC	5007	-74.074	-23.206	39.911	SE SECAN LOS POZOS DE OBSERVACIÓN: 187, 192, 207, 242, 53Y53_R
ES6NC	6471	-90.586	-34.686	57.643	
ES6NC	7932	-126.15	-44.323	72.52	
ES7NA	5007	4.89	-0.011	1.489	
ES7NA	6471	6.726	-0.617	2.476	
ES7NA	7932	7.702	-1.313	3.532	
ES7NB	5007	12.028	3.286	5.81	
ES7NB	6471	11.535	3.173	5.898	
ES7NB	7932	13.022	2.957	5.874	
ES7NC	5007	21.227	5.006	9.038	
ES7NC	6471	23.893	6.641	11.658	
ES7NC	7932	25.17	7.619	13.164	

16. ALTERNATIVA RELACIONADA CON EXTENDER LA VIDA DE UNA PORCIÓN DEL ACUÍFERO BOLSÓN DEL HUECO.

Alternativa 1. Pérdida de almacenamiento desde los años de 2008 hasta 2070, considerando bombeo constante. En esta se muestra el almacenamiento que pierde (salida), el que gana (entrada) y el neto. Este caso muestra como el acuífero se sigue abatiendo.

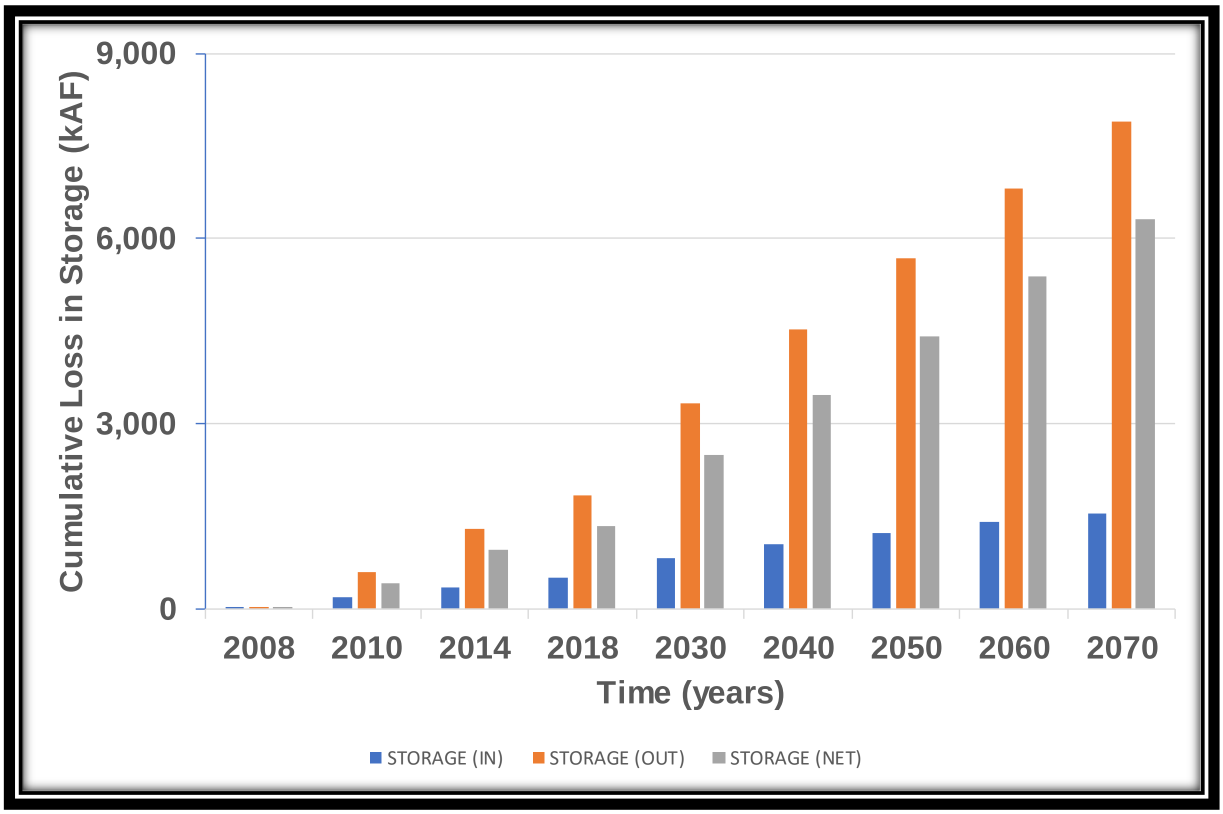


Figura 58. Pérdida de almacenamiento acumulado (2008 a 2070) cuando el bombeo se mantiene constante a través de gráfica de barras

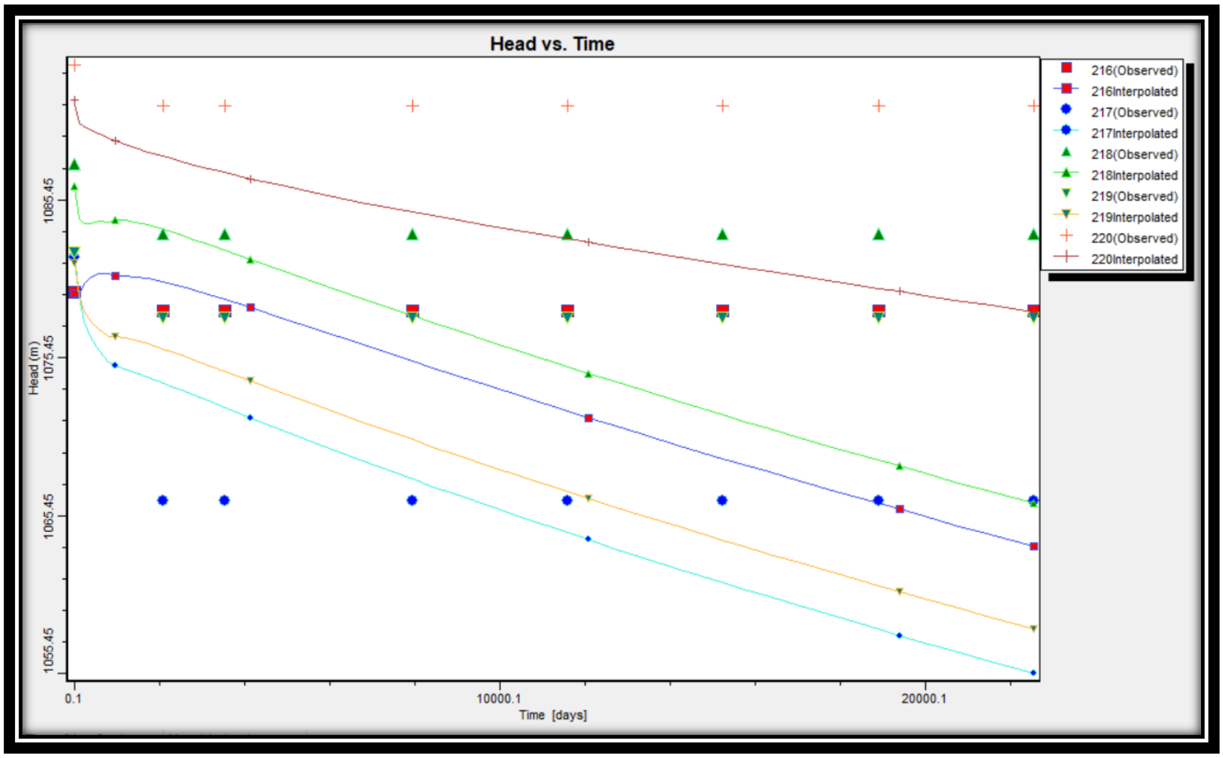


Figura 59. Abatimientos de varios pozos desde el año 2008 y hasta el año 2070, cuando el bombeo se mantiene constante a través del tiempo

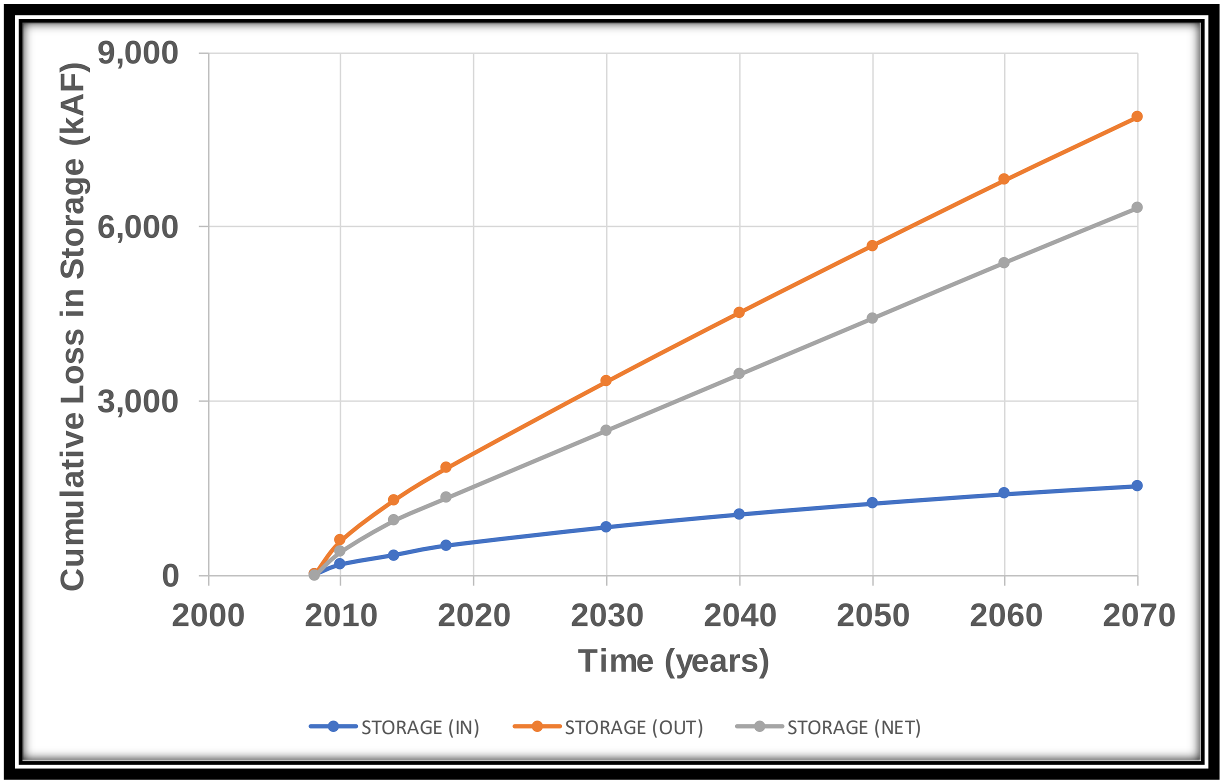


Figura 60. Pérdida de almacenamiento acumulado (2008 a 2070) cuando el bombeo se mantiene constante a través de gráfica de líneas

Alternativa 2. Pérdida de almacenamiento desde los años de 2008 hasta 2070, considerando reducir el bombeo desde 2018 y hasta 2070. En esta se muestra el almacenamiento que pierde (salida), el que gana (entrada) y el neto.

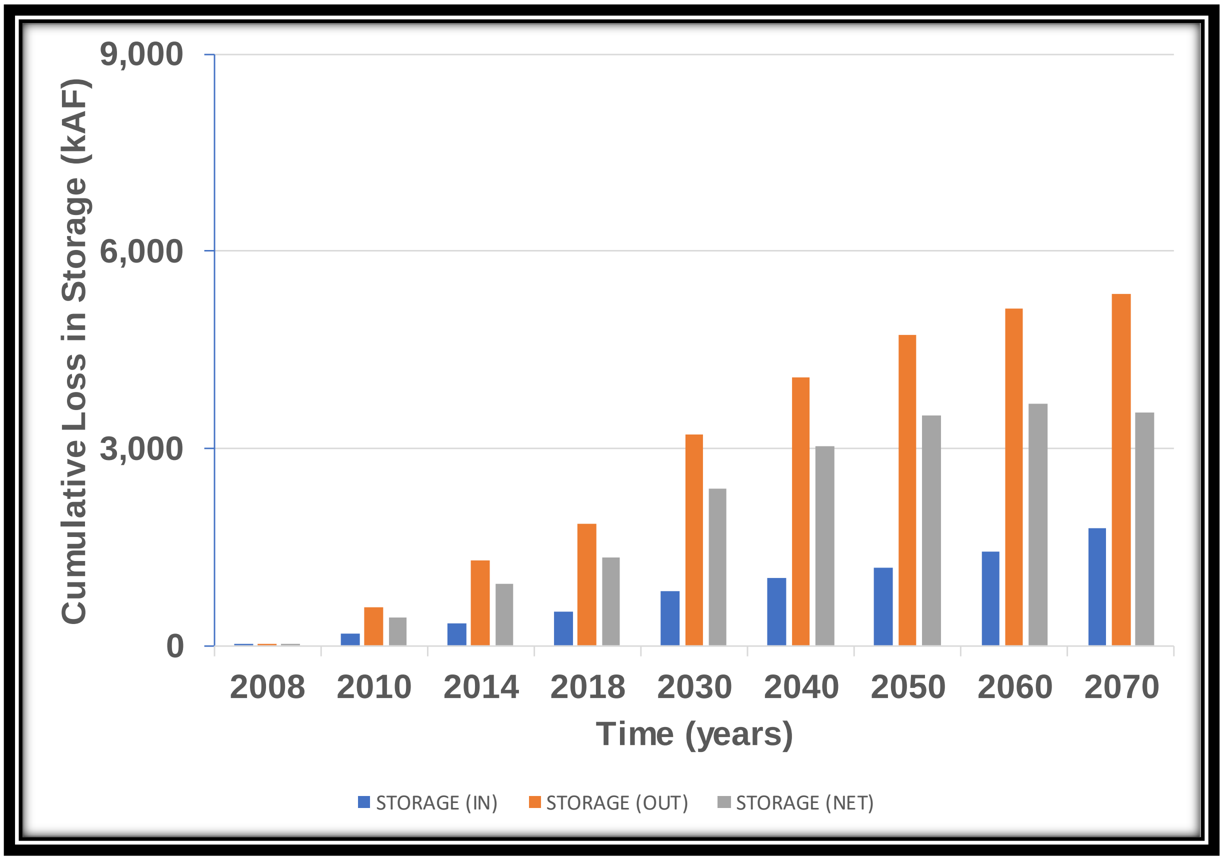


Figura 61. Pérdida de almacenamiento acumulado (2008 a 2070) cuando el bombeo se reduce en el tiempo a través de gráfica de barras

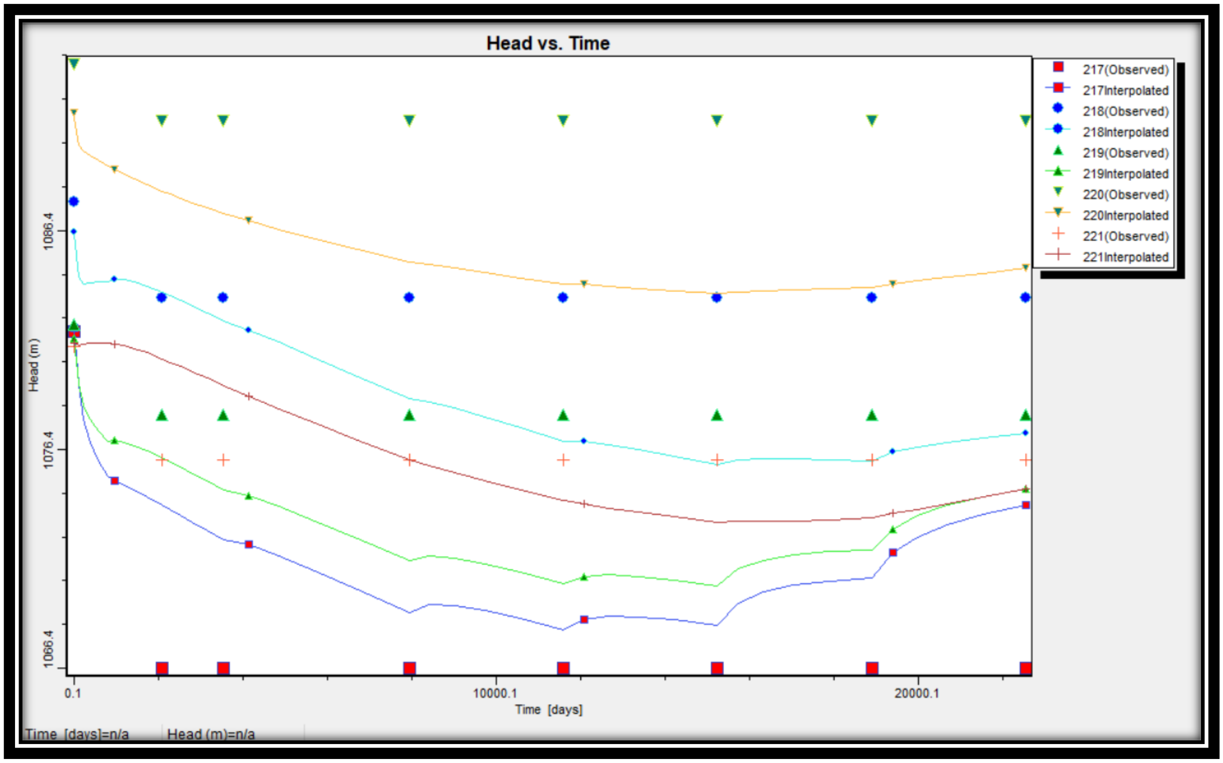


Figura 62. Abatimientos de varios pozos desde el año 2008 y hasta el año 2070, cuando el bombeo se reduce a través del tiempo.

En esta grafica se observa cómo se empiezan a recuperar los niveles de agua subterránea.

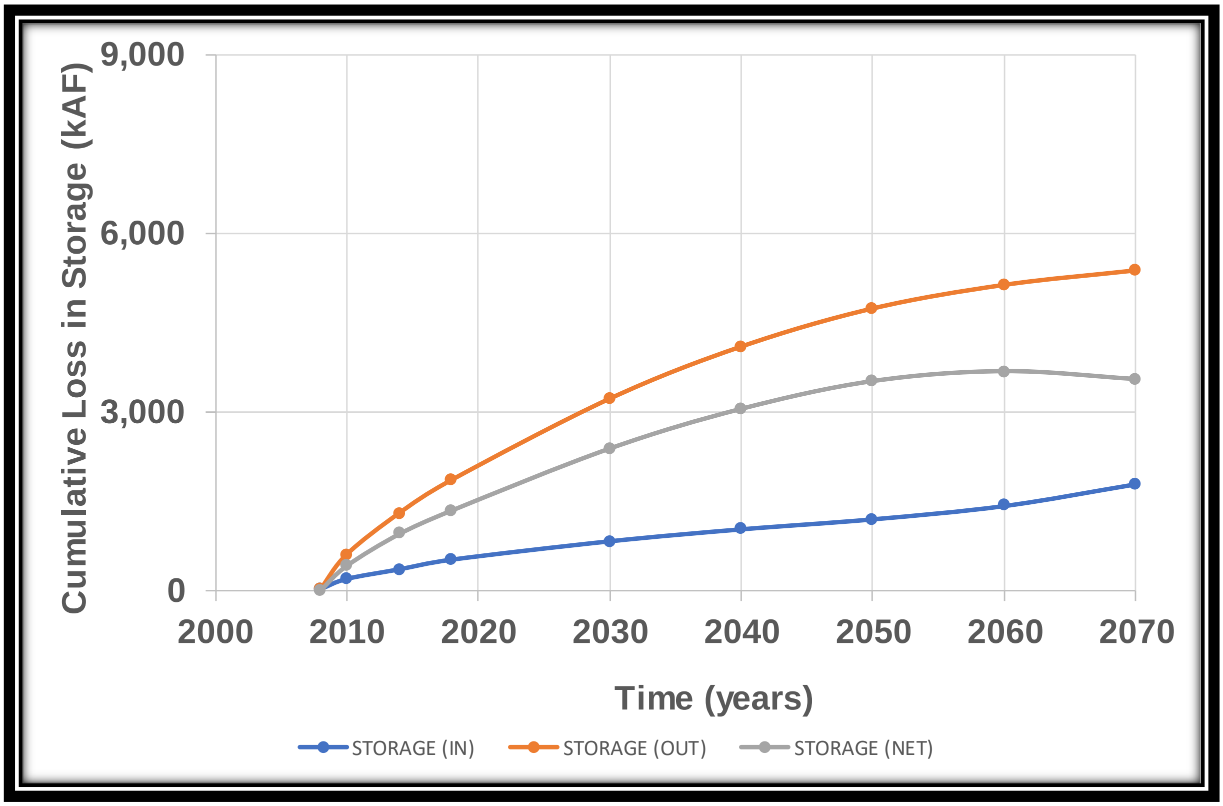


Figura 63. Pérdida de almacenamiento acumulado (2008 a 2070) cuando el bombeo se reduce a través del tiempo, con gráfica de líneas

En esta se observan las pendientes de las curvas, que, al ir disminuyendo la pendiente, va disminuyendo la pérdida de almacenamiento.

Todos estos datos estuvieron encaminados a determinar la cantidad de bombeo que se debe de reducir para poder lograr una estabilización o recuperación del acuífero, como lo muestra la Alternativa 2, aumentando la vida del acuífero Bolsón del Hueco.

Sería también importante en este acuífero diseñar una red de monitoreo geohidrológico y colocar sensores, para poder tener mediciones en tiempo real.

17. CONSTRUCCIÓN DEL MODELO DE FLUJO DEL ACUÍFERO VALLE DE JUÁREZ.

Se construyó el modelo de flujo del acuífero de ciudad Juárez, el cual se localiza en la porción norte de la República Mexicana entre las coordenadas UTM wgs86, zona 13, en la longitud oeste va de 346,000 a 440,500 y de latitud norte va de 3’412,500 a 3’518,000. Cuenta con un área de 3,386 km^2.

La malla del modelo en planta consta de 211 renglones, 189 columnas y 8 capas (Figuras 64, 65 y 66).

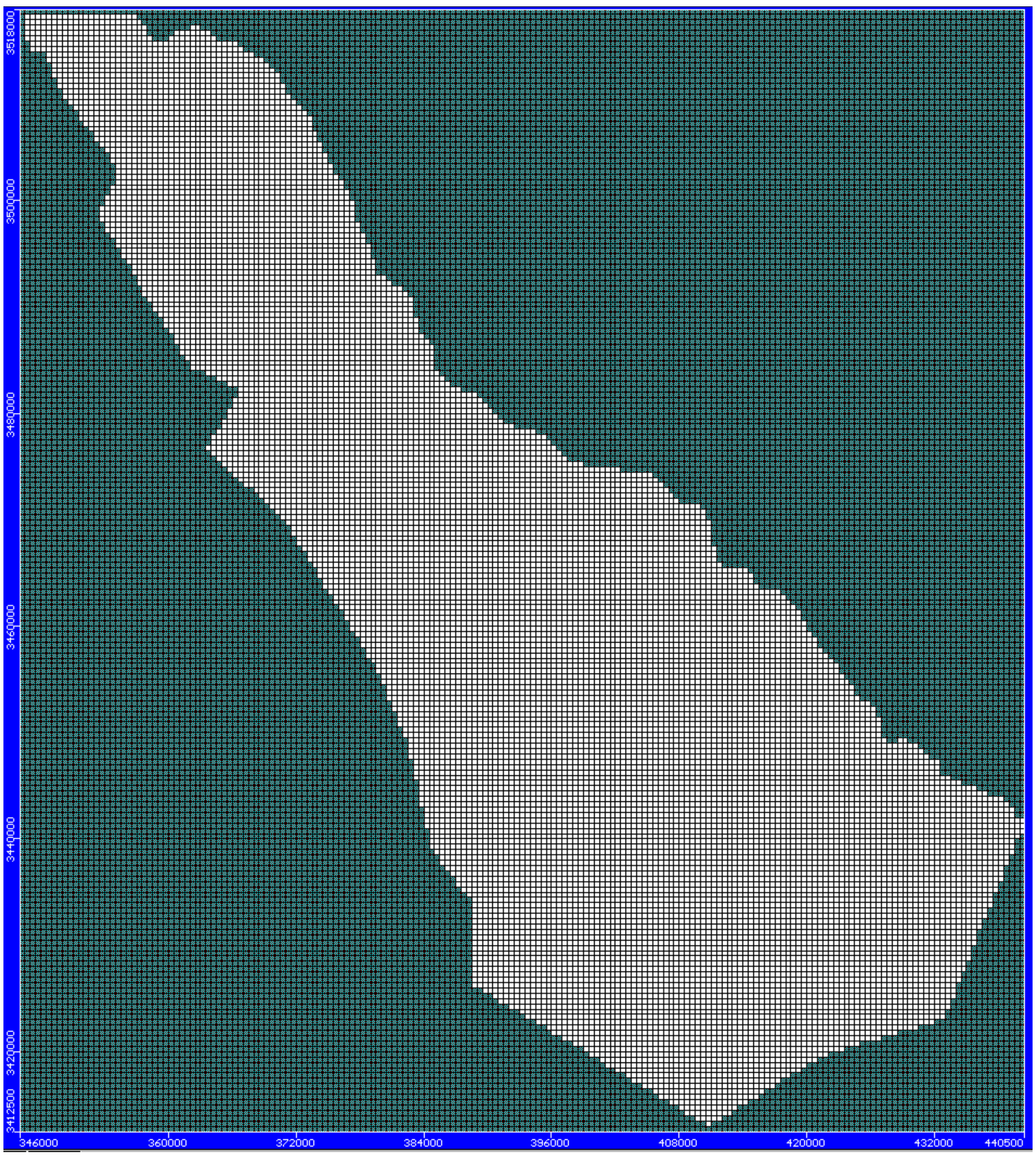


Figura 64. Malla en planta del modelo de flujo del acuífero.

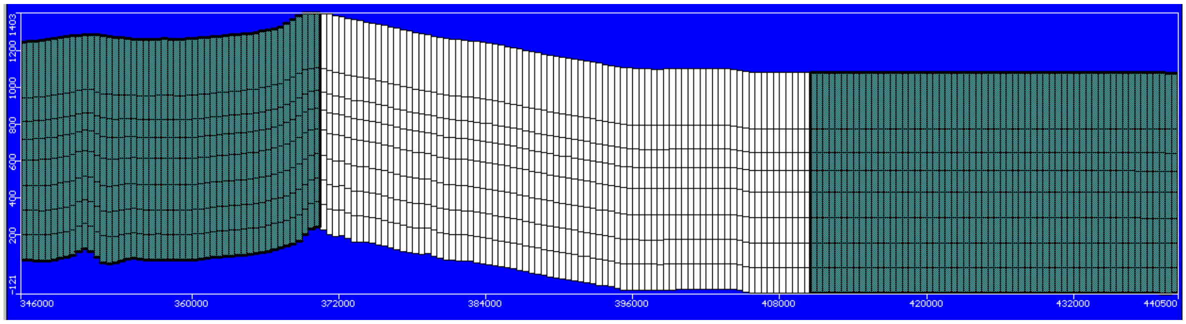


Figura 65. Corte longitudinal a lo largo del renglón 96.

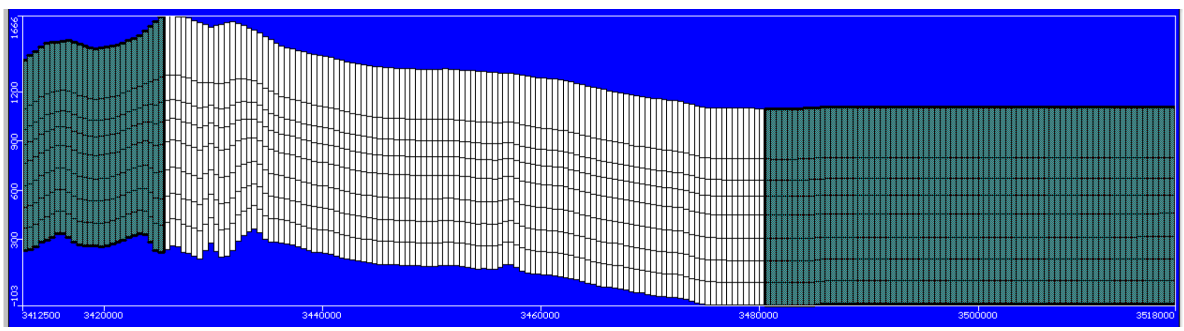


Figura 66. Corte transversal a lo largo de la columna 89.

Cuenta con 625 pozos de extracción de agua subterránea, 417 pozos de observación (Figuras 67 y 68)

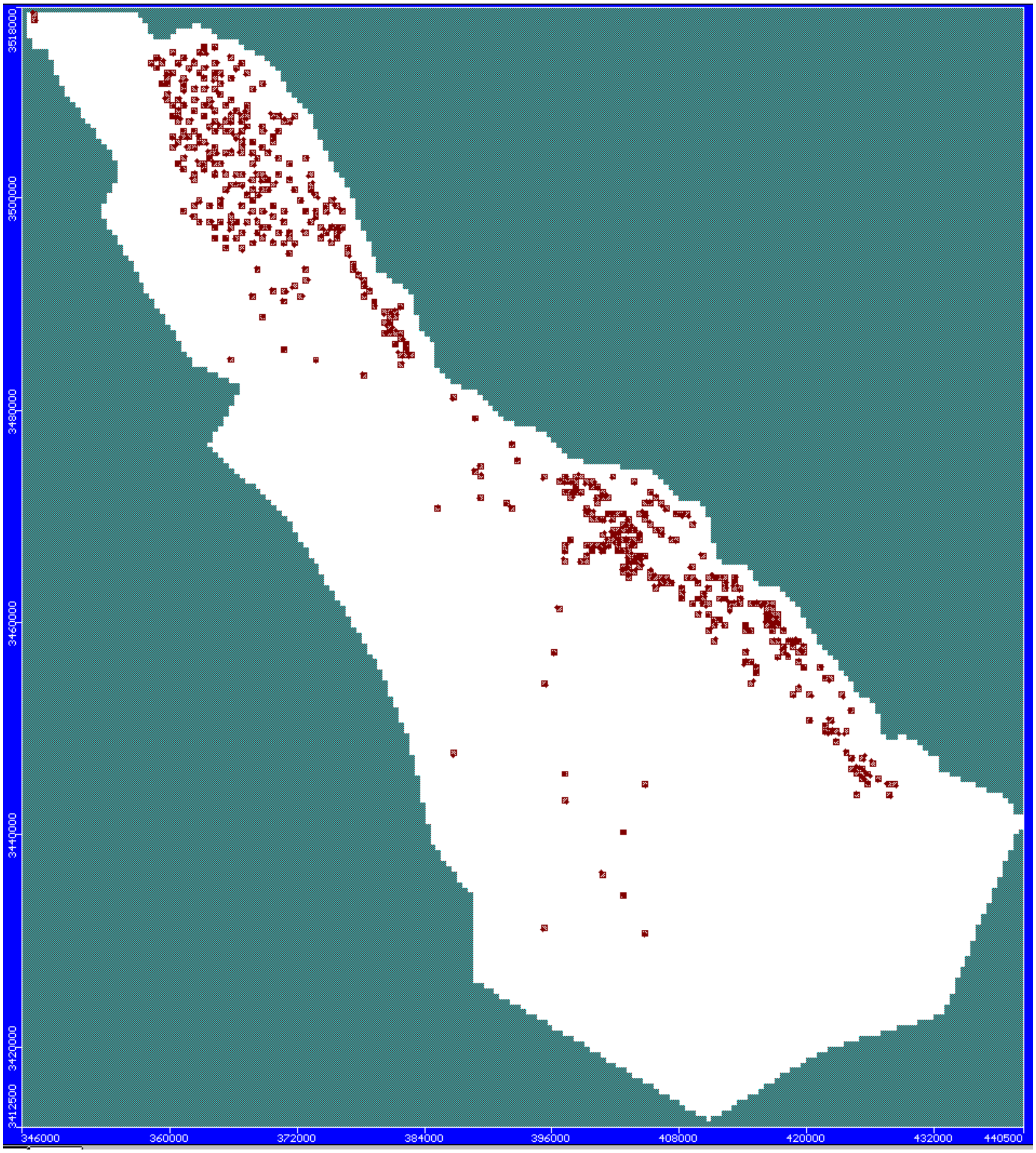


Figura 67. Localización de los pozos de extracción del agua subterránea.

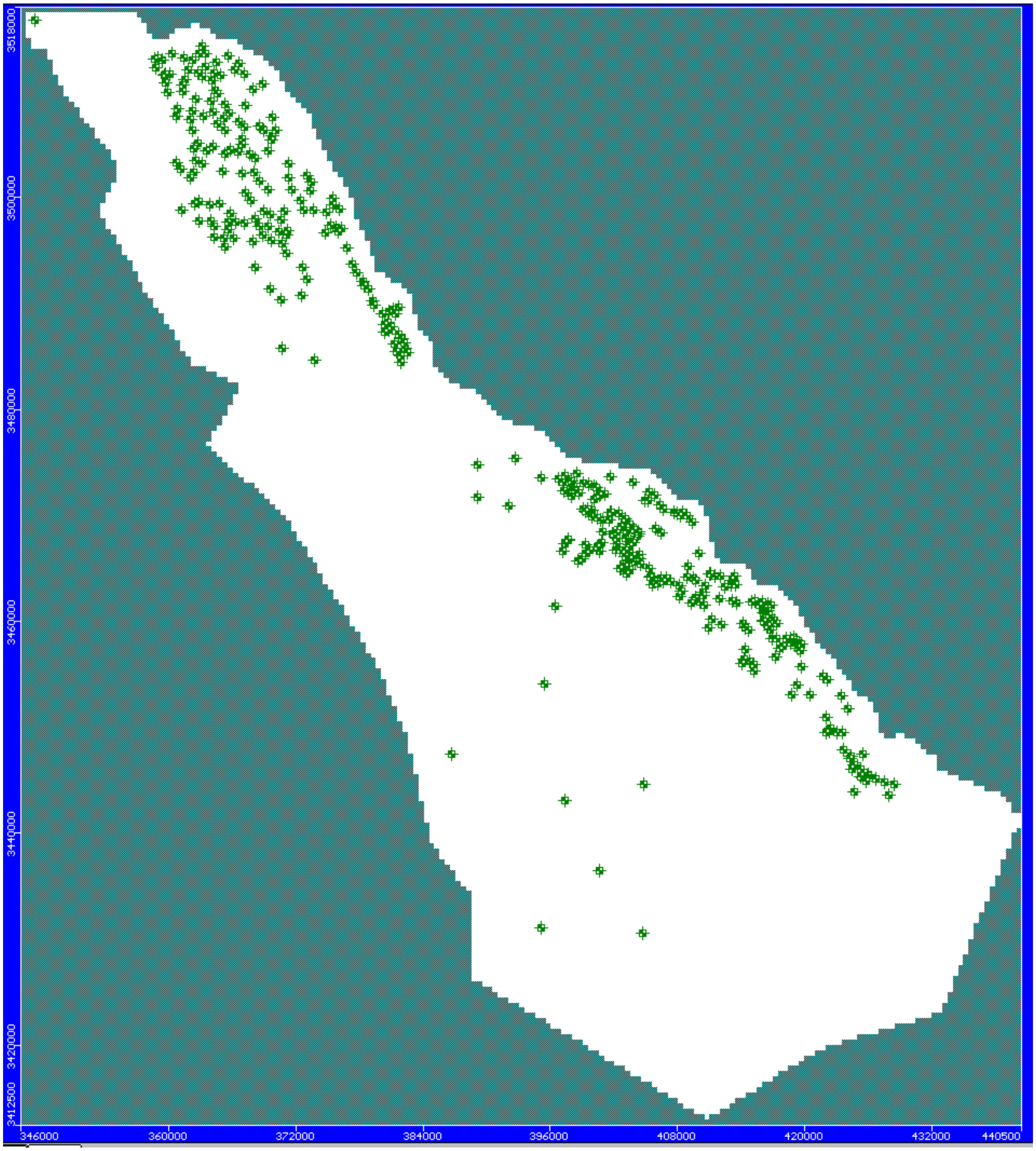


Figura 68. Localización de pozos de observación

En cuanto a las propiedades hidráulicas y fronteras, el modelo cuenta con 30 zonas de conductividad hidráulica y 15 zonas de almacenamiento, así como 98 zonas de recarga, las cuales incluye los valores, zonificaciones obtenidas con el SWAT y se le agregaron además las áreas agrícolas, la urbana y rural (Figuras 69, 70 y 71).

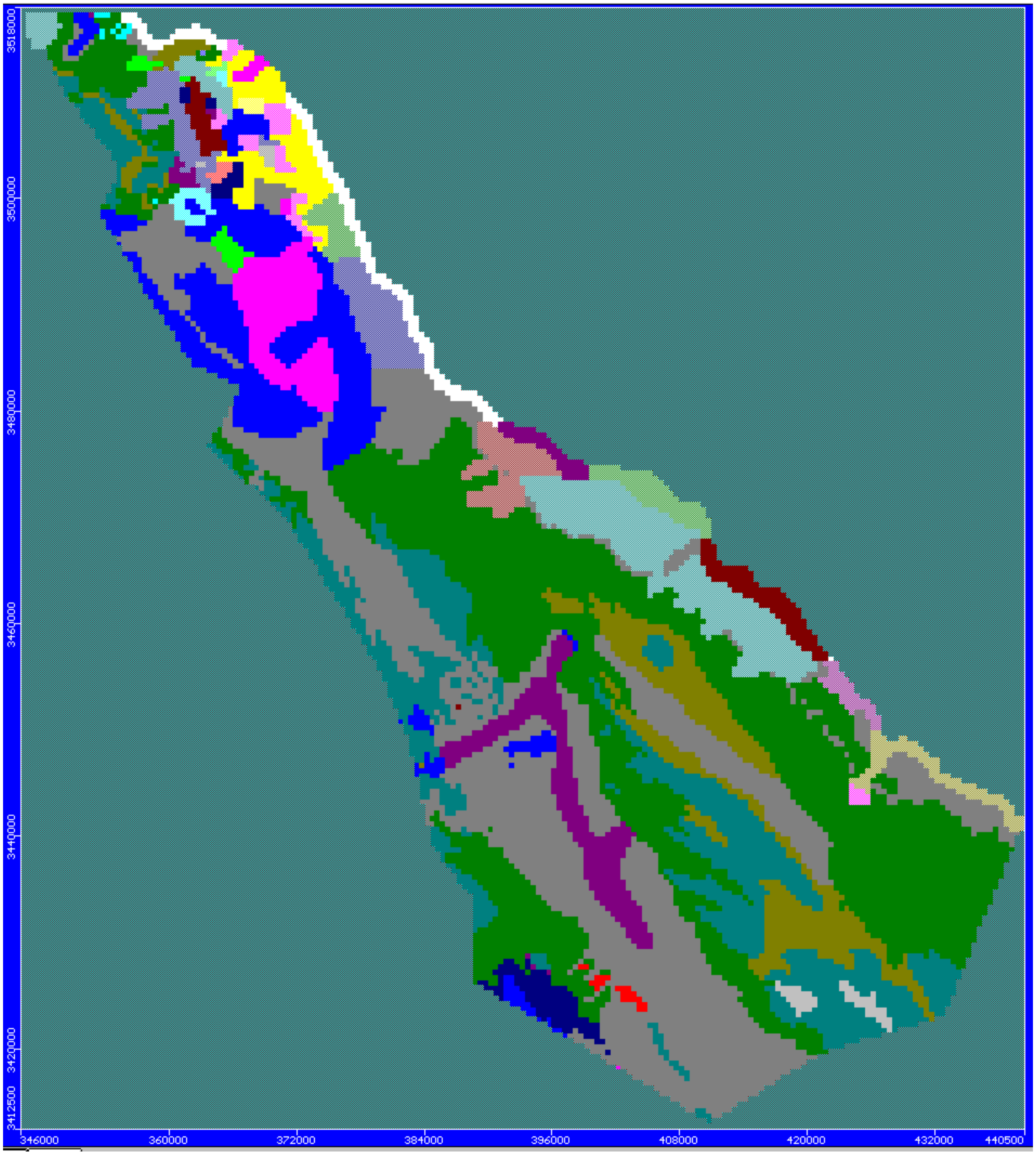


Figura 69. Distribución de la conductividad hidráulica del acuífero.

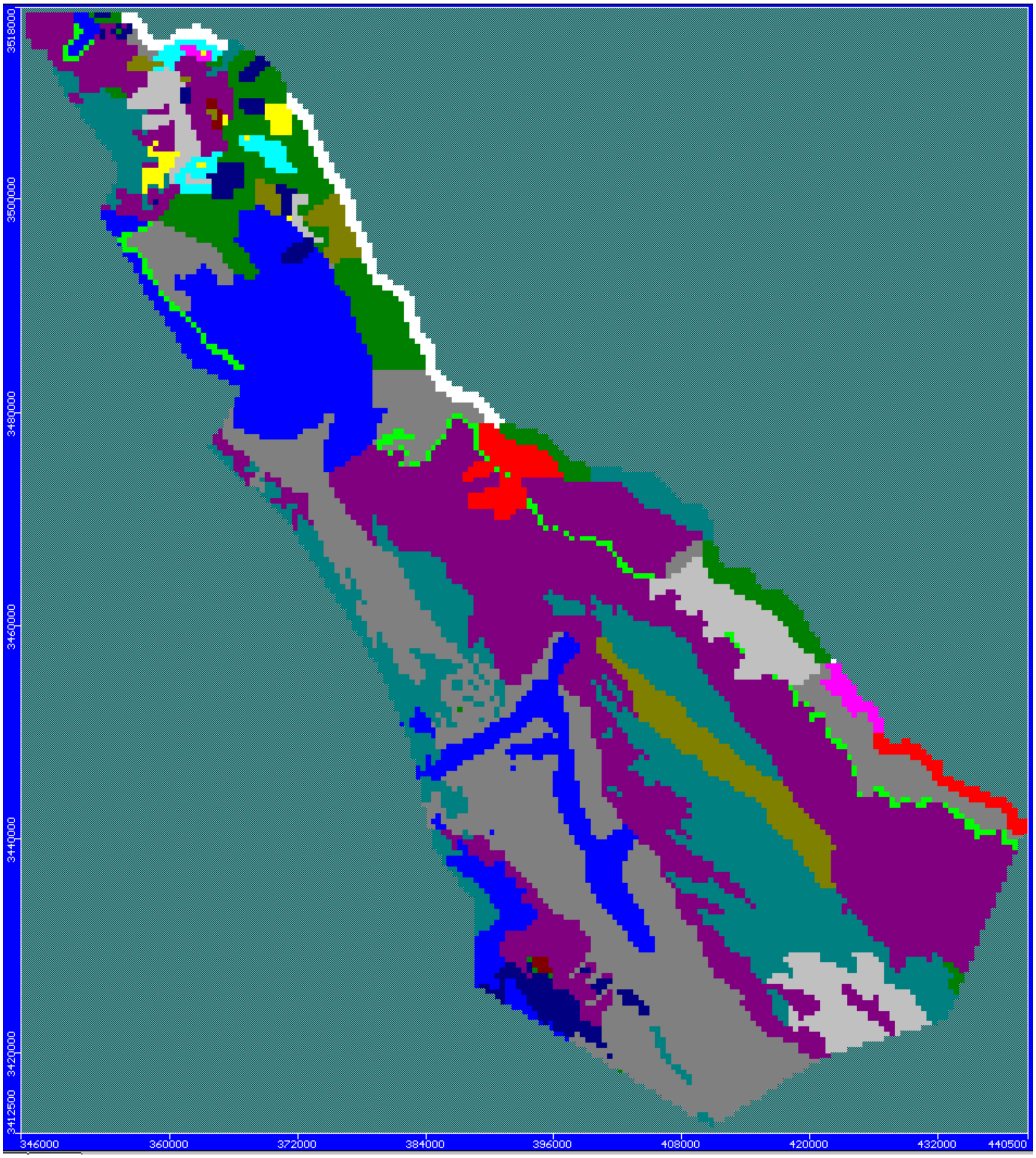


Figura 70. Distribución del almacenamiento y rendimiento específico.

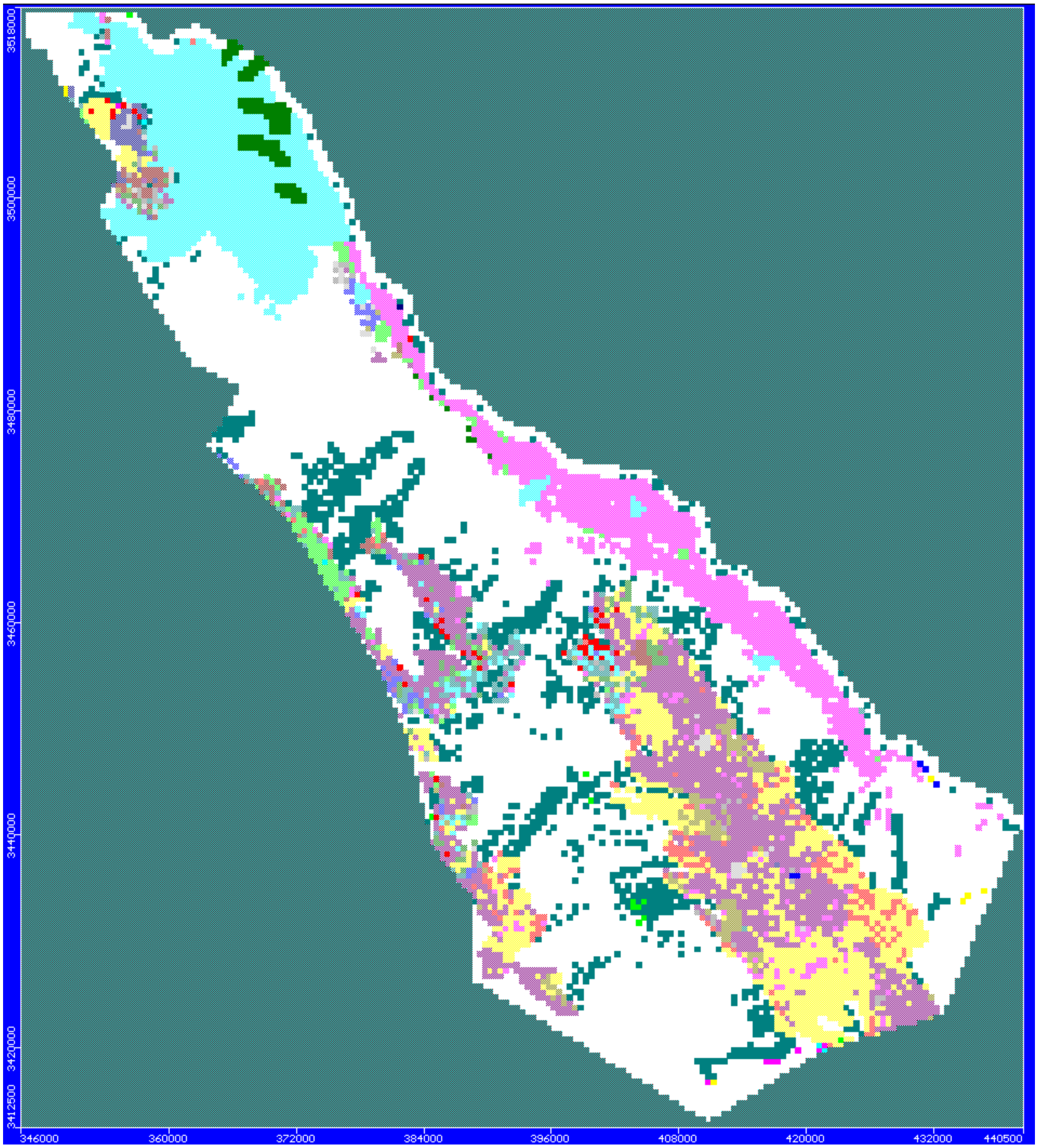


Figura 71. Distribución de la recarga obtenida con SWAT principalmente

De acuerdo con la información recopilada el modelo abarca el periodo comprendido entre el 1 de enero de 1969 y el 30 de diciembre de 2013. Posteriormente el modelo se amplio hasta el año 2070.

Con el modelo terminado se simularon los siguientes escenarios.

Escenario 1.

El propósito de este escenario fue determinar el abatimiento que se tendría desde al año 2020 y hasta el año 2070, si el bombeo se mantiene constante en el periodo comprendido del año 2020 y hasta el año 2070.

El resultado fue que algunos aprovechamientos se secan y de los que no se seca, se tendría un abatimiento máximo que llega a 60.3 m y el abatimiento promedio en 306 aprovechamientos fue de 6.1 m (Figura 72).

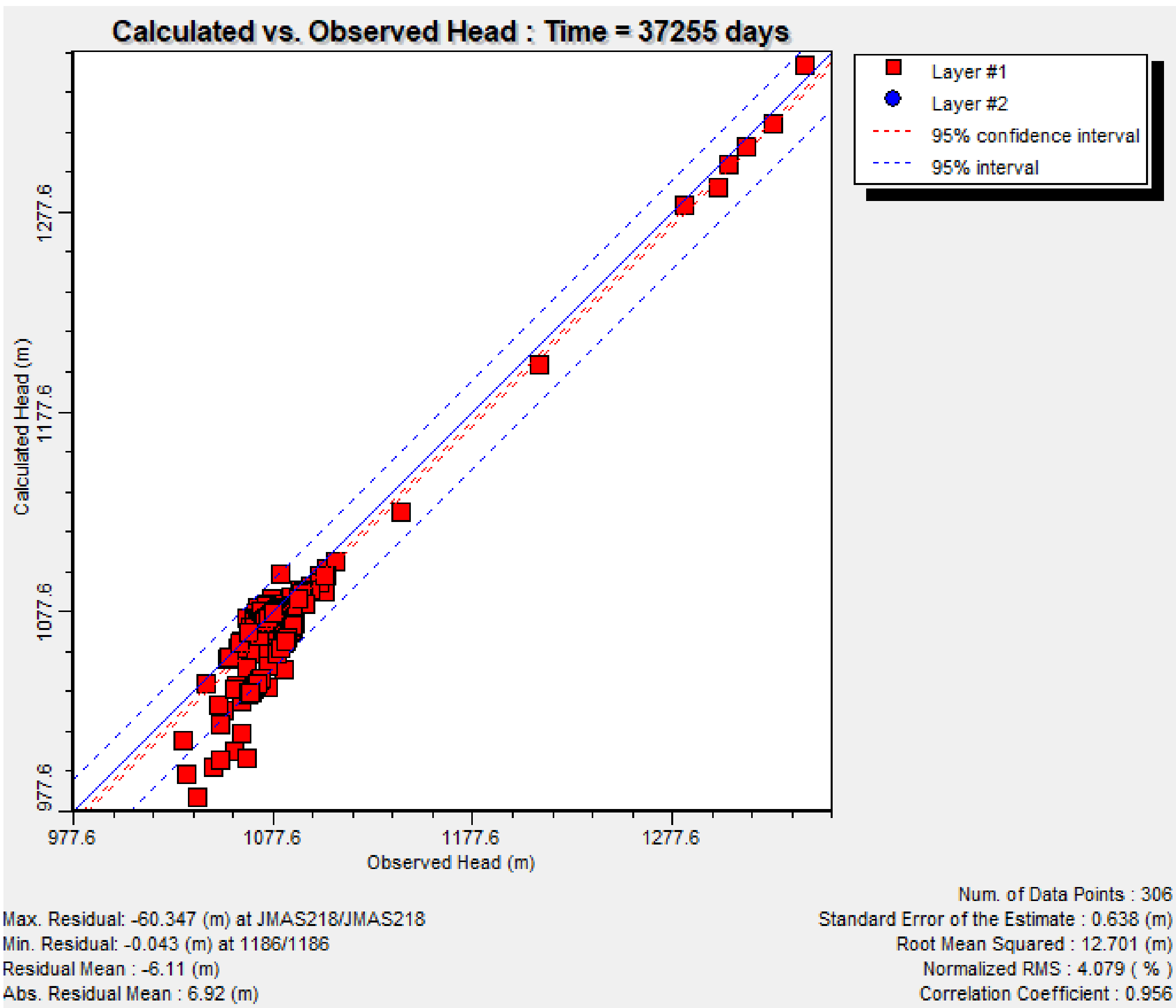


Figura 72. Abatimiento en 306 aprovechamientos del acuífero para el año 2070, del escenario 1.

Escenario 2.

El propósito de este escenario fue determinar el abatimiento que se tendría desde al año 2020 y hasta el año 2070, si el bombeo se aumenta un 5% cada diez años, iniciando el periodo comprendido entre los años 2020 y 2030 y hasta llegar a 25% en el periodo comprendido entre los años de 2060 y 2070.

El resultado fue que algunos aprovechamientos se secan y de los que no se seca, se tendría un abatimiento máximo que llega a 126.8 m y el abatimiento promedio en 306 aprovechamientos fue de 10.2 m (Figura 73).

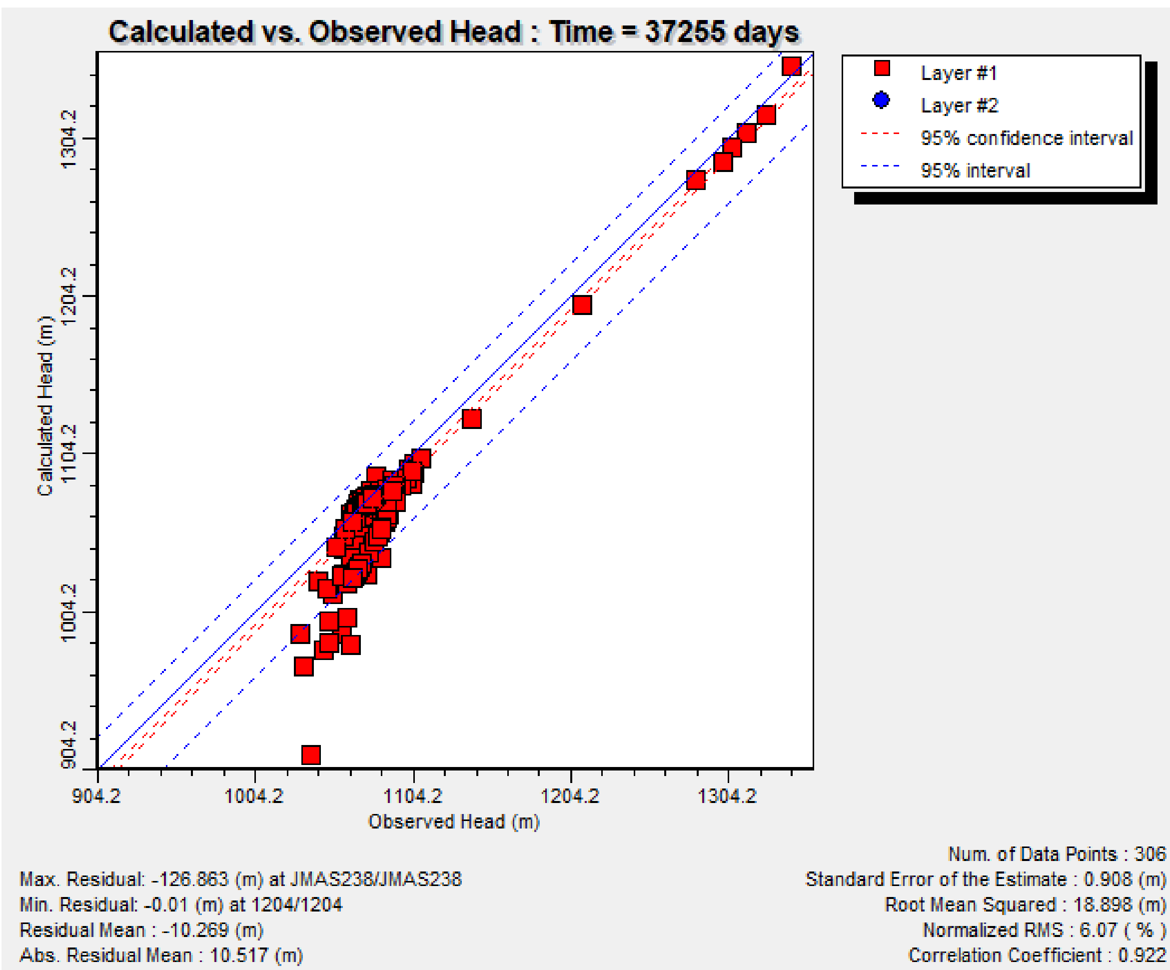


Figura 73. Abatimiento en 306 aprovechamientos del acuífero para el año 2070, del escenario 2.

Escenario 3.

El propósito de este escenario fue también determinar el abatimiento que se tendría desde al año 2020 y hasta el año 2070, si el bombeo se aumenta un 10% cada diez años, iniciando el periodo comprendido entre los años 2020 y 2030 y hasta llegar a 50% en el periodo comprendido entre los años de 2060 y 2070.

El resultado fue que algunos aprovechamientos se secan y de los que no se seca, se tendría un abatimiento máximo que llega a 129.0 m y el abatimiento promedio en 306 aprovechamientos fue de 14.2 m (Figura 74).

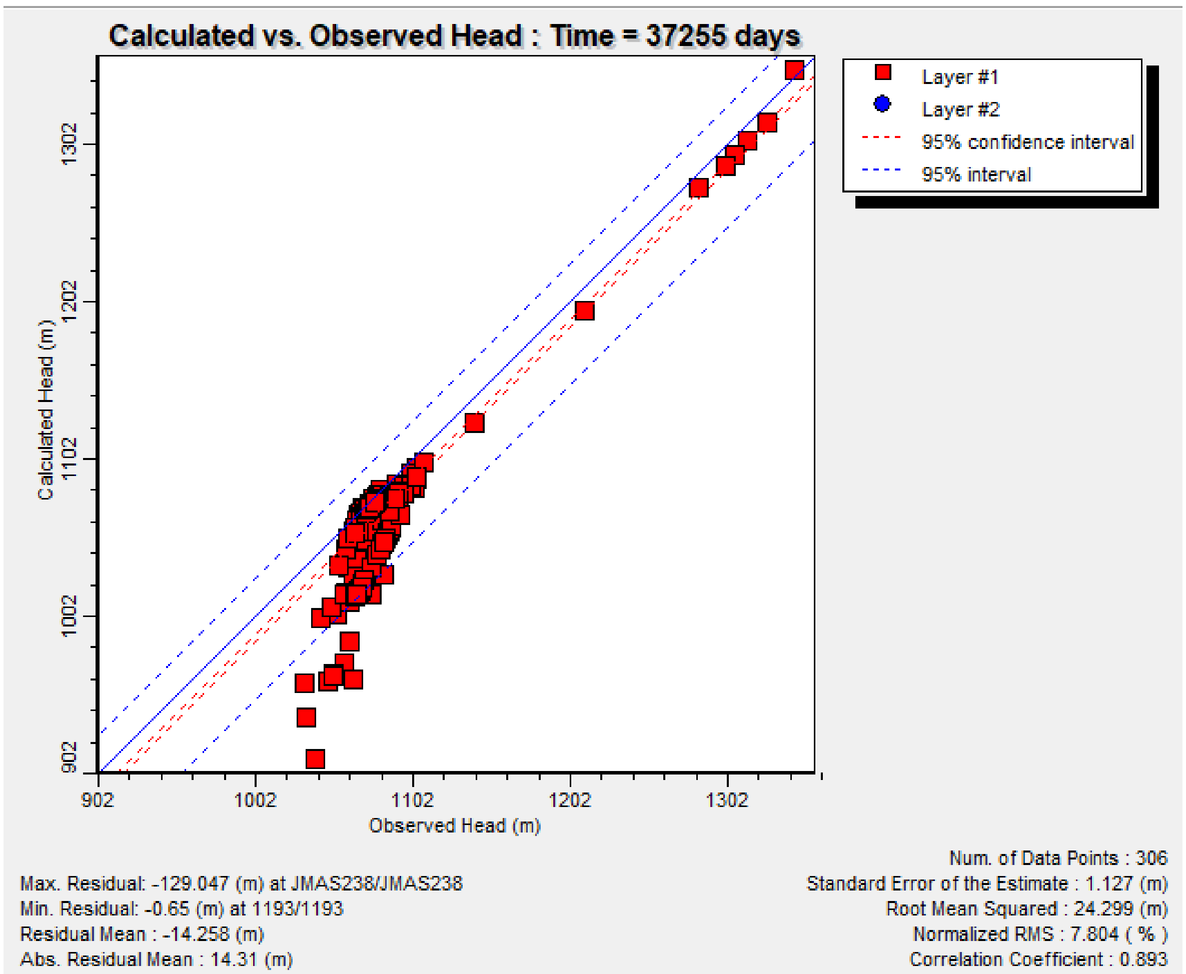


Figura 74. Abatimiento en 306 aprovechamientos del acuífero para el año 2070, del escenario 3.

Escenario 4.

El propósito de este escenario fue determinar el abatimiento que se tendría desde al año 2020 y hasta el año 2070, cuando se presenta una reducción del 30% de la recarga del agua subterránea, si el bombeo se mantiene constante en el periodo comprendido del año 2020 y hasta el año 2070.

El resultado fue que algunos aprovechamientos se secan y de los que no se seca, se tendría un abatimiento máximo que llega a 74.4 m y el abatimiento promedio en 306 aprovechamientos fue de 8.4 m, que representa 2.3 m más que el escenario 1 (Figura 75).

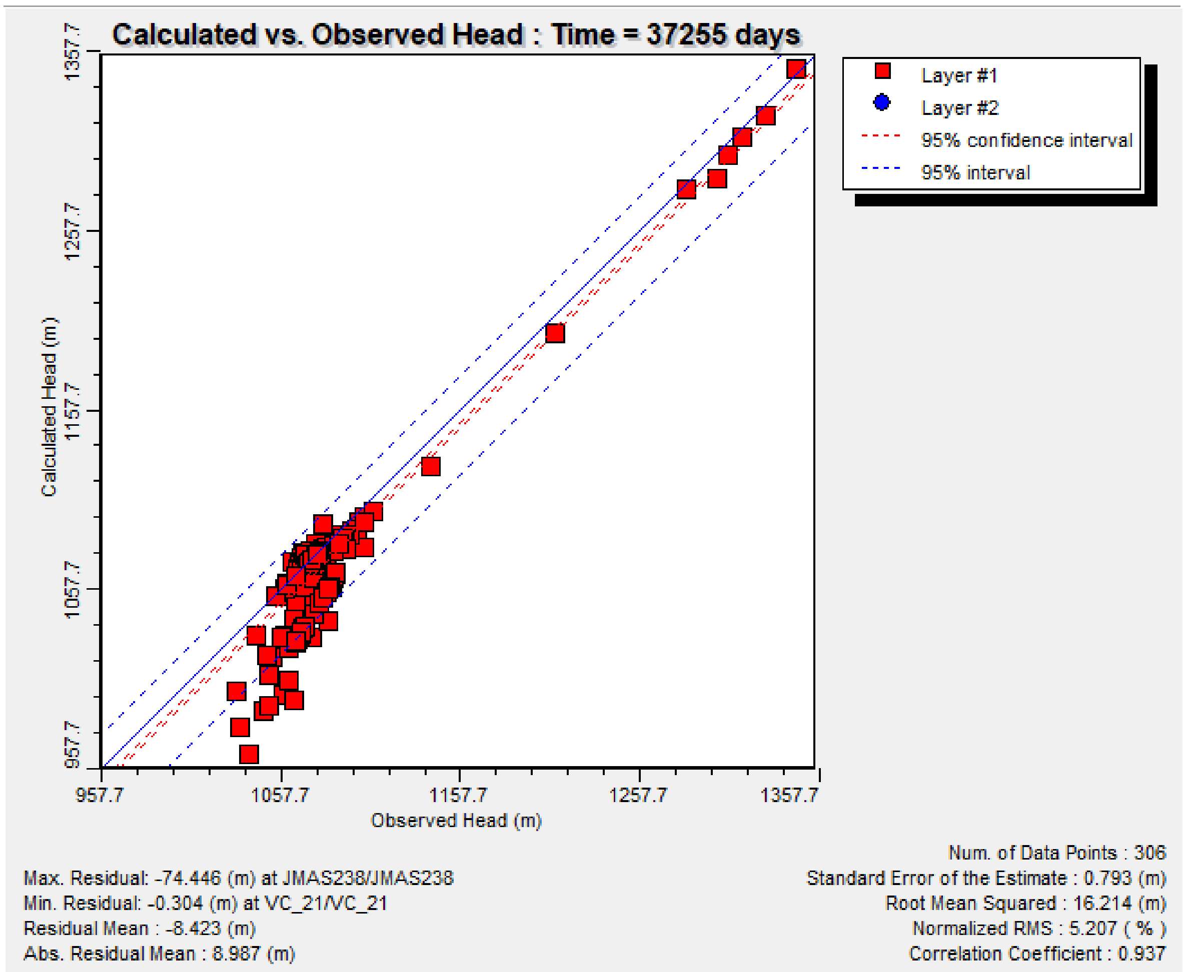


Figura 75. Abatimiento en 306 aprovechamientos del acuífero para el año 2070, del escenario 4.

Escenario 5.

El propósito de este escenario fue determinar el abatimiento que se tendría desde al año 2020 y hasta el año 2070, cuando se presenta una reducción del 30% de la recarga del agua subterránea y si el bombeo se aumenta un 5% cada diez años, iniciando el periodo comprendido entre los años 2020 y 2030 y hasta llegar a 25% en el periodo comprendido entre los años de 2060 y 2070.

El resultado fue que algunos aprovechamientos se secan y de los que no se seca, se tendría un abatimiento máximo que llega a 102.7 m y el abatimiento promedio en 306 aprovechamientos fue de 12.4 m, que representa 2.2 m más que el escenario 2 (Figura 76).

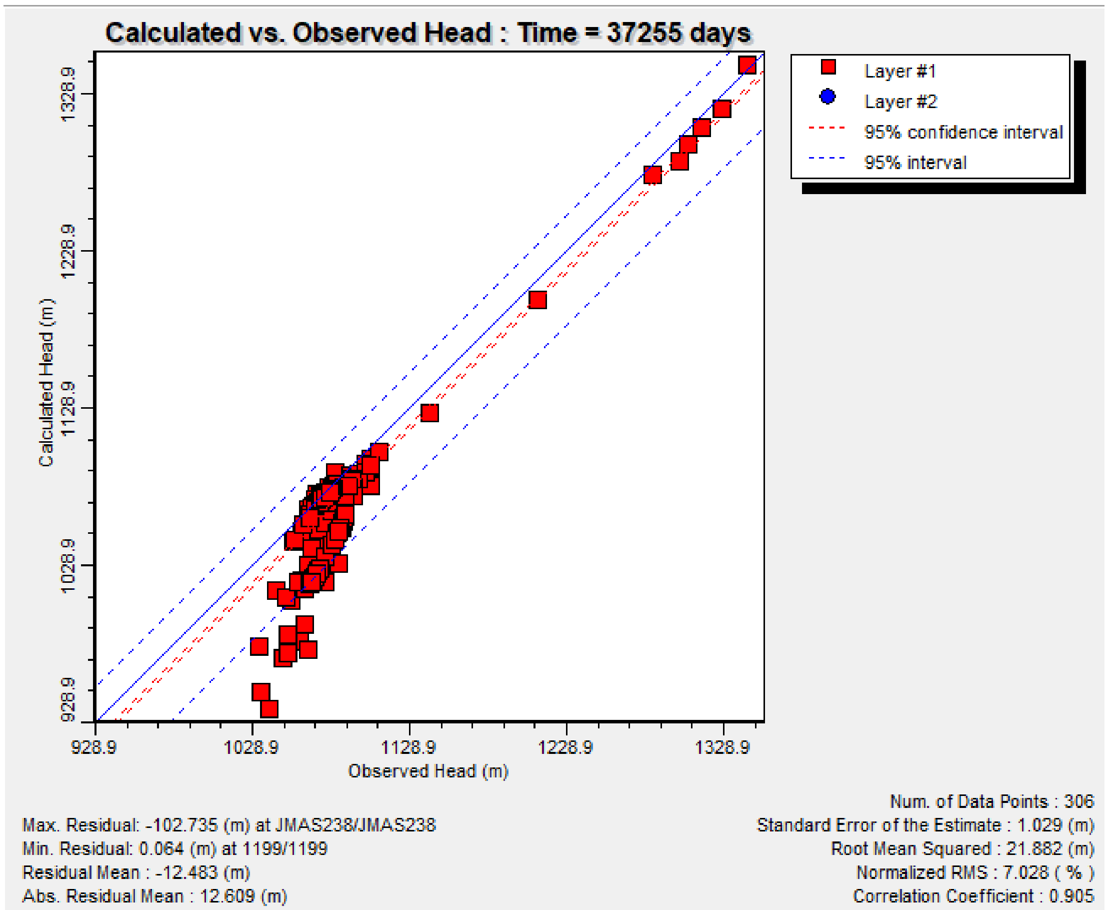


Figura 76. Abatimiento en 306 aprovechamientos del acuífero para el año 2070, del escenario 5.

Como se puede observar en estos escenarios, el incrementar el bombeo al acuífero o el reducir la recarga implica el producir más abatimientos al acuífero, el secado de algunos aprovechamientos y por ende el aumento en el costo del bombeo.

Escenario 6.

El propósito de este escenario fue determinar el abatimiento que se tendría desde al año 2020 y hasta el año 2070, cuando se presenta una reducción del 30% de la recarga del agua subterránea y el bombeo se aumenta un 10% cada diez años, iniciando el periodo comprendido entre los años 2020 y 2030 y hasta llegar a 50% en el periodo comprendido entre los años de 2060 y 2070.

El resultado fue que algunos aprovechamientos se secan y de los que no se seca, se tendría un abatimiento máximo que llega a 111.3 m y el abatimiento promedio en 306 aprovechamientos fue de 15.9 m, que representa 3.5 m más que el escenario 3 (Figura 77).

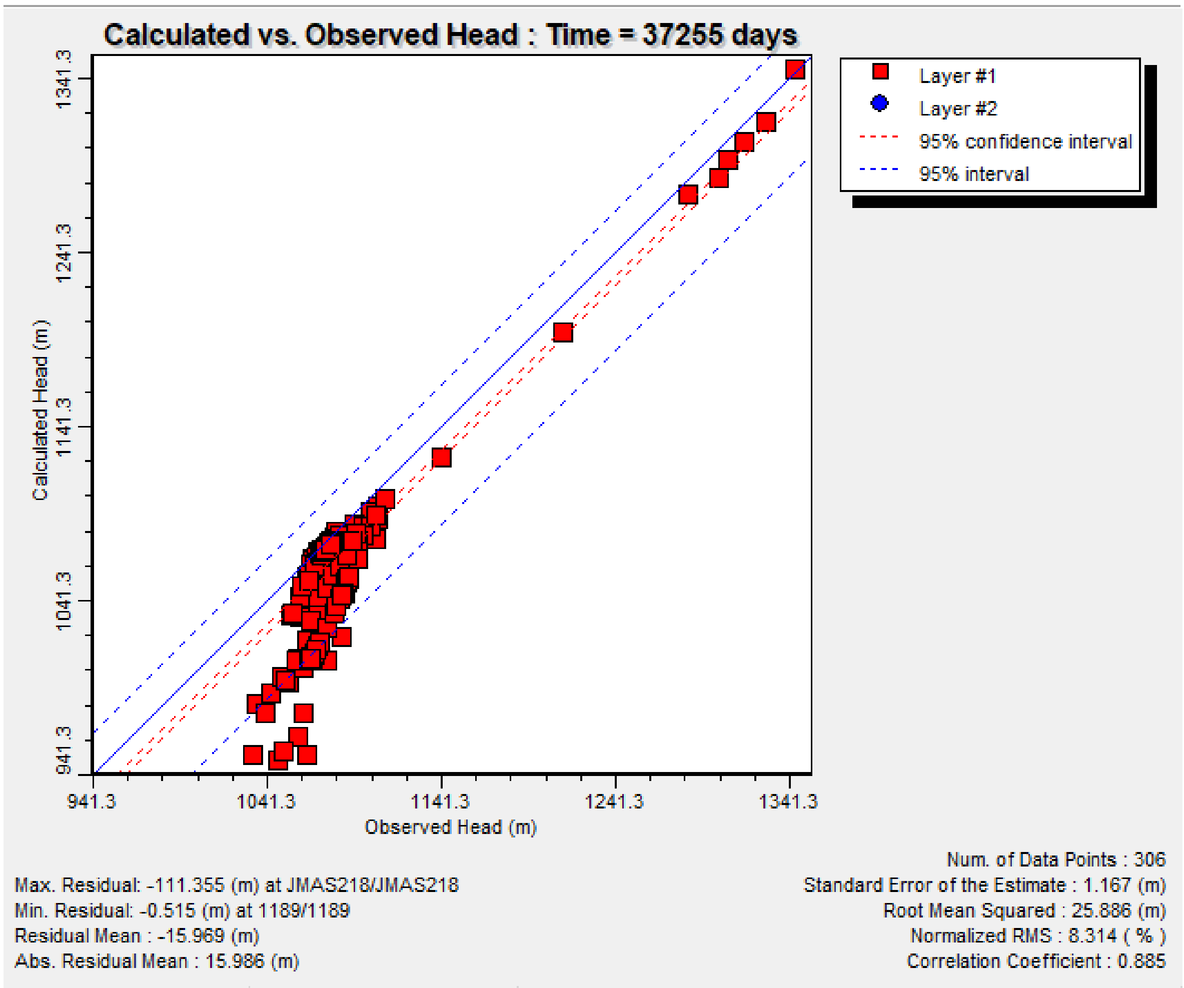


Figura 77. Abatimiento en 306 aprovechamientos del acuífero para el año 2070, del escenario 6.

18. PARTICIPACIÓN EN TESIS DOCTORAL

Se participó en la asesoría de la tesis de Grado del Alumno: M.I. Arturo Soto Ontiveros, con el título: "Disponibilidad de Agua Subterránea y su relación con el Desarrollo Urbano en Ciudad Juárez, Chihuahua: Un análisis retrospectivo y prospectivo durante el periodo 2008 al 2030". La cual se concluyó en este mismo año (Anexo E2).

19 PUBLICACIONES

a) Se participó en la publicación de un artículo titulado: "Evolución temporal del flujo del agua subterránea en Ciudad Juárez, Chihuahua aplicando modelación geoespacial", en la revista arbitrada e indexada TECNOCIENCIA, en diciembre de 2018. Arturo Soto-Ontiveros, Alfredo Granados-Olivas, Adán Pinales-Munguía, Sergio Saúl-Solís y Josiah Mcconnell Heyman (Anexo E3).

b) Se participó en el poster titulado: "Mathematical model of groundwater flow for the Valle de Juarez aquifer, a predictive and prospective analysis 2008-2030", Arturo Soto Ontiveros, Adán Pinales Munguía, Josiah M. Heyman, Alfredo Granados Olivas y Sergio Saúl Solís. Presentado en el SYMPOSIUM, Sustainable Water Resources Management in the Rio Grande/Rio Bravo Basin, el día 8 de enero de 2019 en el Paso Texas (Anexos E4 y 5).

c) Se elaboro un artículo para el congreso de la Unión Geofísica Mexicana, el cual fue aceptado para su presentación oral, el artículo se titula: SIMULACIÓN DEL AGUA SUBTERRÁNEA EN ACUÍFEROS CUYO PRINCIPAL USO ES EL ABASTECIMIENTO PÚBLICO URBANO. CASO DE ESTUDIO: ACUÍFERO VALLE DE JUÁREZ. Adán Pinales Munguía[1], Alfredo Granados Olivas[2], Arturo Soto Ontiveros2, William L. Hargrove[3], Joshia M. Heyman[4], Zhuping Sheng[5], Humberto Silva Hidalgo[1], María Socorro Espino Valdés (Anexo E6).

d) Se elaboró borrador de artículo denominado “MODELO MATEMÁTICO DE FLUJO DE AGUAS SUBTERRÁNEAS PARA EL ACUÍFERO BOLSÓN DEL HUECO (VALLE DE JUÁREZ), UN ANÁLISIS PREDICTIVO Y PROSPECTIVO 2008-2030”, cuyos autores tentativos serían: Arturo SOTO ONTIVEROS, Adán PINALES MUNGUÍA, Alfredo GRANADOS OLIVAS y algunos otros (Anexo E7).

20. REUNIÓN ANUAL INTERNACIONAL

Se asistió a la reunión binacional “SUSTAINABLE WATER RESOURCES SYMPOSIUM”, The University of Texas at El Paso. El 8 de enero de 2019. En donde se tuvieron destacadas participaciones y con la exposición de los avances y trabajo a futuro del proyecto por parte de la representación mexicana en el proyecto (Anexo E8).

21. REUNIONES DE TRABAJO LOCALES

Se ha atendido a las reuniones locales que a través de video conferencias se tienen de forma periódica, con el propósito de dar seguimiento al proyecto.

INFORME DE ACTIVIDADES AREA MODELACION CAMBIO CLIMATICO

Los trabajos realizados en el marco del proyecto “Sustainable Water Resources for Irrigated Agriculture in a Desert River Basin Facing Climate Change and Competing Demands: From Characterization to Solutions” consistieron en la realización de reportes de acuerdo con las necesidades del proyecto. Estos se enlistan a continuación:

1. Cálculo de anomalías para un futuro cercano y futuro lejano a un RCP de 4.5 y 8.5.
2. Respuesta a preguntas concretas referente al proyecto
3. Gráfico de precipitaciones y % de llenado de la presa El Elefante
4. Promedio mensual de precipitación en diferentes escenarios
5. Poster de participación en dos eventos en UTEP
6. Evaluación del impacto del cambio climático en el déficit de áreas verdes en Ciudad Juárez por falta de agua utilizando el modelo SWIM a un futuro 2030.
7. Reporte final

Dichos documentos se componen de diversos análisis, de los cuales los resultados mas relevantes se presentan a continuación:

1.- Anomalías a un futuro cercano y un futuro lejano

			Futuro Cercano	
			Precipitación esperada RCP 4.5	Precipitación esperada RCP 8.5
-45	Enero	0.45	0.4590	0.2475
-42	Febrero	0.46	0.4876	0.2668
-100	Marzo	0.36	0.2016	0.0000
-21	Abril	0.31	0.5115	0.2449
-31	Mayo	0.44	0.3212	0.3036
-89	Junio	0.76	0.2660	0.0836
-11	Julio	1.67	1.7702	1.4863
-2	Agosto	1.59	1.7808	1.5582
-19	Septiembre	1.35	0.9855	1.0935

		Futuro Lejano	
		Precipitación esperada RCP 4.5	Precipitación esperada RCP 8.5
Enero	0.45	0.6075	0.3105
Febrero	0.46	0.5658	0.7452
Marzo	0.36	0.2736	0.0000
Abril	0.31	0.2046	0.0527
Mayo	0.44	0.2156	0.0000
Junio	0.76	0.0912	0.0000
Julio	1.67	1.5030	1.3026
Agosto	1.59	1.3515	1.3515
Septiembre	1.35	0.7965	0.6075

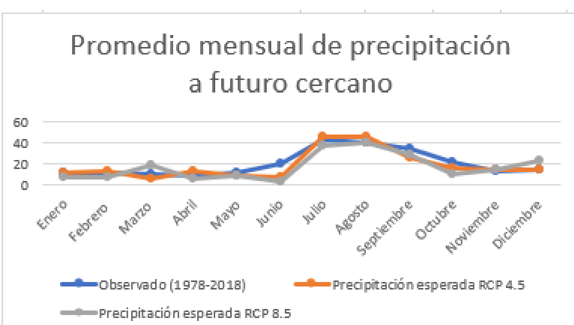
-51	Octubre	0.83	0.6059	0.4067
17	Noviembre	0.49	0.5586	0.5733
53	Diciembre	0.58	0.5684	0.8874

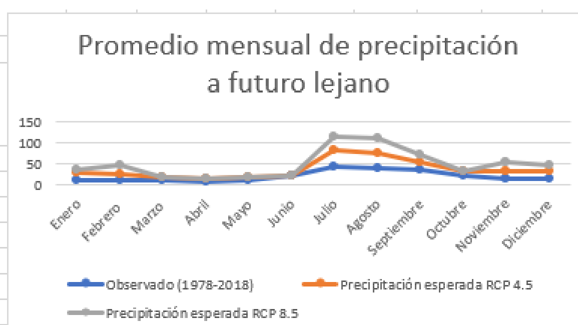
Octubre	0.83	0.4399	0.0000
Noviembre	0.49	0.7105	0.8379
Diciembre	0.58	0.6380	0.6554

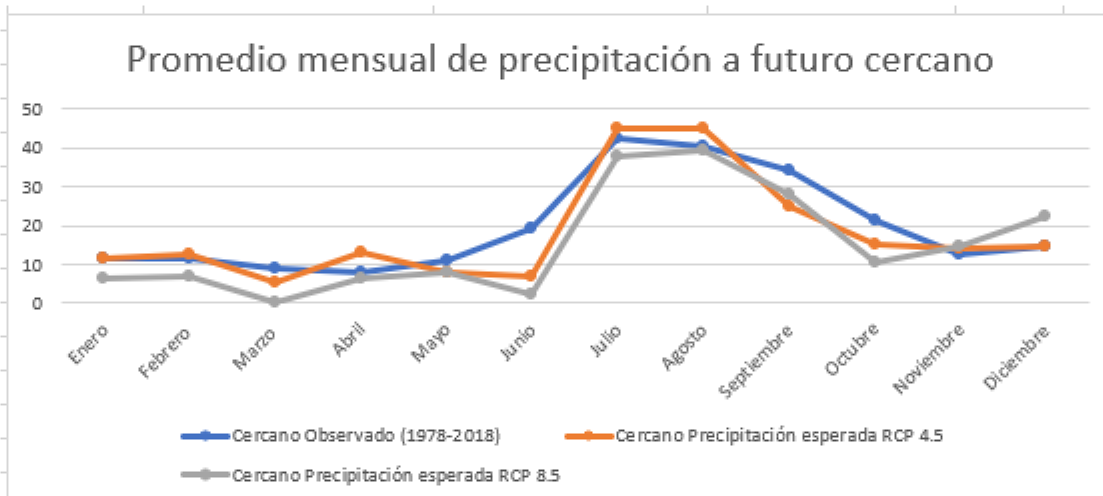
conversión de pulgadas a mm

Cercano					Lejano				
	Observado (1978-2018)	Precipitación esperada RCP 4.5	Precipitación esperada RCP 8.5			Observado (1978-2018)	Precipitación esperada RCP 4.5	Precipitación esperada RCP 8.5	
Enero	11.43	11.659	6.287	55.00	Enero	11.43	15.43	7.89	69
Febrero	11.684	12.385	6.777	58.00	Febrero	11.684	14.37	18.93	162
Marzo	9.144	5.121	0.000	0.00	Marzo	9.144	6.95	0.00	0
Abril	7.874	12.992	6.220	79.00	Abril	7.874	5.20	1.34	17
Mayo	11.176	8.158	7.711	69.00	Mayo	11.176	5.48	0.00	0
Junio	19.304	6.756	2.123	11.00	Junio	19.304	2.32	0.00	0
Julio	42.418	44.963	37.752	89.00	Julio	42.418	38.18	33.09	78
Agosto	40.386	45.232	39.578	98.00	Agosto	40.386	34.33	34.33	85
Septiembre	34.29	25.032	27.775	81.00	Septiembre	34.29	20.23	15.43	45
Octubre	21.082	15.390	10.330	49.00	Octubre	21.082	11.17	0.00	0
Noviembre	12.446	14.188	14.562	117.00	Noviembre	12.446	18.05	21.28	171
Diciembre	14.732	14.437	22.540	153.00	Diciembre	14.732	16.21	16.65	113

Modelo: GISS-E2-R		Estado:			Chihuahua	Latitud:			31°20´33"	RCP: 8.5		
Horizonte Cercano: 2015-2039		Área:			247,460	Longitud:			106°28¨35"	Esc. De Cambio Climático 0.5" x 0.5"		
Municipio: Ciudad Juárez		habitantes			3,556,574	Área:			3,577.69			
						Elevación:			1,126			
	ENE	FEB	MAR	ABR	MAY	JUN	JUL	AGO	SEP	OCT	NOV	DIC
Temperatura Máxima (°C)	15	18.1	22.9	28.1	33.1	38.4	37.9	36	33.2	28.7	20.2	14.9
Temperatura Mínima (°C)	0	1.7	5.5	10.4	15.2	19.8	22	20.7	18.1	11.9	4.6	0.5
Temperatura Promedio (°C)	7.4	9.9	14.1	19.3	24.2	29.2	29.9	28.3	25.7	20.3	12.4	7.7
Precipitación (mm)	4	5	0	4	6	1	29	33	25	7	10	20
% de Camabio de Precipitación	-45	-42	-100	-21	-31	-89	-11	-2	-19	-51	17	53
Tmax- Tmin (°C)	15	16.4	17.4	17.7	17.9	18.6	15.9	15.3	15.1	16.8	15.6	14.4







Modelo: GISS-E2-R		Estado:			Chihuahua	Latitud:			31°20´33"	RCP: 4.5		
Horizonte Cercano: 2015-2039		Área:			247,460	Longitud:			106°28¨35"	Esc. De Cambio		
Municipio: Ciudad Juárez		habitantes			3,556,574	Área:			3,577.69	Climático 0.5" x 0.5"		
						Elevación:			1,188			
	ENE	FEB	MAR	ABR	MAY	JUN	JUL	AGO	SEP	OCT	NOV	DIC
Temperatura Máxima (°C)	14.9	17.8	22.5	27.4	32.6	38	37.2	35.7	33.2	27.7	20.1	15.5
Temperatura Mínima (°C)	0.2	1.8	5.5	10	14.7	19.6	21.6	20.6	17.9	11.3	4.1	0.4
Temperatura Promedio (°C)	7.5	9.8	13.9	18.7	23.6	28.8	29.4	28.1	25.5	19.5	12.1	7.9
Precipitación (mm)	8	9	2	8	8	8	35	38	25	11	10	13
% de Camabio de Precipitación	2	6	-44	68	-27	-65	6	12	-27	-24	14	-2
Tmax- Tmin (°C)	14.7	16	17	17.4	17.9	18.4	15.6	15.1	15.3	16.4	16	15.1

Modelo: GISS-E2-R		Estado:			Chihuahua	Latitud:			31°20´33"	RCP: 8.5		
Horizonte Cercano: 2015-2039		Área:			247,460	Longitud:			106°28¨35"	Esc. De Cambio Climático 0.5" x 0.5"		
Municipio: Ciudad Juárez		habitantes			3,556,574	Área:			3,577.69			
						Elevación:			1,126			
	ENE	FEB	MAR	ABR	MAY	JUN	JUL	AGO	SEP	OCT	NOV	DIC
Temperatura Máxima (°C)	15	18.1	22.9	28.1	33.1	38.4	37.9	36	33.2	28.7	20.2	14.9
Temperatura Mínima (°C)	0	1.7	5.5	10.4	15.2	19.8	22	20.7	18.1	11.9	4.6	0.5
Temperatura Promedio (°C)	7.4	9.9	14.1	19.3	24.2	29.2	29.9	28.3	25.7	20.3	12.4	7.7
Precipitación (mm)	4	5	0	4	6	1	29	33	25	7	10	20
% de Camabio de Precipitación	-45	-42	-100	-21	-31	-89	-11	-2	-19	-51	17	53
Tmax- Tmin (°C)	15	16.4	17.4	17.7	17.9	18.6	15.9	15.3	15.1	16.8	15.6	14.4

2.- Cuestionario Water Sustainability Project

1. **What are plausible future states of elephant butte, and what are the implications of these for ground water storage? Sub-questions: How much snow is needed in the headwaters to fill the reservoir? What would be the benefits of improving surface water storage?**

- The use of suspended covers or modular floating covers to reduce evaporation rates.
- Optimization of wastewater treatment plants to increase the use of this in the urban or agricultural sectors.
- Implementation of crops with low water consumption
- Rotation of the use of water between the stakeholders in a way that less water is consumed, and more water is stored.
- Optimize crop irrigation systems.

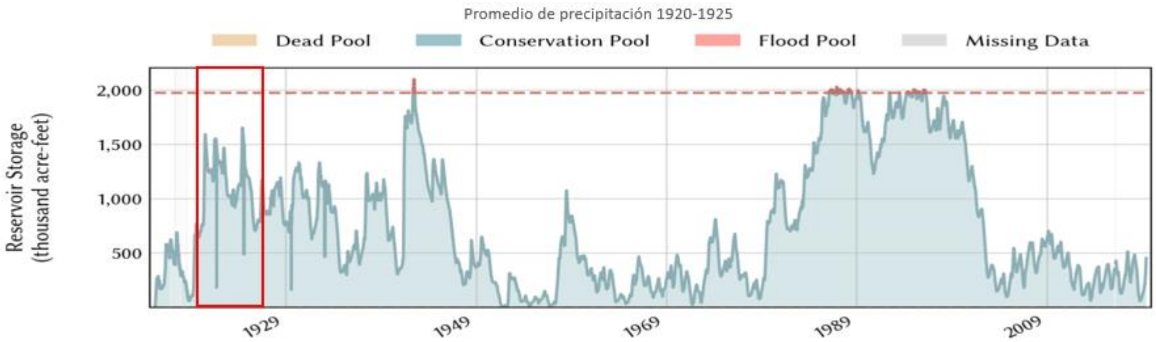
2. How can the life of Hueco Bolson be extended, and what are the compensations?

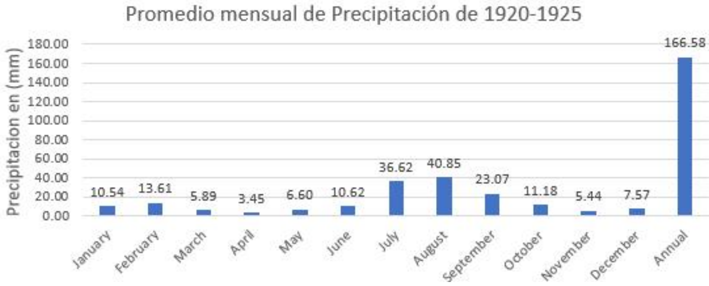
- Optimization of rainwater collection systems for use in the urban sector.
- Ration the water in the dam prioritizing .05% more than its previous year.
- Optimization of wastewater treatment plants to provide water to the industrial sector.
- Artificial water injection treated for later use.

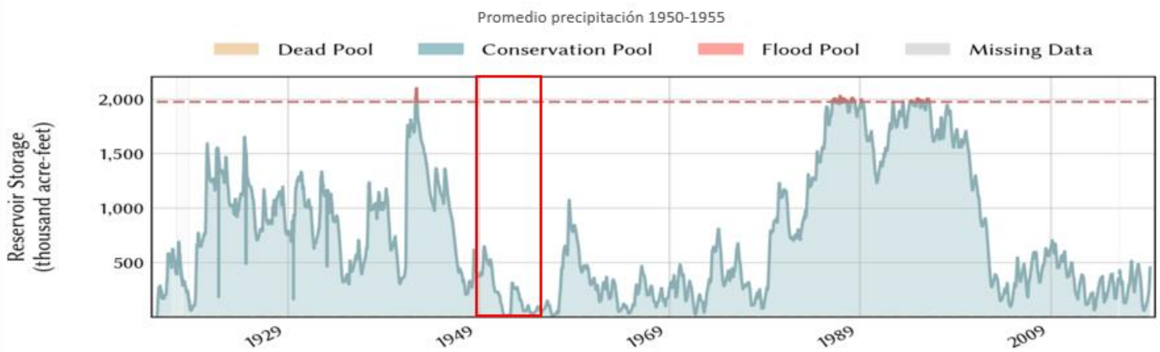
3. Question: How useful has the water become for environmental impulses once every 3 to 10 years, or the flow throughout the year?

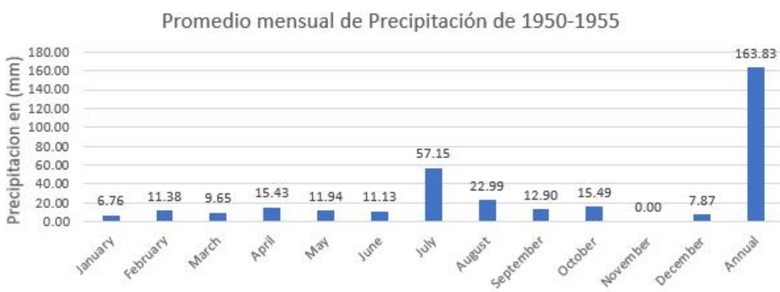
- Implementation of a more optimized wastewater treatment and add the treated water to the elephant butte.
- Implementation of rainwater collection systems in urban and agricultural areas.

3.-Gráfico de precipitaciones y % de llenado de la presa El Elefante

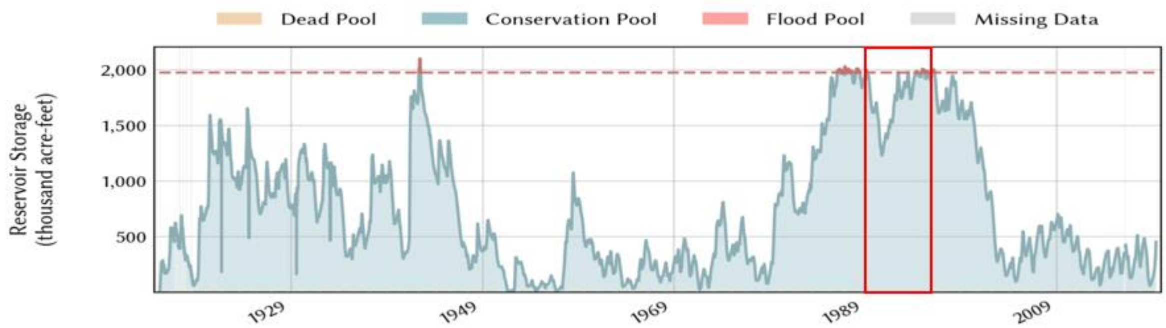


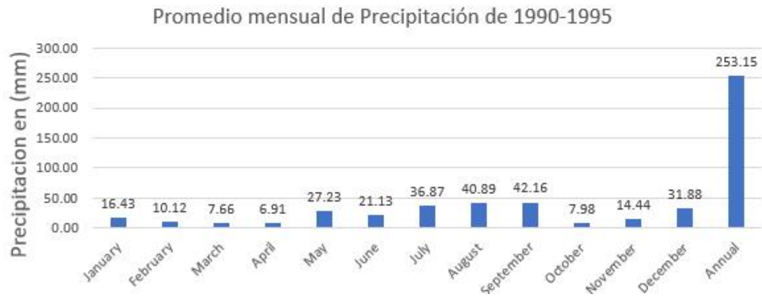




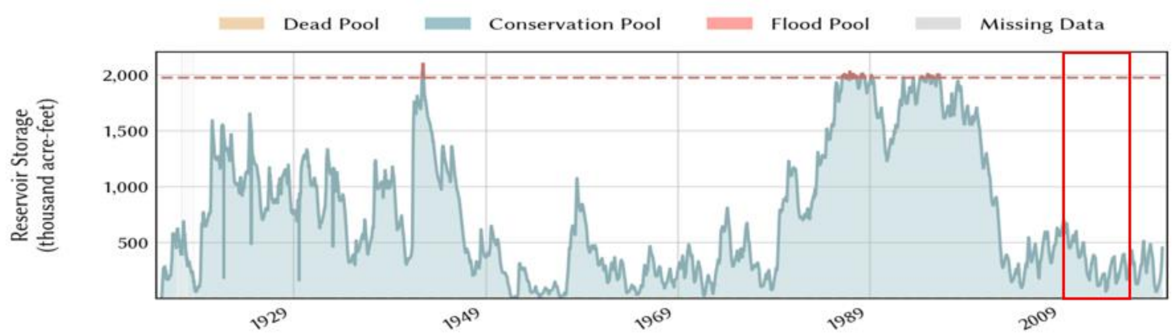


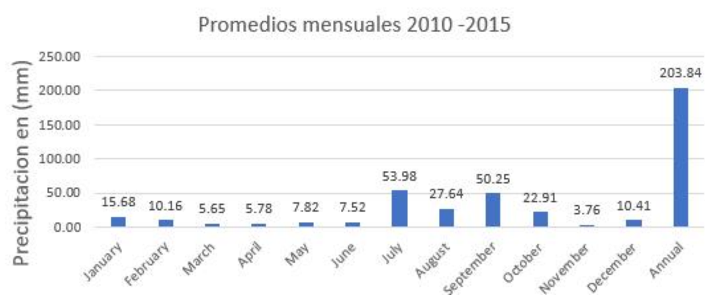
Promedio precipitación 1990-1995





Promedio precipitación 2010 - 2015



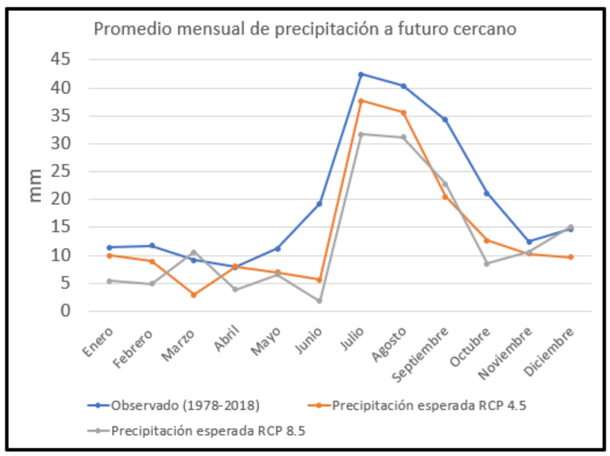


4.- Promedio mensual de precipitación en diferentes escenarios

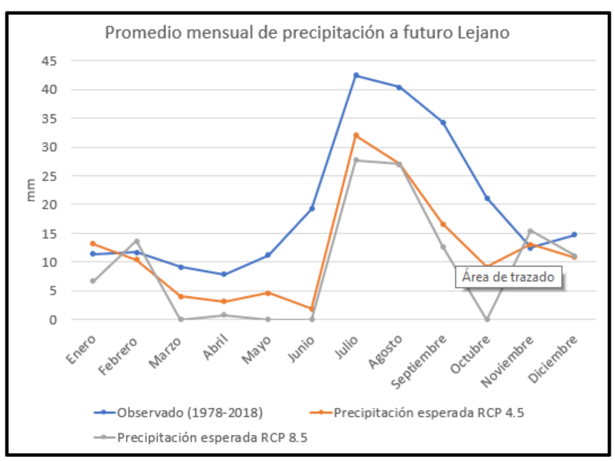
METODOLOGÍA

- Se tomaron datos de precipitación de la estación del aeropuerto de El Paso,Texas; correspondientes al periodo del 1878-2018 (https://www.weather.gov/epz/elpaso_monthly_precip)
- Se realizó un análisis de anomalías de precipitaciones para el área de Ciudad Juárez en base al modelo GISS-E2-R presentado por el Instituto Goddard de estudios espaciales de la NASA en EUA (Rivera-Lozano,L; Vazquez-Galvez,F; Granados-Olivas,A; 2019).
- Los periodos analizados comprenden una proyección del futuro cercano (2015 - 2039) y de futuro lejano (2075-2099); para los escenarios de Forzamiento Radiativo (RCP) de 4.5 y 8.5.

Cercano			
	Observado (1978-2018)	Precipitación esperada RCP 4.5	Precipitación esperada RCP 8.5
Enero	11.43	9.960	5.371
Febrero	11.684	8.953	4.899
Marzo	9.144	2.957	10.561
Abril	7.874	8.013	3.837
Mayo	11.176	6.937	6.557
Junio	19.304	5.587	1.756
Julio	42.418	37.673	31.631
Agosto	40.386	35.561	31.116
Septiembre	34.29	20.534	22.784
Octubre	21.082	12.646	8.488
Noviembre	12.446	10.279	10.549
Diciembre	14.732	9.679	15.112



Lejano			
	Observado (1978-2018)	Precipitación esperada RCP 4.5	Precipitación esperada RCP 8.5
Enero	11.43	13.18	6.74
Febrero	11.684	10.39	13.68
Marzo	9.144	4.01	0.00
Abril	7.874	3.21	0.83
Mayo	11.176	4.66	0.00
Junio	19.304	1.92	0.00
Julio	42.418	31.99	27.72
Agosto	40.386	26.99	26.99
Septiembre	34.29	16.60	12.66
Octubre	21.082	9.18	0.00
Noviembre	12.446	13.07	15.42
Diciembre	14.732	10.86	11.16



CONCLUSIONES

- El modelo (RCP 8.5) de futuro cercano arroja valores para la temporada de lluvia asociadas al NAM una reducción en la precipitación en promedio de 56.96%, sobre todo al inicio y al final del monzón, haciendo la temporada más corta.
- Se observan resultados similares para el futuro lejano (42.27%)
- A partir de estos análisis se propone estudiar el incremento en el déficit de agua para riego de parques y jardines (por efecto de la reducción en las precipitaciones) en ciudad Juárez utilizando escenarios generados mediante plataforma SWIM así como los posibles impactos en la calidad de vida de sus habitantes

5.- Poster de participación en dos eventos en UTEP

Monitoring the influence of atmospheric water vapor fields on the Paso del Norte water basin

Rogelio Alvarado[1], PhD. Felipe A. Vázquez[1], PhD. David K. Adams[2], MSc. Liliana Rivera-Lozano[1]
[1]Universidad Autónoma de Ciudad Juárez (UACJ), Laboratorio de Climatología y Calidad del Aire (LCCA)
[2]Universidad Nacional Autónoma de México (UNAM), Centro de Ciencias de la Atmósfera (CCA)

INTRODUCTION

The goal of this project is to provide reliable meteorological/climatological data for scientific, public and decision-making sectors to assess water governance for the borderland region between Mexico and the United States. Specifically, we intend to create data hub fed by information acquired through several meteorological instruments, including a GPSmet station which provides the total precipitable water vapor in site, and a ceilometer to supply measurements of the planetary boundary layer height. In conjunction with the GPSmet site and ceilometer, we will operate an eddy-covariance flux tower to analyze surface water vapor fluxes. In addition to these atmospheric measurements, the Universidad Autónoma de Ciudad Juárez (UACJ) pluviometric network will provide the necessary estimate of precipitation in the region. This instrument deployment, organized by the Laboratorio de Climatología y Calidad del Aire in the UACJ, will provide a unique opportunity to observe the atmospheric hydrological cycle in this semi-arid region. In addition, this unique dataset can be employed to challenge diverse numerical models of different spatial and temporal scales to evaluate the effects of global climate change over water availability in the Paso del Norte water basin.

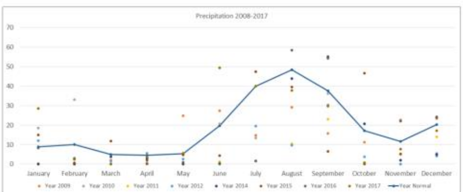


Figure 1. Precipitation data acquired from the IIT-01 station of the UACJ Meteorological Network.

STUDY AREA

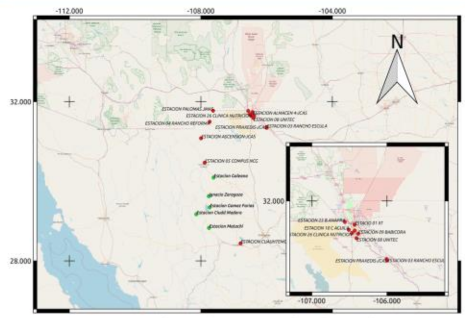


Figure 2. Scheme of UACJ Meteorological Network.

The study area is the El Paso del Norte water basin which "is located at the virtual midpoint of the 1500-mile border" (The United states Regional Stakeholders Committee, 2009). The Basin covers the cities of Las Cruces, El Paso, and Ciudad Juárez, but mainly the two last ones. Approximately 38% of the water distributed in el Paso comes from the hueco bolson (Epwater.org.,2019) while in Ciudad Juarez depends mostly from Hueco bolson wells (Salas-Plata Mendoza, J., 2007) locate in the northern side of Chihuahua state. The UACJ network has 10 automatic meteorological stations available at present , and in the near future it's planned to acquire 7 more stations positioned in the east side of the continental division.

	Station	Instruments		Parameters	Operation	Specifications
UACJ-HUB	GPS	TRIMBLE NET R9 GNSS - SuomiNET		2D Water Vapor	Static GNSS Surveying	Up to 10 km ± 5 cm vertically and ± 3 cm horizontally Set frequency of 5 Hz per time interval of 0.1 seconds
				Precipitable Water Vapor		
	CEILOMETER	MODEL 450 C		Planetary Boundary Layer	The system analize the time lapse and signal strenght between the transmitter and receiver laser pulses to measure the vertical distance of the clouds.	25,000 feet (7.62 km) ± 1% Cycle: 30 seconds in polled mode
	EDDY COVARIANCE	CNR4 Net-Radiometer	Pyrgeometer	Energy fluxes	The thermopile sensor and integrated silicon window absorbs and converts solar radiation it into heat	4.5 to 42 µm with W/m2 -250 to +250
			Pyranometer			nm 300 - 2800 (50% points) with 10 to 20 µV/W/m²
		3D SONIC ANENOMETER		Wind Direction	Values are the standard deviations of instantaneous measurements made of a constant signal. The noise is unaffected by the sample rate.	Operating range temperature from -30 to 50°C Wind speed < 30 m s−1; azimuth angles between ±170°
		LI-7500		H_2O(g) and CO_2	Non-dispersive IF spectroscopy thermally regulated by a lead selenide detector	Modulate frequency of 150 Hz Wavelenghts of 4.26 for CO_2 and 2.59 um for H_2O (g)
	RADIOMETER	CIMEL CE-318 Sun photometer		Precipitable Water	Precipitable water and AOD measurements part of the inversion algorithm developed by AERONET network	Wavelenghts for AOD Measurement: 340,380,440,60,870, 1020 nm
	UACJ MET NETWORK	PLUVIOMETER		Total Precipitation	Based on 10 standar stations located on the northern region of Chihuahua state plus 7 more proposed for the Sierra Tarahumara	Estándar Davis and Campbell Weather Station
		Standar Meteorológica Station		Standar MET		

CONCLUSION

Having all this equipment arranged, will provide a better understanding of the monsoon in the Paso del Norte region and improve research in mesoscale modeling and data assimilation for weather, precipitation, cloud dynamics, regional climate, and hydrology, this dataset is meant to be available to the public in general by following the steps at the flow chart.

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USDA
United States Department of Agriculture

“The impact of climate change on the deficit of green areas in Juárez due to lack of water using the SWIM model to a future 2030”

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INTRODUCTION

Climate change will have an impact over all the resources around the world, and one of the most important resources is water. The purpose of this project is to quantify an approximate volume of water needed for irrigation of green spaces and those needed to reach the green area index of 9.0 m^2 / inhabitant proposed by international organizations, which according to various studies that indicate that maintaining an appropriate index tends to have a positive impact over the population´s metal health specially kids, the elderly and the low socioeconomic status which are the most benefited. The estimated amount of water will include the volume of water obtained by precipitations for the future 2030. Based on these analysis, it is proposed to study the increase in the water deficit for irrigation of parks and gardens (due to the reduction in rainfall) in Ciudad Juárez using scenarios generated through the SWIM platform as well as the possible impacts on the quality of life of its inhabitants.

STUDY AREA

The study area is Ciudad Juárez, Chihuahua, which is a border city, located in the Paso del Norte region, Figure 1. The city borders the city of El Paso, Texas, and Las Cruces, New Mexico.

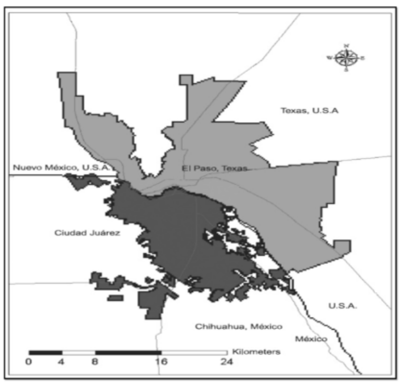
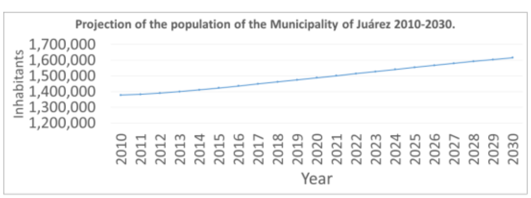


Figure 1. Location of Juárez [1]

Results

According to the information retrieved from shapefile created by IMIP there is a total of 17,372,014.34 m^2, Currently, Ciudad Juárez has a population of 1.4 million [2] inhabitants, and by 2030 the population is expected to increase by approximately 1.6 million inhabitants [2]. Taking these values into account, in 2019 we have an index of green area per inhabitant of 12.2 m^2/ inhabitant and in 2030 there would be an index of 10.70 m^2 / inhabitant.



The conditions of green areas were obtained by using NDVI with sentinel satellite images, this values were classified in three

To know the conditions of the green areas , a sentinel satellite image was used to obtain the NDVI values of the region, once it was processed, then a clip was made so the only values we could see were the ones in the shapefile, were the following map was obtained.

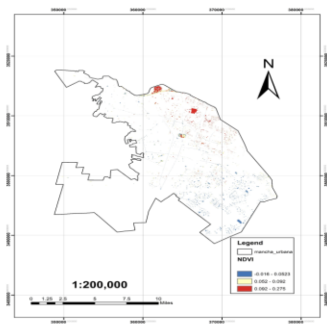
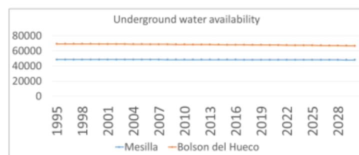


Figure . NDVI values of green areas in Juárez

Most of the NDVI values were between 0.004 and 0.15 which according to Sentera is considered as unhealthy plants. Even the highest value didn’t reach the moderately healthy class which is 0.33. Having this values could mean that the green spaces are not being well irrigated or there is no green space at all just bare soil considered a green space.



Model Swim was used to se the underground water availability changes based in a scenario of Observed Simulation + Extended Drought, throughout the simulation, the water availability in bolson del hueco decreased 9.66% and in Mesilla 0.9%.

CONCLUSION

To increase the quality of green areas, it is necessary to increase the volume of water needed for irrigation of these, such volume cant be acquired from the aquifers, given that agriculture, industry and covering population needs are a priority. All this is based in a scenario of Observed Simulation + Extended Drought

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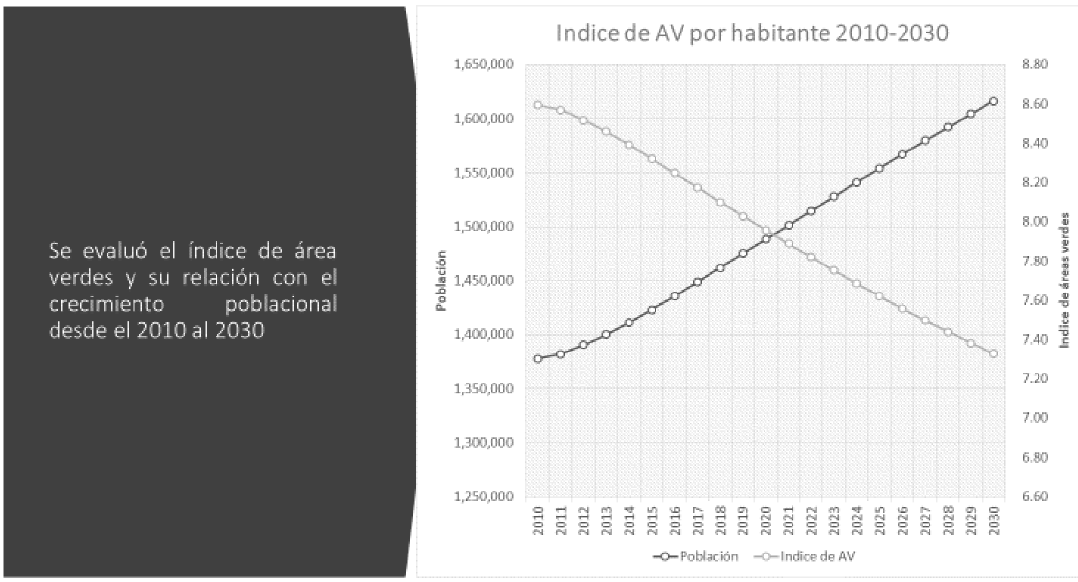
6.- Evaluación del impacto del cambio climático en el déficit de áreas verdes en Ciudad Juárez por falta de agua utilizando el modelo SWIM a un futuro 2030.

OBJETIVO GENERAL

- Estimar del impacto del cambio climático en la disponibilidad de agua de riego para áreas verdes en Ciudad Juárez en base a modelos generados por la plataforma SWIM a diferentes escenarios para un futuro cercano 2030



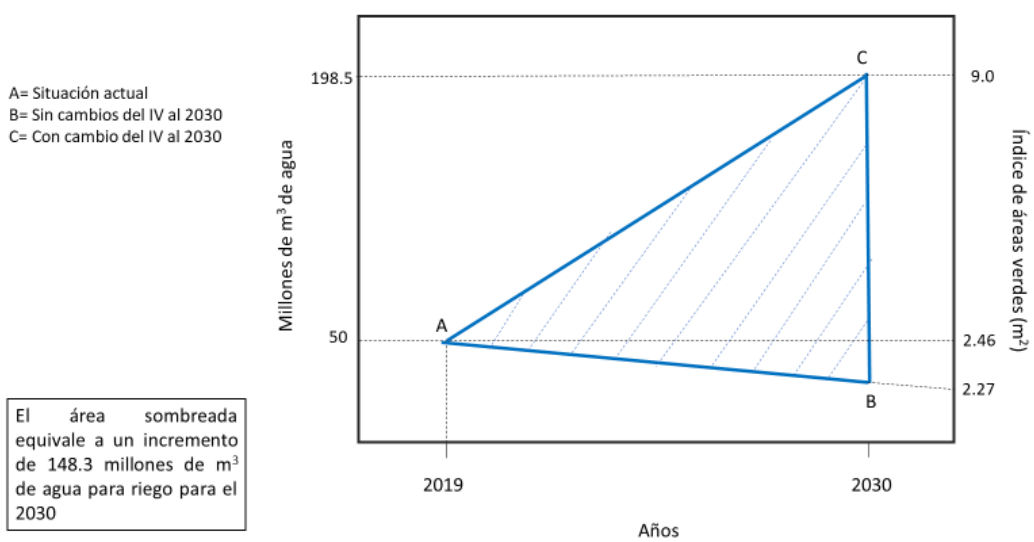
- De acuerdo con el Director General de Cultura del Agua (H. Uranga, comunicación personal, 31 de marzo de 2020) se calcula que para el riego de áreas verdes se utiliza el 26% del total del agua que se extrae de los acuíferos, que representan alrededor de 50 millones de m^3.

Clasificación	NDVI	Pixeles	% total	Área m^2
Sin Vegetación	NDVI > 0.3	99,194	80.89%	9,601,679.709
Con Vegetación	NDVI < 0.3	23,433	19.11%	2,268,243.65
Total		122,627		11,869,923.36

- De acuerdo con la clasificación de las área verdes (sin vegetación y con vegetación), 80% esta clasificada ante el IMIP como área verde, pero carece de vegetación.

Condicionante	Año	Población	áreas verdes efectivas (m^2)	áreas verdes totales (m^2)	Índice de vegetacion efectivas	Índice de vegetación totales	Agua utilizada (m^3)	Deficit en áreas verdes (m^2)	Deficit en agua utilizada (m^3)
Estatus actual	2019	1,488,357.00	2,268,243.65	11,869,923.36	1.52	7.98	50,000,000.00		
Si no se hacen cambios en el número de áreas verdes	2030	1,616,344.00	2,268,243.65		1.40		50,000,000.00		
Si se incrementa el indice de Vegetación	2030	1,616,344.00	14,547,096.00		9.00		320,668,725.34	-12,278,852.35	-270,668,725.34

- Análisis de consume de agua en comparación a las áreas verdes efectivas y las proyección de crecimiento poblacional.



El área sombreada equivale a un incremento de 148.3 millones de m^3 de agua para riego para el 2030

META

- Hay que generar estrategias para abastecer las necesidades hídricas para el riego para garantizar un incremento en el índice de vegetación a 9.
- Se está trabajando en las modelaciones con SWIM para generar las opciones de abastecimiento.

7.- Reporte final

PROYECTO: Sustainable Water Resources for Irrigated Agriculture in a Desert River Basin Facing Climate Change and Competing Demands: From Characterization to Solutions

El trabajo final realizado en el marco del proyecto “Sustainable Water Resources for Irrigated Agriculture in a Desert River Basin Facing Climate Change and Competing Demands: From Characterization to Solutions” tiene como objetivo estimar del impacto del cambio climático en la disponibilidad de agua de riego para áreas verdes en Ciudad Juárez en base a modelos generados por la plataforma SWIM a diferentes escenarios para un futuro cercano 2030.

Lo anterior de acuerdo con informes proporcionados por el Instituto Municipal de Investigación y planeación (IMIP), los juarenses carecen de suficientes áreas verdes en la ciudad, considerando que la norma del Consejo Nacional de Población (CONAPO) establece 9 metros cuadrados por habitante (m^2/hab); peor aún, la Organización Mundial de la Salud (OMS) pide 19 m^2/hab. Para un millón 332 mil 131 habitantes que tenía Ciudad Juárez en 2010, deberían de existir alrededor de 11 millones 989 mil 179 metros cuadrados de vegetación, sin embargo, hasta el 2012, apenas se superaban los 6 m^2, según datos del Instituto Municipal de Investigación y Planeación (IMIP, 2013). En el mismo informe se indica que para el 2012 se contaba con un aproximado de 6 m^2/hab., sin embargo, se carece de la información sobre el estado de salud de la vegetación.

Para cumplir con dicho objetivo se está trabajando en la tesis del becario Rogelio Alvarado Hernández, que llevo el título de “Evaluación del impacto del cambio climático en el déficit de áreas verdes en Ciudad Juárez por falta de agua utilizando el modelo SWIM a un futuro 2030”.

Como parte de la metodología que se siguió para evaluar el impacto del cambio climático en el déficit de áreas verdes fue el análisis de imágenes satelitales. Estas se utilizaron para conocer la proporción y estado de salud de las áreas verdes por habitantes actual en Ciudad Juárez.

Además, se realizó una modelación del balance de agua utilizando el programa SWIM, con el cual se estimó el gasto de agua extraída del Bolsón del Hueco para un futuro 2030.

Con esta información se podrá proponer estrategias viables para reducir la extracción del agua del Bolsón del Hueco utilizada para riego de áreas verdes. Con estas estrategias se busca tener el recurso del vital líquido para incrementar el número de áreas verdes por habitante en la Ciudad.

RESULTADOS

El análisis del NDVI de las imágenes satelitales arrojó el número de pixeles con un Índice de vegetación de diferencia normalizada (NDVI por sus siglas en inglés) menor a 0.2 es indicativo de áreas con vegetación con mala salud o vegetación nula. Mientras que las imágenes con un NDVI superior a 0.2 muestra zonas con vegetación. La imagen que se analizó corresponde al mes de mayo 2020, ya que la presencia de zonas con un NDVI superior a 0.2 es indicativo de zonas verdes que tienen riego constante, ya que, en ese mes el riego por lluvias no es viable. En la tabla 1 se observa una clasificación de zonas de acuerdo con la fuente del agua que utilizan para el riego: agua tratada y agua potable. En dichos datos se muestra que más del 60% de las zonas irrigadas con estos tipos de agua muestran vegetación en mal estado de salud y zonas sin vegetación. Las zonas que se consideraron para el análisis de riego de agua tratada corresponden a los parques del El Chamizal, el Parque central y el campo de Golf Club Campestre. Mientras que las zonas regadas con agua potable corresponden a parques públicos, privados y camellones de la ciudad (Figura 1).

Tabla 1. Clasificación por NDVI

Agua potable				
Clasificación	NDVI	Pixeles	% de AV	Área en m^2
Sin Vegetación	NDVI > 0.2	69,479	74.23%	7,870,475
Con Vegetación	NDVI < 0.2	24,121	25.77%	1,255,618
Total		93,600		9,126,093
Agua tratada				
Clasificación	NDVI	Pixeles	% de AV	Área en m^2
Sin Vegetación	NDVI > 0.2	13,510	50.31%	1,352,103
Con Vegetación	NDVI < 0.2	13,345	49.69%	1,335,589
Total		26,855		2,687,692
General				
Clasificación	NDVI	Pixeles	% de AV	Área en m^2
Sin Vegetación	NDVI > 0.2	82,970	68.88%	8,137,394
Con Vegetación	NDVI < 0.2	37,391	31.04%	3,667,172
Total		120,455		11,813,785

Fuente: Elaboración propia

Figura 1. Imágenes satelitales utilizadas en el estudio

Bajo este esquema, se realizó un análisis del índice de áreas verdes (IAV) en m^2/habitante de áreas verdes, mostrando que para el año 2019 se contaba con un índice de vegetación de 7.94 m^2/habitante, lo anterior para el total de áreas verdes. Sin embargo, este índice disminuye a 2.46 m^2/habitante (tabla 2), si solo se toma en cuenta las áreas verdes identificadas con vegetación de acuerdo con el análisis de las imágenes satelitales (gráfica 1).

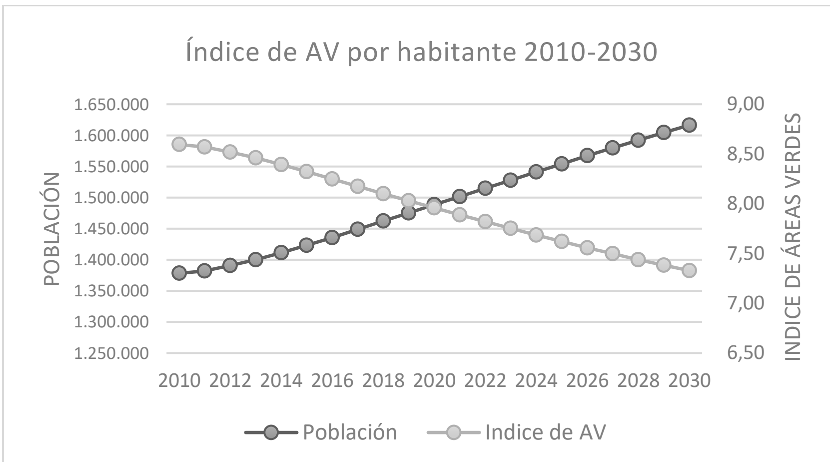
Tabla 2. Estimación del IAV para 2030 para un NDVI superior a 0.2

Condicionante	Año	Población	áreas verdes efectivas (m^2)	Total de áreas verdes (m^2)	Índice de vegetación efectivas (m^2/hab)	Índice de vegetación totales (m^2/hab)
Estatus actual	2019	1,488,357	3,667,172	11,813,785	2.46	7.94
Si no se hacen cambios en el número de áreas verdes	2030	1,616,344	3,667,172		2.27	
Si se incrementa el índice de Vegetación	2030	1,616,344	14,547,096		9.00	

Fuente: Elaboración propia

En la tabla 2 se muestra que, si la ciudad no hace un cambio en el manejo de las áreas verdes, para el 2030 se estima que haya una disminución de casi el 8% en el número de áreas verdes por habitante. En cambio, si se lleva cabo un plan de acciones para incrementar el IAV para el 2030 a 9m^2/habitante, implica que el número de m^2 de áreas verdes incremente en un 500% de acuerdo con los registros del 2019.

Grafica 1. Proyección de crecimiento población vs disminución del IAV para el 2030



Fuente: Elaboración propia

Es evidente que para lograr estos cambios se requiere del diseño de estrategias en el manejo del vital líquido, y estas acciones no pueden estar enfocadas en utilizar el agua del Bolsón del Hueco para el riego de áreas verdes; ya que actualmente este acuífero se encuentra en condiciones de sobreexplotación. De acuerdo con el Director General de Cultura del Agua (H. Uranga, comunicación personal, 31 de marzo de 2020) se calcula que para el riego de áreas verdes se utiliza el 26% del total del agua que se extrae de los acuíferos, que representan alrededor de 50 millones de m^3. En la tabla 3 se observa que para incrementar el IAV a 9m^2/hab. se tendría un déficit de agua de poco más de 148 millones de m^3 de agua (tabla 3).

Tabla 3. Proyección de volumen de agua para el 2030

Condicionante	**Año**	**áreas verdes efectivas (m^2)**	**áreas verdes totales (m^2)**	**Agua utilizada por año para riego de AV (m^3)**	**Déficit en áreas verdes efectivas (m^2)**	**Déficit en agua utilizada por año (m^3)**
Estatus actual	2019	2,268,243	11,813,785	50,000,000		

Si no se hacen cambios en el número de áreas verdes	2030	2,268,243		50,000,000		
Si se incrementa el índice de Vegetación	2030	14,547,096		198,342,136	-10,879,923	-148,342,136

Fuente: Elaboración propia

Mediante la plataforma de SWIM se realizó la modelación de la extracción de agua del Bolsón del Hueco. Se obtuvo que existe un aumento anual aproximadamente de 239.30 millones de m^3 de perdida en el Bolsón del Hueco por usos urbanos, que incluyen el riego de áreas verdes. En la tabla 4 se observa un pico de 349.27 millones de m^3 en el 2030, alcanzando una perdida acumulado de 7814.95 millones de m^3 para el mismo año. De acuerdo con los datos provistos por el director de Cultura del Agua un total de 2,031.887 millones de m^3 (26% del total) serían utilizados para el 2030.

Tabla 4. Perdida y recarga acumulativa Anual en el Bolsón del Hueco en millones de m^3 modelada con SWIM

Año	General	Otros	Utilizado para riego de AV	Recarga en el acuífero	Perdida por fugas
2000	266	197	69	71	79
2001	461	341	120	150	136
2002	655	485	170	229	194
2003	850	629	221	308	252
2004	1045	774	272	387	309
2005	1240	918	322	466	367
2006	1435	1062	373	545	425
2007	1630	1206	424	623	483
2008	1825	1351	475	702	540
2009	2020	1495	525	781	598
2010	2215	1639	576	860	656
2011	2410	1783	627	939	713
2012	2605	1928	677	1018	771
2013	2800	2072	728	1097	829
2014	2995	2216	779	1176	886
2015	3190	2360	829	1255	944
2016	3385	2505	880	1333	1002
2017	3580	2649	931	1412	1060
2018	3775	2793	981	1491	1117

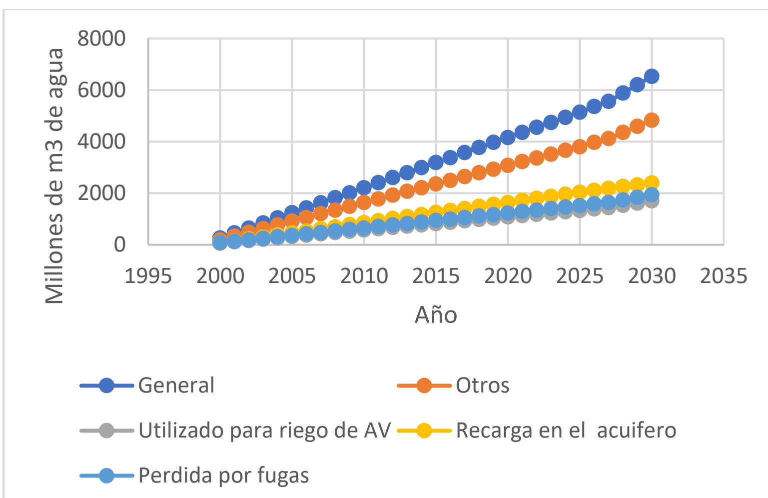
2019	3971	2938	1032	1569	1175
2020	4166	3083	1083	1648	1233
2021	4361	3227	1134	1727	1291
2022	4556	3371	1184	1806	1348
2023	4750	3515	1235	1885	1406
2024	4945	3660	1286	1963	1464
2025	5140	3804	1336	2042	1522
2026	5367	3972	1396	2115	1589
2027	5569	4121	1448	2190	1649
2028	5889	4358	1531	2258	1743
2029	6208	4594	1614	2327	1838
2030	6536	4837	1699	2395	1935

Fuente: Elaboración propia

CONCLUSIONES PRELIMINARES

De acuerdo con lo anterior, se tiene considerado evaluar las estrategias posibles que permitan obtener agua para el riego de las áreas verdes, utilizando otras fuentes distintas al agua del Bolsón del Hueco. Es por lo que se realizó una modelación, en donde se estimaron los efectos en el gasto asociado a varios escenarios (grafico 2).

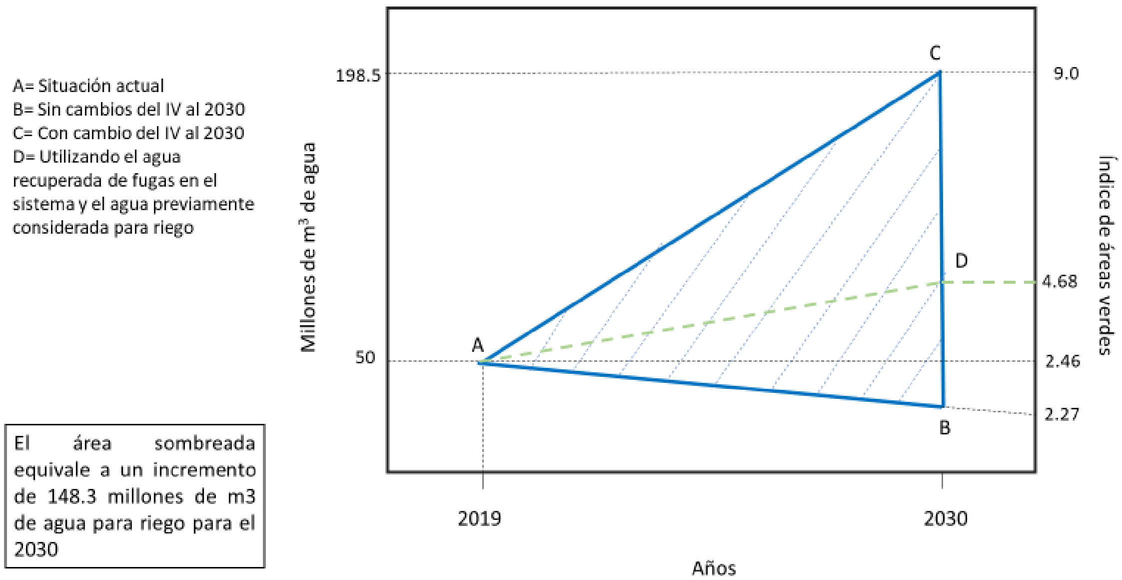
Grafica 2. Balances hídricos en el acuífero Bolsón del Hueco



Fuente: Elaboración propia

Bajo este esquema se planteó la gráfica presentada en el gráfico 3. El área sombreada representa el volumen de agua que se tiene que conseguir para incrementar el IAV de 2.46 a 9 m^2/hab. Esta acción implica tener un suministro de agua para riego mayor (148 millones de m^3 de agua). En dicho grafico se observa el efecto en el incremento en el incremento del IAV a 4.68 m2/hab para el escenario simulado de la disminución del 20% de la perdida de agua asociada a fugas.

Gráfica 3. Comportamiento del volumen de agua vs el IAV



Fuente: Elaboración propia

Las propuestas para el incremento del IAV a 9m^2/hab y una distribución de agua para riego son

1. Mejorar sistemas de riego a sistemas de riego por goteo o de aspersión. Se recomienda utilizar sistemas y medidores inteligentes.
2. Utilizar plantas nativas y adaptadas al medio físico de bajo consumo de agua y de alto valor paisajista, tanto en parques residenciales e infraestructura urbana, con el fin de disminuir el encharcamiento e incrementar la infiltración (infraestructura verde).
3. Optimizar el sistema de detección de fugas mediante sistemas inteligentes de consumo y de administración de presiones en los sistemas de distribución.
4. Fomentar y socializar en la comunidad la cultura de cosecha de agua de lluvia en las casas habitación, y fortalecer la aplicación de la normativa para que propietarios de terrenos, como estacionamientos, comerciales e industriales, implemente sistemas de infiltración.
5. Incrementar la infraestructura de manera estratégica de la línea morado (agua tratada para riego), considerando las dimensiones del área verde con relación a la población servida.

6. Implementar sistemas tecnológicos para la desalinización del agua de acuífero somero, con el fin de incrementar la disponibilidad del agua riego.
7. Dentro de las conclusiones del trabajo se está evaluando el porcentaje de aportación de cada una de las estrategias para el incremento del índice de las áreas verdes a 9m^2/hab. de acuerdo con lo recomendado por las instancias internacionales.

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REPORTE FINAL DEL AREA DE ADMINISTRACION DE LAS BASES DE DATOS GEOGRAFICOS

PROYECTO USDA 2015-2020

DR. HUGO LUIS ROJAS VILLALOBOS

En cualquier proyecto que relacione sistemas de información geográfica (SIG), como lo es este proyecto binacional, involucra tres áreas que co-dependen entre sí: las herramientas como el software y hardware, la técnicas y metodologías, y el recurso humano.

Durante el desarrollo de este proyecto (2015 - 2020) la administración de la información geográfica fue una de las actividades que mayores retos se enfrentó, ya que el tamaño de las capas de información llegó a tener archivos de 1.5 terabytes en imágenes de satélite. Esto conllevó a desarrollar una estrategia de comunicación basada en un servidor FTP y WEB para distribuir los datos entre el equipo de trabajo nacional y en Estados Unidos. Se aprovecho la estructura de telecomunicaciones de la Universidad Autónoma de Ciudad Juárez mediante la infraestructura desarrollada para Internet2, la cual enlaza a los centros de investigación y de educación superior a nivel nacional e internacional de manera transparente para el usuario.

Se utilizó una arquitectura de árbol utilizando una estructura ordenada para la administración de cualquier documento y base de datos que se pudiera utilizar durante el desarrollo del proyecto. Esta estructura se basó en carpetas dentro de un directorio. Las carpetas estuvieron organizadas por tipo de dato o documento y se muestran en la figura 1.

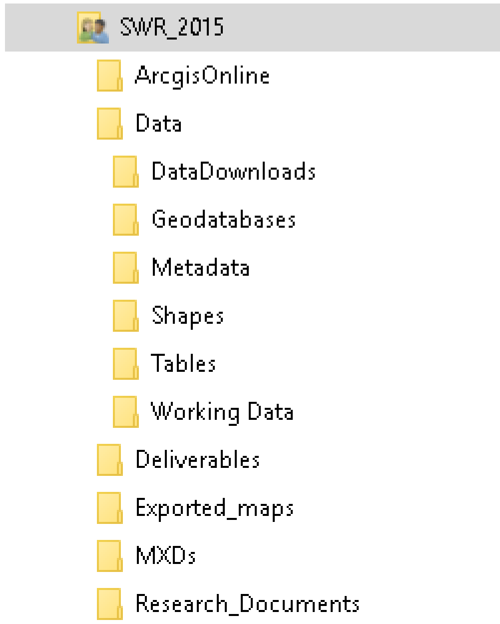

Figura 1. Directorio de trabajo para el proyecto USDA-Mexico

La carpeta “ArcGISOnline” era un repositorio donde se depuraron los datos espaciales del proyecto para ser subidos a la plataforma ArcGIS Online. En la carpeta “Data” se almacenaron datos espaciales en formato geodatabase, datos originales descargados de las fuentes, tablas en Excel o CSV, metadatos, shapefile y un folder especial para manipulación de datos geoespaciales intermedios. En el folder “deliverables” se almacenaron los paquetes de información final que se destinan a otros equipos de investigadores dentro del proyecto. Si se generaron mapas temáticos en formato digital, estos se guardaron dentro del folder “Exported_maps”. Los proyectos en ArcGIS son guardados en su formato MXD en el folder de misma extensión. Por último, cualquier documento que fue utilizado como apoyo y referencia bibliográfica como artículos o libros, fueron guardados en el folder “Research_Documents”.

Como se comentó al inicio, la conectividad y transferencia de base de datos se realizó de cuatro maneras: FTP, WEB, Dropbox, y Wetransfer.

Cuando el administrador de las bases de datos requiere enviar información, se utiliza la distribución por FTP la cual es la manera más sencilla y fácil de enviar información. El folder del proyecto es compartido mediante Dropbox, se utiliza para el intercambio de archivos en forma bidireccional, pero solo es usado para archivos pequeños (menores a 20 Mb). Se utiliza el servicio de Wetransfer (http://www.wetransfer.com) para la recepción de datos desde los otros participantes del proyecto. Este servicio tiene la ventaja de poder enviar archivos de hasta 2 Gb de tamaño. Adicionalmente, se habilitó un espacio en el servidor web con dirección IP 148.210.68.3 donde se descargaban directamente los archivos compartidos mediante un link.

Estandarización de datos

Los insumos para el desarrollo de este proyecto tuvieron fuentes muy variadas como CONAGUA, INEGI, CONABIO y USGS, y debido a esto, el sistema de coordenadas y proyecciones variaban entre sí. Se tomó como base de cálculos la proyección UTM WGS84 Z13 ya que esta zona cubre totalmente el lado mexicano correspondiente a las microcuencas que van desde Rancho Anapra en Ciudad Juárez, Chihuahua hasta Fort Quitman en Texas. Esta re-proyección de los insumos permitió que la compatibilidad de datos entre los miembros del equipo de trabajo fluyera con eficiencia y se cumplieran los requisitos que los softwares de modelación requerían de los insumos.

Portal WEB USDA-México

El portal web USDA-México se encontraba alojado en la dirección web **http://mexusda.uacj.mx** el cual fue desarrollado con una técnica basada en CSS y JavaScript llamado Bootstrap. La principal ventaja de haber utilizado Bootstrap es que la interfaz del sitio web se adapta automáticamente a la pantalla de una PC, una Tablet u otro dispositivo como un Smartphone. Bootstrap utiliza módulos de CSS3 que permite la representación de contenido para adaptarse a condiciones de la resolución de la pantalla del dispositivo en forma automática. Actualmente este sitio web se encuentra deshabilitado para dar paso al sitio oficial del proyecto en **https://water.cybershare.utep.edu/home/es** el cual contiene su traducción al español

A continuación, se muestra una imagen de la pantalla inicial del portal

El sitio tiene las siguientes características:

- La página web está desarrollada para usuarios que hablan español, pero existen documentos o links a sitios que están en lenguaje inglés.

- La sección de educación tiene secciones de cursos y seminarios especializados en temas de agua, documentos de interés general relativos al agua, oportunidades laborales para los estudiantes y profesionistas, y un listado de los estudiantes involucrados en investigación.
- La sección de eventos tiene un calendario Google donde se actualizan las fechas de las siguientes reuniones importantes de los grupos de trabajo del proyecto.
- La sección de publicaciones contiene un repositorio de documentos que puede ser filtrado de acuerdo con el tópico seleccionado. El sistema filtrará todos los documentos etiquetados con los tópicos asociados.
- La sección herramientas tiene tres enlaces: al simulador SWIM 1.0 el cual es obsoleto, SWIM 2.0 y al Mapa Web desarrollado en la plataforma ArcGIS Online donde se puede navegar en las bases de datos geoespaciales del proyecto, así como datos liberados de las simulaciones hídricas.
- La sección espacio es una liga para entrar como miembro del grupo de usuarios del portal para subir documentación, datos, o hace simulaciones en SWIM.

COMPENDIO DE INFORMES ANUALES DE LA COORDINACION GENERAL DEL PROYECTO A LA COORDINACION INTERINSTITUCIONAL (UTEP) Y A LA AGENCIA FINANCIADORA (USDA).

Dr. Alfredo Granados Olivas

A continuación, se presenta el compendio de los informes anuales entregados por parte de la UACJ a la coordinación interinstitucional del proyecto de la UTEP en el formato establecido por esta instancia y como parte de los compromisos contraídos con la agencia financiadora del proyecto.

Ambos informes anuales (el reporte entregado de parte de la coordinación interinstitucional hacia con la agencia financiadora, así como el reporte de parte universitario hacia con la coordinación general del proyecto), son incorporados en este reporte final.

En este compendio se presentaron los avances anuales que se fueron obteniendo a lo largo de la duración del proyecto (2015-2020), los cuales fueron incorporados a un informe general de las instituciones participantes en el proyecto hacia con la agencia financiadora del mismo, el USDA.

Los años de reporte 2019-2020 se integraron en la primera sección de este documento en donde se presentaron los principales resultados de los procesos de modelación y de estrategias y propuestas para la sustentabilidad hídrica del territorio bajo estudio.

De igual forma, se anexa un acervo fotográfico de las diferentes actividades académicas y de divulgación del proyecto, los cuales se realizaron en diferentes etapas durante la duración del proyecto.

ANNUAL REPORT

Yr 1, 2015-16

"Sustainable water resources for irrigated agriculture in a desert river basin facing climate change and competing demands: From characterization to solutions"

Prepared by:

W.L. Hargrove, PI

The University of Texas at El Paso

I. Scientific Participation

[See Attachment 1.]

II. Target Audiences

In summary, our target audiences are all the stakeholders in the future of water in our region. We made a major effort to identify and engage these stakeholders in Yr 1 of our project. This was done in two stages. First, we met with key leaders, agencies, and groups to introduce our project, obtain their reaction to our proposed activities, and solicit their guidance and collaboration in implementing the project. These key leaders, agencies, and groups included:

1) irrigation districts/associations in the region, including those in New Mexico, Texas, and Chihuahua; 2) key government agencies including the Bureau of Reclamation and the International Boundary and Water Commission; and 3) water utilities, including El Paso Water Utilities, Las Cruces Water Utility, and JMAS in Juárez.

This initial contact/meeting was followed by focus group meetings with key groups of stakeholders, including:

a) Small scale Texas farmers
b) Large scale Texas farmers
c) Small scale New Mexico farmers
d) Large scale New Mexico farmers
e) Chihuahua (Mexico) farmers
f) Urban/industrial users from El Paso, Las Cruces, and Ciudad Juárez

g) U.S. Government agencies, state and federal
h) Environmental stakeholders (mainly NGOs)
i) Social justice stakeholders (mainly NGOs)

A meeting with Mexican government stakeholders is planned for early 2016. All of these groups are considered not only target audiences for our work, but also key participants in our work. The majority of stakeholders who participated in focus groups (about 90%) indicated that they wanted to be involved in the project on a continuing basis and wanted to receive results from the project. Over 100 individuals participated in the focus groups, many representing key groups and agencies who have a stake in the future of water in our region.

III. Scientific Publications

[None at this time]

IV. Other Products/Outputs

Team Outputs from Year 1:

1. Web Portal for the project: http://water.cybershare.utep.edu
2. "Bucket Model"
3. Summary of stakeholder input from stakeholder focus groups, interviews, and surveys (Attachment 2.)
4. Executive summary of Water Banking Workshop (partial credit; co-hosted with NM Water Resources Research Institute); see http://waterbank.nmsu.edu/speaker-slides/
5. Presentation at USGS South Central Climate Science Center research conference, Ft Worth TX, 18 Nov 2015: Gutzler, D.S., and S. Chavarria: Seasonal Streamflow Forecasts in the Upper Rio Grande Basin.
6. Presentation at annual meeting of the American Meteorological Society, New Orleans, 13 January 2016: Gutzler, D.S.: Effects of Multidecadal Changes in Temperature, Snowpack and Precipitation on Streamflow in Southwestern Rivers.
7. New course developed at UTEP, "Regional Water Sustainability in a Changing Climate"
8. Six seminars presented in Water Resources Seminar Series at UTEP
9. Matrix of key indicators for measuring project progress (Attachment 3.)

V. Accomplishments (per objective)

Progress towards goals is more medium to long-term and is accomplished through achieving objectives in the short-term. Accomplishments by objective in Year 1 of our project are listed below.

Objective 1. Model development, improvement, integration, validation.

- A web portal has been created that includes: a) a website with standard information about the project; b) a data bank that provides capabilities to upload, access, and store data; c) ability to do online modeling; and d) education and outreach materials. http://water.cybershare.utep.edu
- Sources of data that are required input to run the models of interest (primarily SWAT and MODFLOW) have been identified; some data have been collected, stored, and/or processed for use in models.
- Important output measures have been identified that will be quantified using models. Thirty-three priority state variables were identified, including a mix of stakeholder- and scientist-identified variables. These have been grouped into seven categories: water quantity, water quality, economic, agricultural, land structure, environmental, human wellbeing, and one overall measure of resiliency. Most of these will either be direct output from the biophysical and optimization models, or can be derived from those outputs. Others, salinity in particular, will require additional models and/or modification of existing models.
- A simple coarse-scale basin model that simulates all the major sources, sinks, uses, and losses of water for the Rio Grande has been constructed. Termed by our team "the bucket model", this model has been and will be a useful tool for improving our understanding of the basin and planning our analyses of more specific questions and problems that are important to stakeholders. The first version of the model is a simple "one bucket" model that reflects water storage and use under the Rio Grande Compact. In this first simple version, the three water users in that model are irrigated agriculture, urban demands, and environmental / recreational demands for water volumes in surface storage. Water quality is not yet in the model. Water use is treated as a constrained optimization model that identifies water use patterns that maximize discounted net present value of water by adjusting water use patterns in the river reservoir system for the model's three-year time horizon. Required inputs include hydrologic data such as surface inflows to storage, crop water requirements by crop, surface treaty delivery requirements from the U.S. to Mexico, evaporation rates from surface reservoir storage, and reservoir capacity. Water use demand data include crop yields, costs of production, crop price, price elasticity of demand, and urban population. Model results include total farm income, recreation economic benefits, total urban net benefits, reservoir releases, surface storage volume, 1906 Treaty deliveries by the U.S. to Mexico, reservoir surface evaporation, total water use, and the discounted net present value of total economic benefits.
- Eight modeling work groups have been formed, each one focused on different modeling tasks that need to be addressed. They include: a) Testing and implementing SWAT/MODFLOW/Bucket Model; b) Salt fate and transport/salinization; c) Land transition; d) Scenario formulation; e) Alternative decision-making; f) Online modeling system; g) Riparian impacts; and h) Human wellbeing. The work of these groups will advance our stepwise progress towards a systems dynamic model with geographic specificity and ability to run longer-term and hypothetical scenarios (Objective 3).

- The team has initiated an analysis of urbanization in the region. In the first round of stakeholder meetings, stakeholders identified urbanization as a major concern. Concerns stemmed from conversion of agricultural land to urban uses and loss of agriculture as a way of life; and conversion of water rights from agricultural uses to urban uses. Using satellite imagery from the past 25 years, estimates of land conversion were made in the area around El Paso and Las Cruces. This initial analysis forms the basis for modelling future scenarios of urbanization and its impacts on water use for the region.

Objective 2. Climate scenarios.

- As a starting point for projected climate change, it was decided to use the CMIP3 A1B scenario of increasing greenhouse gases. This scenario has been used in hundreds of scientific papers, typically presented as a "midrange" estimate of increasing greenhouse gases. Across the southwestern U.S., an ensemble average of many climate model simulations based on this scenario yields an average temperature trend of approximately 4C/century. The U.S. Bureau of Reclamation has used this scenario to run climate model simulations of projected upper Rio Grande streamflow that can be used as a boundary condition for our study.
- Data collection and post-processing of surface hydrologic data for study area, including historic monthly values of precipitation, temperature, and surface evaporative fluxes.
- Data collection and preliminary analysis of trends in upper Rio Grande streamflow and assessment of seasonal streamflow forecasts for the Rio Grande (S. Chavarria)
- Our analysis determined the three recent test years to be used in bucket model development; data acquisition and analysis were carried out to derive and compile the surface hydrologic values needed for the model.
- Stakeholders indicated considerable interest in mechanisms that facilitate their access to relevant online resources regarding seasonal and El Niño weather forecasts, and related climate information. 2015-16 being an “El Niño” year has elevated considerably the interest in weather extremes and short and medium term weather information. This is beyond the scope of what we proposed, however we can easily add links to high quality resources from our website as part of our education and outreach efforts.

Objective 3. Dynamic systems model.

- [No direct activities on this objective to report; more direct activity on this objective will come later in the project. However, the work of the modeling teams described above for Objective 1 is advancing our stepwise progress towards a systems dynamic model.]

Objective 4. Stakeholder engagement and participation.

- We conducted a comprehensive literature review of best practices in participatory water modeling with over 70 scholarly items reviewed. This literature review has guided and will guide our design of stakeholder engagement and participation in modeling activities as we move forward.

- We conducted a total of nine stakeholder meetings, involving a total of 109 stakeholders. Each meeting was conducted as a focus group with six predetermined questions, the same for each group. Each of the nine groups was comprised of individuals from a common sector and included one focus group session each for:
  j) Small scale Texas farmers
  k) Large scale Texas farmers
  l) Small scale New Mexico farmers
  m) Large scale New Mexico farmers
  n) Chihuahua (Mexico) farmers
  o) Urban/industrial users from El Paso, Las Cruces, and Ciudad Juárez
  p) U.S. Government agencies, state and federal
  q) Environmental stakeholders (mainly NGOs)
  r) Social justice stakeholders (mainly NGOs)

- We collected a mixture of concerns, issues, questions, scenarios, and desired outcomes from our project from these water stakeholders/users. We organized the output into a systematized thematic list presented in Attachment 2. Some pervasive concerns among agricultural stakeholders included: a) litigation between states and even within states over water rights; b) the perceived "heavy hand of government"; c) prolonged drought and how to cope; d) urbanization/growing urban demands for water; and e) lack of public understanding and appreciation for agriculture and the food system.
- For each stakeholder focus group, a process evaluation survey was also conducted. The results were analyzed by the external evaluator for the project. (See Attachment 4 for Evaluator's Report).
- An online survey was also provided as a follow-up to each meeting. These online surveys are still in progress. The online survey is aimed at assessing stakeholders' values and perceptions about water use and water sustainability in the region.
- A sample of residential consumers in El Paso and Ciudad Juárez were surveyed about water use and perceptions about the future of water. Twelve households with diverse income levels were surveyed. Household consumers are generally concerned about the future of water in the region and would like to conserve. However, they are also concerned about the future cost of water. There is a wide range of conservation measures that they do now or would consider doing in the future. They prioritized the public health impacts of water above all else. We incorporated this input from household consumers into the synthesis of stakeholder input from the focus groups.
- A study of the public policy process related to implementation of direct potable reuse as a technology/policy option by the Public Service Board in El Paso was initiated. We conducted a review of relevant documents and also face-to-face interviews with key actors/informants and residential consumers. This study is still in progress.

- All of this stakeholder output is a voluminous, rich, and highly informative body of information that will be used as input to the modeling enterprise, especially as we begin to develop and evaluate future water scenarios and explore policy and management options.

Objective 5. Dissemination.

- Stakeholders in southern New Mexico expressed an interest in water banking as a policy alternative to promote water conservation. In order to inform local stakeholders about the goals, scope, and limitations of water banking, the project co-hosted a one day workshop on water banking with the New Mexico Water Resources Research Institute. The workshop was held on November 12, 2015 in Las Cruces, NM. In the workshop, invited speakers presented the benefits, limitations, best practices, implementation methods, and future development needs for the establishment of a water bank in the southern New Mexico portion of the Rio Grande Basin. Approximately 100 stakeholders participated including farmers, water user groups, elected officials, university faculty and students, state water agency staff, and other interested individuals. Water banking was presented as a conjunctive water use approach that could enhance benefits from being able to use both surface and ground water allocations in efficient and effective ways to mitigate drought while conserving water at times when river water is more abundant. More information is available at: http://waterbank.nmsu.edu/speaker-slides/

Objective 6. Water resources education and institutional strengthening.

- We developed a water resources seminar series at UTEP during the fall semester, 2015. We hosted six special seminars.

  August 28 – Alex Mayer, Michigan Tech University
  Title: "Impacts of Spatial Variations in Land Use and Intra-Annual Climate Variability and Corresponding Changes in Land Use and Climate on Phosphorus Loads in the Great Lakes Basin"

  September 15 – Brian Hurd, NMSU
  Title: "Groundwater Showdown on the Rio Grande: Summary and Perspectives on Texas v. New Mexico"

  September 17 – Margie Vela, NMSU

  Title: "The National Science Foundation and Broader Impact: Achieving Diversity in the Geosciences"

  October 9 – Catherine Willermet, Central Michigan University

Title: "Teaching Science and Social Justice in an Interdisciplinary Water Course."

October 15 – Alfredo Granados, Professor, Universidad Autónoma de Ciudad Juárez

Title: "Urban Hydrology and Flood Risk Assessment for Ciudad Juárez and its Implications for Aquifer Recharge in the Region"

November 4 - John Zak, Texas Tech University

Title: "Soil Microbial and Nutrient Dynamics in Arid and Semi-Arid Landscapes: Discovering Unexpected System Controls of Activity"

- We have developed a new course at UTEP entitled **Regional water sustainability in a changing climate.** This senior- and master-level course will be team taught. Multiple class projects have been designed to understand and solve local and regional environmental problems that are water-related. Through hands-on experiences and field trips, students will be trained to collect data using state-of-the-art instruments and techniques, analyze their own data as well as larger, more complex datasets, and understand the importance of water resources in society. The course will be offered for the first time in fall, 2016.
- At MTU, a module on Rio Grande water resources was developed for the undergraduate hydrogeology course. See http://www.mtu.edu/news/stories/2015/may/working-together-build-drought-resiliency.html
- We developed baseline indicators for measuring our progress in water resources education and institutional strengthening. The indicators were chosen to reflect measurable research, extension, education, and institutional strengthening outputs and outcomes. A tool for documenting the student training aspect of the project was also developed. Through the use of this tool we will collect, assess, and evaluate the participation of master's and doctoral degree students in the project, as the project unfolds. For a more complete and robust evaluation, monitoring of the indicators will be complemented by focus group discussions with stakeholders, e.g., farmers, students, and faculty, to illuminate what is working well, what needs attention, what lessons are being learned, and to capture positive unanticipated outcomes.
- As part of its commitment to institutional strengthening, UTEP has hired Dr. Ali Mirchi, whose expertise is in water resources modeling. He has over ten years of training and experience using simulation and optimization methods, including system dynamics simulation, linear programming optimization, and hydraulic and hydrologic software packages such as HEC-RAS and HEC-HMS. Most recently he has been participating in an NSF-funded interdisciplinary project in south Florida where he applies hydro-economic optimization modeling to explicitly incorporate the value

of water for preserving ecosystem services alongside water supplies to the Everglades Agricultural Area and urban areas of south Florida's lower east coast. He will be contributing to our project by developing integrative water resources systems models, teaching water resources courses and education modules, and advising graduate and undergraduate students.

VI. Training and Professional Development

UTEP

- Omar Sulaiman Belhaj, Ph.D. student, Env Sci & Eng (ESE) program – reviewed and summarized literature; collected and collated model input data
- Paul Brian Guerrero, M.A. student, Latin America & Border Studies – reviewed literature and co-designed household consumer interview questionnaire, performed household consumer interviews, assisted with stakeholder meetings, researched direct potable reuse
- Izel Barraza, M.A. student, Latin America & Border Studies – reviewed literature and co-designed household consumer interview questionnaire
- Estrella Molina, Ph.D. Student, ESE Program – reviewed Riverware model; described data needs; contributed data
- Luis Chavez Garnica, M.S. student, Comp Sci. – Developed web portal
- Armando Reyes, M.S. student, Comp. Sci. - worked on web portal
- Erick ? , B.S., Computer Science – worked on web portal

NMSU

- Cody Runyan, M.S., Water Science & Management Program – reviewed pecan orchard irrigation and water conservation literature; learned experimental techniques and equipment, planned irrigation experiments
- Margie Vela, Ph.D. student, Water Science & Management Program - reviewed literature, formulated water education plans
- Sarah Sayles, Ph.D. Student, Water Science & Management Program - took notes at stakeholder meetings, built prototype farm income optimization model, reviewed and developed irrigator survey questions.
- Befekadu Habteyes, Ph.D. Student, Water Science & Management Program - assembled data and developed basin scale water economics optimization model
- Sarah Acquah, Ph.D. Student, Water Science & Management Program - assembled data and developed basin scale infrastructure expansion model
- Dina Salman, Ph.D. Student, Water Science & Management Program - developed prototype groundwater economic optimization model
- Miranda Cisneros, B.S. student, Agricultural Economics & Agricultural Business Program - entered water supply and use data into spreadsheets
- Hugo Luis Rojas Villalobos, PhD candidate, Water Science & Management Program - administration of GIS data
- Olga Rodriguez, M.S. student, Water Science & Management Program – data compilation and analyses for model inputs

TAMU

- Shalamu Abudu, Postdoctoral Research Associate - conducted modeling research on hydrological aspects
- Carlos Castro, B.S. student - analyzed baseline properties of pecan field soils, installed irrigation sensors and data loggers, collected sensor data during the irrigation season
- Nesa Serrano, B.S. student - analyzed baseline properties of pecan field soils, installed irrigation sensors and data loggers, collected sensor data during the irrigation season
- Monique Ontiveros, B.S. student - analyzed baseline properties of pecan field soils, installed irrigation sensors and data loggers, collected sensor data during the irrigation season
- Joh Clark, Research Technician – managed data collected from field experiments

UACJ

- Victor Hugo Esquivel Ceballos, PhD candidate, Urban Planning Doctoral Program – collected and processed hydrometeorological data from regional weather stations
- Arturo Soto Ontiveros, PhD candidate, Urban Planning Doctoral Program - collected and processed groundwater data from official sources and evaluating ModFlow
- Ana Cristina Garcia Vasquez, M.S. student, Environmental Engineering – collected and analyzed groundwater quality data
- Oscar Ramirez Villazana, M.S. student - Environmental Engineering – Defined number of aquifer layers for the project through aquifer characterization using geophysics
- Alexis Gabriel Rodriguez Sanchez, B.S. student, Environmental Engineering – reviewed literature and reviewed SWAT model
- Angel Rafael Chavez Rodriguez, B.S. student, Geoinformatics – analyzed LULC geodata

UNM

- Fawn Brooks, PhD student, Earth & Planetary Sci (EPS) Department - reviewed literature on intermittent streams in the project study area; collected streamflow data
- Shaleene Chavarria, MS student, EPS Department - collected streamflow data, analyzed
seasonal streamflow forecasts on the upper Rio Grande

- John Carilli, B.S. student, Physics Department - processed surface hydrologic data for bucket model development

MTU

- Lauren Mancewicz, B.S. student, Environmental Engineering, - reviewed literature on water withdrawals, collected input data
- Leila Saberi, PhD student, Environmental Engineering - assisted in conceptualization of models

Professional Development

- Dr. Stanley Mubako, UTEP, successfully completed a one-week training course in Statistical Downscaling of Global Climate Models using the SDSM 5.2 model under support provided by this project, from December 7-11, 2015 at the Smithsonian-Mason School of Conservation, Front Royal, Virginia. The training focused on the use and application of this decision support tool for assessing local level climate change impacts, and was led by facilitators from the University of Prince Edward Island and University of Toronto in Canada, and Loughborough University in the United Kingdom. Capacity building accomplishments from the course include the ability to (1) access, carry out quality control, and statistically analyze climate data; (2) prepare scenarios of future climate change through ensemble and validation techniques; (3) download and use the SDSM 5.2 software to create a statistical model of climate observations for a region of interest; (4) create site-specific high-resolution scenarios of future climate change; and (5) understand applications of statistically-downscaled model results.
- Two students from UACJ in Mexico were trained in how to map cultivated areas using drones.
- One faculty member at UACJ in Mexico was received Water Harvesting Design Certification.

In addition to providing training and education to these individuals, we have listed and described accomplishments in education and institutional strengthening under Objective #6 in the Accomplishments section of the report.

VII. Dissemination of Results

[See Accomplishments under Objective 5 – Dissemination]

VIII. Plans for Yr 2 (by objective)

Objective 1. Model development, improvement, integration, validation.

1. The “one bucket model” is scheduled to be up scaled to a two-bucket and later a three-bucket model (representing the different aquifers and the river that interacts with them) that accounts for groundwater pumping, groundwater aquifer recharge, and water quality adjustments. In addition, climate data sets, water withdrawal data, and other relevant data are being assembled for use as model inputs. The model will be tested and validated in the coming year. Model validation will include model comparisons against actual surface inflows, changes in reservoir storage, reservoir releases, water used in agriculture, and water used for urban water supply for each year in the model’s time horizon.

2. USDA-ARS (Reno, OK) has recently produced an integrated surface-groundwater model by combining SWAT and MODFLOW. We plan to work with the team that produced this integrated model to test and validate the model for the Middle Rio Grande Basin. The integrated model needs to be modified to simulate salt fate and transport. Simulating salt leaching is fairly straightforward. Estimating the amount that is retained in soil is more difficult. Salt retained in the soil impacts productivity in at least three ways: a) direct toxicity to plants, b) clay dispersion and its impact on soil structure, and c) impacts on the osmotic potential of the soil and thus on water uptake by plants. In order to model the key processes, we need the spatial distribution of soil types and/or clay content in our study area, crop mix in our study area and the change over time, irrigation water quality (past and present), river water quality, amounts of fertilizer and other soil amendments added to crops, and drain concentrations of salt and flows. We will work with the USDA-ARS team to collect the necessary data and make modifications to the SWAT-MODFLOW model to simulate salinization. Bringing salinization processes into the SWAT-MODFLOW model represents a significant advance that will make this modeling suite more applicable to desert river systems common in the Middle East, South Central Asia, North Africa, and the west coast of both North and South America.

3. We will complete the urbanization/land use classification study that has been initiated. We want to ensure that the SWAT-MODFLOW model can be used to simulate land conversion/transition and the concomitant water use. We will inventory data needed for projecting current land use into the future, based on the current trends over time. We will evaluate the need for cellular automata or other approaches. We will use the results of our analyses to identify major land use types and assign water use to be used in the SWAT-MODFLOW model. We will develop rules for conversion of land to riparian uses, and develop storylines for particular stakeholder groups: e.g. farmers, environmental groups, academics.

Objective 2. Climate scenarios.

1. In addition to the "standard" scenario that has been described using the CMIP3 A1B scenario of increasing greenhouse gases, we will develop scenarios of projected climate change to be tested for model sensitivity and impacts on water resources, including:

a) the CMIP5 RCP8.5 scenario featuring a more rapid increase in greenhouse gases, with correspondingly more rapid climate change;

b) a scenario based on successful future implementation and extension of the COP21 Paris agreements resulting in a smaller magnitude climate change scenario;

c) climate variability corresponding to the 1950s drought, superimposed on climate change corresponding to A1B or RCP8.5 scenarios; this scenario would describe the intensification of severe drought under climate change;

2. Dendrochronological reconstructions of upper Rio Grande flows will be examined to consider extreme historical droughts, such as the drought at the turn of the 20th Century, or "megadroughts" in the late 1600s, etc.

3. Characterizing and predicting summer climate conditions, such as projected changes to the frequency and intensity of intense rainfall, are huge challenges for current models. In the short term, we will deal with this component of hydroclimate in a simple scenario fashion. For example, we will just assume something about the statistics of summer rainfall going forward and test the sensitivity of the bucket model to prescribed changes in summer precipitation statistics. The prescribed changes could be very simple, with minimal justification. As a medium-term effort, we could develop a strategy to produce new summer climate scenarios for the region (but this will be difficult).

4. D. Gutzler will continue to monitor the current climate situation as it evolves, in response to concerns expressed by stakeholders about El Niño forecasts, the "end" of early 21st Century drought, and the adequacy of seasonal forecasts for the Rio Grande headwaters. These topics seem somewhat beyond the scope of the core

activities of our project but because of stakeholder interests, we could consider ways to incorporate these topics into the education/ outreach components of the project and/or collaborate with USDA Climate Science Hubs.

Objective 3. Dynamic systems model.

[Activities on this objective will come later after there is more progress on Objs. 1 & 2]

Objective 4. Stakeholder engagement and participation.

1. We plan follow up meetings with the stakeholder groups established in Year 1. At the follow up meetings, we will share results from the first focus group and the online surveys back to the stakeholders for feedback. We will also present a way forward for our modeling work, discussing the key scenarios to be tested and some of the key questions to be addressed using the Bucket Model and the integrated SWAT-Modflow model. Also, we will present preliminary results from the urbanization analyses.

2. We plan one-on-one interviews with farmers to learn more about farmer decision making under conditions of limited water, and their resilience in the face of extreme drought. In addition, we will examine how forces like markets, insurance, and availability of resources affect farmer decisions. Also of interest is understanding which sources of information farmers find most useful in making decisions and how those sources have influenced farm decisions over the past decade or more. An interview instrument has been designed to elicit discussion of on-farm decision making and production history over the past 10-12 years, and plans for facing extreme weather events in the future. Interviews will commence shortly.

Objective 5. Dissemination.

Activities:

1. See above under “Stakeholder engagement and participation”. Results from focus groups will be shared back with stakeholders.

Objective 6. Water resources education and institutional strengthening.

1. We will implement the new field methods course at UTEP in fall, 2016 and offer a course in Water Resources Management in Civil Engineering, taught by the new strategic hire at UTEP.

2. During summer, 2016, we will develop a new course *Water Resources Issues and Solutions,* an interdisciplinary course based on problem-based learning. Students will work in teams to analyze a water resource issue/problem assigned to them and identify and assess potential solutions. We plan to share the course with our partner universities by video conference.

3. We will plan and host a student symposium in January, 2017, for students to present water-related research.

4. We will continue the Water Resources Seminar Series at UTEP, and will plan to offer some of the seminars via video conferencing to other sites in our consortium.

5. We will provide five undergraduate students at UTEP with internships. Internships will either provide undergraduates with research experiences or place students in water management agencies in the region, including the Bureau of Reclamation, Irrigation Management Districts, and others. Undergraduate research opportunities will be provided through UTEP or participating institutions. In addition to the training aspect of internships, they are also aimed at recruiting students into graduate studies in water resources or water-related degree programs.

IX. Major Problems or Requested Changes

Some requested changes are described below.

1. Model development, testing, and validation – We had anticipated using "off the shelf" models for our work. A key model that we planned to use, Riverware, is not yet tested sufficiently and not currently in the public domain for our use. We have changed our plans to using: 1) the simple Bucket Model that we developed ourselves for some answering some large scale questions and 2) the integrated SWAT-MODFLOW for others. SWAT-MODFLOW will require some modifications. Though we had planned to have ready to use models by the end of Year 1, we will be further developing and validating the Bucket Model and modifying and validating SWAT-MODFLOW during Year 2. This represents some delay but not a significant delay to meeting the milestones of our project.

2. Education and institutional strengthening – We had a 10% budget cut in Year 1 and we mainly eliminated some of the student activities to meet the budget cut. However, we are on track to catch up and implement a number of activities in Year 2, including two new courses at UTEP, continuation of Water Resources Seminar

Series, a student symposium, undergraduate student internships, and development of a new problem-based learning graduate course. This represents a change in our expected outputs in Yr 1.

X. Attachments

Attachment 1. Project participation [about 50% complete]

Role	Faculty and Non-Students	Students with Staffing Roles			Computed Total by Role
		Undergraduate	Graduate	Post-Doctorate	
Scientist	2.73	0.0	0.0	0.0	2.73
Professional	0.79	0.0	0.0	0.0	0.79
Technical	018	0.0	0.0	0.0	0.18
Administrative	0.50	0.0	0.0	0.0	0.5
Other	0.0	1.91	5.48	0.0	7.39
Computed Total	4.2	1.91	4.78	0.0	10.89

Attachment 2. Summary of stakeholder input

	Major Themes					
	Water Quantity/ Scarcity	**Water Quality/ Salinization**	**Drought/ Climate**	**Urbanization/ Urban Demands for Water**	**Agricultural Sustainability**	**Governance/ Politics/ Legal Issues**
Stakeholder Concerns/ Research Questions	• What do we have today • Surface - Groundwater interaction • Limits to pumping groundwater • Augmenting water supplies - Reuse - Desalination - Importation - Aquifer recharge and recovery	• Quality for different sources (surface, gw, reuse, etc.) • Salinity for different sources and how it changes with time and distance along the river • Salinization of soils/land and its impacts	• Look at the past • Look to the future • Is current drought over? • Desire for predictability	• Ag land lost to urbanization • Growing competition for water ("urban will win") • Demand projections in relation to economic growth in the region • Household demand; opportunity for conservation • Non-household demands, efficiencies to be gained	• The value of agriculture to economy and food security • The value of water • Management options for agriculture Alternative Crops Salt tolerant crops/ germplasm Alternative Irrigation strategies • Sustainability of small farms	• Ability in models to simulate across jurisdictional boundaries • Can we manage binationally • New policies need to be tried Water banking Transfers …Etc.

Attachment 3. Evaluation indicators

Table 3.1 Institutional strengthening indicators

Focal Project Areas	**Strengthening Indicators**	**Baselines *(Average over past 5 years)***	**Outputs/Year**	**Outcomes (Impact)**			**Objective(s)**
				Short Term	***Medium Term***	***Long Term***	
Research	• Publications in refereed journals						1,2,5
	• Papers presented at professional meetings						1,2,5
	• Poster papers at professional meetings						1,2,5
	• Workshops						3,4,5
	• Field days						3,4,5
Education	• Water-specific courses						5,6,7
	• Water-related courses						5,6,7
	• Water-related internships						5,6,7
	• Water-related research experiences						1,2,6
	• Water-related master's degree programs						1,2,6

Focal Project Areas	Strengthening Indicators	Baselines *(Average over past 5 years)*	Outputs/Year	Outcomes (Impact)			Objective(s)
				Short Term	***Medium Term***	***Long Term***	
	• Water-related doctoral degree programs						1,2,6
	• Water-related certificate programs						5,6
	• Water-related theses						1,2,5,6
	• Water-related dissertations						1,2, 5,6
	• Recruitment programs						6
Institutional Strengthening	• Retention programs						6
	• Mentoring programs						6
	• Professional development						5,6

Table 3.2 Master's and doctoral degree students in programs of study related to water

Project Partner:
September 1, 2015

	Enrl	Comp	#	%	Male	Female	White	Hispanic	Black	Native American	Other
Environmental Science											
Environmental Engineering											
Biology											
Chemistry											
Civil Engineering											
Environmental Science & Engineering (PhD)											
Geology											
Sociology											
Agriculture											
Economics											
Geography											
Other Water-Related											

Notes:
Data to be collected about master's and doctoral students in degree programs related to water
Enrl = The number of students enrolled in the programs in the fall semester of 2015
Comp = The number of students that graduated from the programs in spring of 2016, data to be provided end of Spring semester, 2016.

 # = Difference between enrolled in the program in fall semester and graduated in spring semester, i.e.,percent of enrolled that graduated.

This will enable tracking the individuals that enroll and graduate during the life of the project

Attachment 4. Executive summary of evaluator's report

EXECUTIVE SUMMARY

External Evaluation Report 1.0

I. Introduction

This report covers evaluation activities from January 1 through December 31, 2015. Activities conducted during this period are listed below. This report, however, concentrates on pre- and post-surveys conducted by project directors during meetings with nine stakeholder groups held from October 15 through December 8, 2015 in the El Paso area.

- Establishing and maintaining contact with the Project Director via email and telephone throughout this reporting period
- Participating in all scheduled coordinating phone conferences
- Meeting with Project Director in College Station, February 24, 2015
- Preparing for annual project meeting, March, 2015
- Participating in the annual project meeting at the University of Texas at El Paso (UTEP), April 13, 2015
- Meeting with Project Director in College Station, October 19, 2015
- Preparing survey instruments for stakeholder meetings, October, 2015
- Receiving completed surveys and analyzing data, November 7- December 15
- Preparing this report, December 16-30, 2015

This *Water Sustainability Project* ***focuses*** on the Middle Rio Grande Basin and ***proposes*** that "in spite of dwindling supplies, competing demands, and changing climate, sufficient water supplies can be achieved and managed to sustain irrigated agriculture in the desert Southwest through innovative management and technologies, collaborative decision making, and a better use of integrated data and models to inform policy."

The Water Sustainability Project's ***long-term goals*** are:

1) Improved management of regional water resources to sustain irrigated agriculture in the face of dwindling supply and competing demands.

2) Development of a platform for adaptive management, consisting of knowledge bases, scenario tools, and participatory learning processes, with lessons that can be shared with other sites facing similar challenges.
3) Strengthened capacity to train and prepare water resources professionals in interdisciplinary, holistic, integrative approaches, with a focus on increasing numbers of Hispanic students, which means that the professionals that are trained will also be culturally and linguistically appropriate for the region.

The Water Sustainability project's six ***objectives*** are:

1) Model Scenarios – Model medium to long-term climate scenarios and their impacts.

2) Integrate Simulation Models - Improve and integrate existing simulation models, including climate change impacts, surface-subsurface interactions and changing water demands.

3) Inform Stakeholders – Integrate existing models into a spatially explicit, dynamic systems model that can inform participatory stakeholder meetings.

4) Implement Stakeholder Participation – Implement a stakeholder participatory approach to modeling activities, and reflection/synthesis meetings where solutions will be formulated to:
   a) augment water supplies available to agriculture;
   b) optimize water allocations among competing demands; and
   c) improve water use efficiency and conservation, while reducing environmental impacts.

5) Disseminate Solutions – Disseminate solution technologies and management practices through traditional extension methods.

6) Education and Institutional Strengthening – Strengthen capacity to train water resources professionals. Design and implement a series of activities aimed at:
   a) recruiting and mentoring students in the program, especially Hispanic students;
   b) improving curricula at our partner institutions;
   c) increasing experiential learning, especially for undergraduates which could increase interest in further study of water resources in graduate school or pursuit of water resources careers;
   d) increasing problem-based learning and intensified research experiences; and
   e) exposing students to participatory approaches to research, modeling, and water resources management.

UTEP is the lead institution in this project. Partners are: New Mexico State University (NMSU), The University of New Mexico (UNM), Texas AgiLife Research Center at El

Paso, Michigan Technological University (MTU), and Universidad Autonoma de Ciudad Juárez (UACJ).

II. Method

This report focuses on pre- and post-surveys conducted by project directors during meetings with nine stakeholder groups held from October 15 through December 8, 2015 in the El Paso area. Following is a discussion of the overall evaluation of the project and the methods used for collecting and interpreting data for this report. The major results from these surveys are captured in a PowerPoint presentation attached to the report. (See section III for a summary of results.)

The overall external evaluation will focus on two aspects of the project: 1) baselines and 2) milestone outputs and outcomes regarding: (a) the research, extension, and educational components and (b) strengthening the capacities of partnering institutions. For the integrated research and extension component of the project, benchmarks and outputs in the timeline for the project were identified. Formative and summative approaches will be used to monitor (assess) the production of these outputs and evaluate progress. Data regarding research, extension, and educational components will be collected regularly by project staff and monitored by the evaluator.

The evaluation of educational program and strengthening components of the project are more difficult to evaluate, and the external evaluator will give particular attention to these. Upon approval of this project, participants and the evaluator will identify 10-15 key strengthening indicators to monitor for this project. These indicators will be chosen to reflect student and faculty participation, curriculum, experiential and problem solving-based learning, and research output. Examples include number of undergraduate and graduate students enrolled and graduated, courses related to water resources, research-based outputs in the form of posters, papers, and publications, and grant proposals submitted and approved. The evaluator will identify the necessary data and provide formats for collecting them for the research, extension, and education components and for the strengthening indicators. Base lines from the average outcomes from the past five academic years will be established.

Moving forward, yearly data regarding these indicators to assess progress will be collected. This process will be complemented with focus group discussions with students, faculty, and administrators to illuminate what is working well, what needs attention, and what lessons are being learned. While a specific ethnic outcome (increasing “minority” representation in the scientific workforce) cannot be established in advance, recruitment, course progress, research progress, and degree completion particularly for Hispanic students will be monitored.

Project leaders administered pre- and -post surveys to nine different stakeholder groups: (1) government agencies, (2) Texas small farmers, (3) Texas large farmers, (4) New Mexico small farmers, (5) New Mexico large farmers, (6) Mexican farmers, (7) Environmental stakeholders, (8) Urban/Industrial stakeholders, and (9) Social Justice stakeholders during the fall of 2015. The surveys were sent to the evaluator for analysis and reporting. It should be noted, however, that the pre- and post-survey instruments used with the government agencies were different from those used with the rest of the stakeholder groups, although there were two questions in the pre-survey and three questions in the post-survey questions that could be compared across all groups. (See section III in this report for copies of the survey instruments.)

Quantitative data were coded and analyzed using Statistical Analysis for the Social Sciences (SPSS). Responses to the pre- and post-survey instruments were compared across all groups for interpretation. (See section IV for the results of these quantitative comparisons.)

Qualitative data were content analyzed by two judges using an open-ended question data analysis method. These judgments were tabulated for interpretation. (See section V for the results of these quantitative interpretations.) It should be noted that two questions asked of farmers, which asked about number of acres farmed, number of irrigated acres, water allocation in acre feet, and crops grown during the last and current year were not analyzed. This was because too many farmers did not provide this information. However, the data collected is found in a tabulated form in section V.

IV. Results/Suggestions

As already mentioned, a summary of results is presented in the PowerPoint slides in Section III of this report. Readers of this report are encouraged to review and note this summary. Nonetheless, following are a few general points that merit mentioning.

1. The Project Director and other Leaders of this project are commended for their efforts to engage stakeholders that represent agricultural, environmental, and urban/industrial water users. Clearly, this is a challenging undertaking not only because these are often hard-to-engage audiences but also because of the

emotionally-charged topic of this project in which everyone has a stake to defend and protect their water.

Suggestion: That a lot of attention be given to how joint meetings of these stakeholders are conducted for limited intimidation and greater participation, in harmonious ways.

2. It appears that both Texas and New Mexico small and large famers have greater interest in the quantity and quality of water than the environmental, urban/industrial, and social justice stakeholders who are more concerned with water equity, impact on the environment, and education to the general public.

Suggestion: That the key contentions of these two large groups are openly discussed and that a process is carefully planned to ensure that all groups not only continue to participate but also expand their participation.

3. It feels like the surveys were too long and the respondents somewhat rushed to complete the surveys. It was also interesting to see a trend where farmers, particularly small farmers, tended to disagree or strongly disagree more with the post-survey statements than the other stakeholder groups. Furthermore, there were too many questions not answered and, in some cases, the questions may have been misunderstood.

Suggestion: That ample instruction and time is given during future meetings for collecting pre- and post-survey data.

4. Collecting data from stakeholders will be a pervasive challenge throughout the life of this project, as these data will inform reaching the objectives of the project and allow learning from the experiences of the project to make mid-course adjustments, if necessary.

Suggestion: That the experiences gained from this first set of surveys serve to make necessary adjustments in the content and process for collecting and analyzing future surveys.

VI. Next Evaluation Steps

A. Review the contents of this report with the Project Directors
B. Discuss and finalize the process and timeline for collecting baseline strengthening indicators for research, extension, education, and institutional strengthening
C. Participate in the annual project meeting on January 5-6, 2016

-end of executive summary-

UACJ Annual Report (2015-2016)
Prepared by
Dr. Alfredo Granados-Olivas
Mexican PI on the Project

1. Estimated FTE that you spent on the project as a fraction of 1.0, i.e. if you spent 50% of your time 0.50, if 10 %, 0.10, etc.

   0.75

2. FTE of other personnel working under your supervision in the following categories

   - Professional (pot-docs, research scientist)
   Dr. Luis Carlos Alatorre-Cejudo (0.25)
   Dr. Oscar Ibañez (0.10)
   Dr. Adrian Vazquez (0.10)
   Dr. Sergio Solis (0.10)

   - Graduate students
   Victor Hugo Esquivel Ceballos (PhD Student)(0.50)
   Arturo Soto Ontiveros (PhD Student)(0.50)
   Hugo Luis Rojas Villalobos (PhD Student)(0.25)
   Ana Cristina Garcia Vazquez (MS Student)(0.50)
   Oscar Ramirez Villazana (MS Student)(0.50)

   - Undergraduate students
   Alexis Gabriel Rodriguez Sanchez (Undergrad Student)(050)
   Angel Rafael Chavez Rodriguez (Undergrad Student)(050)

3. Number of total students, graduate and undergraduate, working on the project (not FTE, but how many individuals); for example you might have had a halftime graduate assistant, you report 0.50 above but 1 here; it’s how many indivdual students have worked on the project, not their percent time.

4. Products from the project activities that you produced, such as conferences, demonstrations, field days, symposia, workshops, trainings, curricula, models, software, manuals, etc.

   Mexican team has produced 3 workshop-training meetings within team members and students to update and schedule deliverables for the project as well as to define ongoing strategies for the data gathering process. One successful workshop conference with stakeholders on the farming community for the Mexican side of the project was accomplish; additionally, another one has been schedule with stakeholders with the formal water managers from Mexican agencies. Two meetings with local water agency officials (JMAS Technical Department) were accomplish to establish field strategies and archive access to water extraction volume from local aquifers.

5. Accomplishments – brief summary of major activities, data collected, modeling output, analyses, field research

   Among the major activities taken into account by the Mexican team during the first year was gathering data. Hence, a major accomplishment was the integration of a geodata for the study area related to water (surface and subsurface) infrastructure were the main irrigation channels were map as well as official groundwater wells with volume allocation and ownership were included. Furthermore, the LULC geodata was generated and potential ET values are been modeled based on a Remote Sensing approach. Statistics on ag production and value were integrated for the Mexican side on the project based on official data.

6. Opportunities for training or professional development that you have provided (primarily to students or perhaps to staff)

   Two students (one grad and one undergrad) are been trained on Precision Ag while mapping cultivated areas using the Dron for Precision Agriculture. This training will support calculation of cultivated areas and estimation on ETP. In regards to professional development, one professor will be specializing on Water Harvesting Design Certification with the Water Management Group (WMG) at Tucson, AZ.

ANNUAL REPORT

Yr 2, 2016-17

"Sustainable water resources for irrigated agriculture in a desert river basin facing climate change and competing demands: From characterization to solutions"

Prepared by:

W.L. Hargrove, PI

The University of Texas at El Paso

I. Scientific Participation

[See Attachment 1.]

II. Target Audiences

Our target audiences are all stakeholders concerned about the future of water in our region. We made a major, successful effort to identify and engage these stakeholders in Yr 1 of our project. This was achieved in two stages. First, we met with key leaders, agencies, and groups to introduce our project, obtain their reaction to our proposed activities, and solicit their guidance and collaboration in implementing the project, and second, we conducted a number of focus group meetings with key stakeholders to discuss their vision for the future of water in the region, their concerns and issues, and important research questions regarding the future of water. The results of these meetings were summarized in last year's report.

In the second year of the project we followed up with stakeholders to share what was learned in the first round of meetings and to present and discuss the various modeling tools that we plan to use in the project, including the Bucket Model that we are developing and the SWAT and MODFLOW models. In general, stakeholders have trust in these models as viable tools for use in the project. Much of Yr 2 was spent "backstage" from the target audiences, preparing and validating the models to be used, in order to return to the target audiences in Yr3 with models to address their questions and serve as a platform for further engagement.

III. Scientific Publications (alphabetical by senior author)

Eastoe, Christoper, Alfredo Granados-Olivas and Barry Hibbs, 2016. Tracers of Groundwater Mixing in the Hueco Bolson Aquifer, Ciudad Juárez, Mexico. Environmental & Engineering Geoscience, Vol. XXII, No. 3, August 2016, pp. 195–207

Granados-Olivas, Alfredo, Luis Carlos Alatorre-Cejudo, David Adams, Yolande L. Serra, Víctor Hugo Esquivel-Ceballos, Felipe Adrián Vázquez-Gálvez, Maria Elena Giner, and Chris Eastoe, 2016. Runoff Modeling to Inform Policy Regarding Development of Green Infrastructure for Flood Risk Management and Groundwater Recharge Augmentation along an Urban Subcatchment, Ciudad Juarez, Mexico, Journal of Contemporary Water Research & Education, Special Issue: Groundwater in Urban Areas. Issue No. 159, December 2016. Pag. 50-61. ISSN 1936-7031

Jones, S., and D.S. Gutzler, 2016: Spatial and seasonal variations in aridification across Southwest North America. Journal of Climate, v 29, 4637-4649.

Ramírez-Villazana, O., A. Granados-Olivas, A. Pinales-Munguía. 2016. Clasificación geoespacial de los indicadores del medio físico para la recarga del acuífero Palomas-Guadalupe Victoria, Chihuahua, México. *TECNOCIENCIA Chihuahua 10(1)*: 32-38.

Ward, F. A., Crawford, T. L. (2016). Economic performance of irrigation capacity development to adapt to climate in the American Southwest. Journal of Hydrology, 540 (September 2016), 757-773.

Ward, F. A. (2016). Policy Challenges Facing Agricultural Water Use: An International Look. Water Economics and Policy, 3(2), 14.

IV. Other Products/Outputs

1. **Enhancements to the project's web portal** (http://water.cybershare.utep.edu), including: a) a prototype online modeling interface available at https://water.cybershare.utep.edu/bucket_2/, and b) a workspace for project participants.

2. **The Bucket Model**, our simplified but comprehensive water budget model, was advanced as follows: a) a draft graphical user interface was developed, b) the model study area was established, c) the conceptual model of the system was refined to include an alluvial aquifer that can exchange water with the Rio Grande Channel model, d) preliminary computational models were developed in spreadsheets and

optimization software, and e) a framework for assembling model input data and data for model calibration was developed.

3. **A Water Symposium** was held at UTEP, January 4, 2017. A list of the 32 poster papers, mostly presented by students supported by our project, is presented in Attachment 2.

4. **Nineteen presentations** were made at professional meetings, listed in Attachment 3.

5. **Seven seminars** were presented in the Water Resources Seminar Series at UTEP. The topics and speakers are listed in Attachment 4.

6. **New courses**: a) at UTEP, "Regional Water Sustainability in a Changing Climate" was developed in Yr1 and was offered in Fall semester of 2016 (Yr2); and b) a new course was developed at UNM entitled "Climatic and Hydrologic Forecasting".

V. Accomplishments (by objective)

Progress towards goals is more medium to long-term and is accomplished through achieving objectives in the short-term. Accomplishments by objective in Year 2 of our project are listed below.

Objective 1. Model development, improvement, integration, validation.

- Five of our eight modeling work groups are working concurrently, each one focused on different modeling tasks that need to be addressed. They include: a) Developing, testing, and implementing the Bucket Model and SWATmf; b) Salt fate and transport/salinization; c) Land transition; d) Scenario formulation; e) Online modeling system. The remaining three groups will research impacts, once the modeling frameworks are in place.
- The project web portal has been further enhanced by creating a workspace so participants can directly share resources (i.e., publications, images, datasets) both internally with other participants and externally with the public. The web portal is available at https://water.cybershare.utep.edu .
- The "Bucket Model," a simple basin-scale water balance model that simulates all the major storages, sources, sinks, uses, and losses of water for the project area, continues to be improved. The Bucket Model team was expanded to include Luis Garnica Chavira (UTEP Computer Science), Dr. Rebecca Teasley (University of Minnesota-Duluth), and undergraduate and graduate students at MTU (see Section VI). The team meets for weekly, intensive discussion to solve problems, identify roles and responsibility and enhance coordination among the team preparing varying components of the model. Key advancements include (a) definition of study area boundaries, including sub-watershed and aquifer boundaries and accompanying spatial data; (b) processing of NASA datasets to obtain local, historical climate

inputs and output fluxes and accompanying local runoff; (c) development of model of physically-based aquifer-river channel exchange; (d) compilation of gauged flows along the portion of the Rio Grande in the project area; (e) preliminary identification of data sources for water withdrawals; (f) identification of preliminary climate scenarios (see Objective 2); and (g) identification of key model inputs and outputs to be displayed in the model user interface. Data collection and preliminary analysis of trends in upper Rio Grande streamflow and assessment of seasonal streamflow forecasts for the Rio Grande were conducted. Our analysis determined the three recent test years to be used in bucket model development; data acquisition and analysis were carried out to derive and compile the surface hydrologic values needed for the model.

- A basic semi-distributed hydrologic model was developed using Soil and Water Assessment Tool (SWAT) to simulate surface water processes in the Hydrologic Unit Code (HUC) 8 watershed that contains the Elephant Butte Irrigation District. The model simulates rainfall-runoff processes and streamflow routing, and recharge to groundwater, providing a tool for process-based modeling of the biophysical system whose outputs can be used as boundary condition for coarser-scale models (e.g., the bucket model). Efforts are underway to calibrate and validate the model with regional data to provide a basis for assessing water and land management impacts on water availability and flow.
- The first version of the modeling interface was developed and is available at https://water.cybershare.utep.edu/bucket_2/. The modeling interface enables user to graphically: i) define default or customized parameters representing human activities and climate scenarios, ii) seamlessly run the Bucket Model, iii) graphically explore the outputs of the model, and iv) graphically explore the sources and processing (provenance) of the data for validation purposes.
- Urban water use: Identified method for measuring water vulnerabilities for poor consumers: access; vulnerability to high cost water supply sources. UACJ team obtained urban water quality, supply, economics, and access data for Ciudad Juarez. A study of effects of positive, negative, and balanced framing information on attitudes toward direct potable reuse in El Paso was completed. We also conducted initial ethnographic fieldwork on small utilities: accomplishments and challenges in serving geographically and socially marginalized communities.
- Using satellite imagery from the past 25 years, estimates of land conversion were made in the area around El Paso and Las Cruces. This initial analysis forms the basis for modelling future scenarios of urbanization and its impacts on water use for the region. We are currently evaluating strategies for projecting the identified trends into the future.
- We are converting the existing Hueco Bolson MODFLOW model for groundwater flow simulation and groundwater availability assessment. It will be linked with SWAT. We are revisiting the RiverWare model as to its utility and its ability to link to or provide information needed for the Bucket model.
- We are assessing crop patterns, ET, land uses and water uses for agricultural production to improve the Bucket model and SWAT.
- Accomplishments on the Mexican side of the study area include the following: 1) a field assessment was done in Mexico’s Irrigation District 009-Valle de Juarez; static

and dynamic groundwater levels were measured at selected wells and groundwater samples were collected for evaluation of water quality; b) a Digital Terrain Model (DTM) was developed using the Mexican Elevation Continuous 3.0 (CEM 3.0), with a spatial resolution of 15 m, has a coverage for the entire continental territory of the United Mexican States, and has a mean square error of 4.8 m, INEGI. The altitudinal range shows elevations ranging from 997 to 2199 masl, and the average altitude for the entire area is of the order of 1321 masl; 3) for land use and land cover (LULC), several sources have been chosen, since the time scale of analysis includes from 1985 to 2015. Our map of reference is the cartography of land use and vegetation of the state of Chihuahua (1: 50,000), generated by the Government of the State of Chihuahua, and the valid period of this map is the year 2013. For others years we used the set of vector data of Datos Vectoriales de Uso de Suelo y Vegetación, scale 1:250 000, series I-V of INEGI, which correspond to the years 1985, 1995, 2000, 2007, 2013. Although we have a good data base, we chose to implement LANDSAT images for the years 1985 to 2015, it was necessary to perform classification processes using LANDSAR 5 TM and LANDSAT 8 OLI images. In general, the study area consists mainly of irrigation agriculture, temporary agriculture, human settlements (urban areas), induced pasture, natural grassland and mixed vegetation; 4) To determine the spatial distribution of the average evapotranspiration we chose to use the MODIS Evapotranspiration Data Set database, MOD16 ET, we obtained the mean values for the month of September, the month in which the evapotranspiration is more critical. The MOD16 ET datasets are estimated using Mu et al.'s improved ET algorithm (2011). The ET algorithm is based on the Penman-Monteith equation. Surface resistance is an effective resistance to evaporation from land surface and transpiration from the plant canopy; 5) In order to determine the spatial distribution of the different soil units, we used the vector dataset of Conjunto de datos vectoriales edafológico, escala 1:250000 Serie II. (Continuo Nacional-INEGI).

Objective 2. Climate scenarios.

- Re-analyzed data observed from surface hydrologic data for the expanded study area, including historic monthly values of precipitation, temperature, and surface evaporative fluxes in separate sub-basins of the study area to match the subdomains considered in the bucket model.
- Assessment of observed trends in snowpack and snow-streamflow relationships in the Rio Grande headwaters. This analysis is now being continued under separate support from USGS but our project will use these results as part of projected inflows downstream to Elephant Butte Reservoir.
- We expanded the historical baseline for observations of surface fluxes and upstream flows to the 20-year period 1991-2010. Final compilation of these data is in progress and should be completed by the end of Year 2 next month.
- Projected flows at San Marcial for the 21st Century, derived from a large ensemble of climate models coupled to a surface hydrologic model were assessed and compiled. These will be compared to observed historical flows early in Year 3 for the purpose of developing scenarios of upstream flow for the bucket and SWAT models.

Objective 3. System Dynamics Model.

- A conceptual model of El Paso water resources system was developed for use in a system dynamics modeling framework. The stock and flow simulation model will provide a tool for evaluating future water management policies and associated impacts on different system performance metrics such as reliability, vulnerability, and resilience. In the future, the Bucket Model or SWATmf might become components of this system dynamics model.

Objective 4. Stakeholder engagement and participation.

- We conducted a total of four stakeholder meetings, involving a total of about 50 stakeholders. At these meetings we presented results from the first round of stakeholder meetings regarding the vison for the future of water in the region, concerns and issues, and research questions of interest. We also presented an overview of each modeling tool, including the Bucket Model, SWAT, and MODFLOW. Stakeholders generally expressed at least some familiarity and trust in the models that we presented/discussed.
- A sample of residential consumers in El Paso and Ciudad Juárez was surveyed about water use and perceptions about the future of water. A study of the public policy process related to implementation of direct potable reuse as a technology/policy option by the Public Service Board in El Paso was initiated. We conducted a review of relevant documents and also face-to-face interviews with key actors/informants and residential consumers.
- We conducted one-on-one interviews with farmers to learn more about farmer decision making under conditions of limited water, and their resilience in the face of extreme drought. In addition, we will examine how forces like markets, insurance, and availability of resources affect farmer decisions. Also of interest is understanding which sources of information farmers find most useful in making decisions and how those sources have influenced farm decisions over the past decade or more. An interview instrument has been designed to elicit discussion of on-farm decision making and production history over the past 10-12 years, and plans for facing extreme weather events in the future. Interviews will commence shortly.

Objective 5. Dissemination.

- Stakeholders in southern New Mexico expressed an interest in water banking as a policy alternative to promote water conservation. Sarah Sayles delivered a seminar describing options for handling water banking, and presented it as a poster at the NMWRRI water conference in Silver City, October 2016. An abstract of her presentation as well as several other abstracts from that conference are posted on the web at https://nmwaterconference.nmwrri.nmsu.edu/poster-abstract-guidelines/poster-abstracts/

- We hosted a Water Symposium at UTEP and invited many of our stakeholders. We presented 32 poster papers summarizing some of our work. They are listed in Attachment 2.
- We participated in a conference in Dallas, TX entitled "New Cities, Future Ruins", a collaborative project between Southern Methodist University, UTEP, and Arizona State University. The focus of the conference and the project that is being initiated is to depict in various art forms the challenges of sprawling cities in the desert Southwest who face limited water and other resources. We made a presentation on the challenges of sustainable water resources in the El Paso region facing climate change and competing demands. One outcome of this project is that UTEP will host two or three artists in residence to work with our faculty and students on conveying messages about water through art.
- Presented our results to peers at annual NIFA Project Directors' meeting in Washington DC, October 12-13, 2016.
- Presentations to local stakeholders:
  - Hargrove and Heyman. Presentation to environmental consultative group of TX State Sen. Jose Rodríguez.
  - Sayles. Presentation to Las Cruces Rotary Club.
  - Richard Heerema. 'Irrigation scheduling', Western Pecan Production Short Course, Las Cruces, NM, October 18, 2016.
  - Richard Heerema. 'Measuring plant water status with a pressure chamber: a field demonstration', Western Pecan Production Short Course, Las Cruces, NM, October 19, 2016.
  - Richard Heerema and Marisa Potter. 'Scheduling irrigations with a pressure chamber', Western Pecan Growers Association Conference and Tradeshow, Las Cruces, NM, March 8, 2016.

<u>Objective 6. Water resources education and institutional strengthening.</u>

- New course developed in Yr1 at UTEP, "Regional Water Sustainability in a Changing Climate", was offered in Fall semester of 2016 (Yr2) at senior undergraduate and Masters graduate levels. The syllabus is provided in Attachment 5 . This course had a total enrollment of 26, 15 of whom were MS/PhD students and 11 were juniors/seniors. Our students were from diverse programs at UTEP, including Geological Sciences, Biological Sciences, Chemistry, Environmental Sciences and Engineering, and Civil Engineering. The course combined field trips, laboratory techniques, lectures, discussions and data exercises to cover topics such as quality and quantity of fresh water resources in our region and the challenges we are facing. The course was team-taught, and multiple projects were designed to understand and solve local and regional water-related environmental problems. Through hands-on experiences and field trips, students were trained to collect data using state-of-the-art instruments and techniques, analyze their own data as well as larger, more complex datasets, and understand the importance of water resources in the societal stability.

- A new graduate seminar course at UNM was developed, entitled Climatic and Hydrologic Forecasting, now in progress in the Spring 2017 semester; UNM PI Gutzler presented a well-attended (>150 people) departmental colloquium on hydroclimatic forecasting in the Earth & Planetary Sciences auditorium on 2 Sept 2016.
- Dr. Mirchi at UTEP developed and taught a new graduate level course in Water Resources Management (CE 6313) which was offered in Fall,2016 through Civil Engineering, and developed a graduate level course in Surface Water Hydrology (CE 5340) to be offered in Spring, 2017.
- At MTU, a module on Rio Grande water resources refined and presented in a 35-student undergraduate class on groundwater hydrology. A module also was developed for a 16-student graduate course on advanced hydrology.
- Dr. Rebecca Teasley from the University of Minnesota-Duluth, joined the MTU team in early 2016. Dr. Teasley is a water resources management expert who has prior research on water resources systems modeling in the Rio Grande basin, including modeling decision-making on water resources in the basin. She will co-advise the current MTU PhD student in the development of the water resources systems model and modeling decision-making.
- At NMSU, a seminar series was established beginning Fall 2016, with an emphasis on connections between water science, management, and policy. Five seminars were presented in the fall, most dealing with land or water resource issues in New Mexico. A new tenure track faculty member was hired to support New Mexico State University's Water Science and Management Degree Program, in Fall, 2016, Dr. Hatim M.E. Geli.
- Four undergraduate students at UTEP were supported in summer research internships. The students are listed under UTEP's contributions to training in Section VI. The students made a presentation about their internship to faculty and peers at a special event on 18 Aug., 2016.

VI. Training and Professional Development

We list below all the individuals who have received training or professional developmentthrough the project. *Denotes that the student was supported financially by the project. In addition to these, we have listed and described accomplishments in education and institutional strengthening under Objective #6 in the Accomplishments section of the report.

<u>UTEP</u>

- *Brian Guerrero, MA in Sociology (completed), thesis research on El Paso Water's new program of direct potable reuse.

- *Marlene Flores, MA in Latin American and Border Studies; research on small utilities, especially accomplishments and challenges in serving geographically and socially marginalized rural communities.
- William Vallee, M.A. in Political Science; thesis research on governance of transnational groundwater.
- Diego Sanchez, M.A. in Sociology; thesis research on household water consumption.
- *Omar Sulaiman Belhaj, Ph.D. student, ESE Program; received hands on training on land use land cover classification, reviewed and summarized literature, acquired and processed satellite imagery, prepared and presented a poster at the USDA project symposium at UTEP
- *Carlos S. Reyes, Undergraduate Intern, B.S. Environmental Science; classified satellite imagery for the study region; searched for research articles and summarized literature.
- Jose Caballero, B.S., Computer Science. Mr. Caballero received training in the use of General Algebraic Modeling System (GAMS) to apply his work on model integration funded by NSF Grant HRD-1242122 (Cyber-ShARE Center).
- *Oscar Ricaud, B.S., Computer Science; enhanced web portal to capture and generate aggregate data for project evaluation.
- Smriti Rajkarnikar, M.S., Computer Science; received training in the automated generation of models, inputs and outputs to apply her work on developing a generic provenance pattern to trace back model execution and data sources for the online modeling platform funded by NSF Grant HRD-1242122 (Cyber-ShARE Center).
- Raul Vargas, Ph.D., Computer Science; received training on visualization requirements for the project's web portal to enable the graphical visualization for provenance data of the models generated as part of his work on knowledge representation funded by NSF Grant HRD-1242122 (Cyber-ShARE Center).
- *Neelam Tahneed Jahan, M.S., Civil Engineering; collected and organized model input data, developed a basic SWAT model
- *Maryam Samimi, PhD student, Civil Engineering: reviewed literature; collected and organized model input data, helped with SWAT model design
- Majid Alahmoradi, M.S., Civil Engineering: reviewed literature; worked on system dynamics modeling
- *Tallen Capt, Ph.D., Civil Engineering – developed mathematical model for predicting daily water demand for El Paso as a function of average daily temperature, population, and several other factors.

<u>Summer Research Interns</u>

- Anna Piña. MS, Environmental Science Program. Examined water quality, groundwater depth and aquatic macroinvertebrate communities at the Rio Bosque wetland.
- Carlos Reyes, B.S. Geology. Study of urbanization using remote sensing.
- Joe Candelaria, B.S. Civil Engineering; EPWU wastewater treatment system and potential biogas production
- Gabby Porras, B.S. Civil Engineering. Urban water use modeling and fieldwork on

water quality and water treatment.

NMSU

- *Sarah Sayles, Ph.D. Water Science & Management Program; built prototype farm income optimization model for assessing water banking options in Rio Grande basin for adapting to future water supply shortages.
- *Befekadu Habteyes, Ph.D. Water Science and Management Program: calibrated bucket model for the Elephant Butte and Caballo Rio Grande Project region.
- *Sarah Acquah, Ph.D., Water Science and Management Program; identified and developed future hydrologic and policy scenario impacts to be evaluated by Bucket model.
- *Dina Salman, Ph.D., Water Science and Management Program; working with NMSU engineering professor to assemble crop ET data for New Mexico, Texas, and Mexico.
- Carlos Silva, Ph.D., Water Science and Management Program; working on groundwater-surface water models to support policy analysis as well as optimization models for irrigated agriculture in southern New Mexico.
- Hugo Luis Rojas Villalobos, PhD, Water Science & Management Program; administration of GIS data
- *Olga Rodriguez, M.S., Water Science & Management Program; data compilation and analyses for model inputs

TAMU

- *Shalamu Abudu, Postdoctoral Research Associate, Agricultural Engineering; conducted modeling research on hydrological aspects (RiverWare, MODFLOW)
- *So-ra Ahn, Assistant Research Scientist; conducted modeling research on hydrological aspects (SWAT)
- Erick Reynoso, Research Tech II – GIS and project area delineation
- *Darlina Prieto, Work-Study Student (UTEP), B.S. in Biological Sciences; Compile river flow and diversion data
- *Jacqueline Alfaro, B.S. Environmental Science: analyzed baseline properties of pecan field soils, installed irrigation sensors and data loggers, collected sensor data during the irrigation season
- John Clark, Research Technician – Helped in implementing and data management of laboratory, greenhouse and field experiments

UACJ

Undergraduate students:

- *Mariela Rascón Castillo, Bachelor in Geoinformatics, Department of Architecture, UACJ-Geospatial analysis
- *Mónica Quiñonez González, Bachelor in Geoinformatics, Department of Architecture, UACJ, ModFlow Modeling

- *Obed Alejandro Márquez Barraza, Bachelor in Geoinformatics, Department of Architecture, UACJ, ModFlow Modeling
- *Alfredo Jaquez Granados, Bachelor in Environmental Engineering (Ag Engineering Exchange student from UADHE) Precision Ag and eBee Drone mapping.
- *Ana Laura Ruiz Aragonez, Bachelor in Physics, Department of Physics, UACJ, Spectral analysis of imagery under SEQUOIA camera with eBee Drone
- *Alexis Rodriguez Sanchez, Bachelor in Environmental Engineering at the Department of Civil and Environmental Engineering, UACJ, SWAT geodata integration and modeling.

Graduate Students:

- *Oscar Ramirez Villazana, graduated from the M.S. Environmental Engineering program – He accomplished the first phase on the delineation of aquifer layers for the project through aquifer characterization using geophysics. Presently he has received an offer to work at the state level in Junta Central de Agua participating on an interdisciplinary team to apply these technologies to the planning and infrastructure development for new groundwater wells in the state of Chihuahua.
- *Víctor Hugo Esquivel Ceballos, PhD Candidate at the Urban Studies Program, Department of Architecture, UACJ, Urban Growth, population and groundwater path evolution at Ciudad Juarez, Chih.
- *Arturo Soto, PhD Candidate at the Urban Studies Program, Department of Arquitecture, UACJ, ModFlow modeling at study area in Mexico.
- *Hugo Luis Rojas Villalobos, PhD Candidate Water Science & Management Program at NMSU - administration of GIS data
- *Ana Cristina Garcia, MS Student at the Environmental Engineering Program, Department of Civil and Environmental Engineering, UACJ, Isotopic signature of groundwater samples at the Conejos Medanos-Mesilla Aquifer.

UNM

- *Shaleene Chavarria, MS, Earth and Planetary Science Department; collected streamflow and snowpack data, analyzed seasonal streamflow forecasts on the upper Rio Grande, presented results at NM State Water Conference and Fall AGU meeting.
- *John Carilli, B.S., Physics Department - processed surface hydrologic data for bucket model development
- *Justin Norris, B.S., Earth and Planetary Science Department; analyzed climate model projections of Rio Grande streamflow
- Yu Jin Sung, undergraduate exchange student from South Korea; analyzed surface hydrologic data as part of bucket model development.
- *Justin O'Shea, B.S., Earth and Planetary Science Department; analyzed summer season precipitation and streamflow upstream from Elephant Butte Reservoir and defended a senior undergraduate thesis on this work in December.

MTU

- *Lauren Mancewicz, B.S., Environmental Engineering, Intern; defined study area boundaries, including sub-watershed and aquifer boundaries and accompanying spatial database, collected input data for the bucket model
- *Leslie Hamar, B.S., Environmental Science, Intern; identified spatially-distributed water withdrawal data for the US portion of the study area
- *Ken Thiemann, Ph.D , Environmental Engineering; processing NASA datasets to obtain local climate inputs and output fluxes an accompanying local runoff; compilation of gauged flows along the study area Rio Grande reach; assembly of geodatabase for Bucket Model.

Professional Development

- Dr. Shalamu Abudu, TAMU, successfully completed a one-week training course on SWAT in January, which will help him configure and/or integrate SWAT and RiverWare model for water operations within the project area.
- Dr. Ali Mirchi spent one week in El Reno, OK at USDA-ARS lab to be trained on SWATmf by Dr. Daniel Moriasi.
- Professors and students involved in the project from UACJ were certified by SenseFly Inc as technical experts on Drone flight missions for Precision Ag Technology.
- Special training was accomplish during the fall semester 2016 for MS Student Ana Cristina Garcia from UACJ, at the Mexican Institute of Water Technology (IMTA) in Cuernavaca Mexico, specializing in isotopic analysis to evaluate groundwater quality and age.
- Dr. Sergio Solis, responsible for the UACJ SWAT modeling team, had a summer internship at the University of Warwick in England to evaluate and calibrate surface water modeling
- Dr. Luis Carlos Alatorre from UACJ participated at the XVII SELPER International Symposium celebrated at Puerto Iguazu, Argentina in Nov, 2016.
- Dr. Alfredo Granados from UACJ took a sabbatical leave at UTEP during 2016 to manage and administer the project and coordinate Mexican team efforts.

VII. Dissemination of Results

Dissemination of results is one of our objectives. See accomplishments for Objective 5 for a complete list of dissemination activities. Of particular note is the Water Symposium hosted by UTEP, where our students presented results. We invited many of our stakeholders to this meeting. We presented 32 poster papers, mostly by students supported on the project. They are listed in Attachment 2.

VIII. Plans for Yr 2 (by objective)

Objective 1. Model development, improvement, integration, validation.

- During Year 2, we decided to work on two models in parallel: the water-budget based “Bucket Model,” using aggregate stocks and flows; and the geographically specific, process-based SWATmf model. The reasons for using two models are (1) the models, after calibrated with historical data, can be used to make projections, and can be compared to each other to achieve additional confidence in projections; and (2) the Bucket Model is computationally fast, and thus well-suited for stakeholder participatory events (e.g., we can realistically run novel scenarios and interventions that stakeholders suggest on the spot, which we think is an important asset at meetings). On the other hand, the SWATmf model is computationally very demanding, but geographically specific. Evaluation of projections by SWATmf will have to be run by scientists and presented to stakholders, but can still serve as a very strong platform for discussion with stakeholders about future management, technologies, or policies. We think the effort of two models is justified by the unique utility of each with stakeholders.
- The Bucket Model will be validated using historical data and then deployed to evaluate projections into the future. Key advancements necessary to meet the milestone of having a complete model ready to be validated include (a) completing compilation of historical period model data inputs and data for model calibration, including climate fluxes and accompanying runoff; gauged flows along the Rio Grande, and water withdrawals and return flows; (b) model calibration; and (c) coordination with the development of the model user interface. To be complete, the Bucket model will be populated with improved crop ET data for New Mexico, Texas, and Mexico. It will also be expanded to “three bucketsl” to include the two major aquifers in addition to the river. This will allow the model to be upgraded to account for irrigation recharge to aquifers, evaporation from irrigation fields, urban and agricultural water use in Mexico, surface and groundwater interactions including seepage, pumping, and river-aquifer exchanges, and environmental values of water based recreation and environmental protection flows in selected parts of the basin. After validation with historical data, model capabilities will be presented to stakeholders and we will model projections into the future. Though we might start with projections of our choosing to demonstrate its capabilities, we will quickly get to projections of interest to the stakeholders.
- Progress on SWAT modeling will expand to include regional water management and use. Emphasis will be placed on calibrating the basic model using SWATCUP and manual calibration, and validating it based on regional water management operations, hydrologic patterns and observed trends in the Elephant Butte Irrigation District. We will also work on assembling the output of the SWAT to provide surface water boundary condition for running MODFLOW. Though the model is being built first for the Mesilla Valley portion of the basin in New Mexico, it will be expanded to include Texas and Mexico.
- There are particular needs to be able to model the Mexican side of the basin and aquifers, including: 1) development of GIS shapes to include all of the hydrology and channel network components on the Mexican side; 2) binational collaboration on the collection and review of weather data series, from monitoring sites on Mexico and US within the study watershed area; 3) binational development and revision of land

cover and use distribution maps, including the proper conversion from the FAO or USGS classification systems.

- We plan to create social layers in a GIS by: a) obtaining U.S. census tract shapefiles for study area; b) identifying key housing/water access variables from ACS and related key socio-economic variables; and c) collecting that data from ACS and attributing it to each census tract. We will work with the UACJ team to do the same thing for Mexican AGEBs (Mexican census units and data). We will follow the methodology of Mack and Wrase (2017, PLoS ONE 12(1):e0169488, integrating regional projections of water cost changes and pricing under conditions of long-term drought.
- With respect to assessing urbanization, a major issue of concern to our stakeholders, we plan to: 1) complete urbanization/land use classifications on an annual basis for the 25-year period 1990-2015, using the whole watershed boundary for the project region; 2) provide selected classified images for input to the SWAT-MODFLOW model for simulation of future land conversion/transition scenarios using agent-based modelling, cellular automata or other approaches; 3) provide 15m digital elevation model (DEM) for input to the SWAT-MODFLOW model; and 4) collect, process and harmonize water use data from Texas, New Mexico, and Mexico and provide it for input to the SWAT-MODFLOW model.
- The Online Integrated Modeling Interface will be extended to include: a) a 20 to 50 year planning horizon of scenario runs; b) storage and visualization of input climate scenario data; c) system interaction with excel; d) geo-referenced input/output visualizations; and e) comparison between different scenario runs. The graphical interface will go through formal usability testing before its first release for stakeholder usage.
- Several pieces of experimental work will be done to provide data for modeling or to better quantify processes that need to be modeled. These include: 1) ongoing field projects on water reuse, irrigation water conservation, and soil salinity management; and 2) a new activity to compare irrigation and salinity management under different irrigation systems (flood, drip and micro sprinkler). A new experimental irrigation system is being installed to enable testing of the principle of “partial root zone drying” for up to 10 acres of planted pecan trees on the NMSU Leyendecker farm near Las Cruces, NM. The goal is to discover opportunities to conserve water applied under a drip irrigation system with limited losses to yield and economic returns to pecan growers.
- Considerable work needs to be done to improve the estimation of ET for both the Bucket Model and SWAT. Some relevant data for ET exists in New Mexico and Texas. We will select additional relevant testing sites for ET estimates and physical measurements in Mexico.

Objective 2. Climate scenarios.

- Test the bucket model with a 20-year historical baseline developed from monthly averaged observations of upstream flow on the Rio Grande and estimates of surface hydrologic fluxes across our study area.

- As an initial controlled test of climate change impacts to the water budget, modify the time series of historical observations described above by a simple projected trend (developed from climate model projections), while keeping the interannual variability inherent in the historical observations fixed.
- Develop three projection-based future climate scenarios corresponding to severe projected climate change (RCP8.5), mitigated projected change (probably RCP2.6), and projected change in which a severe drought (either the 1950s drought, or a 'megadrought' inferred from paleoclimate records) is superimposed on a warming trend.
- Downscale the monthly averaged streamflow and surface flux data and projections to the daily time scale for use by SWAT.

Objective 3. System Dynamics model.

We will build a system dynamics simulation model beginning with a conceptual model of El Paso's water resources system, including water and wastewater treatment facilities and their daily operations to meet urban demand. We will also collaborate with computer scientists to develop the cyberinfrastructure to make a test version of the model available online. This prototype will be expanded to include the total water system with possible components that might include SWATmf.

Objective 4. Stakeholder engagement and participation.

We plan a series of follow up meetings with stakeholder groups to present and discuss modeling results, and introduce model user interface. We envision a series of short workshops centered on the theme of climate effects to achieve the following: 1) present model validation results for Bucket Model and SWAT, and demonstrate the model with historical data on the worst drought of record (1950's); 2) present model results for a couple of projected climate scenarios and use the results as a platform for discussion of climate, water supply, and water demand; and 3) introduce the user interface and make the Bucket model available to stakeholders to assess their own climate projections.

Objective 5. Dissemination.

- We plan to host the Water Symposium again in early 2018, including a poster paper session to allow our students to present their results.
- We will continue to make presentations to stakeholders as the demand/opportunity arises.
- We envision opportunities for demonstrating technologies through our field research including drip irrigation, water reuse, water conservation, and soil salinity management.

<u>Objective 6. Water resources education and institutional strengthening.</u>

- UTEP will offer the new field methods course again in fall, 2016 through the Environmental Science program, as well as the course in Water Resources Management in Civil Engineering. The instructors for both will incorporate the feedback that was received through the course evaluation conducted by the project evaluator in our project to revise and update the content. UNM will also continue its new class on Climatic and Hydrologic Forecasting.
- During summer, 2017, we will develop a new course *Water Resources Issues and Solutions,* an interdisciplinary course based on problem-based learning. Students will work in teams to analyze a water resource issue/problem assigned to them and identify and assess potential solutions. The course will be pilot-tested at UTEP with plans to disseminate it to our other partner institutions.
- We will host another water symposium in January, 2018, for students to present water-related research.
- We will continue the Water Resources Seminar Series at UTEP and NMSU and try sharing some of these through video conferencing with UNM and/or MTU.
- We will continue to provide undergraduate internships at UTEP, UNM, and MTU. We will provide at least five at UTEP. Internships will either provide undergraduates with research experiences or place students in water management agencies in the region, including the Bureau of Reclamation, Irrigation Management Districts, and others. Undergraduate research opportunities will be provided through UTEP or participating institutions. In addition to the training aspect of internships, they are also aimed at recruiting students into graduate studies in water resources or water-related degree programs.
- We are also planning two new activities: 1) an integrated Art/Environmental Science course with a focus on water. This will be done in conjunction with two artists in residence at UTEP and an art exhibition at UTEP's Rubin Center for Visual Arts entitled "New Cities, Future Ruins" addressing sustainability in the Sun Belt; and 2) in cooperation with the local State Senator Jose Rodriguez at his request, develop a high school/early undergraduate student engagement event addressing learning and careers in water resources.

IX. Major Problems or Requested Changes

1. A major challenge that has slowed our progress somewhat is getting the Bucket Model and SWATmf complete, running, and validated. Locating some of the data that we need has been a challenge, especially since our area of interest cuts across two U.S. states (Texas and New Mexico) and one Mexican state (Chihuahua). Harmonizing U.S. and Mexico data is a challenge. However, we are making progress and still anticipating having working models in about six months.

2. Given the political climate nationally, we are requesting to change the title of our project from **"Sustainable water resources for irrigated agriculture in a desert river basin facing climate change and competing demands: From characterization to solutions",** to: **"Sustainable water resources for irrigated agriculture in a desert**

river basin facing drought and competing demands: From characterization to solutions”

Changing the term “climate change” to “drought” simply avoids possibly being identified through searches for projects with “climate change” in the title.

X. Attachments

Attachment 1. Project participation

Role	Faculty and Non-Students	Students with Staffing Roles			Computed Total by Role
		Undergraduate	Graduate	Post-Doctorate	
Scientist	6.58	0.0	0.0	0.0	
Professional	1.38	0.0	0.0	0.0	
Technical	0.25	0.0	0.0	0.0	
Administrative	1.00	0.0	0.0	0.0	
Other	0.0	8.11	11.38	050	
Computed Total					

Attachment 2. Poster papers presented at Water Symposium.

1. Towards an Integrated Water Modeling User Interface for Stakeholders. Luis Garnica Chavira, Deana Pennington, Natalia Villanueva-Rosales, UTEP
2. Leveraging Self-contained Web Services for Specification, Execution and Storage of User-defined Scenarios of Scientific Models. Luis Garnica Chavira, Jose Caballero, Natalia Villanueva-Rosales, Deana Pennington, UTEP.
3. Economic analysis of water conservation policies for irrigated agriculture under drought scenarios: an integrated basin approach. Sarah Acquah, New Mexico State University.
4. Small Utilities Facing Drought and Water Quality Issues. Marlene Flores and Josiah Heyman, UTEP
5. Attitudes Toward Direct Potable Reuse of Water in El Paso. Brian Guerrero, UTEP
6. Water Matters: A Health Impact Assessment (HIA) in a U.S.-Mexico Border Rural Community Lacking Piped Water. Jesus Placencia, Michelle Del Rio, Amit Raysoni, and W.L. Hargrove, UTEP
7. Space-based monitoring of land-use/land-cover in the Middle Rio Grande Basin: An opportunity for understanding urbanization trends in a water-scarce transboundary river basin. Carlos S Reyes, Omar Belhaj, Stanley Mubako, W.L. Hargrove, Josiah Heyman, and Deana Pennington, UTEP
8. Changes in aquatic macroinvertebrate communities in a desert wetland and how these contribute to regional macroinvertebrate diversity. Vanessa Lougheed, Anna Piña, and Viridiana Orono, UTEP.
9. Feasibility of partial root zone drying for water conservation in southwestern pecans. Curt A. Pierce, Blair Stringham, and Richard J. Heerema, New Mexico State University
10. Use of Drones to Monitor ETP and Precision Agriculture at a Desert Watershed. Ana Laura Ruiz Aragonez, Alfredo Jaquez Granados, Dr. Alfredo Granados Olivas, UACJ
11. Analysis of urban growth of Ciudad Juarez, Chihuahua, Mexico: Impacts on the demand and water availability, and dejection of aquifer. Victor Hugo Esquivel Ceballos, Luis Carlos Alatorre Cejudo, Agustín Robles Morua, UACJ.
12. Rapid water storage estimation of water bodies through three-dimensional topobathymetric models constructed using sonar data and UAV-based photogrammetry. Hugo Rojas-Villalobos, Chris Brown, Alfredo Granados-Olivas, NMSU and UACJ.
13. Comparison of methods for evapotranspiration (ET) estimations, applied in the hydrological basin of Valle de Juárez, Chih, México. Alexis Rodríguez Sánchez and Sergio Saúl Solís, UACJ.
14. Heat waves in Ciudad Juárez, Chihuahua, Mexico for the period 2008-2016 and its effect on human health. Alejandra Nayeli Arauz Solano, Felipe Adrián Vázquez Gálvez and Angelina Domínguez Chicas, UACJ.

15. Availability of Groundwater and its relationship with Urban Development in Ciudad Juárez, Chihuahua: A retrospective and prospective analysis during the period 1980 to 2030. Arturo Soto Ontiveros and Alfredo Granados-Olivas, UACJ.
16. Isotopic study for the determination of the groundwater age in the aquifer Conejos-Medanos in Juarez, Mexico. Ana Cristina Garcia and Alfredo Granados-Olivas, UACJ.
17. Design and construction of a hydrometric station to measure flow at rivers applying the Arduino System. Miguel O. Durán Rangel; Adrián Vicente Peña López; Dr. Felipe Adrián Vásquez; Ing. Haimar Ariel Vega Serrano; Ing. Fabian Leonardo Yory Sanabria, UACJ and Liberty University of Colombia.
18. Urban growth in Ciudad Juárez (1995-2015): Impact on urban LULC and LULC of the territory. Mariela Rascón Castillo, Luis Carlos Alatorre Cejudo; Alfredo Granados Olivas, UACJ.
19. Modeling groundwater flows in the aquifer of Cuauhtémoc, Chihuahua, México: Visual MODFLOW. Obed Alejandro Márquez Barraza, Mónica Quiñonez González, Luis Carlos Alatorre Cejudo, and Alfredo Granados Olivas, UACJ
20. Projected Streamflow Changes in the Middle Rio Grande Basin. Justin Norris, David Gutzler, UNM.
21. Testing Impacts of Active Management and Policy Choices From Use of the Rio Grande Bucket Model. Dina Salman and Frank Ward, NMSU.
22. Utilizing NetCDF Data in Raster Form as a Means of Flux and Storage for Bucket Modelling on the Middle Rio Grande Basin. Ken Thiemann and Dr. Alex S. Mayer, Michigan Tech University; Dr. Rebecca Teasley, University of Minnesota Duluth; Dr. Frank Ward, NMSU; Luis Garnica Chavira, UTEP.
23. Using Boron isotopes to trace urban salinity inputs to the Rio Grande River in Southwest USA. Sandra Garcia and Lin Ma, UTEP; Pascale Louvat and Jerome Gaillardet, Institut de Physique du Globe de Paris, Paris, France.
24. Model Calibration for analysis of Stakeholder Preferences for Water Programs in the Middle Rio Grande Basin. Befekadu Habteyes, NMSU.
25. Principles Guiding the Design of Water Banking for Shortage Adaptation in the Middle Rio Grande River Basin. Sarah Sayles, NMSU.
26. Modeling Surface Water Availability in Elephant Butte Irrigation District. Neelam Tahneen Jahan, UTEP.
27. Impacts of environmental changes to the middle Rio Grande landscape on Ysleta del Sur Pueblo’s cultural and ceremonial sustainability. Andrea L. Everett, Deana D. Pennington, Tom Gill, UTEP
28. Provenance of integrated water modeling workflows using design patterns and controlled vocabularies. Smriti R. Tamrakar and Natalia Villanueva Rosales, UTEP
29. Approaches for Infilling the Incomplete Measured Eddy-Covariance Pecan Tree Evapotranspiration Data. Olga Rodriguez, Zhuping Sheng, Shalamu Abudu, Sora Ahn, Erick Reynoso, Jorge Chavez Frederick, and Darlina Prieto, Texas A&M AgriLife Research Center at El Paso.

30. Delineation of USDA Project Study Area. Jorge Chavez, Dr. Zhuping Sheng, Dr. Shalamu Abudu, Dr. Sora Ahn, Dr. Qi Liu, Olga Rodriguez, Erick Reynoso, and Darlina Prieto, Texas AgriLife-El Paso; Alfredo Granados Olivas, UACJ; Alex Mayer and Ken Thiemann, Michigan Tech; Rebecca Teasley, University of Minnesota Duluth; and Lauren Mancewicz, Michigan Tech.
31. A Predictive Water Demand Model for El Paso. Capt Tallen, UTEP
32. Changes in the plant community at the Rio Bosque, a created desert wetland. Lisa Baughman and Vanessa Lougheed, UTEP

Attachment 3. Presentations at professional meetings.

1. W.L. Hargrove and J.M. Heyman. 2016. "Sustainable water resources for irrigated agriculture in a desert river basin facing climate change and competing demands: From characterization to solutions". Poster paper presented at USDA-NIFA Annual Project Directors Meeting, October 12-13, Washington, DC.
2. Presentation to University of New Mexico Law School, 20 Oct 2016: Gutzler, D.S. and S. Chavarria: Climate Change and Streamflow in the Upper Rio Grande Basin.
3. Presentation to Los Alamos National Laboratory Climate Science Conference, Pojoaque NM, 16 Nov 2016: Gutzler, D.S.: Hydroclimatic Forecasting in the Upper Rio Grande Basin
4. Presentation to Fall Meeting of the American Geophysical Union, 12 Dec 2016: Gutzler, D.S., J. Carilli, J. Norris, J. O'Shea, M. Salgado and Y.J. Sung: Streamflow Outlooks for Southwestern Rivers in a Changing Climate.
5. Mirchi, A. "Modeling Water and Land Management Adaptation in New Mexico-Texas Border Region". Abstract submitted to and accepted for oral presentation at World Environmental and Water Resources Congress (EWRI 2017), May 21-25, 2017, Sacramento, California.
6. Title: Sheng Z., Abudu S., Michelsen A. J.P. King. 2016. Variable exchange between a stream and an aquifer in the Rio Grande Project Area, 2016 AGU Fall Meeting, December 12-16, San Francisco, CA, Abstract, Poster.
7. Abudu S., Sheng Z., Michelsen A., Rodriguez, O, King J.P. 2016. Evapotranspiration and Crop Coefficient for Pecan Trees in El Paso, Texas, Proc. Irrigation Show and Education Conference, December 4-7, Las Vegas, NV, 8p. Presentation.
8. Sheng Z., Michelsen A., Abudu S., King, P. 2016. How can a gaining river become a losing stream in an arid region? Universities Council on Water Resources/National Institutes for Water Resources Annual Conference, June 21-23, Pensacola Beach, FL, Abstract, Presentation.
9. Sheng, Z., Abudu, S., Rodriguez, O. 2016 Strategic water operations planning to tackle the drought in the El Paso-Juarez Valley along the Rio Grande, Proc. Of World Environmental and Water Resources Conference, ASCE, May 21-26, West Palm Beach, FL, Abstract, Presentation.
10. Zhuping Sheng and Shalamu Abudu made four presentations on "Overview of Hydrological Models in the Rio Grande Project Area" at Stakeholders meetings, May 18, May 19, May 24 and 25.
11. Ganjegunte, G.K. and J.A. Clark. 2016. "Improved Irrigation Scheduling for Freshwater Conservation in Pecan Fields of El Paso, Texas, USA". International Conference on Agricultural Sciences and Food Technologies for Sustainable Productivity and National Security, August 25-27, 2016, Bangalore, India (Invited Presentation).
12. Ganjegunte, G.K. 2016. "Using High TDS Waters for Irrigation". Invited presentation at TAMU-Institution de Recherche et de l'Enseignement Supérieur

Agricoles (IRESA) Linkage program Workshop, May 30 – June 6, 2016, College Station, TX (Invited Presentation).

13. Ganjegunte, G.K. 2015. “Salinity Management”. Invited presentation at “Training and Scientific Exchange Program” for “Delegation of High-Efficiency Use and Management of Agricultural Water Resources from Center for Agricultural Resources Research, Chinese Academy of Sciences”, September 17 – September 30, 2015, Texas A&M AgriLife Research Center at El Paso, TX (Invited Presentation).
14. Ganjegunte, G.K., and J.A. Clark. 2016. “Improved Irrigation Scheduling for Freshwater Conservation in Pecan Fields of El Paso, Texas, USA”. Proceedings of ASA, CSSA and SSSA International Meetings “Resilience emerging from scarcity and abundance”, 1 page [on Web], November 6-9, 2016, Phoenix, AZ. Abstract, Presentation.
15. Ganjegunte, G.K., and J.A. Clark. 2016. “Evaluation of Sulfur Burner for Salinity Management in Irrigated Cotton Fields in the West Texas”. Proceedings of ASA, CSSA and SSSA International Meetings “Resilience emerging from scarcity and abundance”, 1 page [on Web], November 6-9, 2016, Phoenix, AZ. Abstract, Poster.
16. Ganjegunte, G.K. 2016. “Salinity Management”. Presentation at Stake-Holders meeting for USDA-NIFA Project” Sustainable water resources for irrigated agriculture in a desert river basin facing climate change and competing demands: From characterization to solution” held on on May 18, 2016 at El Paso County Water Improvement District #1 Office, Clint, TX.
17. Overview of USDA Project and water issues in the Rio Grande basin: Seminar presentation at La Salle Beauvais Polytechnic Institute
18. “Space-based monitoring of land-use/land-cover in the Upper Rio Grande Basin: An opportunity for understanding urbanization trends in a water-scarce transboundary river basin”. Oral presentation at the 2016 Annual Fall Meeting of the American Geophysical Union
19. Students involved in the project from UACJ presented a poster at the “2do Congreso Internacional de Medio Ambiente y Sociedad” celebrated in Ciudad Juarez, Chih., Mex.

Attachment 4. Water Resources Seminars hosted at UTEP.

1. “Accelerate H2O: A New Statewide Water Initiative for Texas”, Ed Archuleta, Director of Water Initiatives, CERM, UTEP. Friday, March 18.
2. “Stakeholder Perspectives on the Future of Water in the Paso del Norte Region”, W.L. Hargrove, Director, CERM, & J.M. Heyman, Director, CIBS. Friday, April 15.
3. “The Evolving Water Crisis in the American Southwest”, Brad Udall, Colorado State University, Centennial Lecture at UTEP. Tuesday, April 26.
4. “A Systems Approach to Evaluating Water Management Scenarios in the Transboundary Rio Grande/Bravo Basin”, Rebecca Teasley, Assistant Professor, Department of Civil Engineering, University of Minnesota-Duluth. Tuesday, May 17.
5. “Water Resources Management in the Internet Age: Embracing the Data Deluge”, Suarav Kumar, Research Assistant Professor, Department of Civil Engineering, UTEP. Friday, September 23.
6. “The Thermoelectric-Water Nexus: Background and Future”, Gregory Torell, Assistant Professor, Natural Resources Economics, Texas A&M AgriLife Center – El Paso. Friday, October 28.
7. “Satellite-based hydro-economic analysis tools for agricultural water management: The importance of scale to address water poverty”, Marco P. Maneta, Associate Professor, Department of Geosciences, University of Montana, Missoula, Wednesday, November 16.

Attachment 5. Syllabus for new experiential learning field course in water sustainability

Regional water sustainability in a changing climate

ESCI 4315 (CRN#18202)/ESCI 5315(CRN#18212)

Wednesday 9:30-12:30; Biology B206

Fall 2016

Instructors:

Dr. Vanessa Lougheed: Office: 316 BIOL, Tel: 747-6887, email: vlougheed@utep.edu

Office Hours: by appointment

Dr. Lixin Jin, Office: 221A Geology, Tel: 747-5559, email: ljin2@utep.edu

Office Hours: by appointment

Guest Instructors:

Dr. William Hargrove: Office: 202 Kelly Hall, Tel: 747-6942, Email: wlhargrove@utep.edu

Dr. Stanley Mubako: Office: 210 Kelly Hall, Tel: 747-7372, Email: stmubako@utep.edu

Dr. Deana Pennington: Office: 305C Geology, Tel: 747-5867, Email: ddpennington@utep.edu

Dr. Shane Walker: Office: A305 Engineering, Tel: 747-8729, Email: wswalker2@utep.edu

Dr. Ali Mirchi: Office: A206 Engineering, Tel: 747-6908, Email: amirchi@utep.edu

Required Textbook: NONE

Goals:

This senior-level and Master-level course is team-taught. Multiple projects are designed to understand and solve local and regional environmental problems that are water-related. Through hands-on experiences and field trips, students will be trained to collect data using state-of-the-art instruments and techniques, analyze their own data as well as larger, more complex datasets, and understand the importance of water resources in the societal stability.

The objectives are to:

1. Increase awareness of water-related issues;
2. Provide experiential learning and train our students to become future water professionals;
3. Encourage team work and group discussion; and
4. Improve analytical, writing and oral skills.

Who are our water suppliers in the El Paso region today?

Tentative Schedule:

WEEK	TOPIC
1 (8/24)	Introduction: Global water cycles and water quantity (Jin, Lougheed)
2 (8/31)	Exercise 1: Effect of climate on stream discharge (Lougheed)
3 (9/7)	Exercise 2: Natural versus managed hydrographs (Jin)
4 (9/14)	*****Mandatory field trip ***** **NEW DATE** Visit USGS gaging station, collect water samples from Rio Grande, and measure stream discharge
5 (9/21)	Exercise3: Flood hazard evaluation for the region, NADP precipitation data (Jin)
6 (9/28)	Water policy, economics, trans boundary water issues (Ward)
7 (10/5)	Working across disciplines (Pennington)
8 (10/12)	Watershed Modeling (Mirchi)
9 (10/19)	GIS applied to hydrology (Mubako)
10 (10/26)	Water remediation and treatment (Walker)
11 (11/2)	Introduction on water quality & laboratory tours
12 (11/9)	*****Mandatory field trip ***** Agricultural drains and canals, Rio Bosque, wastewater treatment plant
13 (11/16-23)	Group Lab work-Data analysis (four groups)
14 (11/30)	Student discussion- group presentations - debate.

Grades:

	ESCI 5315	ESCI 4315
Weekly Assignments	75	85

Journal articles discussion	10	0
Participation and peer evaluation	15	15

Lecture notes, instructions, rubrics for reports and grades will be posted on Blackboard.

Course policies:

Class participation: You are expected to come to class prepared to answer questions about the assigned readings. Although attendance at each lecture is not mandatory, pop-quizzes may be given at any time during the lecture period and counted as a homework assignment.

E-mail and Blackboard:

You are required to provide the teaching team with a UTEP e-mail address and check your UTEP e-mail and Blackboard daily. We will use your UTEP e-mail to contact you and you will use your UTEP e-mail to contact us as well. Do not use Blackboard for e-mail.

Dropping the course:

Students may drop the class and receive a W (withdrawal) on their transcript prior to October 28th, 2016. You must consult the Instructor prior to dropping. Due to the University's six-drop rule, dropping the course may not be in your best interest. After April 6th, a drop will result in an F on your transcript. Receiving either a W or an F in any course may prevent you from meeting the satisfactory Academic Progress requirements necessary to receive financial aid.

Student Conduct:

Each student is responsible for notice of and compliance with the provisions of the Regents' Rules and Regulations, available at http://www.utsystem.edu/bor/rules/homepage.htm. All students are expected to behave as courteous, responsible adults. We will have frequent discussions and students are expected to tolerate and respect the opinions of others.

Cellular and electronic devices:

Cell phones and other electronic and recording devices must be turned off during class time to minimize classroom disruptions and protect the integrity of test-taking situations. This means you cannot make calls, send text messages, or use social media during class. You may use your laptop or tablet to take notes in class, but this privilege will be revoked if the devices are used inappropriately.

Students who fail to follow this rule may incur disciplinary action up to and including dismissal from the class and upon repeated offenses, the course.

Academic Integrity:

All graded assignments must be entirely the work of the *individual* student. *"Plagiarism" means the appropriation, buying, receiving as a gift, or obtaining by any means another's work and the unacknowledged submission or incorporation of it in one's own academic work offered for credit, or using work in a paper or assignment for which the student had received credit in another course without direct permission of all involved instructors.* (from the Regents' Rules and Regulations) Plagiarism is a serious violation of university policy and will not be tolerated. All cases of suspected plagiarism will be reported to the Dean of Students for further review.

Disability accommodations:

If you have or suspect you might have a disability and need an accommodation you should contact the Center for Accommodations and Support Services (CASS) at 747-5148 or at cass@utep.edu or go to Room 106 Union East Building. Students are responsible for providing any CASS accommodation letters and instructions. http://sa.utep.edu/cass/

ANNUAL REPORT

Yr 2, 2016-2017

"Sustainable water resources for irrigated agriculture in a desert river basin facing climate change and competing demands: From characterization to solutions"

Prepared by:
Alfredo Granados-Olivas, Mexico's PI
The Autonomous University of Ciudad Juarez

Section III. Scientific pubs (Note: most of these pubs are partially related to the project based on the ongoing Binational collaboration and student involvement on the project. We are planning to publish in Spanish at least one peer review paper in a Mexican journal, in which project participants (professors and students) are going to be invited as collaborators).

Granados-Olivas, Alfredo; Luis Carlos Alatorre-Cejudo, David Adams, Yolande L. Serra, Víctor Hugo Esquivel-Ceballos, Felipe Adrián Vázquez-Gálvez, Maria Elena Giner, and Chris Eastoe, 2016. Runoff Modeling to Inform Policy Regarding Development of Green Infrastructure for Flood Risk Management and Groundwater Recharge Augmentation along an Urban Subcatchment, Ciudad Juarez, Mexico, Journal of Contemporary Water Research & Education, Special Issue: Groundwater in Urban Areas. Issue No. 159, December 2016. Pag. 50-61. ISSN 1936-7031

Ramírez-Villazana, O., A. Granados-Olivas, A. Pinales-Munguía. 2016. Clasificación geoespacial de los indicadores del medio físico para la recarga del acuífero Palomas-Guadalupe Victoria, Chihuahua, México. *TECNOCIENCIA Chihuahua 10(1)*: 32-38.

Eastoe, Christoper; Alfredo Granados-Olivas and Barry Hibbs, 2016. Tracers of Groundwater Mixing in the Hueco Bolson Aquifer, Ciudad Juárez, Mexico. Environmental & Engineering Geoscience, Vol. XXII, No. 3, August 2016, pp. 195–207

Serra, Y., D. Adams, C. Minjarez-Sosa, J. Moker, Jr., A. Arellano, C. Castro, A.Quintanar, L. Alatorre, A. Granados-Olivas, E. Vazquez, K. Holub, and C. DeMets, 2016: The North American Monsoon GPS Transect Experiment 2013. Bull. Amer. Meteor. Soc. doi:10.1175/BAMS-D-14-00250.1, in press.

Section IV. Other Products/Outputs;
Professors and Students involved in the project were certified by SenseFly Inc as technical experts on Drone flight mission for Precision Ag Technology.
Students involved in the project presented a poster at the "2do Congreso Internacional de Medio Ambiente y Sociedad" celebrated in Ciudad Juarez, Chih., Mex. (Fig 1)

Fig 1. Poster Session at the International Meeting on Environment and Society

V. Accomplishments (by objective)
Objective 1. Model development, improvement, integration, validation.
Field work at Irrigation District 009 Valle de Juarez
Field Work was accomplished at Irrigation District 009-Valle de Juarez in Mexico while taking groundwater samples for quality and measuring static and dynamic groundwater levels at selected wells (fig 2, 3, 4 and 5)

Figure 2. Measuring groundwater levels at Irrigation District 009-Valle de Juarez, Chih.,Mexico

Figure 3. Analyzing groundwater quality from wells at Irrigation District 009-Valle de Juarez, Chih, Mexico

Figure 4. Irrigation ditch with mixed groundwater from well and treated waste water from Ciudad Juarez, Mexico.

Figure 6. UACJ team members during field work at Irrigation District 009- Valle de Juarez

Development of the Geospatial component of the project at CJ

The following describes the databases and methodological processes to be able to generate the geographic information of the territory included in the study area. In general, most of the information has been obtained from institutions such as the National Institute of Statistics and Geography (INEGI), National Commission for the Knowledge and Use of Biodiversity (CONABIO), National Water Commission (CONAGUA), United States Geological Survey (USGS-USA), among others.

The delimitation of the study area required several meetings to define the geographical limits of the watershed and sub-basins, this was necessary to guarantee compatibility with the database generated by our colleagues in the USA. The database of the hydrographic basin was obtained from INEGI, Red hidrográfica, subcuencas hidrográficas de México', escala: 1:50000. Edición: 2. The study area is comprised of 6 hydrographic sub-basins, which together have an area of approximately 4697 km2.

One of the most important aspects for the correct modeling with SWAT, among others, is to have a Digital Terrain Model (DTM) with good precision. Therefore, it was decided to use the Mexican Elevation Continuous 3.0 (CEM 3.0), with a spatial resolution of 15 m, has a coverage for the entire continental territory of the United Mexican States, and has a mean square error of 4.8 m, INEGI. The altitudinal range shows elevations ranging from 997 to 2199 masl, and the average altitude for the entire area is of the order of 1321 masl.

For the land use and land cover (LULC) present in the study area, several sources have been chosen, since the time scale of analysis includes from 1985 to 2015. Our map of reference is the cartography of land use and vegetation of the state of Chihuahua (1: 50,000), generated by the Government of the State of Chihuahua (local), and the valid period of this map is the year 2013. For others years we used the set of vector data of Datos Vectoriales de Uso de Suelo y Vegetación, scale 1:250 000, series I-V of INEGI, which correspond to the years 1985, 1995, 2000, 2007, 2013. Although we have a good data base, we chose to implement remote sensors to be able to generate information through LANDSAT satellite, for the years 1985 to 2015, it was necessary to perform classification processes using LANDSAR 5 TM and LANDSAT 8 OLI images (Table 1; Glovis USGS). In general, the study area consists mainly of irrigation agriculture, temporary agriculture, human settlements (urban areas), induced pasture, natural grassland and mixed vegetation.

Table 1. LANDSAT scenes for the construction of the mosaic of each year of study.

Images	Date	Sensor
LT50320381985185AAA02	04/07/1985	Landsat 5 TM
LT50320391985185AAA02	05/07/1985	Landsat 5 TM
LT50330381985144AAA07	24/05/1985	Landsat 5 TM
LT50320381995165XXX01	14/06/1995	Landsat 5 TM
LT50320391995165XXX01	14/06/1995	Landsat 5 TM
LT50330381995204XXX00	23/07/1995	Landsat 5 TM
LT50320382005176PAC01	25/06/2005	Landsat 5 TM
LT50320392005192EDC00	11/07/2005	Landsat 5 TM
LT50330382005215EDC00	03/08/2005	Landsat 5 TM
LT50320382008153PAC01	01/06/2008	Landsat 5 TM
LT50320392008153EDC00	01/06/2008	Landsat 5 TM
LT50330382008160PAC01	08/06/2008	Landsat 5 TM
LC80320392013214LGN00	02/08/2013	Landsat 8 OLI

LC80330382013173LGN00	22/06/2013	Landsat 8 OLI
LC80320392015204LGN00	23/07/2015	Landsat 8 OLI
LC80330382015163LGN00	12/06/2015	Landsat 8 OLI

To determine the spatial distribution of the average evapotranspiration we chose to use the MODIS Evapotranspiration Data Set database, MOD16 ET, we obtained the mean values for the month of September, the month in which the evapotranspiration is more critical. The MOD16 ET datasets are estimated using Mu et al.'s improved ET algorithm (2011) over previous Mu et al.'s paper (2007a). The ET algorithm is based on the Penman-Monteith equation (Monteith, 1965). Surface resistance is an effective resistance to evaporation from land surface and transpiration from the plant canopy.

In order to determine the spatial distribution of the different soil units, we used the vector dataset of Conjunto de datos vectoriales edafológico, escala 1:250000 Serie II. (Continuo Nacional-INEGI).

Development of the Soil and Water Assessment Tool (SWAT) model.

Central tasks developed from early 2016, with the objective to begin the construction of the SWAT model, were comprised mainly of information gathering, included but not limited to: Geographical Information Systems (GIS) maps, Digital Elevation Models (DEM), land use and cover, soil types, surface hydrology information, including major basin and sub-basins. Climatological databases from monitoring stations within the Mexican side of the watershed. Revision of gathered geodata, in terms of quality control, setup of previously defined coordinate system, datum, projection and other information, were conducted by PhD student Hugo Rojas who compiled and reviewed all of the initial information.

Familiarization of the SWAT model was done by completing the proper tutorial materials, revision of operational manuals and related academic articles. This allowed to identify the required steps and setup of components for the cited model. The watershed delineation tool highlighted several issues to be solved, when the hydrologic elements of the study system could not be accurately duplicated with the physical components within the basin. A revision of previous hydrologic models developed by public entities (IMIP, 2004), underlined the need to better define the extent of sub-basins and to incorporate the necessary point sources, inlets, outlets, control structures and channel network, in the SWAT model. For the definition of the Hydrologic Response Units (HRU) of the cited model, GIS Land use and cover layers are needed, these are currently being reviewed and developed using national coverage layers from the Instituto Nacional de Estadistica Geografia e Informatica (INEGI).

A number of online meetings and reunions from September through November, were conducted in coordination with our counterpart at the University of Texas at El Paso, in particular with Dr. Ali Mirchi, with particular emphasis in the sharing of knowledge and experience, regarding the data integration and watershed delineation at the border, from this several concerns were exposed between differences in data usage from the US and Mexican approaches, including the following:

- Necessity of bi-national data integration at the borderline (El Paso – Cd. Juárez)
- Watershed delineation and conection with US side (boundaries and sub-basins)
- Differences in watershed DEM pixel size (15m v 10m)
- Stream/Channel network delineation (Automatic v Physical based)
- Land Use/Cover classification maps conversion (FAO v USGS)
- Inclusion of water Source points and data (WWTP, Wells, Rio Grande, others)
- Outlet connections from US side to Rio Grande (WWTP, Pluvial, others)
- Agreement on common/shared GIS covers
- Agreement on Climatological data, sources, time series

From the US approach, they started with the selection of a sub-basin study area near Elephant butte dam for the completion of a SWAT model that when finished can be calibrated with measured field parameters, so this experience can be duplicated at other parts of the overall watershed area, at this point they have not begun the construction of the model within city environments. The Mexican effort began with the analysis of the upper part of the Mexican side of the watershed which included Cd. Juarez – El Paso areas. From the above approximation, it has been considered also to select a sub-basin area previously analyzed in terms of surface hydrology characteristics, within the Cd. Juarez area, in which a SWAT model can be completed for that particular area, and a calibration procedure can also performed, selection of such area still under discussion.

As part of the integration of students into this research project, during this period the undergraduate student Alexis Rodriguez Sanchez, from the environmental engineering program of the Universidad Autónoma de Ciudad Juarez, focused on the detailed analysis of Evapotranspiration (ET) processes and estimation models, as part of his dissertation, being able to produce a poster titled: *Comparison of methods for Evapotranspiration (ET) estimations, applied in the hydrological basin of Valle de Juárez, Chih., México*, under the supervision of Dr. Sergio Solis. Acquired knowledge from this work will be incorporated to the ET calculations incorporated within the SWAT model.

Development of the geodatabase architecture.

The database architecture consists of folders that store data, deliverable documents, maps exported to graphic formats, projects developed in ArcGIS, and various documents that support the products delivered (Figure 1). To maintain simplicity in data transmission, it has been chosen to work under the Dropbox structure. This has allowed a fluidity within the working groups and the project coordinator.

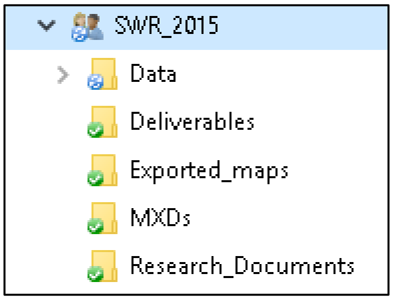

Figure 1. General database structure

Only the Data folder is the main working repository. This folder consists of five structured subfolders for collaborative work (Figure 2).

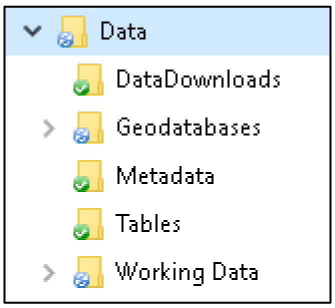

Figure 2. Data folder structure

Description of the DATA sub-structure.

The DataDownloads folder is a space that is used to download complementary data in raw format, ie original from the source.

The folder Geodatabases is the most important of the entire structure as it contains the geographic database that supports deliverables within the workflow of the project.

Although the Geodatabase contains the project metadata, the Metadata folder stores documents that describe and supplement, if necessary, the data stored in the Geodatabase.

Some of the information provided may include tabular data. These data can have different types as binary format, Excel, CVS, Text, and DBF.

Finally, the working data folder is a place where information is shared among the researchers of the Mexican side project.

Geodatabase Structure

The file geodatabase may contain spatial and non-spatial information such as vector and raster data, images, tables, toolboxes, and schematic datasets. One of the biggest reasons for choosing this type of structure is the storage capacity of the database that can be from 1 to 256 TB and has multiuser capabilities. The projection and the Datum are defined in WGS-1984 for UTM zone 13 for the whole project as a standard in the production and cartographic storage. This allows us to have a facility to export the information to any projection required by SWAT models.

The archive structure consists of a general data storage including Rasters and Images, a dataset of basic data as political boundaries of countries and states, populations, and other ancillary data, and a folder destined for data that is used in the SWAT modeling (Figure 3).

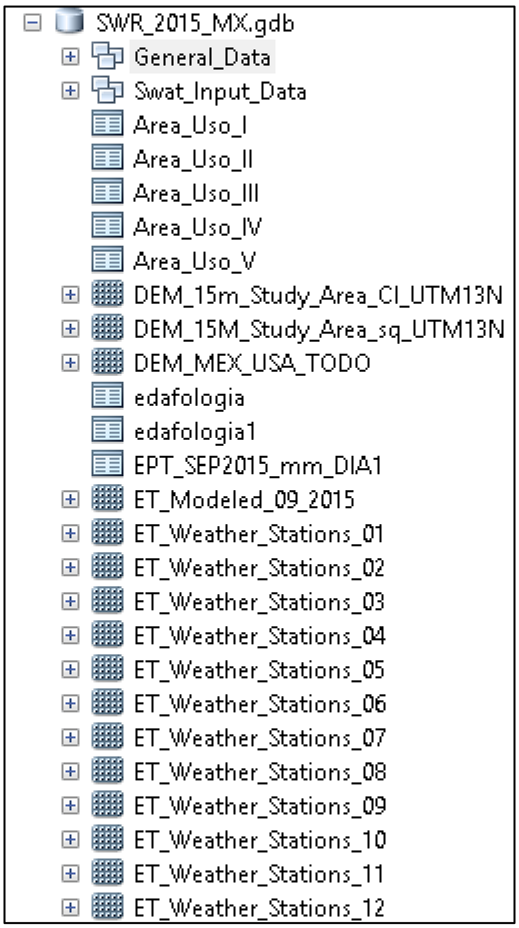

Figure 3. File Geodatabase structure

Objective 6. Water resources education and institutional strengthening.

Special training was accomplish during the fall semester 2016 for MS Student Ana Cristina Garcia, at the Mexican Institute of Water Technology (IMTA) in Cuernavaca Mexico, specializing on Isotopic analysis to evaluate groundwater quality and age.

Dr. Sergio Solis, responsible for the UACJ SWAT modeling team, had a summer internship at the University of Warwick in England to evaluate and calibrate surface water modeling

Dr. Luis Carlos Alatorre participated at the XVII SELPER International Symposium celebrated at Puerto Iguazu, Argentina in Nov, 2016.

Dr. Alfredo Granados took a sabbatical leave at UTEP during 2016 to manage and administrate the project and coordinate Mexican team efforts.

Section VI. Tranining and Professional Development

Undergraduate students:

Mariela Rascón Castillo, Bachelor in Geoinformatics, Department of Arquitecture, UACJ-Geospatial analysis

Mónica Quiñonez González, Bachelor in Geoinformatics, Department of Arquitecture, UACJ, ModFlow Modeling

Obed Alejandro Márquez Barraza, Bachelor in Geoinformatics, Department of Arquitecture, UACJ, ModFlow Modeling

Alfredo Jaquez Granados, Bachelor in Environmental Engineering (Ag Engineering Exchange student from UADHE) Precision Ag and eBee Drone mapping.

Ana Laura Ruiz Aragonez, Bachelor in Physics, Department of Physics, UACJ, Spectral analysis of imagery under SEQUOIA camera with eBee Drone

Alexis Rodriguez Sanchez, Bachelor in Environmental Engineering at the Department of Civil and Environmental Engineering, UACJ, SWAT geodata integration and modeling.

Graduate Students

Oscar Ramirez Villazana, graduated from the M.S. Environmental Engineering program – He accomplished the first phase on the delineation of aquifer layers for the project through aquifer characterization using geophysics. Presently he has received an offer to work at the state level in Junta Central de Agua participating on an interdisciplinary team to apply these technologies to the planning and infrastructure development for new groundwater wells in the state of Chihuahua.

Víctor Hugo Esquivel Ceballos, PhD Candidate at the Urban Studies Program, Department of Arquitecture, UACJ, Urban Growth, population and groundwater path evolution at Ciudad Juarez, Chih.

Arturo Soto, PhD Candidate at the Urban Studies Program, Department of Arquitecture, UACJ, ModFlow modeling at study area in Mexico.

Hugo Luis Rojas Villalobos, PhD Candidate Water Science & Management Program at NMSU - administration of GIS data

Ana Cristina Garcia, MS Student at the Environmental Engineering Program, Department of Civil and Environmental Engineering, UACJ, Isotopic signature of groundwater samples at the Conejos Medanos-Mesilla Aquifer.

Section VIII. Plans for Yr 3, by objective, esp. Objective 1, but others as appropriate. Please include expected outputs and outcomes.

Future work for 2017.

Objective 1. Model development, improvement, integration, validation.

The following tasks are envisioned to be developed during 2017, including but not limited to:

- Development of GIS shapes to include all of the hydrology and channel network components at the Mexican side of the project. We are expecting to have a final draft by May 2017.
- Binational collaboration on the collection and review of weather data series, from monitoring sites on Mexico and US within the study watershed area. Continuous during all year.
- Binational development and revision land cover and use distribution maps, including the proper conversion from the FAO or USGS classification systems. Final draft for Binational LULC information should be ready by May 2017.
- Develop the Soil Water Assessment Tool (SWAT) model, for the Mexican watershed study area; review all of the results from the constructed model. Final draft expected by May 2017.
- Experimental design for the selection of statistical relevant testing sites for ET estimates and physical measurements. Probably by sept 2017.

Estimates of ET at discrete sites, applying the selected modeling methodologies, analysis of obtained ET results, establish statistical correlations and errors. Probably by sept 2017.

  - Recollection and revision of stratigraphic and geologic databases, well pumping, recharge and hydrology data (from SWAT), and other pertinent data, for the construction of a Ground water flow model using Visual ModFlow. Probably by Oct 2017.
- Finish the integration of requested Mexican water related information for bucket model. Expected to be ready by the end of Feb, 2017.

Objective 4. Stakeholder engagement and participation.

We will call for two meetings at the 2017 fall semester: one with the farmer community and the other with official water agencies to show/evaluate outcomes of the first approximation to the modeling and will calibrate accordingly with their specific demands.

Attachment 1. Time commitment to project

Dr. Alfredo Granados Olivas 0.75 EFT
Dr. Luis Carlos Alatorre 0.50 EFT
Dr. Sergio Saul Solis 0.50 EFT
MS Arturo Soto 0.50 EFT
MS Victor H. Esquivel 0.50 EFT
MS Hugo L. Rojas Villalobos 0.25 EFT
MS Ana Cristina Garcia 0.50 EFT
Mariela Rascón Castillo 0.50 EFT
Mónica Quiñonez González 0.50 EFT
Obed Alejandro Márquez Barraza 0.50 EFT
Alfredo Jaquez Granados 0.50 EFT
Ana Laura Ruiz Aragonez 0.50 EFT
Alexis Rodriguez Sanchez 0.50 EFT

Note 1: Students (Grad and undergrad) are not allowed to work more than half of their enrolment time at UACJ.
Note 2: Attachment 2. (Summary of stakeholder input), are basically the same items requested by Mexican stakeholder participants.

Table 3.1 Institutional strengthening indicators

Focal Project Areas	**Strengthening Indicators**	**Baselines *(Average over past 5 years)***	**Outputs/Year**	**Outcomes (Impact)**			**Objective(s)**
				Short Term	***Medium Term***	***Long Term***	
Research	• Publications in refereed journals	2	3		X		1,2,5
	• Papers presented at	2	1	X			1,2,5

Focal Project Areas	Strengthening Indicators	Baselines *(Average over past 5 years)*	Outputs/Year	Outcomes (Impact)			Objective(s)
				Short Term	***Medium Term***	***Long Term***	
	professional meetings						
	• Poster papers at professional meetings	2	2	X			1,2,5
	• Workshops	2	1		X		3,4,5
	• Field days	5	2			X	3,4,5
Education	• Water-specific courses	2	1	X			5,6,7
	• Water-related courses	2	1	X			5,6,7
	• Water-related internships	2	2		X		5,6,7
	• Water-related research experiences	2	2			X	1,2,6
	• Water-related master's degree programs	2	2		X		1,2,6
	• Water-related doctoral degree programs	1	1			X	1,2,6

Focal Project Areas	Strengthening Indicators	Baselines *(Average over past 5 years)*	Outputs/Year	Outcomes (Impact)			Objective(s)
				Short Term	***Medium Term***	***Long Term***	
	• Water-related certificate programs	1	1		X		5,6
	• Water-related theses	2	2		X		1,2,5,6
	• Water-related dissertations	1	1			X	1,2, 5,6
	• Recruitment programs	1	0			X	6
Institutional Strengthening	• Retention programs	1	1	X			6
	• Mentoring programs	1	1	X			6
	• Professional development	2	2		X		5,6

Table 3.2 Master's and doctoral degree students in programs of study related to water

Project Partner: September 1, 2015								
	Enrl	**Comp**	**#**	**%**	**Male**	**Female**	**White**	**Hisp**
Environmental Science								
Environmental Engineering	6	2	30	30	1	1		2

Biology								
Chemistry								
Civil Engineering								
Environmental Science & Engineering (PhD)	1				1			1
Geology								
Sociology								
Agriculture								
Economics								
Geography								
Other Water-Related								

Notes:
Data to be collected about master's and doctoral students in degree programs related to wate
Enrl = The number of students enrolled in the programs in the fall semester of 2015
Comp = The number of students that graduated from the programs in spring of 2016, data to be prov 2016.
 # = Difference between enrolled in the program in fall semester and graduated in spring semester, i. graduated. *This will enable tracking the individuals that enroll and graduate during the life of the project*

ANNUAL REPORT

Yr 3, 2017-18

"Sustainable water resources for irrigated agriculture in a desert river basin facing drought and competing demands: From characterization to solutions"

Prepared by:

W.L. Hargrove, PI

The University of Texas at El Paso

I. Scientific Participation

[See Attachment 1.]

II. Target Audiences

Our target audiences are all stakeholders concerned about the future of water in our region, and as our approach is based on engagement and participation of stakeholders from beginning to end, their involvement is a process that builds upon each encounter. We made a major, successful effort to identify and engage these stakeholders in Yr 1 of our project. This was achieved in two stages. First, we met with key leaders, agencies, and groups to introduce our project, obtain their reaction to our proposed activities, and solicit their guidance and collaboration in implementing the project, and second, we conducted a number of focus group meetings with key stakeholders to discuss their vision for the future of water in the region, their concerns and issues, and important research questions regarding the future of water.

In the second year of the project we followed up with stakeholders to share what was learned in the first round of meetings and to present and discuss the various modeling tools that we plan to use in the project, including the Bucket Model that we developed and the SWAT and MODFLOW models. In general, stakeholders have trust in these models as viable tools for use in the project. Much of Yr 2 was spent "backstage" from the target audiences, preparing and validating the models to be used.

In Yr 3, we convened meetings with stakeholders to present validation results for the Bucket Model and to present the User Interface. We were successful in demonstrating the efficacy of the model in simulating the major parts of water supply including the reservoir storage, river flow, and decline of the aquifers as pumping increased. We presented results for a projected 10-yr drought. In Yr 4, we will evaluate a number of other climate scenarios, evaluate the impacts of competing demands, and begin to evaluate interventions to improve the sustainable use of water in the region. These will be presented to and discussed with stakeholders through group meetings.

III. Scientific Publications (alphabetical by senior author)

Acquah, Sarah, and Frank A. Ward, “Optimizing Adjustments to Transboundary Water Sharing Plans: A Multi Basin Approach,” Water Resources Management, DOI 10.1007/s11269-017-1794-3, August 2017.

Chavarria, S.B, and D.S. Gutzler, 2018: Observed changes in climate and streamflow in the upper Rio Grande basin. J. American Water Resources Assn., accepted for publication.

Cox, C., L. Jin, G. K. Ganjegunte, D. Borrok, V. Lougheed, and L. Ma. 2018. Soil Quality changes due to flood-irrigation in agricultural fields along the Rio Grande in western Texas. Applied Geochemistry 90:87-100.

Ganjegunte, G.K. and J.A. Clark. 2017. Improved Irrigation Scheduling for Freshwater Conservation in the Desert Southwest U.S. Irrigation Science 35: 315-326.

Ganjegunte, G.K., A. Ulery, G. Niu, Y. Wu. 2017. Effects of Treated Municipal Wastewater Irrigation on Soil properties, Switchgrass Biomass Production and Quality under Arid Climate. Industrial Crops and Products 99:60-69.

Ganjegunte, G.K., B. Leinauer, E. Sevostianova, M. Serena and R. Sallenave. 2017. Soil salinity of an urban park after long-term irrigation with saline groundwater. Agronomy Journal 109:3011–3018.

Ganjegunte, G.K., G. Niu, A. Ulery, and Y. Wu. 2018. Treated urban wastewater irrigation effects on bioenergy sorghum biomass, quality and soil salinity in an arid environment. Land Degradation & Development (In press; DOI:10.1002/ldr.2883).

Ganjegunte, G.K., G. Niu, A. Ulery, Y. Wu. 2018. Organic carbon, nutrient, and salt dynamics in saline soil and switchgrass (Panicum virgatum L.) irrigated with treated municipal wastewater. Land Degradation & Development 29: 80-90.

Granados Olivas, Alfredo, Arturo Soto Ontiveros y Ana Cristina García Vásquez, 2017. Agua del Valle de Juárez: caso localidad de Práxedis. El Valle de Juárez: su historia, economía y ambiente para el uso de energía fotovoltaica. El Colegio de Chihuahua, Esmeralda Cervantes Rendón / Coordinadora. Primera edición 2017. Pag 37-79. ISBN: 978-607-8214-43-3

Habteyes, Befekadu, and Frank A. Ward, "Economic Performance of Water Conservation and Storage Capacity Development to Adapt to Climate in the American Southwest," New Mexico Water Resources Research Institute Technical Report, July 2017.

Villanueva-Rosales, N., Chavira, L.G., Tamrakar, S.R., Pennington, D., Vargas-Acosta, R. A., Ward, F., and Mayer, A.S. (2017). Capturing scientific knowledge for water resources sustainability in the Rio Grande area. Proceedings of the Second International Workshop on Capturing Scientific Knowledge, D. Garijo and M. de Vos, Editors, December 4, 2017, Austin, Texas.

IV. Other Products/Outputs

Below is a brief description of some of the major products/outputs.

1. Enhancements to the project's web portal (http://water.cybershare.utep.edu), including: a) a functional online user interface (https://water.cybershare.utep.edu/bucket_05/home); and b) prototype online GIS for map display of model inputs and outputs.

2. USDA-Mexico WEB Portal, which is in Spanish, is hosted at the web address http://smiley.nmsu.edu/USDA_MEX which is developed with CSS and JavaScript,

based on a technique called Bootstrap. The main advantage of Bootstrap is that the website interface automatically adapts to the screen of a PC, a Tablet or other device such as a Smartphone. Bootstrap uses CSS3 modules that automatically allows the representation of content adapted to conditions of the screen resolution of the device.

3. The Bucket Model, our simplified but comprehensive water budget model, was improved and enhanced by adding a more comprehensive water balance model that accounts for all inflows (precipitation, river inflows, groundwater recharge, etc.) and outflows (evapotranspiration, river outflows, pumping) and determines storage in reservoir and groundwater aquifers and river flows in the project area. The User Interface was developed for stakeholders to run the model and interpret its output on a computer of their convenience. The Bucket Model can now be run as a spreadsheet water balance or a hydroeconomic optimization model.

4. A Water Symposium was held at UTEP, January 8, 2018. A list of the 29 poster papers, mostly presented by students supported by our project, is presented in Attachment 2.

5. Twenty-five presentations were made at professional meetings, listed in Attachment 3.

6. Five seminars were presented in the Water Resources Seminar Series at UTEP. The topics and speakers are listed in Attachment 4. Four additional seminars were delivered at NMSU: Michael D. Hatch, April 2017; Daniel Carter, April 2017; Rebecca Teasley, May 2017; and Rhonda Diaz, March 2017.

V. Accomplishments (by objective)

Objective 1. Model development, improvement, integration, validation.

- We have work groups working on different modeling tasks that need to be addressed. They include: a) Developing, testing, and implementing the Bucket Model and SWATmf; b) Salt fate and transport/salinization; c) Land transition; d) Scenario formulation; and e) the online user interface modeling system.
- The project web portal, available at https://water.cybershare.utep.edu, has been updated with new content and enhanced functionality for content management.
- A functional version of the user interface was developed and updated based on the most recent version of the Bucket Model

(https://water.cybershare.utep.edu/bucket_05/home). The modeling interface enables users to graphically: i) define default or customized parameters representing human activities and climate scenarios, ii) seamlessly run the Bucket Model, iii) graphically explore the outputs of the model, and iv) graphically explore the sources and processing (provenance) of the data for validation purposes. During the past year substantial functionality was added to enable processing of simulations with: different historical and future climate scenario inputs; customization of water supply inflows to Elephant Butte; different policy objectives; more complex crop data; many more parameter choices; faster display of results; improved organization of content and user interaction functionality; prototype display of input and output data in an online GIS; and download of data in JSON-LD format to promote data exchange with other relevant tools.

- The Bucket Model was advanced in several important ways. Sub-models were developed for reservoir evaporation rates, reservoir elevation-storage-surface area, irrigated agriculture evapotranspiration and return flows, urban evapotranspiration and return flows, groundwater-surface water exchanges, and groundwater elevations. Data and sub-models were incorporated into an annual water balance model. The annual water balance model was calibrated by varying a small number of parameters (pan evaporation coefficient, return flow coefficients for irrigated agriculture and urban water users, and aquifer storage coefficients and recharge) over the period 1993-2014. The calibration resulted in matches between modeled and observed data of R2 = 0.77 to 0.93, indicating successful calibration. The annual water balance model was converted from a calibration/historical period mode to a prediction/future periods mode. The predictive mode was used to simulate storages and flows for climate scenarios. The Bucket Model now simulates all the major sources, sinks, uses, and losses of water for the Middle Rio Grande. It is ready to be used as a decision support framework for improving our understanding of the basin, evaluating scenarios, and answering questions that are important to stakeholders. The Bucket Model can be used as a regional water budget accounting model as well as a hydroeconomic optimization model.

- To better assess urban water use, a daily water demand prediction model for El Paso was developed. Also, we are evaluating social justice issues related to urban water use. We identified a methodology (Mack and Wrase 2017) and gathered comprehensive data to model the social impacts on vulnerable consumers of long-term water trends, especially increasingly more costly alternative supplies. These data can be linked to Bucket Model projections.

- The GIS team produced historical and current land use/land cover maps and the results have been used for the Bucket model as well as by the SWAT modelling teams, to model the water use implications of land use change.

- The SWAT model was calibrated and validated for the HUC 8 watershed that contains the Elephant Butte Irrigation District in New Mexico and for the Texas/Chihuahua portion of the study area. MODFLOW models for the Hueco Bolson and Mesilla Basin were converted to the MODFLOW 2005 version for linkage between SWAT and MODFLOW. The model was validated in the Texas portion of the study area for a dry year, assessing the impacts of water supply, crop acreage, soil water storage, and groundwater recharge. Linkage of SWAT and RiverWare was developed to improve accuracy of simulation of flow as well as salinity loading. The model facilitates the assessment of climate change impacts on water availability. A spreadsheet reservoir simulation model was developed to simulate reservoir releases under projected inflows in order to facilitate the application of the SWAT model for climate change impact assessments. The process of integrating SWAT and MODFLOW for simultaneous simulation of surface water and groundwater processes is near complete. The Mexican team was able to run a preliminary assessment for surface water using SWAT in the Chihuahua portion of the basin. Twenty SWAT modeling exercises were developed, in four of the five sub-basins in Chihuahua, for the years 2005, 2007, 2009, 2011 and 2013.

- Progress in modeling salinity processes include development of a Bayesian Network to simulate factors that impact salinity; developing a system dynamic model in isee STELLA® for field scale salinity in cotton; modification of MODFLOW to add unsaturated zone flows and unsaturated zone chemistry, and to modify the RT3D model; and investigating the use of aerial sensing using UAS to assess crop yield, soil moisture, and salinity at a field scale.

- A complex surface drip irrigation system was installed in 2017 in a 10-acre block of ‘Pawnee’ pecan trees at the NMSU Leyendecker farm near Las Cruces, NM. The system design will permit testing the use of partial root zone drying and regulated deficit irrigation to conserve water while minimizing yield/economic losses where insufficient water is available to fully meet annual orchard evapotranspiration demands. The results will help calibrate our models with respect to water use by pecans, management interventions, and new technology.

Objective 2. Climate scenarios.

- We developed several different climate scenarios to use for simulations in the Bucket Model. These included a historical baseline time series using observed data for a 20-year period (1994-2013); two "extended drought" scenarios, in which the driest year in the data record (2011) was repeated five times, and another in which the driest three years (2011-2013) are repeated for a 20-year drought; and a climate change scenario in which projected streamflow into Elephant Butte Reservoir and precipitation over the study area through 2070 were adapted from a climate model simulation. Conducted preliminary climate change impact assessments using SWAT and reservoir simulation models.

- A medium stress climate scenario has been incorporated into the bucket model reflecting a series of climate stressed inflows through the year 2040. For two time periods (1994-2013 and post-2013) the climatic inputs that create streamflow in the simulation — snowpack in the headwaters, precipitation downstream — come from a freely-running coupled ocean-atmosphere climate model (the British HadGEM model). In addition, this particular simulation includes an imposed increase in future atmospheric greenhouse gases such that an additional 8.5 W/m^2 of longwave radiation reaches the surface by 2100 (the so-called RCP 8.5 scenario). Thus, the temperature gets warmer and snowpack ultimately decreases as the 21st Century proceeds, but with lots of precipitation variability superimposed on the greenhouse gas-forced long-term trends. The natural variability of this simulation includes a relatively wet decade in the 2020s so we anticipate it will provide an illuminating 'Future Baseline' simulation that will contrast dramatically with an imposed 20-year drought.

- Two climate scenarios were simulated with the annual water balance model. The climate scenarios provide river inflows to the project study area and local climatology. An extended drought scenario was simulated, which extends the 2011-2014 drought another five years. As expected, reservoir storage and surface water allocations dropped to minimum levels after another two-three years and groundwater pumping increased in response. A pessimistic, 30-year future climate scenario based on global circulation models was simulated. The sensitivity of reservoir storage and surface water allocations to future water demand and minimum reservoir storage constraints was explored, revealing that, over the expected ranges of water demand and minimum reservation storages, reservoir storage and surface water allocations dropped to minimum levels within 5 to 15 years.

Objective 3. System Dynamics Model.

- A system dynamics simulation model of El Paso water resources system was developed to investigate the effects of urban water management policies taking into account feedbacks between urban and agricultural water use.
- In predictive mode, the water balance model was extended to include several dynamic interactions, including evapotranspiration rates based on local climate, surface water allocations based on historical policies and minimum storage, and groundwater pumping rates based on surface water allocations.

Objective 4. Stakeholder engagement and participation.

- Through six meetings, we updated stakeholders—agriculture in New Mexico and in Texas; US government agencies and urban institutions; environmentalists; agriculture in Mexico and government/urban institutions in Mexico on basic features of the Bucket Model and its validation, simulation of a ten-year drought scenario, and demonstration of the user interface.

- Held one focus group meeting with environmental professionals to discuss ideas for modeling ecosystem services. The environmental stakeholders provided documentation on environmental flow policies for the Caballo-El Paso reach of the Rio Grande. The documentation includes recommended inter-annual frequencies, intra-annual timing (seasonal timing), flow durations (number of hours to days) of environmental flows along the Caballo-El Paso reach. This information is sufficient to impose environmental flow constraints in the water balance model.

- Farmer participatory field studies were initiated in cotton and pecan fields to determine on-farm irrigation water use efficiencies under different methods (flood, surge, and drip). In addition to WUE, we will be determining changes in salinity and sodicity within the root-zone to develop practices that can improve WUE without adversely impacting yield and soil properties (salinity and sodicity).

- Two "hands on" workshops were offered in Juárez, which were open to the public. Farmers, water officials, and the general public attended. Project overviews and modeling outputs were presented at two hands-on workshops where stakeholders from both farming communities and government offices in Mexico (ie. CONAGUA, CILA, JMAS, JCAS, SAGARPA). The User Interface was demonstrated and participants were allowed to manipulate parameters and observe preliminary outputs.

- Pecan producers and other regional growers were interviewed to develop a more comprehensive understanding of choices of water use patterns in agriculture as well as preferences for policies that would promote a more sustainable future.

- Midday stem water potential (i.e., plant water status) and soil moisture data were collected at the end of three flood irrigation dry-down cycles in a mature 'Western' pecan orchard. Comparisons were made between trees at different stages of mechanical pruning re-growth, with the goal of describing how pruning affects pecan tree water requirements. These data may further allow pecan producers to fine-tune the application of such water conserving techniques as micro-irrigation, partial rootzone drying, and regulated deficit irrigation.

Objective 5. Dissemination.

- Heyman, Josiah and Hargrove, William L. Listening to Complex and Diverse Stakeholders in the Paso Del Norte Water Region; presentation at Public Science Day in Santa Fe, NM; March 28, 2017.

- Report by Marlene Flores (GRA) on key findings of small utility project distributed to three utilities that provided interviews, Tornillo, TX; Anthony, TX; and Anthony, NM.

- Heyman presentation (regional water overview) to high school and college students at Water Resources and Conservation Symposium, July 14, 2017, sponsored by TX State Sen. José Rodríguez.

- Representation of project at Rio Grande/Rio Bravo Binational Forum on November 7-8, 2017, El Paso.

- Presentation on binational water issues to students from US and Mexico in study abroad exchange, through the 100,000 Strong in the Americas Innovation Fund awarded to UTEP and UNAM.

- Presented our results to peers through a poster paper at annual NIFA Project Directors' meeting in Washington DC, January 29-31, 2018.

- A book chapter was published that discussed water issues in the Lower Valle de Juárez, Irrigation District # 9.

- Presentation of project progress to the EBID Board of Directors, May 16, 2017

- Drought workshop co-sponsored with USDA Climate Science Hubs and TXAgriLife-El Paso; one-day workshop for stakeholders regarding how to manage under drought, August 15, 2017.

- Implemented two rainwater harvesting demonstrations in a colonia near Presidio, TX. The residents haul water for household use. Implementing rainwater harvesting to capture water for small livestock, gardening, and landscaping reduced hauled water by about half.

- Screened a documentary entitled "Last Call at the Oasis" and hosted a panel discussion about global and regional water management challenges at El Paso Convention And Performing Art Center, open to the public. A total of about 60 participants attended the event.

- One invited seminar delivered at Oregon State University by Frank A. Ward "Managing the Food-Energy-Water Nexus: An International Look," November 2017.

- Dr. Richard Hereema who participates in our project, worked with Western Pecan Growers Association Board to organize an educational program on water management at their annual conference and tradeshow, March 5-7. Two invited speakers spoke on aspects of irrigation efficiency in pecan orchards: 1) "Hedging and tree water stress", which led to an experiment conducted in the 2017 as part of the project; and 2) "Considerations in converting flood irrigated pecan orchards to micro-irrigation".

- Dr. Hereema presented at a pistachio workshop in Otero County, NM on the topic of "Orchard Irrigation".

- Dr. Hereema presented "Salinity Considerations for Pecan Orchards" at an El Paso County Pecan Growers Workshop on 5/11/17.

- Dr. Hereema published article in 2017 for Pecan South magazine (major trade magazine for pecan industry) on topic of Irrigation Scheduling.

Objective 6. Water resources education and institutional strengthening.

- Supporting role in water-themed study abroad program 100,000 Strong in the Americas Innovation Fund awarded to UTEP and UNAM.

- Dr. Pennington conducted a unique, ten-day summer workshop for Ph.D. students around the nation who are conducting research on large, interdisciplinary water resource projects. The workshop included content on regional water sustainability, methods that facilitate systems thinking and participatory modeling, and developed teamwork skills.

- A new graduate seminar course at UNM, entitled Climatic and Hydrologic Forecasting, was offered by the UNM PI in the Spring 2017 semester. The course evaluations from students were extremely enthusiastic (e.g. in response to the question "How much did you learn?" the average student score was 4.83 on a scale of 1-5).

- The Environmental Science undergraduate major at UNM was significantly revised to incorporate much more curricular structure, instead of just requiring a set number of credits from a wide variety of courses. The restructured major now includes required upper division courses in both Physical Hydrology and Climatology.

- Ms. Shaleene Chavarria, M.S. student at UNM supported by this project, graduated and now is employed by the US Geological Survey as a Hydrologist.

- The new course developed and offered at UTEP, "Regional Water Sustainability in a Changing Climate" in Yr2 was offered again in 2017 at the undergraduate level. The course had a total enrollment of 11. Based on student survey and evaluation results, we modified the course slightly, by incorporating lectures on application of remote sensing, and geophysics techniques in watershed hydrology and included two guest lectures from outside of UTEP discussing research, education, and outreach activities (Z. Sheng, Texas AgriLife), plus career options in water science (Amy Wagler, Frontera Land Alliance, NGO).

- Two students graduated from UACJ and presented theses related to the project. (one undergrad and one grad student).

- Dr. Ali Mirchi at UTEP developed and taught graduate level course in Surface Water Hydrology (CE 5340).

- An NMSU seminar series was established beginning Fall 2016, with an emphasis on connections between water science, management, and policy. Two seminars were presented in spring 2017, both of which dealt with land and water resource issues in New Mexico.

- Educational modules on the Middle Rio Grande system were developed and used in an undergraduate geohydrology class, a graduate hydrology class, and a graduate mathematical modeling course at MTU.

VI. Training and Professional Development

We list below all the individuals who have received training or professional development through the project. *Denotes that the student was supported financially by the project. In addition to these, we have listed and described accomplishments in education and institutional strengthening under Objective #6 in the Accomplishments section of the report. It is significant to note that 50% of the students supported by the project are Hispanic, an underrepresented group in water resources professions nationally.

UTEP

- *Brian Guerrero, MA in Sociology (completed), thesis research on El Paso Water's new program of direct potable reuse.
- *Marlene Flores, MA in Latin American and Border Studies (completed); research on small utilities, especially accomplishments and challenges in serving geographically and socially marginalized rural communities.
- Diego Sanchez, MA in Sociology (completed); thesis research on attitudes and behaviors to water among El Paso household consumers.
- *Karen De Anda, MA in Latin American and Border Studies; research on impact of water sustainability issues on alternative agriculture.
- *Evan Lopez, MA in Latin American and Border Studies; literature review on transboundary water on the U.S.-Mexico border.
- *Alondra Soltero, BS in Geological Sciences (completed); data compilation in ArcGIS on social variables in project study area.
- *Jose Caballero, MS in Software Engineering; research and development on the automated data exchange between the Water Modeling User Interface and the modeling system GAMS.
- *Omar Sulaiman Belhaj, Ph.D. student, ESE Program, UTEP – land use/land cover classification, acquired and processed satellite imagery.
- *Carlos S. Reyes, undergraduate research assistant, B.S. Environmental Science; classified satellite imagery for the study region. Graduated from UTEP with undergraduate degree.
- *Andrew Ellerson, M.S. in Civil Engineering; working on system dynamic modeling for field scale salinity and SWAT-MODFLOW-RT3D connection for salinity assessment.

- *Yohtaro Kobayashi, B.S. in Civil Engineering; working on developing a graphical model, based on Bayesian Networks, that can categorize the impacts of irrigation method on salinity.

- *Neelam Tahneed Jahan, M.S., Civil Engineering; collected and organized model input data, developed a basic SWAT model.

- *Maryam Samimi, PhD student, Civil Engineering; developed a SWAT watershed model and a reservoir simulation model for climate change impact assessment.

- *Tallen Capt, Ph.D., Civil Engineering – predictive modeling for municipal water consumption and wastewater production as a function of climate parameters.

- Alahmoradi, M., M.S.Civil Engineering; Graduated 2017; Thesis: Developing a system dynamics model of the El Paso water resources system.

Summer Research Interns

- Lisa Baughman, M.S., Environmental Science – "Wetland Vegetation Monitoring at the Rio Bosque Wetlands Park"

- Anna Ortiz, Ph.D. Environmental Science and Engineering – "Reactive Transport Modeling of CO2 Emission and Calcite Precipitation Kinetics in Dryland Agriculture"

- Ivy Trevizo, M.S., Environmental Science – "Climate Change Communication"

- Gerardo Montero, B.S., Civil Engineering – "Estimating Evaporation in the Middle Rio Grande Irrigation Delivery System"

NMSU

- *Sarah Sayles, Ph.D. Student, Water Science & Management Program - built prototype farm income management model for assessing water banking options in Rio Grande basin for adapting to future water supply shortages.

- *Befekadu Habteyes, Ph.D. Student, Water Science and Management Program - calibrated bucket model for the Elephant Butte and Caballo Rio Grande Project region.

- *Sarah Acquah, Ph.D. Student, Water Science and Management Program – assembled poster for project symposium meeting January 4, 2017, describing future hydrologic and policy scenario impacts for bucket model. Completed dissertation in December 2017.

- *Dina Salman, Ph.D. Student, Water Science and Management Program – working with NMSU engineering professor to assemble crop ET data for New Mexico, Texas, and Mexico. Completed dissertation in May 2017.

- Carlos Silva, Ph.D. Student, Water Science and Management Program – working on groundwater-surface water models to support policy analysis as well as optimization models for irrigated agriculture in southern New Mexico.

- Hugo Luis Rojas Villalobos, PhD Student, Water Science & Management Program - administration of GIS data

- Bernard Bah Kuma, PhD Student, Water Science & Management Program – economic optimization of water use patterns in a river basin with competing and complementary uses.

- *Olga Rodriguez, M.S. student, Water Science & Management Program – data compilation and analyses for model inputs.

- *Curt Pierce, M.S. student, Water Science & Management Program/Plant & Environmental Sciences Department—design and installation of drip irrigation system for pecan orchard experiments, data collection and analysis, assisting course instructor/co-teaching undergraduate-level irrigation and drainage course.

- Alfredo Aragon (major: Horticulture) and Daniel Ibañez (major: Geography), undergraduate students—assist with installation and running of micro/drip irrigation systems, assist graduate student and faculty with data collection/entry.

TAMU

- Minki Hong, Ph.D., Agricultural and Biological Engineering (TAMU), research on interaction of groundwater and surface water.

- Olga Rodriguez, M. Eng., Civil Engineering (NMSU), thesis research on water consumptive uses of pecan with Eddy Covariance observation.

- David Ruiz, B.Eng., Civil Engineering (UTEP), flow data compilation and analysis.

- Jeff Downey, PhD, Agribusiness and Managerial Economics. Examined water-energy nexus for electricity production and hydro-fracking.

- JhamnDas Suthar, an exchange student from Pakistan, has initiated a greenhouse study to evaluate salinity tolerance of cluster bean (Cyamopsis tetragonoloba L).

- John Clark (Technican), Carlos Castro (UTEP), Monique Ontiveros (UTEP) and Priscilla Reyes (UTEP) have been getting on the job training on field and laboratory protocols related to irrigation water use efficiencies, water reuse and salinity management practices.

Summer Research Interns

- Carolina V. Solis, B.S. Environmental Sciences – Geoscience (UTEP), compilation and analysis of groundwater data.
- Paola I. Soto-Montero, B.S. Environmental Sciences – Geoscience (UTEP), compilation and analysis of groundwater data, continued working at the Center after the summer intern.

Visiting Students

- Mingyi Huang, Ph.D. Water Conservancy and Hydropower Engineering (Hohai University), SWAT simulations and hydrological assessment.
- Xiaole Kong, Ph.D. Urban and Rural Planning and Management & Resources Environment (Chinese Academy of Sciences), Hydrological model simulation of flow and salt loading.

UACJ

Undergraduate students:

- Sergio Granados González and Gabriela Veleta Jáquez, Geoinformatics Bachelor Program at UACJ (Cuauhtémoc Extension). LULC development and geospatial analysis.
- Ana Laura Ruiz Aragonez, Physics Bachelor Program at UACJ. ETP analysis and Crop spectral signature using eBee Drone.
- Katya Esquivel Herrera, Geoscience Bachelor Program at UACJ. SWAT modeling

Graduate Students:

- Arturo Soto Ontiveros, PhD Program on Urban Studies; MODFLOW modeling.
- Hugo Luis Rojas Villalobos, PhD Program on Water Science and Management at NMSU. GIS Master and project web page.
- Ana Cristina Garcia, MS Environmental Engineering Program. Groundwater quality.

UNM

- *Nolan Townsend, M.S. student, EPS Department - worked on development of climate change scenarios, including the normalization of naturalized flow projections to make projected flows appropriate for use in models developed by the project.
- *John Carilli, B.S. student, Physics Department - processed surface hydrologic data for bucket model development; decoded daily precipitation and evapotranspiration data for use in environmental flow assessements.
- *Justin Norris, B.S. student, EPS Department - analyzed climate model projections of Rio Grande streamflow
- Sean Leister, B.S. student, EPS Department - analyzed relationships between temperature, precipitation and streamflow in the study area.

MTU

- *Jessica Alger, MS Environmental Engineering started as an hourly research assistant and is now an MS student working on reservoir evaporation and urban evapotranspiration modeling.
- *Ken Thiemann, PhD Environmental Engineering is the lead graduate on the development of the water balance model.
- *Azad Heidari, PhD Civil Engineering assisted in the development of irrigated agriculture evapostranspiration sub-models.
- *Marjan Monfarednasab, MS Environmental Engineering started as an hourly research assistant and is now an MS student working on groundwater-surface water exchange modeling.
- *Hannah Weeks, BS Geological Engineering assisted in the processing of data for the water balance model and the urban evapotranspiration model.
- *Tristan Odekirk, MS Environmental Engineering worked as an hourly research assistant on processing the groundwater elevation data and collecting literature on local groundwater aquifers.
- *Huiling Piao, BS Environmental Engineering assisted in the processing of data for the water balance model.

Professional Development

- *Maryam Samimi, Ph.D. student at UTEP, and So Ra Ahn, Post-Doc at TAMU-El Paso, attended a week-long training program on SWAT-MODFLOW coupling at Colorado State University.

VII. Dissemination of Results

Dissemination of results is one of our objectives. See accomplishments for Objective 5 for a complete list of dissemination activities. Of particular note is the Water Symposium hosted by UTEP, where our students presented results. We invited many of our stakeholders to this meeting. We presented 29 poster papers, mostly by students supported on the project. They are listed in Attachment 2.

VIII. External Evaluation (this section submitted by the External Evaluator)

The intent of the external evaluation is to contribute to the success of the project by a continuous formative assessment and summative evaluation of baselines and milestone outputs and outcomes regarding: (a) research, extension, and educational components and (b) institutional strengthening of participating universities. During this reporting period, six external evaluation reports informed project leaders to enable assessing progress, engaging with stakeholders, and learning from the experience to make adjustments, as necessary. This included preflection and reflection surveys and focus group discussions with seven interns, feedback and information from four model validation workshops conducted with government and urban stakeholders, environmental and social justice stakeholders, and New Mexico and Texas irrigators, and a mid-term external evaluation report prepared for the annual project meeting.

It is clearly evident that the project is having an important impact on graduate and undergraduate students involved in project activities, e.g., research experiences, presentations in conferences and workshops, publications, and internships. Evidence of this is the feedback received from seven interns who not only expressed learning a lot but also experiencing potential future work environments and networking with many professionals. At the same time, the interns provided feedback that will inform future internships.

Significant information was gained from four stakeholder group meetings where government and urban and environmental and social justice stakeholders may be more knowledgeable and interested in computer-based water sustainability modeling than irrigators. At the same time, irrigators want information that enables them to make short-term water use decisions in accordance with the markets of their agricultural products.

A project mid-term report indicated that impressive progress has been made with objectives 1, 4, and 6 and adequate progress has been made with objectives 2 and 5. Moving expeditiously to accomplish objective 3 and expanding and improving stakeholder participation will be the major challenges in years 4 and 5. However, it is extremely important to highlight an unanticipated outcome that merits special mention. It is the impact that this project is having on undergraduate and graduate students, post-doctoral fellows, and young professors. It is the way project leaders and partners, i.e., seasoned and experienced researchers, are modeling harmonious and effective efforts involving five universities and a myriad of researchers and students from a wide range of disciplines. They are modeling how to work in teams and how to be respectful and be able to give and receive constructive feedback. This is felt to be unusual in a project of this size that is addressing a very complicated issue with huge potential for long-term impact in similar conditions in many parts of the world. In the future, universities will need to respond to challenging scientific and political issues that cut across cultures, languages, religions, borders, and ideologies. Students and others who are participating in this project are witnessing how this project is led, which can serve as a model to be adopted/ adapted in a range of future efforts.

Summaries of the evaluation reports are presented in Attachment 5.

IX. Plans for Yr 4 (by objective)

Objective 1. Model development, improvement, integration, validation.

- With respect to the User Interface, we aim to have a version of the Bucket Model sufficiently ready for use by stakeholders in the User Interface by March 1, 2018. This version will contain all of the functionality deemed essential by team members, based on our experience and feedback from stakeholder meetings. We will freeze this version in the online interface so that it is consistent across the next set of meetings with stakeholders. This will enable interactive participatory modeling at organized stakeholder meetings as well as stand-alone user interaction via the interface. This central activity (participatory modeling of futures) of our project will move to the forefront in year 4. Based on feedback from stakeholders, we will continue to improve the User Interface version of the Bucket Model and the functionality and usability of the interface itself. Some of these improvements include:
    - Incorporate climate stress and temperature as drivers in the bucket model

o Incorporate meteorological and economic factors into urban water demand analysis.

o Allow stakeholders to raise water delivery efficiency to farm use from river diversions.

• Although we have a locked-in version for the user interface, we will also continue to improve the Bucket Model for use by researchers to address important research questions. The "three bucket model" is scheduled for additional upgrades to account for irrigation recharge to aquifers, evaporation from irrigation fields, urban and agricultural water use in Mexico, surface and groundwater interactions including seepage, pumping, and river-aquifer exchanges, and environmental values of water based recreation as well as environmental protection flows in selected parts of the basin. This will be accomplished by adding various submodels and improved crop ET data for New Mexico, Texas, and Mexico. For the hydroeconomic Bucket Model, we will allow choices that raise agricultural water price through increased scarcity or policy and assess those impacts.

• Environmental flow constraints for the Caballo-El Paso reach will be confirmed and constraints for the El Paso-Ft. Quitman reach will be developed. Naturalized flows time series will be analyzed to determine alternative environmental flow constraints. The water balance model will be used to investigate the impacts on storages and water allocations. Economic studies will be performed to determine the value of environmental flows by determining corresponding economic losses with the bucket-optimization model.

• The experimental irrigation system installed on the NMSU Leyendecker farm near Las Cruces will be used to collect important water use data and to test the strategy of partial root zone drying and deficit irrigation. The goal here is to discover opportunities to conserve water applied under a drip irrigation system with limited losses to yield and economic returns to pecan growers.

• GIS tasks in progress include production of annual land use/land cover maps covering the 25-year period 1990-2015; acquiring or estimating current and future water service coverage areas for the cities of El Paso, Las Cruces and Ciudad Juarez; and collection of geospatial data to assess social and geographic impact of present and future water policies. We will complete the remaining 40% urbanization/land use classification on an annual basis for the period 1990-2015, and harmonize water use data and water supply coverage areas from Texas, New Mexico, and Mexico as input to the SWAT-MODFLOW model.

• The calibration of the SWAT model will be completed for the whole study area. Linkage between SWAT and MODFLOW models will be accomplished with the SWAT-MF module. Impacts of climate change scenarios and extreme drought conditions will be evaluated using SWAT-MF by incorporating climate model inputs for inflows and temperature patterns. The water operations options will be generated with the

RiverWare model under extreme drought conditions for inputs into the SWAT-MF model. Spatiotemporal variation of water budget within the watershed will be assessed using the SWAT model, especially under extreme drought conditions. We will conduct a comprehensive climate change impact assessment using climate change scenarios and projected surface water flows. We will be able also to use it to evaluate interventions such as changes in management, technology, and/or policy.

- To evaluate costs and benefits of water allocation to riparian habitat, we will extend the hydro-economic Bucket Model to include environmental flows for Willow Flycatcher habitat. This will be used to determine the basin-wide opportunity cost of providing Willow Flycatcher habitat.

- Finish development of the Bayesian Network Model for Salinity. Generalize the Bayesian Network Model. Develop the System Dynamic Model for cotton, alfalfa, and pecan. Continue with efforts to link SWAT-MODFLOW-RT3D. Conduct field scale investigation of aerial imaging for salinity assessment.

- With respect to urban water demands, simplify water demand forecasting model to annual timescale and implement into the HydroEconomic Bucket Model to enable climate sensitivity for stakeholder engagement. Develop wastewater production model for annual water volume limit of direct potable reuse. Develop economic modeling for three alternative water supplies: brackish desalination, direct potable reuse, and interbasin importation.

Objective 2. Climate scenarios.

- We plan to (a) implement the extended 20-year drought scenario using the bucket model (b) examine additional climate model projections for the range of hydrologic futures implied by different model projections (c) extend our scenarios to higher resolution for use in spatially distributed hydrologic models (d) document and interpret these scenarios for stakeholders as part of the continuing dialogue with them. Task (d) may become more important as the potential for historic drought this water year unfolds.

- A new series of climate scenarios generated from the global circulation models will be simulated with the water balance model. An analytical frame work will be developed to determine risks to water storage and streamflows due to climate scenarios.

Objective 3. System Dynamics model.

- The dynamic interactions in the water balance will be improved, including evapotranspiration rates based on local climate, surface water allocations based on historical policies and minimum storage, and groundwater pumping rates based on surface water allocations.

- We will begin to model the urban/agricultural water interface, including existing and projected transfers between these sectors, and the hydrological effects of land use changes and alternative policies for that domain.

Objective 4. Stakeholder engagement and participation.

We plan a series of meetings with stakeholder groups to present and discuss modeling results, demonstrate the user interface, and encourage its use. We envision a series of short meetings, discussions, or focus group sessions focused on specific topics with modeling results. For example, we plan to present modelling results for a couple of projected climate scenarios of prolonged drought and use the results as a platform for discussion of climate, water supply, and water demand. We will also model interventions, such as changes in management, technology, or policy, as we move to a stage where we can discuss not only past patterns and future scenarios, but also the impacts of emerging solutions from farm to regional scale. We think this solutions approach will be engaging for stakeholders. Thus, this year will be an important stage in enacting our participatory modeling, now that we have usable models for exploring water projections and solutions.

In farmer participatory field research, we will continue evaluating irrigation water use efficiencies under different methods (flood, surge and drip). Determine changes in effective root-zone soil salinity and sodicity under different irrigation methods.

Objective 5. Dissemination.

- We plan to host the Water Symposium again in early 2019, including a poster paper session to allow our students to present their results.
- We will continue to make presentations to stakeholders as the demand/opportunity arises.
- We envision opportunities for demonstrating technologies through our field research including drip irrigation, water reuse, water conservation, and soil salinity management.

Objective 6. Water resources education and institutional strengthening.

- UNM will offer the course on hydrologic forecasting again in Fall, 2018.

- The “Regional Water Sustainability in a Changing Climate” course has been approved by UTEP Undergraduate Curriculum Committee, and we are in the process of making it a required course at the senior level for the Environmental Science program. In the next offering, we plan to include a bucket model exercise developed by the research team.
- We will host another water symposium in January, 2019, for students to present water-related research.
- We will continue the Water Resources Seminar Series at UTEP and NMSU and try sharing some of these through video conferencing with UNM and/or MTU.
- We will continue to provide undergraduate internships at UTEP, UNM, and MTU. We will provide at least five at UTEP. Internships will either provide undergraduates with research experiences or place students in water management agencies in the region, including the Bureau of Reclamation, Irrigation Management Districts, and others. Undergraduate research opportunities will be provided through UTEP or participating institutions. In addition to the training aspect of internships, they are also aimed at recruiting students into graduate studies in water resources or water-related degree programs.
- We are also planning an integrated Art/Environmental Science course with a focus on water. This will be done in conjunction with two artists in residence at UTEP and an art exhibition at UTEP’s Rubin Center for Visual Arts entitled “New Cities, Future Ruins” addressing sustainability in the Sun Belt.
- Educational modules for undergraduate and graduate classes will continue to be refined and implemented.

IX. External Evaluation

In the upcoming reporting period, the external evaluator will continue to be an integral working member of the project team and participate in all project planning meetings in-person or via phone and all project activities on the campuses of the university partners or off-campus at outreach events and activities of the university partners. Satisfaction surveys and/or focus group discussions will be used to assess successes and concerns of the project. Additionally, attention will be given to identifying other research questions that may emerge and merit illumination, registering unanticipated outcomes, and projecting possible next steps that may need to be taken that are beyond the scope of the project.

More specific, in the next reporting period the external evaluator will (a) collect formative evaluation data from all stakeholder groups, (b) prepare reports to submit to the

Principal Investigator; and (c) report findings to all partners and stakeholders at the annual project meeting in early 2019.

X. Major Problems or Requested Changes

We propose to add Dr. Blair Strigam, Associate Professor in Plant, Soil, and Environmental Science Department at NMSU as a collaborator/participant. We will submit his biosketch and a rationale for this addition in our renewal document.

XI. Attachments

Attachment 1. Project participation

Role Faculty and

Non-Students Students with Staffing Roles Computed Total by Role

Undergraduate Graduate Post-Doctorate

Scientist

6.0

Professional

Technical

3.25

Administrative

2.00

Other

20.5

Computed Total 11.25 9.8 9.2 1.5 31.75

Attachment 2. Poster papers presented at Water Symposium.

1. Improved Irrigation Methods for Conserving Freshwater in Irrigated Pecans of the Desert Southwest U.S. Girisha Ganjegunte, John Clark, Texas A&M AgriLife Research; W.L. Hargrove, UTEP; and Richard Heerema, NMSU

2. Urban Demand Forecast Modeling: A Systematic Approach to Modern

Modeling and Forecasting in El Paso. Tallen Capt, W. Shane Walker, and Ali Mirchi, UTEP

3. Combining geochemical tracers with geophysical tools to study sources of groundwater salinity in the Mesilla Bolson aquifer of the semi-arid Rio Grande watershed. Lin Ma, Matthew Hiebing, Sandra Garcia, Anna Szynkiewicz, Diane Doser; University of Texas at El Paso and University of Tennessee.

4. Middle Rio Grande Hydroeconomic Model for Policy Analysis: the Bucket Model. Frank A. Ward, New Mexico State University; Alex Mayer, Michigan Technological University; David Gutzler, University of New Mexico; Befekadu Habteyes, New Mexico State University.

5. Spectral Signatures of Chile and Bean Crop Fields: A geospatial analysis applying NDVI to evaluate potential water use efficiency for Precision Agriculture

Ana Laura Ruiz-Aragonez and Alfredo Granados-Olivas, UACJ/UADHE.

6. Temporal Evolution of Static Water Levels in Ciudad Juárez, Chihuahua applying geospatial modeling. Arturo Soto-Ontiveros and Alfredo Granados-Olivas, UACJ.

7. Integration of SWAT scenarios and geodata in a Web Map environment.

Hugo L. Rojas-Villalobos and Luis C. Alatorre, UACJ.

8. Supervised Classification Process for Land Use and Land Cover USA-México (2005-2015). Gabriela Veleta-Jáquez, Sergio Granados-Olivas, Luis Carlos Alatorre-Cejudo, Alfredo Granados- Olivas, UACJ.

9. On the Development of Hydrological Variables from the Hueco Bolson – Valle de Juarez basin, Using the Soil and Water Assessment Tool (SWAT). Katya Esquivel, Hollman Salazar, Sergio Saúl Solís, Alfredo Granados, UACJ.

10. Water Challenges for the Alternative Agriculture Sector: Initial Research Considerations. Karen De Anda, UTEP.

11. Mobility of Trace Metals in Agricultural Fields: A Quantitative Assessment of the Presence of Trace Metals in Soils and Groundwater. Emmanuel Sosa, Anna Ortiz, Lin Ma, and Lixin Jin, UTEP.

12. Water Matters: A Residential Rainwater Harvesting Demonstration in a Low Resource Community in Presidio County, Texas. Jesus Placencia, Michelle Del Rio, Jesus Baca, Miguel Fraga, and W.L. Hargrove, UTEP.

13. Changes in the water delivery system in a desert wetland and its effects on macroinvertebrate communities. Anna Piña, Viridiana Orona, and Dr. Vanessa Lougheed, University of Texas at El Paso.

14. SWAT Watershed Modeling Considering Auto-irrigation of the Agricultural Area in the Rincon Valley, New Mexico. Mingyi Huang, Sora Ahn, Shalamu Abudu, and Zhuping Sheng, Texas A&M AgriLife Research Center at El Paso; Ali Mirchi, William Hargrove and Maryam Samimi, University of Texas at El Paso; & Minki Hong, Texas A&M University.

15. Using Unmanned Aircraft System for Assessing Changes in Built Environment and Natural Systems. Wissam Atwah, Andrew Ellerson, Giselle Andrade, and Saurav Kumar, The University of Texas at El Paso.

16. Using a Bayesian Network based model to improve decision making for farms dealing with salinity. Yohtaro Kobayashi, Andrew Ellerson, Wissam Atwah, Saurav Kumar, UTEP.

17. IWASM: The Integrated Water Sustainability Modeling Framework. Luis Garnica Chavira, Git Gud Consulting SAS; Jose Caballero, Deana Pennington, Natalia Villanueva-Rosales, UTEP; Frank Ward, NMSU Alex Mayer, MTU, David Guztler, UNM.

18. Assessing Evapotranspiration of Pecan Tree using Eddy-Covariance Measurements. Olga Rodriguez, Mingyi Huang, Zhuping Sheng, Shalamu Abudu, Mingdong Zang, Texas A&M AgriLife Research Center at El Paso.

19. Linked SWAT and RiverWare Model for Monthly Flow and Salinity in Rincon Valley, New Mexico. Xiaole Kong, Mingyi Huang, Shalamu Abudu, So-Ra Ahn, Zhuping Sheng, Olga Rodriguez, and David Ruiz; Texas A&M AgriLife Research and Extension Center at El Paso.

20. Assessing Technology and Tools to Improve Water Management within the Rio Grande Basin. Allen Berthold1, Juan Enciso2, Alexander Fernald3,4, Hatim Geli3,4, Charles Hillyer5, Robert Sabie3,4, Zohrab Samani4, and Qingwu Xue2; 1 Texas Water

Resources Institute, 2 Texas A&M AgriLife Research, 3 New Mexico Water Resources Research Institute, 4 New Mexico State University, 5 Texas A&M AgriLife Extension.

21. Normalized Simulated Streamflow Estimates for Inflows into Elephant Butte Reservoir. Nolan Townsend and David Gutzler, University of New Mexico.

22. Modeling Hydrological Processes in New Mexico-Texas-Mexico Border Region

Maryam Samimi, Neelam Tahneen Jahan, and Ali Mirchi; Department of Civil Engineering and Center for Environmental Resource Management, The University of Texas at El Paso.

23. Recent developments in sub-models in the Middle Rio Grande Water Balance Model: Urban evapotranspiration, Reservoir evaporation, Groundwater-surface water interactions, and Groundwater elevation modeling. Jessica Alger, Marjan Monfarednasab, Tristan Odekirk, and Hannah Weeks; Civil and Environmental Engineering, Michigan Technological University; and Sara Alian, Department of Geological Sciences, University of Texas at El Paso.

24. A Comparison of Evapotranspiration Between a Natural and Engineered System in an Arid Basin Along the Rio Grande-Bravo River. Thiemann K.; Gutzler, D.; Mayer, A.; and Teasley, R.; Michigan Tech, University of New Mexico, and University of Minnesota-Duluth.

25. Analyzing Water Bank Success Markers for the Rio Grande Compact Region

Sarah Sayles, NMSU.

26. Statistical Analysis of Terrestrial Water Storage Change over Southwestern United States. Iyasu G. Eibedingil, Stanley T. Mubako, William L. Hargrove, and Alan C. Espino, UTEP.

27. Monitoring Impacts of Long-Term Drought on Surface Water Quantity and Quality in Middle Rio Grande Basin Reservoirs Using Multispectral Remote Sensing and GIS. Stanley T. Mubako and William .L. Hargrove, UTEP.

28. Partial root zone drying in field-grown pecans: is water use efficiency programmable? Curt A. Pierce, Blair L. Stringam, and Richard J. Heerema, NMSU.

29. Middle Rio Grande Land-use/Land-cover Change Detection 1994-2004.

Omar Belhaj, Carlos Reyes, and Stanley Mubako, UTEP.

Attachment 3. Presentations at professional meetings.

1. Flores, Marlene. Huge Farms and Small Municipal Water Systems under Conditions of Worsening Drought. Society for Applied Anthropology, Santa Fe, NM, March 29, 2017.

2. Garnica-Chavira, L., Caballero, J., Villanueva-Rosales, N., and Pennington, D. (2017). Leveraging self-contained Web Services for specification, execution and storage of user- defined scenarios of scientific models. Poster presentation. Annual Meeting of the USDA Middle Rio Grande Water Sustainability project, January 4, 2017.

3. Garnica-Chavira, L., Pennington, D., and Villanueva-Rosales, N. (2017). Towards an integrated water modeling user interface for stakeholders. Poster presentation. Annual Meeting of the USDA Middle Rio Grande Water Sustainability project, January 4, 2017.

4. Heyman, Josiah. Bracing for Conflict: The Political Ecology of Water Institutions Facing Looming Climate Change. Society for Applied Anthropology, Santa Fe, NM, March 29, 2017.

5. Pennington (2017). “Climate Change and Regional Sustainability.” Sierra Club. November 28, 2017.

6. Pennington, D., Chavira, L., and Villanueva-Rosales, N. (2017). Middle Rio Grande Water Sustainability in Extreme Drought: Using Provenance to Trace Modeling Scenarios Selected by Users. Annual Meeting of the American Geophysical Union, December 11-15, 2017, New Orleans, Louisiana.

7. Trevizo, I. G., and Pennington, D. (2017). Active learning effect on the public's perception of anthropogenic global climate change (poster). Annual Meeting of the Geological Society of America (GSA 2017), October 22-25, 2017, Seattle, Washington.

8. Treviso, I. and Pennington, D. (2017). Anthropogenic climate change a topic of debate? Active learning effect on the public's perception of anthropogenic global climate change. Geological Science Annual Spring Colloquium, University of Texas at El Paso, March 3, 2017.

9. Water resources management in a transboundary desert river basin facing climate change and competing water demands: An overview of challenges and opportunities for sustainable solutions. Seminar presentation, UniLaSalle, Beauvais France, January 24, 2018.

10. Mubako, S. and W. Hargrove. 2017. Monitoring impacts of long-term drought on surface water quantity and quality in Middle Rio Grande Basin reservoirs using multispectral remote sensing and Geographic Information Systems. Oral presentation, 2017 Annual Fall Meeting of the American Geophysical Union, New Orleans.

11. Gutzler, D.: “Water Resources and New Mexico agriculture” [invited] Rio Grande Community Farm, Albuquerque, Jun 20.

12. Gutzler, D.: “Historical Drought and Water Resources in West Texas” [invited] USDA

Southwest Climate Hub Drought Management symposium, El Paso, Aug 15.

13. Gutzler, D.: “Water Supply Vulnerability in New Mexico” [invited] . Association for University Business and Economic Research (AUBER) Fall Conference, Albuquerque, Oct 23.

14. Gutzler, D.: “Snowmelt Runoff in Southwestern Rivers in a Changing Climate” [contributed] . NOAA Climate Diagnostics and Prediction Workshop, Norman OK, Oct 26.

15. Gutzler, D.: “Climate Change in the Rio Grande Basin” [invited] Rio Grande/Rio Bravo Binational Forum, El Paso, Nov 7.

16. Gutzler, D., and S. Chavarria: " Streamflow Outlooks for Southwestern Rivers in a Changing Climate" [contributed] American Geophysical Union, Dec 11.

17. Abudu, S., Ahn, S. and Sheng, Z. (2017). Modeling Dissolved Solids in the Rincon Valley, New Mexico using RiverWare, 2017 AGU Fall Meeting, New Orleans, LA, December 11-15,

18. Ahn, S., Abudu, S. and Sheng. Z. (2017). Hydrological Responses of Weather Conditions and Crop Change of Agricultural Area in the Rincon Valley, New Mexico, 2017 AGU Fall Meeting, New Orleans, LA, December 11-15.

19. Ahn, S., Abudu, S., and Sheng. Z. (2017). Hydrological cycle analysis of crop areas based on SWAT model for the Rincon Valley in New Mexico, 2017 UCOWR/NIWR Conference: Water in a Changing Environment, Fort Collins, CO, June 13-15.

20. Ganjegunte, G.K. 2017. Evaluation of sulfur burner for salinity management in irrigated cotton fields in the west Texas. Presentation at Annual meetings of the Texas State Support Committee, November 29-30, 2017, Lubbock, TX.

21. Ganjegunte, G.K. and J.A. Clark. 2017. Evaluation of sulfur burner treatment of irrigation water to manage saline-sodic cotton soils. Presented at the 82nd Annual Convention of Indian Society of Soil Science, December 11-14, 2017, Kolkata, India.

22. Ganjegunte, G.K., A. Ulery, G. Niu, Y. Wu. 2017. Organic carbon and nutrients dynamics in saline soils under switchgrass irrigated with treated municipal wastewater. Managing Global Resources for a Secure Future, 2017 Annual meetings of Soil Science Society of America, October 22-25, 2017 Tampa, FL.

23. Ganjegunte, G.K., W. Hargrove, J.A. Clark. 2017. Irrigation effects on salinity. Managing Global Resources for a Secure Future, 2017 Annual meetings of Soil Science Society of America, October 22-25, 2017 Tampa, FL.

24. Rodriguez, O., Sheng, Z. and Abudu, S. (2017). Comparison of Statistical Approaches for Infilling Gaps of Evapotranspiration Measurements in Pecan Orchard, NM Section ASABE Annual Meeting, Las Cruces, NM, March 31.

25. Sheng, Z., Abudu, S., Michelsen, A., King, J.P. and Gunjegunte, G. (2017). Stochastic Modeling and Analysis of Salt Loading Variations in the Rio Grande Project Area, USA, International Perspective on Water Resources and the Environment, Wuhan, China, January 4-6.

26. Tahneen Jahan, N., Samimi, M., Vasquez, M., Moriasi, D., Mirchi, A. Modeling water and land management adaptation in New Mexico–Texas-Mexico border region using SWAT. World Environmental and Water Resources Congress 2017, Sacramento, California

27. Mirchi, A. Water Resources Management in the New Mexico-Texas-Mexico Border Region. Institute of Hydropower and Hydroinformatics, Dalian University of Technology, Dalian, China, August, 2017.

28. Mirchi, A. Ensure access to water and sanitation for all, 8th World Water Forum Symposium at ASCE World Environmental and Water Resources Congress 2017, Sacramento, California

29. Samimi, M., Tahneen Jahan, N., R., Mirchi, A. Modeling hydrological processes in New Mexico Texas-Mexico border region. American Geophysical Union Fall Meeting 2017, New

Orleans, Louisiana.

30. Mirchi, A. The Use of monitoring and smart metering for sustainable groundwater management. The Fifth Arab-American Frontiers Symposium, Rabat, Morocco, 2017.

Attachment 4. Water Resources Seminars hosted at UTEP.

1. “Let’s Talk about Water”. Sam Sandoval-Solis, University of California- Davis. Panel discussion. March 3, 2017.

2. “Exploring Models for Effective Environmental Leadership: A Discussion for Advancing Public Environmental Change”. Daniel Kahl, Associate Director, Community and Economic Development Initiative of Kentucky (CEDIK), Department of Community and Leadership Development, University of Kentucky, April 21, 2017.

3. “Simulating Water Flow and Solute Transport in Coupled Groundwater-Surface Water Systems using SWAT-MODFLOW”. Ryan Bailey, Assistant Professor, Department of Civil and Environmental Engineering, Colorado State University. May 12, 2017.

4. Student Intern presentations, August 30, 2017:

Lisa Baughman – Wetland Vegetation Monitoring at the Rio Bosque Wetlands Park”

Anna Ortiz – “Reactive Transport Modeling of CO2 Emission and Calcite Precipitation Kinetics in Dryland Agriculture: Lessons Learned and Challenges Encountered”

Ivy Trevizo – “USDA Climate Hub: Climate Change Communication”

5. “Reading the Seasons: Tribal Agriculture in a Changing Climate” - Maureen McCarthy, Director of the Tahoe and Great Basin Program, and Professor, Hydrological Sciences, University of Nevada Reno. January 8, 2018.

6. “Diversifying the Water Portfolio in the Rio Grande Basin” - John Tracy, Director, Texas Water Resources Research Institute, TAMU. January 8, 2018.

Attachment 5. Summaries of External Evaluator’s Reports (8.0, 9.0, 10.0, 11.0, 12.0, and 13.0).

External Evaluation Report 8.0 Summary and Suggestions

This report focuses on responses to a reflection survey provided by three interns who participated in internships during the summer of 2016.

It was clear that the internships had huge impacts on the interns. Not only did they learn a lot about what they expected to learn but also acquired hard science skills, e.g., data collection and analysis, and soft skills, e.g., exercising leadership, critical thinking, working with others, and making sense of complex data for presentation to lay persons. It was interesting to note a slight shift in their perceptions about how they could contribute to water sustainability in the region. In the preflection exercise their perceptions related to contributions through science-based efforts, e.g., determining water quality and its effect on wildlife. In the reflection exercise their perceptions were oriented more toward interpreting science-based outcomes to others, e.g., having more intelligent conversations with others about water issues in the region. It was also evident that personal expectations were met. The interns acquired new knew knowledge and skills and punctuated the opportunity to prepare and deliver presentations about their work. They reported that they knew they had achieved personal expectations when they were able to work alone and to make sense of their findings for others, e.g., presentations.

The interns liked the work environment, supportive atmosphere, access to information, and the opportunity to select a topic of their interest and wanted to start earlier in their projects, more hands-on experiences, and visits to other local sites related to their interests.

The internships definitely influenced decisions about future studies or professional aspirations. For one intern it confirmed a career related to water sustainability. For another intern, the exposure and experience with science revealed a stronger passion for science that now the student would like to pursue a profession in the medical field.

Suggestion – That the preflection and reflection reports be shared with the internship supervisors because there were lessons that could contribute to how future internships are planned and carried out.

External Evaluation Report 9.0 Summary and Suggestions

This report covers focuses on responses to a preflection survey provided by four interns participating in internships during the summer of 2017.

Two general observations across all responses are worthy of mention. First, it is evident that the interns seek knowledge and skills related to water in the region. This was clear in their comments related to specific topics and skills related to water, e.g., proficiency with GIS. Second, however, is the expressed interest to acquire a better understanding of the broader related aspects and to be able to share these with the public, i.e., educate people in the region about water issues. It is important to note these two general interests.

Suggestion – That the preflection report be shared with the internship supervisors so they may know the interns' expectations.

External Evaluation Report 10.0 Summary and Suggestions

This report focuses responses to mid-internship focus group discussion and survey conducted with four interns participating in internships during the summer of 2017.

The interns were very enthusiastic about what they were doing and learning. It appeared that their internships were very much in line with their interests and future research for their theses. They were very, very positive and motivated. It was a pleasure to hear them talk about what they were doing, despite the hot weather. They particularly liked the people with whom they were working and the fact that they are passionate about the topics they are researching. The research permits field work, connection with the USDA, and financial support.

They suggested that more students should be made aware of this opportunity and that the internship should be for a longer period of time. They also mentioned wanting more guidance regarding their final presentations and seminars or meetings to learn more about the USDA's research and work opportunities.

Needless to say, they were all very appreciative of this opportunity and expressed particular thanks to the project directors and mentors.

Suggestion – That this report be shared with the internship supervisors and attention be given to preparing the interns for their final presentations.

External Evaluation Report 11.0 Summary and Suggestions

This report covers focuses on responses to feedback from four model validation workshops conducted with government and urban stakeholders, environmental and social justice stakeholders, and New Mexico and Texas irrigators.

As expected, the government and urban and environmental and social justice stakeholders may be more knowledgeable and interested in computer-based water sustainability modeling than the irrigators. At the same time, the irrigators want information that enables them to make short-term water use decisions in accordance with the markets of their agricultural products.

Regardless, and of most importance, it seems that great progress was made in creating an understanding among all groups not only about the long-term goals and objectives of the project but also about the use of computer-based water sustainability modeling. In this regard, then, the objective of validating the model and developing confidence in the work was achieved.

Suggestion 1 – That particular attention be given to collecting feedback from all participants in future workshops.

Suggestion 2 – That if demographic data is to be collected that this request not be optional and be placed at the top of future surveys

Suggestion 3 – That the project team reflect closely on what was learned from the interactions with the four stakeholder groups to plan next steps in the project.

Suggestion 4 – That the objectives for future events be closely examined and consider using different approaches for the different stakeholder groups.

External Evaluation Report 12.0 Summary and Suggestions

This report focuses on responses to an internship reflection survey conducted with three of four interns participating in internships during the summer of 2017.

The ternships had an impact on each of the students. They reported learning about the interaction between water and plants and production of minerals, use of drones to assess water issues, and the importance of being able to communicate scientific information to the lay public, including translation to Spanish. They acquired new skills such as use of Photoscan, graphical coding, conducting literature reviews and time management. They all felt they can contribute to water sustainability by using what they have learned.

They felt that what they have learned met their personal expectations and has influenced their educational career goals. One student wrote, “I gained new experiences working in real world situations, I gained new contacts, and I learned about the climate hubs.” Another student wrote, “I learned more about climate change communication which is what my thesis is on and what my career goal is as well. This internship enhanced my education on this topic and the literature research I did this summer allowed me to implement what I learned in my own research for my thesis.”

The interns particularly liked the atmosphere in which they worked, the networking the internships provided, and the research skills they acquired. One student wrote, “Being linked to the USDA through an internship, gives higher value to my research experience and CV.” They also provided some suggestions for future internships, e.g., joint seminars with the other interns, more communication with the USDA, and more fieldwork, and longer internships.

Suggestion – That this report be shared with the internship supervisors and taken into account in future internships.

External Evaluation Report 13.0 Summary and Suggestions

This report focuses is a “mid-term” external evaluation report prepared for the annual project meeting.

Year 1 focused on developing models with input from stakeholders in nine meetings. Years 2 and 3 research concentrated on model development and testing and validating the Bucket Model and User Interface with feedback from stakeholders in five meetings. The linked SWAT/MODFLOW is in the final stages of testing and will be validated with stakeholders early in year 4. Impressive progress has been made with objectives 1, 4, and 6 and adequate progress has been made with objectives 2 and 5. Moving expeditiously to accomplish objective 3 and expanding and improving stakeholder participation will be the major challenges in years 4 and 5. In writing the proposal, project leaders wrote, “While our participatory framework cannot eliminate or overcome these structural problems and jurisdictional conflicts, it can provide a channel for improved understanding, visioning ‘water resources futures,’ and identifying and discussing solutions, perhaps resulting in the emergence of compromise and consensus.”

Of importance is that there is one unanticipated outcome that merits special mention. It relates to the impact that this project is having on undergraduate and graduate students, post-doctoral fellows, and young professors. It stems from the way project leaders and partners, i.e., seasoned and experienced researchers, are modeling harmonious and effective efforts involving five universities and a myriad of researchers and students from a wide range of disciplines. They are modeling how to work in teams and how to be respectful and be able to give and receive constructive feedback. This is unusual in a project this large that is addressing a very complicated issue with huge potential for long-term impact in similar conditions in many parts of the world.

In the future, universities will have to respond on behalf of society to enormous scientific and political issues that cut across culture, language, religions, borders, and ideologies. Students and others who are participating in this project are witnessing how this project is led and can serve as a model to be adopted or adapted for applying in a wide range of future efforts. The leadership and partners are complimented for demonstrating this unanticipated and important outcome that is and will extend beyond the life of this project.

1) Cover Page

USDA NIFA

WATER FOR AGRICULTURE CHALLENGE AREA

2017 Continuation Justification

Grant Agreement #2015-68007-23130

“Sustainable water resources for irrigated agriculture in a desert river basin facing climate change and competing demands: From characterization to solutions”

W.L. Hargrove, Center for Environmental Resource Management (CERM)
The University of Texas at El Paso

Requested Funding: $1,000,000

2) Review of Past Accomplishments

Our annual report identifies our specific outputs from the past year. We provide a table summarizing our outputs in Attachment 1. These are discussed briefly below, along with the associated or expected outcomes.

Research Outputs and Outcomes

Six journal article publications – They are listed in our annual report. All relate to water sustainability under changing climate, especially in our region, where there is dependence on both surface and groundwater to meet the needs of agricultural and urban users, and where climate outcomes are mostly related to higher temperatures and greater demand.

Enhancements to the project's web portal - (http://water.cybershare.utep.edu), including: a) a prototype online modeling interface available at https://water.cybershare.utep.edu/bucket2/, and b) a workspace for project participants. The expected outcome of the workspace for project participants is the improvement of interdisciplinary collaboration within the project. The interface will provide a platform for stakeholders to access models that we are using in the project and to conduct model runs on their own. This will greatly enhance stakeholder participation in modeling future scenarios.

Advancement of the Bucket Model - Our simplified but comprehensive water budget model was advanced as follows: a) a draft graphical user interface was developed, b) the model study area was established, c) the conceptual model of the system was refined to include an alluvial aquifer that can exchange water with the Rio Grande Channel model, d) preliminary computational models were developed in spreadsheets and optimization software, and e) a framework for assembling model input data and data for model calibration was developed. The significance of these outputs is that we are advancing the Bucket Model to a useable tool to evaluate the water system, on an aggregated scale, in response to the main drivers of change: climate and competing demands.

Education Outputs and Outcomes

Enhancement of curriculum - New courses: a) at UTEP, "Regional Water Sustainability in a Changing Climate" was developed in Yr1 and was offered in Fall semester of 2016 (Yr2) in the Environmental Science program (this course was a specific output in our original proposal), and "Water Resource Management" was developed and offered in Civil Engineering; and b) a new course was developed at UNM entitled "Climatic and Hydrologic Forecasting". These new courses are advancing our goals of institutional strengthening and building our capacity to train water resources professionals. The syllabus for "Regional Water Sustainability in a Changing Climate" is provided in Attachment 2.

Water Resources Seminar Series - Seven seminars were presented during 2016 at UTEP the individual seminar titles and presenters are listed in Attachment 3. These seminars are engaging UTEP, NMSU, and TAMU faculty in the region and are providing enhanced learning opportunities for UTEP students and building interest in water resources issues.

Extension/Dissemination Outputs and Outcomes

Water Symposium - Held at UTEP, January 4, 2017, this half day symposium included six invited speakers from related projects outside our own, plus 33 poster papers (listed in Attachment 4), mostly presented by students supported by our project. We invited stakeholders as well as other water professionals outside our project. The result was an opportunity to learn about ongoing related projects and to share early results from our project.

Presentations at Professional Meetings - Twenty presentations were made at professional meetings (listed in Attachment 5). The resulting outcome is that our early results are being disseminated to the scientific and professional community.

Accomplishments by Objective and Their Significance

Objective 1. Model development, improvement, integration, validation.

- Data collection and preliminary analysis of trends in upper Rio Grande streamflow and assessment of seasonal streamflow forecasts for the Rio Grande were conducted, using the Bucket Model. Our analysis determined the three recent test years to be used in bucket model improvement/validation. Data acquisition and analysis were carried out to derive and compile the surface hydrologic values needed for the model. The significance of this accomplishment is that we are advancing the Bucket Model to a useable tool with stakeholders to evaluate their questions about the future of water.
- A basic semi-distributed hydrologic model was developed using Soil and Water Assessment Tool (SWAT) to simulate surface water processes in the Hydrologic Unit Code (HUC) 8 watershed that contains the Elephant Butte Irrigation District. The model simulates rainfall-runoff processes and streamflow routing, and recharge to groundwater, providing a tool for process-based modeling of the biophysical system whose outputs can be used as boundary condition for coarser-scale models (e.g., the bucket model). Efforts are underway to calibrate and validate the model with regional data to provide a basis for assessing water and land management impacts on water availability and flow. The SWAT model will provide a process-based, geo-specific modeling tool to address more specific, detailed research questions.
- Using satellite imagery from the past 25 years, estimates of land conversion were made in the area around El Paso and Las Cruces. This initial analysis forms the basis for modelling future scenarios of urbanization and its impacts on water use for the region. We are currently evaluating strategies for projecting the identified trends into the future. Urbanization and conversion of agricultural land to urban/residential uses was a major concern of agricultural stakeholders.
- Data were collected to enhance our understanding of urban water use. We identified a method for measuring water vulnerabilities for poor consumers accounting for lack of access and vulnerability to high cost water supply sources.

The UACJ team obtained urban water quality, supply, economics, and access data for Ciudad Juárez. A study of effects of positive, negative, and balanced framing information on attitudes toward direct potable reuse in El Paso was completed. We also conducted initial ethnographic fieldwork on small utilities to better understand advancements and challenges in serving geographically and socially marginalized communities. This information is vital to understanding and modeling urban water use.

- A number of other improvements to our models are in process, including: 1) converting the existing Hueco Bolson MODFLOW model to be linked with SWAT; 2) evaluating the RiverWare Model for its ability to be linked with the Bucket Model; 3) assessing crop patterns, ET, land uses and agricultural water uses to improve the Bucket model and SWAT; and 4) obtaining data on the Mexican side to be integrated into the Bucket model and SWAT. The significance of these improvements is that for the first time, we will be able to link surface and groundwater and include both the U.S. and Mexican sides of the border.

Objective 2. Climate scenarios.

- Assessment of observed trends in snowpack and snow-streamflow relationships in the Rio Grande headwaters. This analysis is now being continued under separate support from USGS but our project will use these results as part of projected inflows downstream to Elephant Butte Reservoir.
- We expanded the historical baseline for observations of surface fluxes and upstream flows for the 20-year period 1991-2010. Projected flows at San Marcial for the 21st Century, derived from a large ensemble of climate models coupled to a surface hydrologic model were assessed and compiled. These will be compared to observed historical flows for the purpose of developing scenarios of upstream flow for the Bucket and SWAT models. This is part of the model validation process and will advance our models to the stage of utility with stakeholders.

Objective 3. System Dynamics Model.

- A conceptual model of El Paso water resources system was developed for use in a system dynamics modeling framework. The stock and flow simulation model will provide a tool for evaluating future water management policies and associated impacts on different system performance metrics such as reliability, vulnerability, and resilience. This is a first step in developing a system dynamics model, our ultimate goal for this project. Our other modeling tools could also eventually become a part of a more basin wide system dynamics model.

Objective 4. Stakeholder engagement and participation.

- We conducted a total of four stakeholder meetings, involving a total of about 50 stakeholders. At these meetings we presented results from the first round of stakeholder meetings regarding the vison for the future of water in the region, concerns and issues, and research questions of interest. We also presented an overview of each modeling tool, including the Bucket Model, SWAT, and MODFLOW. Stakeholders generally expressed at least some familiarity and trust in the models that we presented/discussed. This step was prerequisite to initiating any participatory modeling activities.

- We conducted one-on-one interviews with farmers to learn more about farmer decision making under conditions of limited water, and their resilience in the face of extreme drought. In addition, we will examine how forces like markets, insurance, and availability of resources affect farmer decisions. Also of interest is understanding which sources of information farmers find most useful in making decisions and how those sources have influenced farm decisions over the past decade or more. This information will improve our understanding of farmer decision making, especially under conditions of water scarcity.

Objective 5. Dissemination.

- We hosted a Water Symposium at UTEP and invited many of our stakeholders. We presented 33 poster papers summarizing some of our work. They are listed in Attachment 3.
- We participated in a conference in Dallas, TX entitled “New Cities, Future Ruins”, a collaborative project between Southern Methodist University, UTEP, and Arizona State University. The focus of the conference and the project that is being initiated is to depict in various art forms the challenges of sprawling cities in the desert Southwest who face limited water and other resources. We made a presentation on the challenges of sustainable water resources in the El Paso region facing climate change and competing demands. One outcome of this project is that UTEP will host two or three artists in residence to work with our faculty and students on conveying messages about water through art.
- Presentations to local stakeholders:
    - Hargrove and Heyman. Presentation to environmental consultative group of TX State Sen. Jose Rodríguez.
    - Sayles. Presentation to Las Cruces Rotary Club.
    - Richard Heerema. ‘Irrigation scheduling’, Western Pecan Production Short Course, Las Cruces, NM, October 18, 2016.
    - Richard Heerema. ‘Measuring plant water status with a pressure chamber: a field demonstration’, Western Pecan Production Short Course, Las Cruces, NM, October 19, 2016.
    - Richard Heerema and Marisa Potter. ‘Scheduling irrigations with a pressure chamber’, Western Pecan Growers Association Conference and Tradeshow, Las Cruces, NM, March 8, 2016.
    - Sarah Sayles delivered a seminar describing options for implementing water banking, and presented it as a poster at the NMWRRI water conference in Silver City, October 2016. An abstract of her presentation from that conference is posted on the following website: https://nmwaterconference.nmwrri.nmsu.edu/poster-abstract-guidelines/poster-abstracts/

This topic was identified as an interest by agricultural stakeholders in our first meetings.

Objective 6. Water resources education and institutional strengthening.
New courses, seminars, and internships are raising the visibility of water resources programs on participating university campuses. The seminar series are engaging more faculty into water resources discussions. The internships are engaging students in water resources management research and interesting them to go to graduate school. Two of the four interns at UTEP are going on to graduate school in water resources management. Specific accomplishments are discussed below.

- New course developed in Yr1 at UTEP, "Regional Water Sustainability in a Changing Climate", was offered in Fall semester of 2016 (Yr2) at senior undergraduate and Masters graduate levels. The syllabus is provided in Attachment 2. The course combined field trips, laboratory techniques, lectures, discussions and data exercises to cover topics such as quality and quantity of fresh water resources in our region and the challenges we are facing. Through hands-on experiences and field trips, students were trained to collect data using state-of-the-art instruments and techniques, analyze their own data as well as larger, more complex datasets, and understand the importance of water resources in the societal stability.
- A new graduate seminar course at UNM was developed, entitled Climatic and Hydrologic Forecasting, at UNM; UNM Co-PI Gutzler presented a well-attended (>150 people) departmental colloquium on hydroclimatic forecasting in the Earth & Planetary Sciences auditorium on 2 Sept 2016.
- Dr. Mirchi at UTEP developed and taught a new graduate level course in Water Resources Management (CE 6313) which was offered in Fall,2016 through Civil Engineering, and developed a graduate level course in Surface Water Hydrology (CE 5340) to be offered in Spring, 2017.
- At MTU, a module on Rio Grande water resources was refined and presented in a 35-student undergraduate class on groundwater hydrology. A module also was developed for a 16-student graduate course on advanced hydrology.
- At NMSU, a seminar series was established beginning Fall, 2016, with an emphasis on connections between water science, management, and policy. Five seminars were presented during the fall semester, most dealing with land or water resource issues in New Mexico.
- Four undergraduate students at UTEP were supported in summer research internships. The students are listed under UTEP's contributions to training below. The students made a presentation about their internship to faculty and peers at a special event on 18 Aug., 2016.

Activities in External Evaluation

The intent of the external evaluation is to contribute to the success of the project by a continuous formative assessment and summative evaluation of baselines and milestone outputs and outcomes regarding: (a) research, extension, and educational components and (b) institutional strengthening of participating universities. During this reporting period, seven external evaluation reports informed project leaders to enable assessing progress, engaging with stakeholders, and learning from the experience to make adjustments, as necessary. This included information, feedback, and input from 11 different stakeholder groups from Texas, New Mexico, and Mexico and graduate and undergraduate students participating in internships, enrolled in two courses, and participants in a project-wide water symposium. For example, 36 stakeholders from Mexico indicated that they liked the format, duration, content, and facilitation of a meeting; that the researchers listened to their points of view and captured the essence of their discussions in their notes; that they found value in the meeting, as it allowed discussion about a wide array of issues and concerns related to water in the region; and strongly agreed or agreed that they would like to continue participating in future meetings. This positive feedback is representative of the feedback received from other stakeholders.

Summaries of the evaluation reports for the two new courses developed and offered by UTEP and the Water Symposium held in January, 2017 at UTEP are presented in Attachment 6. These summaries share additional results and comments, especially from graduate students who are participating in the program.

3) Prospectus – Plan of Work

<u>Objective 1. Model development, improvement, integration, validation.</u>

- We are working on two models in parallel: the water-budget based "Bucket Model," using aggregate stocks and flows; and the geographically specific, process-based SWATmf model. The reasons for using two models are (1) the models, after calibrated with historical data, can be used to make projections, and can be compared to each other to achieve additional confidence in projections; and (2) the Bucket Model is computationally fast, and thus well-suited for stakeholder participatory events (e.g., we can realistically run novel scenarios and interventions that stakeholders suggest on the spot, which we think is an important asset at meetings). On the other hand, the SWATmf model is computationally very demanding, but geographically specific. Evaluation of projections by SWATmf will have to be run by scientists and presented to stakeholders, but can still serve as a very strong platform for discussion with stakeholders about future management, technologies, or policies. We think the effort of two models is justified by the unique utility of each with stakeholders. These two modeling tools can meet the needs and requests made by our stakeholders.
- The Bucket Model will be validated using historical data and then deployed to evaluate projections into the future. Key advancements necessary to meet the milestone of having a complete model ready to be validated include (a) completing compilation of historical period model data inputs and data for model calibration, including climate fluxes and accompanying runoff; gauged flows along the Rio Grande, and water withdrawals and return flows; (b) model calibration; and (c) coordination with the development of the model user interface. To be complete, the

Bucket model will be populated with improved crop ET data for New Mexico, Texas, and Mexico. It will also be expanded to "three buckets" to include the two major aquifers in addition to the river. This will allow the model to be upgraded to account for irrigation recharge to aquifers, evaporation from irrigation fields, urban and agricultural water use in Mexico, surface and groundwater interactions including seepage, pumping, and river-aquifer exchanges, and environmental values of water based recreation and environmental protection flows in selected parts of the basin. After validation with historical data, model capabilities will be presented to stakeholders and we will model projections into the future. Though we might start with projections of our choosing to demonstrate its capabilities, we will quickly get to projections of interest to the stakeholders.

- Progress on SWAT modeling will expand to include regional water management and use. Emphasis will be placed on calibrating the basic model using SWATCUP and manual calibration, and validating it based on regional water management operations, hydrologic patterns and observed trends in the Elephant Butte Irrigation District. We will also work on assembling the output of the SWAT to provide surface water boundary condition for running MODFLOW. Though the model is being built first for the Mesilla Valley portion of the basin in New Mexico, it will be expanded to include Texas and Mexico.
- There are particular needs to be able to model the Mexican side of the basin and aquifers, including: 1) development of GIS shape files to include all of the hydrology and channel network components on the Mexican side; 2) binational collaboration on the collection and review of weather data series, from monitoring sites on Mexico and US within the study watershed area; 3) binational development and revision of land cover and use distribution maps, including the proper conversion from the FAO or USGS classification systems.
- We plan to create social layers in a GIS by: a) obtaining U.S. census tract shapefiles for study area; b) identifying key housing/water access variables from the ACS and related key socio-economic variables; and c) collecting that data from the ACS and attributing it to each census tract. We will work with the UACJ team to do the same thing, relying on Mexican census units and data. We will develop regional projections of water cost changes and pricing under conditions of long-term drought.
- With respect to assessing urbanization, a major issue of concern to our stakeholders, we plan to: 1) complete urbanization/land use classifications on an annual basis for the 25-year period 1990-2015, using the whole watershed boundary for the project region; 2) provide selected classified images for input to the SWAT-MODFLOW model for simulation of future land conversion/transition scenarios using agent-based modelling, cellular automata or other approaches; 3) provide 15m digital elevation model (DEM) for input to the SWAT-MODFLOW model; and 4) collect, process and harmonize water use data from Texas, New Mexico, and Mexico and provide it for input to the SWAT-MODFLOW model.
- The Online Integrated Modeling Interface will be extended to include: a) a 20 to 50 year planning horizon of scenario runs; b) storage and visualization of input climate scenario data; c) system interaction with excel; d) geo-referenced input/output visualizations; and e) comparison between different scenario runs. The graphical interface will go through formal usability testing before its first release for stakeholder

usage.

- Several pieces of experimental work will be done to provide data for modeling or to better quantify processes that need to be modeled. These include: 1) ongoing field projects on water reuse, irrigation water conservation, and soil salinity management; and 2) a new activity to compare irrigation and salinity management under different irrigation systems (flood, drip and micro sprinkler). A new experimental irrigation system is being installed to enable testing of the principle of “partial root zone drying” for up to 10 acres of planted pecan trees on the NMSU Leyendecker farm near Las Cruces, NM. The goal is to discover opportunities to conserve water applied under a drip irrigation system with limited losses to yield and economic returns to pecan growers.
- Considerable work needs to be done to improve the estimation of ET for both the Bucket Model and SWAT. Some relevant data for ET exists in New Mexico and Texas. We will select additional relevant testing sites for ET estimates and physical measurements in Mexico.

<u>Objective 2. Climate scenarios.</u>

- We will test the bucket model with a 20-year historical baseline developed from monthly averaged observations of upstream flow on the Rio Grande and estimates of surface hydrologic fluxes across our study area.
- As an initial controlled test of climate change impacts to the water budget, we will modify the time series of historical observations described above by a simple projected trend (developed from climate model projections), while keeping the interannual variability inherent in the historical observations fixed.
- We will develop three projection-based future climate scenarios corresponding to severe projected climate change (RCP8.5), mitigated projected change (probably RCP2.6), and projected change in which a severe drought (either the 1950s drought, or a 'megadrought' inferred from paleoclimate records) is superimposed on a warming trend.
- We will downscale the monthly averaged streamflow and surface flux data and projections to the daily time scale for use by SWAT.

<u>Objective 3. System Dynamics model.</u>

We will build a system dynamics simulation model beginning with a conceptual model of El Paso’s water resources system, including water and wastewater treatment facilities and their daily operations to meet urban demand. We will also collaborate with computer scientists to develop the cyberinfrastructure to make a test version of the model available online. This prototype will be expanded to include the total water system with possible components that might include SWATmf.

Objective 4. Stakeholder engagement and participation.

We plan a series of follow up meetings with stakeholder groups to present and discuss modeling results, and introduce the model user interface. We envision a series of short workshops centered on the theme of climate effects to achieve the following: 1) present model validation results for Bucket Model and SWAT, and demonstrate the model with historical data on the worst drought of record (1950's); 2) present model results for several projected climate scenarios and use the results as a platform for discussion of climate, water supply, and water demand; and 3) introduce the user interface and make the Bucket model available to stakeholders to assess their own climate projections.

Objective 5. Dissemination.

- We plan to host the Water Symposium again in early 2018, including a poster paper session to allow our students to present their results.
- We will continue to make presentations to stakeholders as the demand/opportunity arises.
- We envision opportunities for demonstrating technologies through our field research including drip irrigation, water reuse, water conservation, and soil salinity management.

Objective 6. Water resources education and institutional strengthening.

- UTEP will offer the new field methods course again in Fall, 2017 through the Environmental Science program, as well as the course in Water Resources Management in Civil Engineering. The instructors for both will incorporate the feedback that was received through the course evaluation conducted by the project evaluator in our project to revise and update the content. UNM will also continue its new class on Climatic and Hydrologic Forecasting.
- During Summer, 2017, we will develop a new course *Water Resources Issues and Solutions,* an interdisciplinary course based on problem-based learning. Students will work in teams to analyze a water resource issue/problem assigned to them and identify and assess potential solutions. The course will be pilot-tested at UTEP with plans to disseminate it to our other partner institutions.
- We will host another water symposium in January, 2018, for students to present water-related research.
- We will continue the Water Resources Seminar Series at UTEP and NMSU and try sharing some of these through video conferencing with UNM and/or MTU.
- We will continue to provide undergraduate internships at UTEP, UNM, and MTU. Internships will either provide undergraduates with research experiences or place students in water management agencies in the region. Undergraduate research opportunities will be provided through UTEP or participating institutions. In addition to the training aspect of internships, they are also aimed at recruiting students into graduate studies in water resources or water-related degree programs.

- We are also planning two new activities: 1) an integrated Art/Environmental Science course with a focus on water. This will be done in conjunction with two artists in residence at UTEP and an art exhibition at UTEP's Rubin Center for Visual Arts entitled "New Cities, Future Ruins" addressing sustainability in the Sun Belt; and 2) in cooperation with the local State Senator Jose Rodriguez at his request, develop a high school/early undergraduate student engagement event addressing learning and careers in water resources.

Activities in External Evaluation

In the upcoming reporting period, the external evaluator will continue to be an integral working member of the project team and participate in all project planning meetings in-person or via phone and all project activities on the campuses of the university partners or off-campus at outreach events and activities of the university partners. Satisfaction surveys and/or focus group discussions will be used to assess successes and concerns of the project. Additionally, attention will be given to identifying other research questions that may emerge and merit illumination, registering unanticipated outcomes, and projecting possible next steps that may need to be taken that are beyond the scope of the project.

More specifically, in the next reporting period the external evaluator will (a) collect formative evaluation data from all stakeholder groups, i.e., <u>on-line</u> from government, environmental NGOs, urban/industrial water users, and social justice stakeholders and <u>in-person</u> from Mexico, small and large Texas farmers, and small and large New Mexico farmers; (b) prepare reports to submit to the Principal Investigator; and (c) report findings to all partners and stakeholders at the annual project meeting in early 2018.

4) Training

We list below all the individuals who have received training or professional development through the project. *Denotes that the student was supported financially by the project. In addition to these, we have listed and described accomplishments in education and institutional strengthening under Objective #6 in the Accomplishments section of the report. A summary table of the students supported for training is provided in Attachment 7. It is significant to note that 60% of the students supported by the project are Hispanic, an underrepresented group in water resources professions nationally.

<u>UTEP</u>

- *Brian Guerrero, MA in Sociology (completed), thesis research on El Paso Water's new program of direct potable reuse.
- *Marlene Flores, MA in Latin American and Border Studies; research on small utilities, especially accomplishments and challenges in serving geographically and socially marginalized rural communities.

- William Vallee, M.A. in Political Science (completed); thesis research on governance of transnational groundwater.
- Diego Sanchez, M.A. in Sociology; thesis research on household water consumption.
- *Omar Sulaiman Belhaj, Ph.D. student, ESE Program; received hands on training on land use land cover classification, reviewed and summarized literature, acquired and processed satellite imagery, prepared and presented a poster at the USDA project symposium at UTEP.
- *Carlos S. Reyes, Undergraduate Intern, B.S. Environmental Science; classified satellite imagery for the study region; searched for research articles and summarized literature.
- Jose Caballero, B.S., Computer Science. Mr. Caballero received training in the use of General Algebraic Modeling System (GAMS) to apply his work on model integration funded by NSF Grant HRD-1242122 (Cyber-ShARE Center).
- *Oscar Ricaud, B.S., Computer Science; enhanced web portal to capture and generate aggregate data for project evaluation.
- Smriti Rajkarnikar, M.S., Computer Science; received training in the automated generation of models, inputs and outputs to apply her work on developing a generic provenance pattern to trace back model execution and data sources for the online modeling platform funded by NSF Grant HRD-1242122 (Cyber-ShARE Center).
- Raul Vargas, Ph.D., Computer Science; received training on visualization requirements for the project's web portal to enable the graphical visualization for provenance data of the models generated as part of his work on knowledge representation funded by NSF Grant HRD-1242122 (Cyber-ShARE Center).
- *Neelam Tahneed Jahan, M.S., Civil Engineering; collected and organized model input data, developed a basic SWAT model.
- *Maryam Samimi, PhD student, Civil Engineering: reviewed literature; collected and organized model input data, helped with SWAT model design.
- Majid Alahmoradi, M.S., Civil Engineering: reviewed literature; worked on system dynamics modeling.
- *Tallen Capt, Ph.D., Civil Engineering – developed mathematical model for predicting daily water demand for El Paso as a function of average daily temperature, population, and several other factors.

<u>Summer Research Interns</u>

- Anna Piña. MS, Environmental Science Program. Examined water quality, groundwater depth and aquatic macroinvertebrate communities at the Rio Bosque wetland.
- Carlos Reyes, B.S. Geology. Study of urbanization using remote sensing.
- Joe Candelaria, B.S. Civil Engineering; EPWU wastewater treatment system and potential biogas production.
- Gabby Porras, B.S. Civil Engineering. Urban water use modeling and fieldwork on water quality and water treatment.

NMSU

- *Sarah Sayles, Ph.D. Water Science & Management Program; built prototype farm income optimization model for assessing water banking options in Rio Grande basin for adapting to future water supply shortages.
- *Befekadu Habteyes, Ph.D. Water Science and Management Program: calibrated bucket model for the Elephant Butte and Caballo Rio Grande Project region.
- *Sarah Acquah, Ph.D., Water Science and Management Program; identified and developed future hydrologic and policy scenario impacts to be evaluated by Bucket model.
- *Dina Salman, Ph.D., Water Science and Management Program; working with NMSU engineering professor to assemble crop ET data for New Mexico, Texas, and Mexico.
- Carlos Silva, Ph.D., Water Science and Management Program; working on groundwater-surface water models to support policy analysis as well as optimization models for irrigated agriculture in southern New Mexico.
- Hugo Luis Rojas Villalobos, PhD, Water Science & Management Program; administration of GIS data.
- *Olga Rodriguez, M.S., Water Science & Management Program; data compilation and analyses for model inputs.

TAMU

- *Shalamu Abudu, Postdoctoral Research Associate, Agricultural Engineering; conducted modeling research on hydrological aspects (RiverWare, MODFLOW).
- *So-ra Ahn, Assistant Research Scientist; conducted modeling research on hydrological aspects (SWAT).
- Erick Reynoso, Research Tech II – GIS and project area delineation.
- *Darlina Prieto, Work-Study Student (UTEP), B.S. in Biological Sciences; Compile river flow and diversion data.
- *Jacqueline Alfaro, B.S. Environmental Science: analyzed baseline properties of pecan field soils, installed irrigation sensors and data loggers, collected sensor data during the irrigation season.
- John Clark, Research Technician – Helped in implementing and data management of laboratory, greenhouse and field experiments.

UACJ

Undergraduate students:

- *Mariela Rascón Castillo, Bachelor in Geoinformatics, Department of Architecture, UACJ-Geospatial analysis.
- *Mónica Quiñonez González, Bachelor in Geoinformatics, Department of Architecture, UACJ, ModFlow Modeling.
- *Obed Alejandro Márquez Barraza, Bachelor in Geoinformatics, Department of Architecture, UACJ, ModFlow Modeling.

- *Alfredo Jaquez Granados, Bachelor in Environmental Engineering (Ag Engineering Exchange student from UADHE) Precision Ag and eBee Drone mapping.
- *Ana Laura Ruiz Aragonez, Bachelor in Physics, Department of Physics, UACJ, Spectral analysis of imagery under SEQUOIA camera with eBee Drone.
- *Alexis Rodriguez Sanchez, Bachelor in Environmental Engineering at the Department of Civil and Environmental Engineering, UACJ, SWAT geodata integration and modeling.

Graduate Students:

- *Oscar Ramirez Villazana, graduated from the M.S. Environmental Engineering program – He accomplished the first phase on the delineation of aquifer layers for the project through aquifer characterization using geophysics. Presently he has received an offer to work at the state level in Junta Central de Agua participating on an interdisciplinary team to apply these technologies to the planning and infrastructure development for new groundwater wells in the state of Chihuahua.
- *Víctor Hugo Esquivel Ceballos, PhD Candidate at the Urban Studies Program, Department of Architecture, UACJ, Urban Growth, population and groundwater path evolution at Ciudad Juarez, Chih.
- *Arturo Soto, PhD Candidate at the Urban Studies Program, Department of Arquitecture, UACJ, ModFlow modeling at study area in Mexico.
- *Hugo Luis Rojas Villalobos, PhD Candidate Water Science & Management Program at NMSU - administration of GIS data.
- *Ana Cristina Garcia, MS Student at the Environmental Engineering Program, Department of Civil and Environmental Engineering, UACJ, Isotopic signature of groundwater samples at the Conejos Medanos-Mesilla Aquifer.

<u>UNM</u>

- *Shaleene Chavarria, MS, Earth and Planetary Science Department; collected streamflow and snowpack data, analyzed seasonal streamflow forecasts on the upper Rio Grande, presented results at NM State Water Conference and Fall AGU meeting.
- *John Carilli, B.S., Physics Department - processed surface hydrologic data for bucket model development.
- *Justin Norris, B.S., Earth and Planetary Science Department; analyzed climate model projections of Rio Grande streamflow.
- Yu Jin Sung, undergraduate exchange student from South Korea; analyzed surface hydrologic data as part of bucket model development.
- *Justin O'Shea, B.S., Earth and Planetary Science Department; analyzed summer season precipitation and streamflow upstream from Elephant Butte Reservoir and defended a senior undergraduate thesis on this work in December.

MTU

- *Lauren Mancewicz, B.S., Environmental Engineering, Intern; defined study area boundaries, including sub-watershed and aquifer boundaries and accompanying spatial database, collected input data for the bucket model.
- *Leslie Hamar, B.S., Environmental Science, Intern; identified spatially-distributed water withdrawal data for the US portion of the study area.
- *Ken Thiemann, Ph.D , Environmental Engineering; processing NASA datasets to obtain local climate inputs and output fluxes an accompanying local runoff; compilation of gauged flows along the study area Rio Grande reach; assembly of geodatabase for Bucket Model.

Professional Development

- Dr. Shalamu Abudu, TAMU, successfully completed a one-week training course on SWAT in January, which will help him configure and/or integrate SWAT and RiverWare model for water operations within the project area.
- Dr. Ali Mirchi spent one week in El Reno, OK at USDA-ARS lab to be trained on SWATmf by Dr. Daniel Moriasi.
- Professors and students involved in the project from UACJ were certified by SenseFly Inc as technical experts on Drone flight missions for Precision Ag Technology.
- Special training during the Fall semester 2016 for MS Student Ana Cristina Garcia from UACJ, at the Mexican Institute of Water Technology (IMTA) in Cuernavaca Mexico, specializing in isotopic analysis to evaluate groundwater quality and age.
- Dr. Sergio Solis, responsible for the UACJ SWAT modeling team, had a summer internship at the University of Warwick in England to evaluate and calibrate surface water modeling.
- Dr. Luis Carlos Alatorre from UACJ participated at the XVII SELPER International Symposium celebrated at Puerto Iguazu, Argentina in Nov, 2016..
- Dr. Alfredo Granados from UACJ took a sabbatical leave at UTEP during 2016 to manage and administer the project and coordinate Mexican team efforts.

XI) Concluding Statement

Our project focuses on water quantity and availability for agricultural use in a desert river basin with due attention to water quality, especially salt concentrations and accumulation. We are relying on a modeling-based approach to address a number of key questions about the future of water posed by diverse stakeholders in the region. A better understanding of the conjunctive surface and groundwater system, the competing demands for water, and a changing climate, is prerequisite to identifying alternative futures that will result in sustainable water supplies for irrigated agriculture, both locally and regionally in the Southwest. Our expected outcomes include an improved understanding, by both stakeholders and scientists, of the drivers of water supply and demand and solutions that are acceptable and workable at a local and regional level.

These solutions will be more water-use efficient, conserving, and less polluting. They will be transferrable approaches and solutions for arid/semi-arid basins in which irrigated agriculture faces challenges from climate change, competing demands, and salinization. Significant areas of the western U.S. also fall into this category, as do other intensively used desert river basins around the world, such as the Nile, Jordan, Tigris, and Euphrates. Thus, the Middle Rio Grande basin is a compelling research site to explore solutions for long-term water sustainability for agriculture in relationship to urban and environmental uses.

Furthermore, we are accomplishing these goals while contributing to the need for well-trained future professionals, including those from traditionally under-represented populations. We are integrating research, extension, and education activities in our project, focusing especially on research and education. At the same time, we are strengthening our capacity to conduct water resources research and extension in a majority Hispanic region in which agriculture is vital, while training water resources professionals to address the water challenges of the 21st century.

XI) Additional Materials – Attachments

Attachment 1. Summary of Yr 2 Outputs

Function Area	Output Category	Outputs for Yr 2 (March 1, 2016-February 28, 2017)	Related to Project Goal #	Related to Project Objective(s) #
Research	• Scientific Publications	6 publications in refereed journals (listed on pp 1-2)	2	1,2,5
	• Presentations at roject l meetings	• 20 oral and poster papers (listed in Attachment 3) • 1 NMWRRI seminar (listed on p. 5) • 1 NIFA project directors meeting (listed on p. 6)	2	1,2,5
	• Models	• Bucket Model (described on p. 2) • User interface on web portal (described on p. 2)	2	1,2,5
Extension/ Dissemination	• Symposium	• 33 Posters, Water Symposium (listed in Attachment 2)	2	1,2,5
	• Stakeholder Meetings/Workshops	• 5 presentations to stakeholders (listed on p. 6) • 4 stakeholder meetings/workshops (described on p. 5)	1	3,4,5
Education	• New Courses/Modules	• 3 new courses (described on pp.6-7) • 2 new course modules incorporated into existing courses (described on p.7)	3	5,6
	• Seminars	• 7 Water Resources Seminars at UTEP (listed on p. 2) • 5 Water Science, Management, and Policy Seminars at NMSU (described on p. 7)	3	5,6

Function Area	Output Category	Outputs for Yr 2 (March 1, 2016-February 28, 2017)	Related to Project Goal #	Related to Project Objective(s) #
	• Internships	• 4 Undergraduate internships at UTEP (listed on p. 8)	3	5,6
	• Student Support/Training	• 15 undergraduate students supported by the project and 1 receiving training but not supported by the project (listed on pp. 7-10) • 7 M.S. students supported by the project and 3 receiving training but not supported by the project (listed on pp. 7-10) • 13 Ph.D. students supported by the project and 4 receiving training but not supported by the project (listed on pp. 7-10) • 2 Post-docs supported by the project (listed on pp. 7-10) • 2 Technicians receiving training but not supported by the project	3	5,6
	• Professional development	• 5 faculty, 1 Post-doc, 2 students participated in specialized training (described on p. 10)	3	5,6

Attachment 2. Syllabus for new experiential learning field course in water sustainability

Regional water sustainability in a changing climate

ESCI 4315 (CRN#18202)/ESCI 5315(CRN#18212)

Wednesday 9:30-12:30; Biology B206

Fall 2016

Instructors:

Dr. Vanessa Lougheed: Office: 316 BIOL, Tel: 747-6887, email: vlougheed@utep.edu

Office Hours: by appointment

Dr. Lixin Jin, Office: 221A Geology, Tel: 747-5559, email: ljin2@utep.edu

Office Hours: by appointment

Guest Instructors:

Dr. William Hargrove: Office: 202 Kelly Hall, Tel: 747-6942, Email: wlhargrove@utep.edu

Dr. Stanley Mubako: Office: 210 Kelly Hall, Tel: 747-7372, Email: stmubako@utep.edu

Dr. Deana Pennington: Office: 305C Geology, Tel: 747-5867, Email: ddpennington@utep.edu

Dr. Shane Walker: Office: A305 Engineering, Tel: 747-8729, Email: wswalker2@utep.edu

Dr. Ali Mirchi: Office: A206 Engineering, Tel: 747-6908, Email: amirchi@utep.edu

Required Textbook: NONE

Goals:

This senior-level and Master-level course is team-taught. Multiple projects are designed to understand and solve local and regional environmental problems that are water-related. Through hands-on experiences and field trips, students will be trained to collect data using state-of-the-art instruments and techniques, analyze their own data as well as larger, more complex datasets, and understand the importance of water resources in the societal stability.

The objectives are to:

5. Increase awareness of water-related issues;
6. Provide experiential learning and train our students to become future water professionals;
7. Encourage team work and group discussion; and
8. Improve analytical, writing and oral skills.

Who are our water suppliers in the El Paso region today?

Tentative Schedule:

WEEK	TOPIC
1 (8/24)	Introduction: Global water cycles and water quantity (Jin, Lougheed)
2 (8/31)	Exercise 1: Effect of climate on stream discharge (Lougheed)
3 (9/7)	Exercise 2: Natural versus managed hydrographs (Jin)
4 (9/14)	*****Mandatory field trip ***** **NEW DATE** Visit USGS gaging station, collect water samples from Rio Grande, and measure stream discharge
5 (9/21)	Exercise3: Flood hazard evaluation for the region, NADP precipitation data (Jin)
6 (9/28)	Water policy, economics, trans boundary water issues (Ward)
7 (10/5)	Working across disciplines (Pennington)
8 (10/12)	Watershed Modeling (Mirchi)
9 (10/19)	GIS applied to hydrology (Mubako)
10 (10/26)	Water remediation and treatment (Walker)
11 (11/2)	Introduction on water quality & laboratory tours
12 (11/9)	*****Mandatory field trip ***** Agricultural drains and canals, Rio Bosque, wastewater treatment plant
13 (11/16-23)	Group Lab work-Data analysis (four groups)
14 (11/30)	Student discussion- group presentations – debate.

Grades:

	ESCI 5315	ESCI 4315
Weekly Assignments	75	85
Journal articles roject	10	0
Participation and peer evaluation	15	15

Lecture notes, instructions, rubrics for reports and grades will be posted on Blackboard.

Course policies:

Class participation: You are expected to come to class prepared to answer questions about the assigned readings. Although attendance at each lecture is not mandatory, pop-quizzes may be given at any time during the lecture period and counted as a homework assignment.

E-mail and Blackboard:

You are required to provide the teaching team with a UTEP e-mail address and check your UTEP e-mail and Blackboard daily. We will use your UTEP e-mail to contact you and you will use your UTEP e-mail to contact us as well. Do not use Blackboard for e-mail.

Dropping the course:

Students may drop the class and receive a W (withdrawal) on their transcript prior to October 28th, 2016. You must consult the Instructor prior to dropping. Due to the University's six-drop rule, dropping the course may not be in your best interest. After April 6th, a drop will result in an F on your transcript. Receiving either a W or an F in any course may prevent you from meeting the satisfactory Academic Progress requirements necessary to receive financial aid.

Student Conduct:

Each student is responsible for notice of and compliance with the provisions of the Regents' Rules and Regulations, available at http://www.utsystem.edu/bor/rules/homepage.htm. All students are expected to behave as courteous, responsible adults. We will have frequent discussions and students are expected to tolerate and respect the opinions of others.

Cellular and electronic devices:

Cell phones and other electronic and recording devices must be turned off during class time to minimize classroom disruptions and protect the integrity of test-taking situations. This means you cannot make calls, send text messages, or use social media during class. You may use your laptop or tablet to take notes in class, but this privilege will be revoked if the devices are used inappropriately.

Students who fail to follow this rule may incur disciplinary action up to and including dismissal from the class and upon repeated offenses, the course.

Academic Integrity:

All graded assignments must be entirely the work of the *individual* student. *"Plagiarism" means the appropriation, buying, receiving as a gift, or obtaining by any means another's work and the unacknowledged submission or incorporation of it in one's own academic work offered for credit, or using work in a paper or assignment for which the student had received credit in another course without direct permission of all involved instructors.* (from the Regents' Rules and Regulations) Plagiarism is a serious violation of university policy and will not be tolerated. All cases of suspected plagiarism will be reported to the Dean of Students for further review.

Disability accommodations:

If you have or suspect you might have a disability and need an accommodation you should contact the Center for Accommodations and Support Services (CASS) at 747-5148 or at cass@utep.edu or go to Room 106 Union East Building. Students are responsible for providing any CASS accommodation letters and instructions. http://sa.utep.edu/cass/

Attachment 3. Poster papers presented at Water Symposium.

33. Towards an Integrated Water Modeling User Interface for Stakeholders**.** Luis Garnica Chavira, Deana Pennington, Natalia Villanueva-Rosales, UTEP
34. Leveraging Self-contained Web Services for Specification, Execution and Storage of User-defined Scenarios of Scientific Models**.** Luis Garnica Chavira, Jose Caballero, Natalia Villanueva-Rosales, Deana Pennington, UTEP.
35. Economic analysis of water conservation policies for irrigated agriculture under drought scenarios: an integrated basin approach. Sarah Acquah, New Mexico State University.
36. Small Utilities Facing Drought and Water Quality Issues. Marlene Flores and Josiah Heyman, UTEP
37. Attitudes Toward Direct Potable Reuse of Water in El Paso. Brian Guerrero, UTEP
38. Water Matters: A Health Impact Assessment (HIA) in a U.S.-Mexico Border Rural Community Lacking Piped Water. Jesus Placencia, Michelle Del Rio, Amit Raysoni, and W.L. Hargrove, UTEP
39. Space-based monitoring of land-use/land-cover in the Middle Rio Grande Basin: An opportunity for understanding urbanization trends in a water-scarce transboundary river basin. Carlos S Reyes, Omar Belhaj, Stanley Mubako, W.L. Hargrove, Josiah Heyman, and Deana Pennington, UTEP
40. Changes in aquatic macroinvertebrate communities in a desert wetland and how these contribute to regional macroinvertebrate diversity. Vanessa Lougheed, Anna Piña, and Viridiana Orono, UTEP.
41. Feasibility of partial root zone drying for water conservation in southwestern pecans. Curt A. Pierce, Blair Stringham, and Richard J. Heerema, New Mexico State University
42. Use of Drones to Monitor ETP and Precision Agriculture at a Desert Watershed. Ana Laura Ruiz Aragonez, Alfredo Jaquez Granados, Dr. Alfredo Granados Olivas, UACJ
43. Analysis of urban growth of Ciudad Juarez, Chihuahua, Mexico: Impacts on the demand and water availability, and dejection of aquifer. Victor Hugo Esquivel Ceballos, Luis Carlos Alatorre Cejudo, Agustín Robles Morua, UACJ.
44. Rapid water storage estimation of water bodies through three-dimensional topobathymetric models constructed using sonar data and UAV-based photogrammetry. Hugo Rojas-Villalobos, Chris Brown, Alfredo Granados-Olivas, NMSU and UACJ.
45. Comparison of methods for evapotranspiration (ET) estimations, applied in the hydrological basin of Valle de Juárez, Chih, México. Alexis Rodríguez Sánchez and Sergio Saúl Solís, UACJ.
46. Heat waves in Ciudad Juárez, Chihuahua, Mexico for the period 2008-2016 and its effect on human health. Alejandra Nayeli Arauz Solano, Felipe Adrián Vázquez Gálvez and Angelina Domínguez Chicas, UACJ.

47. Availability of Groundwater and its relationship with Urban Development in Ciudad Juárez, Chihuahua: A retrospective and prospective analysis during the period 1980 to 2030. Arturo Soto Ontiveros and Alfredo Granados-Olivas, UACJ.
48. Isotopic study for the determination of the groundwater age in the aquifer Conejos-Medanos in Juarez, Mexico. Ana Cristina Garcia and Alfredo Granados-Olivas, UACJ.
49. Design and construction of a hydrometric station to measure flow at rivers applying the Arduino System. Miguel O. Durán Rangel; Adrián Vicente Peña López; Dr. Felipe Adrián Vásquez; Ing. Haimar Ariel Vega Serrano; Ing. Fabian Leonardo Yory Sanabria, UACJ and Liberty University of Colombia.
50. Urban growth in Ciudad Juárez (1995-2015): Impact on urban LULC and LULC of the territory. Mariela Rascón Castillo, Luis Carlos Alatorre Cejudo; Alfredo Granados Olivas, UACJ.
51. Modeling groundwater flows in the aquifer of Cuauhtémoc, Chihuahua, México: Visual MODFLOW. Obed Alejandro Márquez Barraza, Mónica Quiñonez González, Luis Carlos Alatorre Cejudo, and Alfredo Granados Olivas, UACJ
52. Projected Streamflow Changes in the Middle Rio Grande Basin. Justin Norris, David Gutzler, UNM.
53. Testing Impacts of Active Management and Policy Choices From Use of the Rio Grande Bucket Model. Dina Salman and Frank Ward, NMSU.
54. Utilizing NetCDF Data in Raster Form as a Means of Flux and Storage for Bucket Modelling on the Middle Rio Grande Basin. Ken Thiemann and Dr. Alex S. Mayer, Michigan Tech University; Dr. Rebecca Teasley, University of Minnesota Duluth; Dr. Frank Ward, NMSU; Luis Garnica Chavira, UTEP.
55. Using Boron isotopes to trace urban salinity inputs to the Rio Grande River in Southwest USA. Sandra Garcia and Lin Ma, UTEP ; Pascale Louvat and Jerome Gaillardet, Institut de Physique du Globe de Paris, Paris, France.
56. Model Calibration for analysis of Stakeholder Preferences for Water Programs in the Middle Rio Grande Basin. Befekadu Habteyes, NMSU.
57. Principles Guiding the Design of Water Banking for Shortage Adaptation in the Middle Rio Grande River Basin. Sarah Sayles, NMSU.
58. Modeling Surface Water Availability in Elephant Butte Irrigation District. Neelam Tahneen Jahan, UTEP.
59. Impacts of environmental changes to the middle Rio Grande landscape on Ysleta del Sur Pueblo’s cultural and ceremonial sustainability. Andrea L. Everett, Deana D. Pennington, Tom Gill, UTEP
60. Provenance of integrated water modeling workflows using design patterns and controlled vocabularies. Smriti R. Tamrakar and Natalia Villanueva Rosales, UTEP
61. Approaches for Infilling the Incomplete Measured Eddy-Covariance Pecan Tree Evapotranspiration Data. Olga Rodriguez, Zhuping Sheng, Shalamu Abudu, Sora Ahn, Erick Reynoso, Jorge Chavez Frederick, and Darlina Prieto, Texas A&M AgriLife Research Center at El Paso.
62. Delineation of USDA Project Study Area. Jorge Chavez, Dr. Zhuping Sheng, Dr. Shalamu Abudu, Dr. Sora Ahn, Dr. Qi Liu, Olga Rodriguez, Erick Reynoso, and Darlina Prieto, Texas AgriLife-El Paso; Alfredo Granados Olivas, UACJ; Alex Mayer

and Ken Thiemann, Michigan Tech; Rebecca Teasley, University of Minnesota Duluth; and Lauren Mancewicz, Michigan Tech.

63. A Predictive Water Demand Model for El Paso. Capt Tallen, UTEP
64. Changes in the plant community at the Rio Bosque, a created desert wetland. Lisa Baughman and Vanessa Lougheed, UTEP
65. Dryland Flood-Irrigation and its Impact on CO2 Production and the Accumulation of Pedogenic Carbonate in West Texas. Anna Ortiz and Lixin Jin, UTEP

Attachment 4. Water Resources Seminars hosted at UTEP.

8. “Accelerate H2O: A New Statewide Water Initiative for Texas”, Ed Archuleta, Director of Water Initiatives, CERM, UTEP. Friday, March 18.
9. “Stakeholder Perspectives on the Future of Water in the Paso del Norte Region”, W.L. Hargrove, Director, CERM, & J.M. Heyman, Director, CIBS. Friday, April 15.
10. “The Evolving Water Crisis in the American Southwest”, Brad Udall, Colorado State University, Centennial Lecture at UTEP. Tuesday, April 26.
11. “A Systems Approach to Evaluating Water Management Scenarios in the Transboundary Rio Grande/Bravo Basin”, Rebecca Teasley, Assistant Professor, Department of Civil Engineering, University of Minnesota-Duluth. Tuesday, May 17.
12. “Water Resources Management in the Internet Age: Embracing the Data Deluge”, Suarav Kumar, Research Assistant Professor, Department of Civil Engineering, UTEP. Friday, September 23.
13. “The Thermoelectric-Water Nexus: Background and Future”, Gregory Torell, Assistant Professor, Natural Resources Economics, Texas A&M AgriLife Center – El Paso. Friday, October 28.
14. “Satellite-based hydro-economic analysis tools for agricultural water management: The importance of scale to address water poverty”, Marco P. Maneta, Associate Professor, Department of Geosciences, University of Montana, Missoula, Wednesday, November 16.

Attachment 5. Presentations at professional meetings.

20. W.L. Hargrove and J.M. Heyman. 2016. "Sustainable water resources for irrigated agriculture in a desert river basin facing climate change and competing demands: From characterization to solutions". Poster paper presented at USDA-NIFA Annual Project Directors Meeting, October 12-13, Washington, DC.
21. Presentation to University of New Mexico Law School, 20 Oct 2016: Gutzler, D.S. and S. Chavarria: Climate Change and Streamflow in the Upper Rio Grande Basin.
22. Presentation to Los Alamos National Laboratory Climate Science Conference, Pojoaque NM, 16 Nov 2016: Gutzler, D.S.: Hydroclimatic Forecasting in the Upper Rio Grande Basin
23. Presentation to Fall Meeting of the American Geophysical Union, 12 Dec 2016: Gutzler, D.S., J. Carilli, J. Norris, J. O'Shea, M. Salgado and Y.J. Sung: Streamflow Outlooks for Southwestern Rivers in a Changing Climate.
24. Mirchi, A. "Modeling Water and Land Management Adaptation in New Mexico-Texas Border Region". Abstract submitted to and accepted for oral presentation at World Environmental and Water Resources Congress (EWRI 2017), May 21-25, 2017, Sacramento, California.
25. Title: Sheng Z., Abudu S., Michelsen A. J.P. King. 2016. Variable exchange between a stream and an aquifer in the Rio Grande Project Area, 2016 AGU Fall Meeting, December 12-16, San Francisco, CA, Abstract, Poster.
26. Abudu S., Sheng Z., Michelsen A., Rodriguez, O, King J.P. 2016. Evapotranspiration and Crop Coefficient for Pecan Trees in El Paso, Texas, Proc. Irrigation Show and Education Conference, December 4-7, Las Vegas, NV, 8p. Presentation.
27. Sheng Z., Michelsen A., Abudu S., King, P. 2016. How can a gaining river become a losing stream in an arid region? Universities Council on Water Resources/National Institutes for Water Resources Annual Conference, June 21-23, Pensacola Beach, FL, Abstract, Presentation.
28. Sheng, Z., Abudu, S., Rodriguez, O. 2016 Strategic water operations planning to tackle the drought in the El Paso-Juarez Valley along the Rio Grande, Proc. Of World Environmental and Water Resources Conference, ASCE, May 21-26, West Palm Beach, FL, Abstract, Presentation.
29. Zhuping Sheng and Shalamu Abudu made four presentations on "Overview of Hydrological Models in the Rio Grande Project Area" at Stakeholders meetings, May 18, May 19, May 24 and 25.
30. Ganjegunte, G.K. and J.A. Clark. 2016. "Improved Irrigation Scheduling for Freshwater Conservation in Pecan Fields of El Paso, Texas, USA". International Conference on Agricultural Sciences and Food Technologies for Sustainable Productivity and National Security, August 25-27, 2016, Bangalore, India (Invited Presentation).
31. Ganjegunte, G.K. 2016. "Using High TDS Waters for Irrigation". Invited presentation at TAMU-Institution de Recherche et de l'Enseignement Supérieur Agricoles (IRESA) Linkage program Workshop, May 30 – June 6, 2016, College Station, TX (Invited Presentation).

32. Ganjegunte, G.K. 2015. “Salinity Management”. Invited presentation at “Training and Scientific Exchange Program” for “Delegation of High-Efficiency Use and Management of Agricultural Water Resources from Center for Agricultural Resources Research, Chinese Academy of Sciences”, September 17 – September 30, 2015, Texas A&M AgriLife Research Center at El Paso, TX (Invited Presentation).
33. Ganjegunte, G.K., and J.A. Clark. 2016. “Improved Irrigation Scheduling for Freshwater Conservation in Pecan Fields of El Paso, Texas, USA”. Proceedings of ASA, CSSA and SSSA International Meetings “Resilience emerging from scarcity and abundance”, 1 page [on Web], November 6-9, 2016, Phoenix, AZ. Abstract, Presentation.
34. Ganjegunte, G.K., and J.A. Clark. 2016. “Evaluation of Sulfur Burner for Salinity Management in Irrigated Cotton Fields in the West Texas”. Proceedings of ASA, CSSA and SSSA International Meetings “Resilience emerging from scarcity and abundance”, 1 page [on Web], November 6-9, 2016, Phoenix, AZ. Abstract, Poster.
35. Ganjegunte, G.K. 2016. “Salinity Management”. Presentation to stakeholders” May 18, 2016 at El Paso County Water Improvement District #1 Office, Clint, TX.
36. Mubako, S.T. 2016. Overview of USDA Project and water issues in the Rio Grande basin. Seminar presentation at La Salle Polytechnic Institute, Beauvais, France.
37. Ward, Frank. 2016 Water Policy in the U.S. and New Mexico. Seminar presentation via Skype at La Salle Polytechnic Institute, Beauvais, France.
38. “Space-based monitoring of land-use/land-cover in the Upper Rio Grande Basin: An opportunity for understanding urbanization trends in a water-scarce transboundary river basin”. Oral presentation at the 2016 Annual Fall Meeting of the American Geophysical Union, San Francisco, CA.
39. Students involved in the project from UACJ presented a poster at the “2do Congreso Internacional de Medio Ambiente y Sociedad” celebrated in Ciudad Juarez, Chih., Mex.

Attachment 6. Summaries of External Evaluator's Reports on Two New Courses (5.0 and 6.0) and the Water Symposium (7.0).

Evaluation Report 5.0 Summary and Suggestions

This report focuses on reflection survey responses from 16 students enrolled in CE 6313 Water Resources Management offered at the University of Texas at El Paso (UTEP) in the fall semester of 2016.

It is abundantly clear that the topic of water sustainability and management at UTEP is present at many levels of the university, which is impacting positively on courses like this one. Evidence of this is the importance that faculties give to courses like this one, the reasons the students give for taking this course, and the responses they give related to what they learned and what they would like to know more about. Clearly, a significant spark has created an important interest in this topic. It is also interesting to note the importance that the students give to leadership, communications, knowing stakeholders, politics and economics of water, and knowing the history of the region. With the foregoing in mind, only two suggestions are presented.

Suggestion 1. That attention and opportunity be given as part of this course to develop or improve leadership and communications skills, e.g., poster and paper presentations and class discussions.

Suggestion 2. That attention and opportunity be given as part of this course to engage more directly with stakeholder groups that are impacted by water sustainability and management, e.g., urban dwellers, environmentalists, and agricultural producers, perhaps through service-learning community level projects.

Evaluation Report 6.0 Summary and Suggestions

This report focuses on reflection survey responses from 25 students enrolled in ESCI 4315 /5315 Regional Water Sustainability in a Changing Environment course offered at UTEP in the fall semester of 2016,

This course clearly had an impact on the students. It appears that going into the course they were more interested in technical and scientific points related to water sustainability. Coming out of the course it appears that they are more aware of the complexity of water sustainability and about broader issues, such as future climate conditions and politics related to water and its impact on the economy of the region. This appeared to be a recurring underlying theme in many of the responses. This expanded view is important as it opens up a much larger perspective on not only the complicated issues related to water but also of wider career opportunities in this field of work. It also appears that the students are more cognizant about what they do not know and are now curious to know more, e.g., use of technology for modeling and politics and economics of water.

It was interesting to note that the majority of the students would recommend the course but that there were some who would recommend it but with encouraging reservations and a couple who would not recommend the course. Most of those that responded that they would recommend the course appeared to want to know more about the topic and could see the relevance of the course to the region. Those that recommended with encouraging recommendations indicated that students who enroll in the course would need to know more about performing statistical analyses and if they were interested in water dynamics and climate change. It should not be ignored that some students felt the course was not yet quite developed and that some speakers were not quite prepared. Regardless, many positive comments were made about the professors of record and several of the speakers.

Specifically, as it related to the opinion of the students about the skills and qualifications of professionals in this area of work, it was very interesting to note an important shift between the preflection and reflection surveys. In the preflection surveys, the students indicated that professionals should "have passion and communication skills," 9 of 67 (13.4%) responses. In the reflection surveys, the students indicated that professionals should "be a leader," 18 of 71 (25.5%) responses and "understand the region," 13 of 71 (18.3%) responses. It is possible to consider these two in the general category of leadership, particularly when more closely looking at the responses. If these two in the reflection survey could be combined they would represent 31 (43.7) of the responses. So, it is very interesting to see the importance that the students give to professionals being able to not only be technically competent but also exercise leadership within the context of the prevailing regional environment, i.e., knowing the environment and the people.

As already mentioned, clearly the course had an important impact on the students and Drs. Vanessa Lougheed and Lixin Jin are commended for the effort and outcomes from this course. It is evident that they sparked interest among the students and that the students learned a great deal. Teaching a course for the first time is always a challenge, but obviously they were very successful.

Following are a few suggestions:

Suggestion 1 – That readers of this report look at the tabulations and responses carefully and deduce their own interpretations to make adjustments in future courses.

Suggestion 2 – That course organizers compare the responses to questions from the preflection and reflection surveys, i.e., IV and II, V and III, and VII and VI, respectively, to assess the responses to similar questions and evaluate the impact of the course on the students.

Suggestion 3 – That careful consideration be given to inclusion of such topics as leadership, communication, and knowing the region and its stakeholders in the curricula in future courses, as these appear to be consistently emerging topics in this course and others.

Evaluation Report 7.0 Summary and Suggestions

This report focuses on reflection survey responses from 18 students that participated in the Water Sustainability Symposium.

It is obvious that this event was a success. All the responses from the students were constructive and nearly all were very positive and motivating. They appear to appreciate the opportunity to network with students from other universities to learn about their research and with faculty from a wide array of disciplines. It appears that they are more cognizant of how their respective disciplines are intricately related to other disciplines and may pursue more interdisciplinary work in the future. This is a huge impact for the future of this increasingly important worldwide topic. The students also indicated an appreciation to have the opportunity to synthesize their research into presentations that can be understood by lay persons. This was evident in the visits with the students during the poster presentations. They also emphasized how appreciative they were to have the opportunity to visit UTEP and expressed interests in visiting other universities. The entire experience impacted the students in many positive ways that may influence their future professional directions. The organizers of this event are complimented for this effort.

Only three suggestions are made:

Suggestion 1 – That organizers of future events of this type review carefully the suggestions that the student made, particularly to time management and the time and space allocated for the poster presentations.

Suggestion 2 – That this event be repeated, perhaps at one of the partner universities in the project and that time be allowed for the students to visit campus research facilities.

<u>Suggestion 3</u> – That thought be given to using this type of activity to cast more attention on the effort, perhaps by inviting opinion leaders, decision-makers, and policy-makers, e.g., local, state, and federal lawmakers.

Attachment 7. Undergraduate, master's, and doctoral degree students by gender and ethnicity

University	UG	Master's	Doctoral	Male	Female	Hispanic	Non-Hispanic
MTU	2		1	1	2		3
NMSU		1	6	3	4	3	4
TAMU	2				2	2	
UACJ	6	2	3	5	6	11	
UNM	4	1		4	1	1	4
UTEP	6	9	3	13	5	11	7
Sub-Total	20	13	13	26	20	28	18
Percent	43.5%	28.3%	28.3%	56.5%	43.5%	60.9%	39.1%
Totals	46			46		46	

ANNUAL REPORT

Yr 3, 2017-18

"Sustainable water resources for irrigated agriculture in a desert river basin facing climate change and competing demands: From characterization to solutions"

Prepared by:

Alfredo Granados-Olivas, PI

UACJ

XI. Scientific Participation

[See Attachment 1.]

XI. Target Audiences

[Bill will write]

XI. Scientific Publications (alphabetical by senior author)

Granados Olivas, Alfredo, Arturo Soto Ontiveros y Ana Cristina García Vásquez, 2017. Agua del Valle de Juárez: caso localidad de Práxedis. El Valle de Juárez: su historia, economía y ambiente para el uso de energía fotovoltaica. El Colegio de Chihuahua, Esmeralda Cervantes Rendón / Coordinadora. Primera edición 2017. Pag 37-79. ISBN: 978-607-8214-43-3

XI. Other Products/Outputs

A summary table of all project outputs from Yr 3 is presented in Attachment 2. Below is a

brief description of some of the major products/outputs. [Includes websites, models,

presentations, seminars, new courses, etc.]

V. Accomplishments (by objective)

Progress towards goals is more medium to long-term and is accomplished through achieving objectives in the short-term. Accomplishments by objective in Year 3 of our project are listed below.

Objective 1. Model development, improvement, integration, validation.

The Mexican team was able to run a preliminary essay for surface water while using SWAT and different sources of data bases that where integrated for the modeling. Different calibration process were done and output calculation for runoff, ETP, precipitation, Percolation, and other hydrologic parameters were generated.

Objective 2. Climate scenarios.

Objective 3. Dynamic Systems Model.

Objective 4. Stakeholder engagement and participation.

Two “hand on” workshops were offered open to the public at which farmers, water officials and the general public attended and learned from the different experts showing them results.

Objective 5. Dissemination.

One book chapter was publish whish discussed water issues at the Lower Valle de Juarez, Irrigation District # 9.

Objective 6. Water resources education and institutional strengthening.

Two students graduated while presenting thesis related to the project. (one undergrad and one grad students)

VI. Training and Professional Development

We list below all the individuals who have received training or professional development through the project. *Denotes that the student was supported financially by the project. In addition to these, we have listed and described accomplishments in education and institutional strengthening under Objective #6 in the Accomplishments section of the report. A summary table of the students supported for training is provided in Attachment 7. It is significant to note that 60% of the students supported by the project are Hispanic, an underrepresented group in water resources professions nationally.

<u>UTEP</u>

- *Brian Guerrero, MA in Sociology (completed), thesis research on El Paso Water's new program of direct potable reuse.
- *Marlene Flores, MA in Latin American and Border Studies; research on small utilities, especially accomplishments and challenges in serving geographically and socially marginalized rural communities.

<u>Summer Research Interns</u>

- Anna Piña. MS, Environmental Science Program. Examined water quality, groundwater depth and aquatic macroinvertebrate communities at the Rio Bosque wetland.
- Carlos Reyes, B.S. Geology. Study of urbanization using remote sensing.
- Joe Candelaria, B.S. Civil Engineering; EPWU wastewater treatment system and potential biogas production.
- Gabby Porras, B.S. Civil Engineering. Urban water use modeling and fieldwork on water quality and water treatment.

<u>NMSU</u>

<u>TAMU</u>

<u>UACJ</u>

- Sergio Granados González and Gabriela Veleta Jáquez, Geoinformatics Bachelor Program at UACJ (Cuauhtémoc Extension). LULC development and geospatial roject .
- Ana Laura Ruiz Aragonez, Physics Bachelor Program at UACJ. ETP analysis and Crop spectral signature using eBee Drone.
- Katya Esquivel Herrera, Geoscience Bachelor Program at UACJ. SWAT modeling
- Arturo Soto Ontiveros, PhD Program on Urban Studies at UACJ. Modflow modeling.

- Hugo Luis Rojas Villalobos, PhD Program onWater Science and Management at NMSU. GIS Master and roject web page.
- Ana Cristina Garcia, MS Environmental Engineering Program at UACJ. GW quality.

UNM

MTU

Professional Development

- Dr. Shalamu Abudu, TAMU, successfully completed a one-week training course on SWAT in January, which will help him configure and/or integrate SWAT and RiverWare model for water operations within the project area.
- Dr. Ali Mirchi spent one week in El Reno, OK at USDA-ARS lab to be trained on SWATmf by Dr. Daniel Moriasi.
- Dr. Alfredo Granados from UACJ took a sabbatical leave at UTEP during 2016 to manage and administer the project and coordinate Mexican team efforts.

VII. Dissemination of Results

Dissemination of results is one of our objectives. See accomplishments for Objective 5 for a complete list of dissemination activities. Of particular note is the Water Symposium hosted by UTEP, where our students presented results. We invited many of our stakeholders to this meeting. We presented 33 poster papers, mostly by students supported on the project. They are listed in Attachment 3.

VIII. External Evaluation

[Summaries]

IX. Plans for Yr 4 (by objective)

Objective 1. Model development, improvement, integration, validation.

Calibration and scenarios modeling. Integration of SWAT and Modflow modeling.

Objective 2. Climate scenarios.

Objective 3. Dynamic Systems model.

Objective 4. Stakeholder engagement and participation.

Planning and implementing two Workshops

Objective 5. Dissemination.

Publication at Mexican peer review journals

Objective 6. Water resources education and institutional strengthening.

Continue efforts to graduate and promote students to pursue further studies.

IX. External Evaluation

X. Major Problems or Requested Changes

XI. Attachments

Attachment 1. Project participation

Role	Faculty and Non-Students	Students with Staffing Roles			Computed Total by Role
		Undergraduate	Graduate	Post-Doctorate	
Scientist	3	0.0	0.0	0.0	
Professional	1	5	2	0.0	
Technical		0.0	0.0	0.0	

Administrative	1.00	0.0	0.0	0.0
Other	0.0			
Computed Total				

Attachment 2. Project Outputs

USDA-Mexico WEB Portal

The USDA-México web portal is hosted at the web address http://smiley.nmsu.edu/USDA_MEX which is developed with CSS and JavaScript; based on technique called Bootstrap. The main advantage of using Bootstrap is that the website interface automatically adapts to the screen of a PC, a Tablet or another device such as a Smartphone. Bootstrap uses CSS3 modules that allows the representation of content to adapt to conditions of the screen resolution of the device automatically.

MX Modeling

The development of the models has been done in a sequential manner, from the recollection and exchange of information from basin variables of interest, at a binational level, and by initially integrating natural hydrological network information, then the network of canals and hydraulic infrastructure, as well as local weather statistics, also specific contributions of waters within the sub- basins, and hydrometric monitoring and control stations. The procedures of modeling, was divided into four main stages, namely: Delineation of the basin, Definition of hydrologic Response Unit (HRU), Weather information and Configuration of simulation scenarios.

The model was built from data of free access from governmental institutions.
The Mexican coverage area includes the location of the American dam up to the hydrometric station located at Fort Quitman, Tx., additionally flow rates from the American dam, the Acequia Madre and effluents from wastewater treatment plants in Ciudad Juárez, Chihuahua, were integrated, as well as the historical climatological records from the stations within the study area. Based on the sequence of processes previously specified, the layers of soil type and uses and the spatial definition of hydrological response units, were generated.

From the establishment of the hydrological response units, as well as the relevant configuration protocols and programming, twenty SWAT modeling exercises have been developed, in four of the five sub-basins, for the years 2005, 2007, 2009, 2011 and

2013, respectively. Estimating temporal monthly and yearly trends for the hydrological variables such as: Evapotranspiration (ET), Precipitation, Percolation, Aquifer recharge and Potential Evapotranspiration (PET).

From the obtained results, it was possible to establish the spatial distribution of the mentioned variables, through the generation of coverage maps for each sub basin.

Presentations

Project presentations and outputs dissemination on preliminary results were given at two main “hands on” workshops, where stakeholders (both farming community and officials from the different water offices in Mexico (ie. CONAGUA, CILA, JMAS, JCAS, SAGARPA), were conducted during the meetings to manipulate and “play” with the project preliminary outputs.

ANNUAL REPORT

Yr 4, 2019-2020

"Sustainable water resources for irrigated agriculture in a desert river basin facing climate change and competing demands: From characterization to solutions"

Prepared by:

Alfredo Granados-Olivas, PI

UACJ

I. Scope of Work for the period of the extension –

- UACJ team members will work during this extension period on accomplishing a set of tasks that will allow the completion of several ongoing activities:

  - LULC team will work on accomplishing temporal changes "ag to urban changes" statistics. Among the detected ag changes, we´ll estimate areas under pecan orchards using remote sensing technology.
  - An analysis of temporal trends of LULC and its relations with climatic variables will be evaluated
  - The development of a spectral index to determine salinity concentrations in the Juarez Valley will be completed
  - SWAT-ModFlow modeling team will work on integrating both tools for the MX side of project
  - Modeling of hydrological variables within the sub basins of the Mexican watershed from 1995 to 2015 will be accomplish
  - Development and upgrade of the land use and cover maps, for each year from 1994 to 2015 will be accomplish
  - Revision and refinement of agricultural data and other variables from the Valle de Juarez, irrigation district (Jan 2019), while using SWAT models, will be integrated
  - Exchange of binational hydrological data from both sides of the border will be completed and enhance for transboundary hydrological modeling for both surface and groundwater.
  - Students and professors will participate on several national and international meetings showing their research results.

- The modeling of projected climate change impacts to Ciudad Juarez urban landscapes will be evaluated.
- A ModFlow sensitivity analysis for the Valle de Juarez Aquifer will be generated
- Three groundwater flow models scenarios will take place while using different pumping policies
- Depth, elevation and groundwater evolution configurations will take place for the ModFlow modeling procedures to estimate inputs and outputs of groundwater for the border region
- A GIS web page on the project will be completed for information dissemination and stakeholder's training and for downloading products in GIS format.
- The implement of cartographic base products and simulation results that can be represented geographically in a GIS-WEB system for online publication will be accomplish.

II. Progress in Yr 5

MX team successfully completed several tasks among the different topic areas on which the project was divided:

- During this period, we successfully completed the generation of the annual LULC maps from 1990-2015 for the entire USA-Mexico study area
- The generation of LULC change models for the years 2020, 2025, 2030, 2035, and 2040, using the MARKOV model were accomplish
- A spectral index is under development to determine salinity concentrations in the Juarez Valley, supported by field sampling
- Research activities have been accomplished for the thesis "Determination of Land Cover and Land Use of Rio Bravo (1990-2015): Process of Changes and Evolution of the NDVI", which must be submitted to the thesis committee in December of 2019.
- Initial modeling trial runs were built under SWAT using observed hydrological and climatological variables from 1994 to 2015
- Modeling efforts are currently underway for a time horizon from 2016 to 2040, and they include future estimations on climate change and its variables, population growth and water demand, land use, and water deliveries from the US – Mexico treaty.
- UAC students submitted progress research material to the 6th edition of the conference and competition Encuentro de Jovenes Investigadores del Estado de Chihuahua.
- UACJ has strength a working group dedicated to climate and had publish scenarios of rain water changes based on the output of global circulation models.
- UACJ climate change team was able to assist in the interpretation of climate models assimilated to the Bucket model for Chihuahua.

- A paper related to the project was accepted to be presented as an oral presentation at the Mexican Geophysics Union Annual Meeting
- Groundwater modeling scenarios have begun for the total area of the Valle de Juarez simulated for the period of 2008-2070
- For the construction of the ModFlow groundwater model, the delimitation of the study area was accomplished which included the following flow modeling elements: Design of modeling mesh, stress periods, pumping rates, initial conditions, border conditions, hydraulic parameters, diffuse recharge, and flow model calibration.
- A georeferenced and vectorize process has initiated to define the apparent salinity map of the Juarez Valley.
- A digital process to change web page from Bootstrap technology to WordPress was initiated.

III. Yr 1-5 Progress

A. Outcomes

- Discussion of published results of rain water shortages for the short-term climate scenarios had supported the decision of the State of Chihuahua water utility (JCAS) to elaborate executive projects for the use of green infrastructure as a strategy to reduce flooding in 24 sectors of Ciudad Juarez
- Irrigation District 009 Valle de Juarez CONAGUA officer collaborated on providing information and are evaluating how the integrated hydrological data will support decision making to enhance irrigation water efficiency
- Groundwater model for the urban area of Ciudad Juarez has been shared with state and local water agencies (JCAS-JMAS) to evaluate future urban water demands

B. Outputs

1- Publications

a. Miguel Duran Rangel *et al.* (2019). *Modelación hidrológica de recarga al acuífero Bolsón del Hueco, simulando efectos por inclusión de políticas de administración del agua*. Congreso Jóvenes Investigadores, UACJ.

b. Katya Esquivel et al. (2019). Modelación hidrológica de la recarga del valle de Juárez de 1995 al 2040, incorporando un modelo de cambio climático RCP 4.5 Congreso Jóvenes Investigadores, UACJ.

c. Rivera-Lozano, L., Vazquez-Galvez, F. A., & Granados-Olivas, A. (2019). Valoración del impacto climático en las principales ciudades de la frontera norte de México. In J. C. Rueda-Abad (Ed.), ¿Aun estamos a tiempo para el 1.5 C? (pp. 425–440). Mexico City: UNAM. Retrieved from http://www.pincc.unam.mx/DOCUMENTOS/LIBRO/aunestamosatiempo_isbn.pdf

d. ARTURO SOTO-ONTIVEROS, ALFREDO GRANADOS-OLIVAS, ADAN PINALES-MUNGUIA,SERGIO SAUL-SOLIS, JOSIAH McCONNELL HEYMAN, 2018. EVOLUCIÓN TEMPORAL DEL FLUJO DEL AGUA SUBTERRÁNEA EN CIUDAD JUÁREZ, CHIHUAHUA APLICANDO MODELACIÓN GEOESPACIAL. Tecnociencia Chihuahua, 2018. ISSN: 1870-6606. Vol. XII, Núm. 2 • Mayo-Agosto 2018; pags 103-113. DOI: http://tecnociencia.uach.mx/v10n1.php

e. Alatorre Cejudo, Luis Carlos, Alfredo Granados-Olivas, Luis Carlos Bravo, Maria Elena Torres, Lara Cecilia Wiebe, Mario Ivan Uc, Manuel Octavio Gonzalez, Erick Sanchez, Victor Manuel Salas, 2019. Agricultural furrow irrigation inefficiency in the basin of the Laguna de Bustillos, Chihuahua, Mexico: geometric characteristics of agricultural plots and aquifer depletion. Tecnología y Ciencias del Agua, 2019. Accepted for publication. ISSN electrónico: 2007-2422 ISSN impreso: 0187-8336 DOI: 10.24850/j-tyca-imta

f. Granados Olivas, Alfredo; Luis Carlos Alatorre Cejudo; Josiah M. Heyman; Arturo Soto Ontiveros; Adán Pinales Munguia; Sergio Saúl Solis; Hugo Luis Rojas Villalobos, Adrián Vázquez Galvez, María Elena Torres Olave; Luis Carlos Bravo Peña; Oscar Ibañez; William L. Hargrove; Alex Meyer; Shuping Sheng, 2019. "Las oportunidades para la sustentabilidad hídrica en las Cuencas de Chihuahua: Estrategias para compensar las demandas socioeconómicas y ambientales ante los retos del cambio climático (Agua-Energía-Alimentación) ". Book chapter in: “Problemáticas del agua y medidas sustentables en dos estados desérticos de México: Chihuahua y Sonora”. Sección: A) Identificación y descripción de problemáticas sociales, ambientales y/o económicas relacionadas al agua. El Colegio de Chihuahua y El Colegio de Sonora, In Edition 2019, Accepted for publication. ISBN: 978-607-8214-43-3

g. Adán Pinales Munguía, Alfredo Granados Olivas, Arturo Soto Ontiveros, William L. Hargrove, Joshia M. Heyman, Zhuping Sheng, Humberto Silva Hidalgo, María Socorro Espino Valdés, 2019. SIMULACIÓN DEL AGUA SUBTERRÁNEA EN ACUÍFEROS CUYO PRINCIPAL USO ES EL ABASTECIMIENTO PÚBLICO URBANO. CASO DE ESTUDIO: ACUÍFERO VALLE DE JUÁREZ. UGM 2019.

2- Other products

a. A special web page for the USDA project was created on the UACJ servers. http://mexusda.uacj.mx/
b. A map server was integrated into the project website using the ArcGIS Online platform. http://mexusda.uacj.mx/WebMap.html
c. An information transfer protocol was generated using a secure file transfer protocol (sftp) and remote instructions on the server using a secure shell (SSH) to place links to compacted geographic data files. This process facilitated the transfer of massive data among the members of the work team.

3- Training/education

a. Estudiante: Mariela Rascón Castillo
Grado: Geoinfomática
Lugar: UACJ Cuauhtémoc, Chihuahua, México.
Año: 2017
Tesis: Análisis del crecimiento urbano en Ciudad Juárez y su impacto en las coberturas y uso de suelo urbano y del territorio 1985 – 2002, 2002 – 2015.

b. Estudiante: Gabriela Veleta Jáquez
Grado: Geoinfomática
Lugar: UACJ Cuauhtémoc, Chihuahua, México.
Año: DIC-2019
Tesis: Determinación de la Cobertura y Uso de Suelo del Rio Bravo (1994-2015).
Proceso de Cambios y Evolución del NDVI.

c. Estudiante: Víctor Hugo Esquivel Ceballos
Grado: Ph D en Estudios Urbanos
Lugar: UACJ- Juárez.
Año: DIC-2019
Tesis: Análisis del crecimiento urbano de Ciudad Juárez, Chihuahua, México: repercusiones sobre la demanda y disponibilidad hídrica, y abatimiento del acuífero.

d. Student: Mariela Rascón Castillo
Degree: Geoinfomática
Place: UACJ Cuauhtémoc, Chihuahua, Mexico.
Year: 2017
Thesis: Analysis of urban growth in Ciudad Juárez and its impact on the coverage and use of urban land and territory 1985 - 2002, 2002 - 2015.

e. Student: Gabriela Veleta Jáquez
Degree: Geoinfomática
Place: UACJ Cuauhtémoc, Chihuahua, Mexico.
Year: DEC-2019
Thesis: Determination of the Coverage and Land Use of Rio Bravo (1994-2015). Process of Changes and Evolution of the NDVI.

f. Student: Víctor Hugo Esquivel Ceballos
Degree: Ph D in Urban Studies
Place: UACJ- Juárez.
Year: DEC-2019

Thesis: Analysis of urban growth in Ciudad Juárez, Chihuahua, Mexico: repercussions on demand and water availability, and depletion of the aquifer.

g. Student: Alfredo Jaquez Granados
Degree: Bachelor on Agribusiness
Place: UACJ- Casas Grandes.
Year: DEC-2021
Thesis: Changes on NDVI values on pecan orchards using SEQUOIA camera.

h. Student: Katya Esquivel
Degree: Bachelor in Geosciences
Place: UACJ- Juárez.
Year: DEC-2020
Thesis: *Development of Hydrological Variables from the Hueco Bolson – Valle de Juarez basin, Using the Soil and Water Assessment Tool (SWAT) program*.

i. Student: Carolina Salazar
Degree: Bachelor on Environmental Engineering
Place: UACJ- Juárez.
Year: DEC-2020
Thesis: *On the integration and refinement of land use cover and agricultural parameters, for the modeling of Hydrological Variables of the Hueco Bolson Basin.*

j. Student: Arturo Soto Ontiveros
Degree: Ph D in Urban Studies
Place: UACJ- Juárez.
Year: May-2019
Thesis: “Disponibilidad de Agua Subterránea y su relación con el Desarrollo Urbano en Ciudad Juárez, Chihuahua: Un análisis retrospectivo y prospectivo durante el periodo 2008 al 2030”.

k. Student: Víctor Hugo Esquivel Ceballos
Degree: Ph D in Urban Studies
Place: UACJ- Juárez.
Year: DEC-2019
Thesis: Analysis of urban growth in Ciudad Juárez, Chihuahua, Mexico: repercussions on demand and water availability, and depletion of the aquifer.

l. Student: Rogelio Alvarado
Degree: Bachelor on Environmental Engineering
Place: UACJ- Juárez.
Year: DEC-2022
Thesis: “Monitoring the influence of atmospheric water vapor fields on the Paso del Norte water basin”

m. Student: Miguel Duran Rangel
Degree: Master on Environmental Engineering
Place: UACJ- Juárez.
Year: DEC-2022
Thesis *Modelación hidrológica de recarga al acuífero Bolsón del Hueco, simulando efectos por inclusión de políticas de administración del agua*.

The Future of Water in the Middle Rio Grande Basin –
A Science Exhibition

Evaluation Report 29.0
University of Texas at El Paso

for

"Sustainable water resources for irrigated agriculture in a desert river basin facing climate change and competing demands: From characterization to solutions"
(Water Sustainability Project)

by

Manuel Piña, Jr., Ph.D.

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December 16, 2019
External Evaluation Report 29.0

The Future of Water in the Middle Rio Grande Basin –
A Science Exhibition

I. Introduction

This report covers evaluation activities from October 20 through December 16, 2019. Activities conducted during this period are listed below. This report focuses on EL FUTURO DEL AGUA A MITAD DEL RÍO GRANDE: UNA EXHIBICIÓN DE CIENCIA (The Future of Water in the Middle Rio Grande Basin – A Science Exhibition) held at the Centro Cultural de las Fronteras at the Universidad Autonóma de Ciudad Juárez on November 22, 2019.

- Establishing and maintaining contact with the Project Director via email, telephone, and in person throughout this reporting period
- Researching for project graduate student impact
- The Future of Water in the Middle Rio Grande Basin – A Science Exhibition held at the Texas AgriLife Research Center in El Paso, Texas on September 24, 2019 (External Evaluation Report 27.0, pending)
- Dr. Tallen Capt for UTEP Graduate Student Exit Interview (External Evaluation Report 29.0, pending)
- Preparing External Evaluation Report 29, December 5-16, 2019

II. Method

This report is based on responses from 23 participants who participated in EL FUTURO DEL AGUA A MITAD DEL RÍO GRANDE: UNA EXHIBICIÓN DE CIENCIA (The Future of Water in the Middle Rio Grande Basin – A Science Exhibition) held at the Centro Cultural de las Fronteras at the Universidad Autonóma de Ciudad Juárez on November 22, 2019. Attachment A is a copy of the survey instrument. Quantitative responses were coded and analyzed using Statistical Package for the Social Sciences (SPSS). The analyzed data is included in attachment B. The responses to four open-ended responses were grouped into themes by two independent judges and these are found in attachment C.

III. Results

There were 23 participants attending the exhibition, including 20 males, 3 females. Participants were asked to indicate their water management interests in the contexts of agriculture, urban areas, environment, industry, government, and/or research; how they agreed or disagreed with ten statements using a five-point Likert-type scale; and to provide responses to four open-ended questions related to the exhibition.

Table 1 shows the number of responses that each context area received. It should be noted that respondents could indicate interest in one or several context areas. The context area receiving the largest number of indications was urban, followed by environment, government, industry, agriculture, and research. (See attachment B for SPSS analysis.)

Table 1. Context Interests

Context Interest	Number of Responses	Percent of Respondents

Urban	20	87.0%
Environment	16	69.6%
Government	12	52.2%
Industry	11	47.8%
Agriculture	11	47.8%
Research	10	43.5%

Table 2 lists the statements to which the respondents agreed or disagreed and the number of responses that each statement received. There were 28 responses that indicated the respondents strongly disagreed or disagreed with being aware of nine ((9) statements related to the exhibition. There were also 22 responses that indicated the respondents were unsure about being aware of nine (9) statements related to the exhibition. This total of 50 responses correspond with 22.1% percent of the total of 226 responses across all statements.

However, the majority of the total of all responses indicated that respondents agreed or strongly agreed with all statements. These were 176 of the total of 226 or 77.8% across all statements.

Regardless, it is worthy to review all of the ten statements to which the respondents strongly agreed or disagreed with being aware. (See attachment B for SPSS analysis.) For example, eight (8) respondents (40%) indicated they disagreed with statement 2, “Of the need to pump more groundwater because of reduced surface water.” At the same time, nine (45%) indicated they agreed or strongly agreed with the statement. Four (20%) were unsure about this statement.

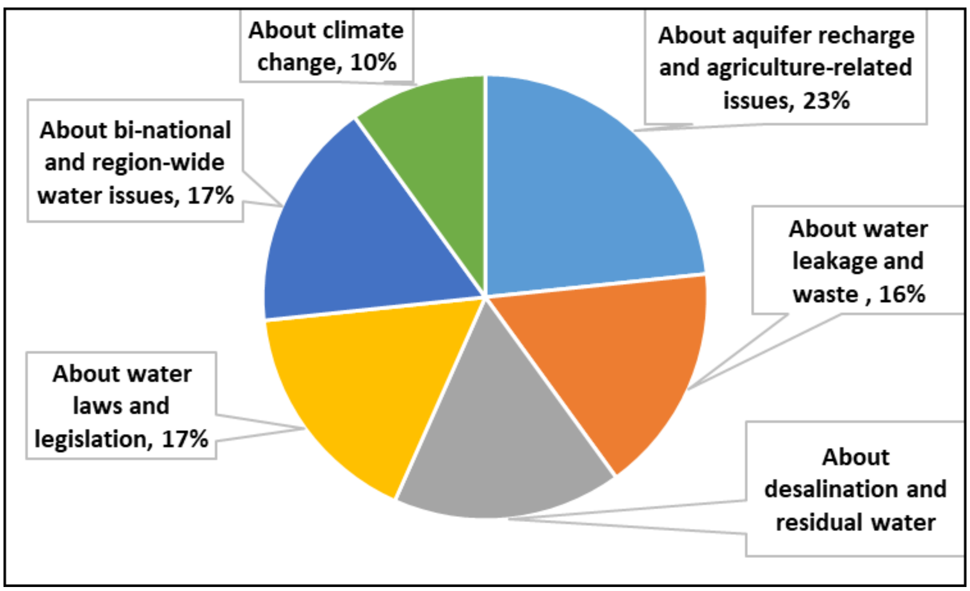
Similar comparisons could be made with other statements that merit study and interpretation for future work of this type.

Table 2. Agreement or disagreement with statements

	Statement	Strongly Disagree	Disagree	Unsure	Agree	Strongely Agree
1	Of the reduction of water availability from the aquifer	2 (8.7%)	2 (8.7%)	4 (17.4%)	6 (26.1%)	9 (31.1%)
2	Of the need to pump more groundwater because of reduced surface water	2 (8.7%)	8 (34.8%)	4 (17.4%)	5 (21.7%)	4 (17.4%)
3	Of the differences in urban water use between El Paso, Las Cruces, and Juarez	4 (17.4%)	3 (13.0%)	1 (4.3%)	7 (30.4%)	1 (4.3%)
4	Of that the cost of water from alternative sources will rise for urban consumers		1 (4.3%)	2 (4.3%)	11 (47.8)	10 (43.5%)
5	Of how the SWIM model allows stakeholders to explore future water availability impact			2 (8.7%)	5 (21.7%0	16 (69.6%)
6	Of how the SWIM model considers climate change, technologies, and human use		1 (4.3%)	1 (4.3%)	9 (39.1%)	12 (52.2%)
7	Of the importance of diversifying sources of water for agriculture in the region		1 (4.3%)	3 (13.0%)	10 (43.5%)	9 (39.1%)
8	Of the need to consider traditional and other crops in the region that are salt-tolerant		1 (4.3%)	3 (13.0%)	12 (53.2%)	7 (30.4%)
9	Of aware of the need to understand water balance to improve water use efficiency in irrigated crops such as pecans		1 (4.3%)	2 (4.3%)	8 (34.8%)	13 (56.5%)
10	Of the need to improve irrigation management and water use efficiency		2 (4.3%)		3 (13.3%)	19 82.6%

The participants were asked the following four open-ended questions. Following are summaries of a content analysis of the responses to each of the questions. Readers of this report are encouraged to review all the responses found in attachment C.

11. ¿Qué otros temas relacionados con el agua en la región le gustarían saber más? *(What other topics related to water in the region would you like to know more about?)*		
Theme	**Number**	**Percent**
About aquifer recharge and agriculture-related issues	7	23.3%
About water leakage and waste	5	16.7%
About desalination and residual water recovery	5	16.7%
About water laws and legislation	5	16.7%
About bi-national and region-wide water issues	5	16.7%
About climate change	3	10.0%
Total	30	100.0%



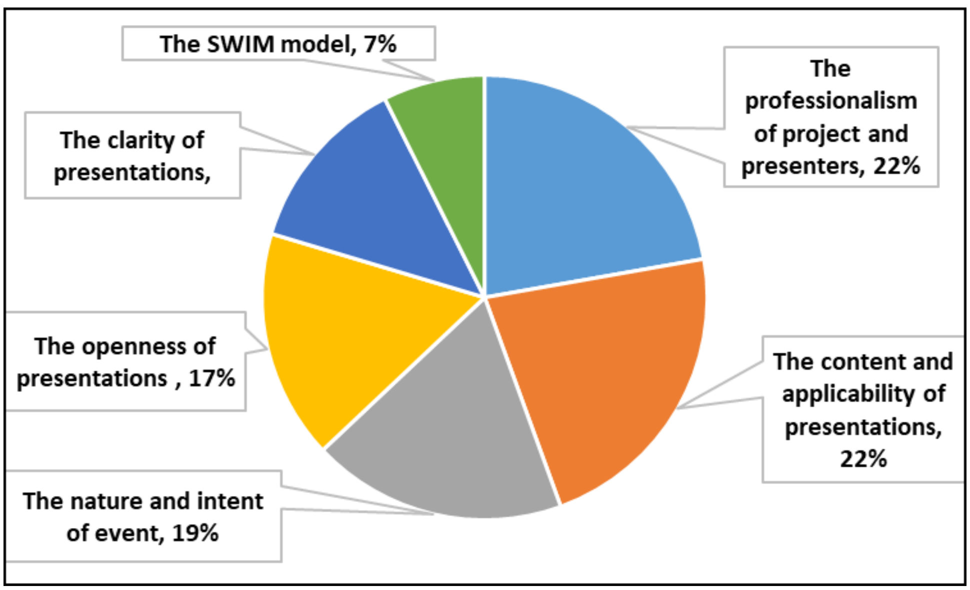
Although 11 (47.5%) of the participants indicated agriculture as an area of interest the largest area of which they would like to know more about [7 (23.3%] indicating wanting to know about the aquifer recharge and agriculture-related issues. Of the remaining five themes that emerged, four were evenly distributed, each with five responses. While two of the themes related to leakage, waste, desalination, and recovery, of note is that two themes related to prevailing water laws and legislation and bi-national and region-wide water issues. Another note, climate change received only three responses.

All written statements and derived themes are found in attachment C. Following are samples of the statements related to this theme:

- *Recargas al acuífero*
- *Eficiencia sistema de riego zona agrícola*

- *La manera en que una vez utilizada el agua para riego es tratada y/o programas para tratamiento e inyección a los acuíferos*
- *Derechos de la ciudadanía y el público consumidor*
- *Límites permisibles para el uso agrícola y urbano*
- *La exposición de al agua compartida binacionalmente*
- *Infraestructura y proyectos de conservación en ambas ciudades fronterizas (Posibles resultados con su implementación)*

12. Cuéntenos tres (3) cosas que le gustaron de la exposición *(Tell us three (3) things you liked about the exhibition)*		
Theme	**Number**	**Percent**
The professionalism of project and presenters	12	22.2%
The content and applicability of presentations	12	22.2%
The nature and intent of event	10	18.5%
The openness of presentations	9	16.7%
The clarity of presentations	7	13.0%
The SWIM model	4	7.4%
Total	54	100.0%



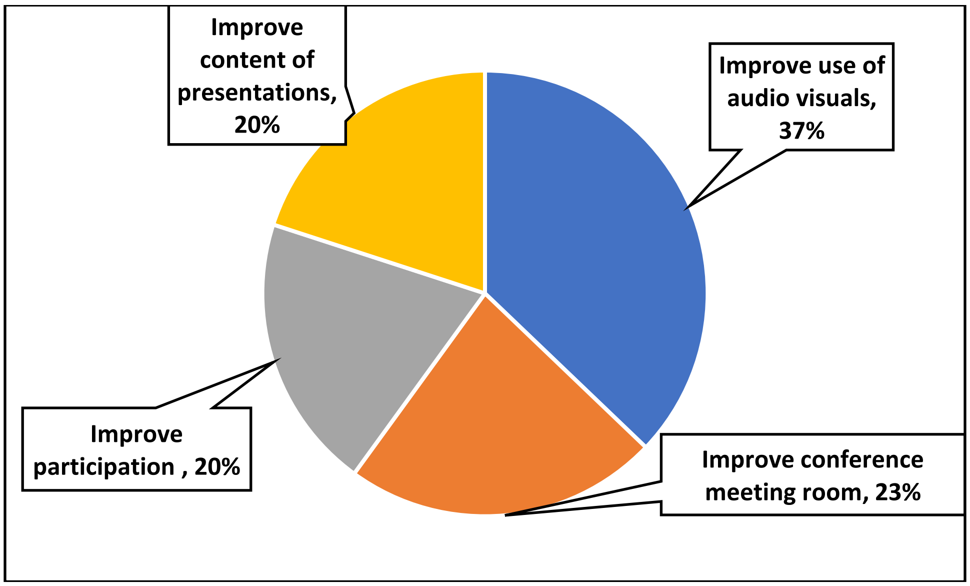
Clearly, the participants liked the exposition and praised the organizers for their professionalism, the content and applicability of the event, and the openness and clarity of the presentations.

All written statements and derived themes are found in attachment C. Following are samples of the statements related to this theme:

- *Profesionalismo*
- *Entrega de artículo en papel previo a la presentación*
- *La planeación al futuro*

- *Transparencia*
- *La claridad de la información dada*

13. Cuéntenos tres (3) cosas que podemos hacer de manera diferente en futuras exposiciones. (Tell us three (3) things we can do differently in future exhibitions).		
Theme	**Number**	**Percent**
Improve use of audio visuals	13	37.1%
Improve conference meeting room	8	22.9%
Improve participation	7	20.0%
Improve content of presentations	7	20.0%
Total	35	100.0%



Although the participants indicated satisfaction with the exposition, they nonetheless made suggestions for improvement that could be considered for future similar events. The suggestions included improving the use of audio visuals to share information more effectively, a different meeting room that would be larger and quieter, improve the number of participants, and improve the content of the presentations.

All written statements and derived themes are found in attachment C. Following are samples of the statements related to this theme:

- *Ayuda visual a color*
- *Presentación de resultados de manera gráfica, no solo hablando (cerca de expositor)*
- *Área o salón más amplio*
- *Un lugar con menos ruido*
- *Mayor participación de las comunidades*
- *Abrir un poco más el público – en general*
- *Mejorar la participación de los tomadores de decisiones*

- *Muchos sectores involucrados (stakeholders) están del todo ausentes*

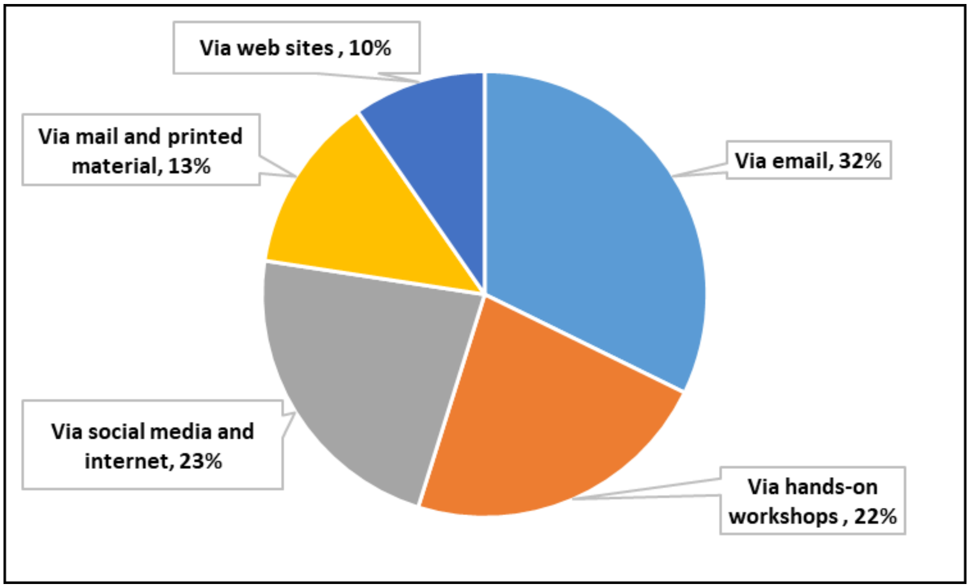
14. ¿Prefiere este formato de "feria de ciencias" o algún otro formato como clase o formato de taller para recibir información sobre el proyecto? *(Do you prefer this "science fair" format or some other format like classroom lecture or workshop format for receiving information about the project?)*

Because there were only five mixed responses to this question, no attempt was made to content analyze them. Because they are inconclusive, they are presented here in their entirety.

Theme: Mixed responses

- *Si*
- *Me gusto el formato*
- *Depende de los objetivos*
- *Prefiero talleres prácticos*
- *Este formato de feria de ciencias*

15. Díganos cómo prefiere recibir información/resultados. *(Tell us how you prefer to receive information/results.)*		
Theme	**Number**	**Percent**
Via email	10	32.3%
Via hands-on workshops	7	22.6%
Via social media and internet	7	22.6%
Via mail and printed material	4	12.9%
Via websites	3	9.7%
Total	31	100.0%



A little over a third of the respondents indicated they preferred to receive information via email. Nearly a quarter indicated they preferred hands-on or interactive workshops. Another quarter preferred social media and the internet. Some still prefer printed material via mail.

All written statements and derived themes are found in attachment C. Following are samples of the statements related to this theme:

- *Por correo electrónico*
- *Notificaciones mediante correo electrónico de las actualizaciones y resultados de programa Taller participativo*
- *Redes sociales*
- *Como informe impreso*
- *Revistas especializadas*
- *Página de internet*

IV. Summary and Conclusion

It is evident that the participants felt that this event was conducted in a very professional manner in which there was ample time allotted for questions, answers, and clarifications. Very positive comments were written about this aspect of the exposition. Clearly, there is interest and concern related to water in Mexico and efforts should be continued to maintain and strengthen the relationship and joint efforts with Mexican counterparts and stakeholders.

However, there are four key points that merit attention for future work follow. One is the locale of the event. Several respondents mention that the room was too small and too loud, i.e., there was competing noise from another event taking place on the next floor up. Two is the use of visuals to complement the panel presentations. While the articles to be discussed were shared prior to the presentations, these were not supported by any visual images. Three related to not only the limited number of participants but to the very narrow range of stakeholder groups present. Some participants suggested more representation from community members and policy makers. A few participants mentioned during the event the need to treat the water issue from a bi-national perspective, i.e., consider water issues and related prevailing policies from the perspectives and needs of stakeholders from both sides of the border.

Table 2 summarizes the degree to which the respondents judge they are aware of key water issues and is worthy of review as it may illuminate future areas of research and outreach that merit attention. It is worthy to review all ten statements to which the respondents strongly agreed or disagreed with being aware. The tables and charts related to the four open-ended questions may point out a few areas for research and outreach and provide feedback and insight for future events of this type.

Overall, the responses to both the statements and questions leave a very positive impression of the impact of the exposition and project leaders are commended for this outcome. Certainly, some of the presentations provoked lively discussions that may offer insight to future directions related to water in the border area.

There is only one suggestion from this report: That project leaders review the contents of this report and take it into consideration for future workshops of this nature.

Evaluation Next Steps

1. Review this report with Project Director
2. Have phone interviews with project leaders to prepare survey to assess impact of project on students and impact of students on the project, Evaluation Report 26.0.
3. Prepare and submit report for evaluating the Science Exhibition held at the Texas AgriLife Research Center in El Paso, Texas on September 24, 2019, External Evaluation Report 27.0.
4. Contact Dr. Tallen Capt for Student Exit Interview, External Evaluation Report 29.0.
5. Continue contacting the presenters at the Science Exhibition at Las Cruces to get their feedback on the event (External Evaluation 30.0)

-end of report-

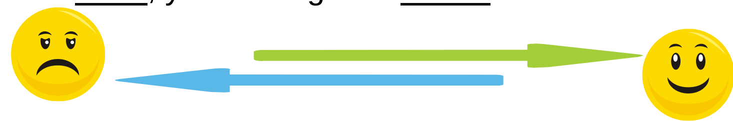
Attachment A. Survey Instrument

EL FUTURO DEL AGUA A MITAD DEL RÍO GRANDE: UNA EXHIBICIÓN DE CIENCIA

Viernes, 22 de noviembre de 2019, Centro Cultural de las Fronteras, Ciudad Juárez, Chih

Yo estoy interesado en como el agua es usada/manejada en el contexto de: (seleccione todas las que apliquen): agricultura ___, área urbana___, medio ambiente___, industria____, gobierno____, y/o investigación_____.

Yo soy hombre______ mujer_______



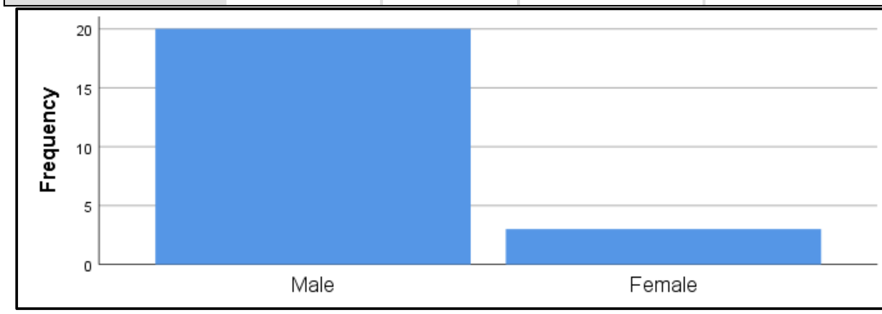
Marca con una “X” si estás de acuerdo o en desacuerdo con cada una de estas declaraciones; Relacionado con la disponibilidad futura de agua en nuestra región, ahora soy más consciente:	**Totalmente en desacuerdo (1)**	**Desacuerdo (2)**	**Inseguro (3)**	**De acuerdo (4)**	**Totalmente de acuerdo (5)**
1. De la reducción de la disponibilidad de agua en el acuífero en el futuro					
2. De la necesidad de bombear más agua subterránea debido a la reducción de agua superficial					
3. De las diferencias del uso del agua urbana entre El Paso, Las Cruces y Ciudad Juárez					
4. De que el costo del agua procedente de fuentes alternativas aumentará para los consumidores urbanos					
5. De cómo modelos de planeación (ejemplo: SWIM) permiten a las partes interesadas explorar el impacto futuro de la disponibilidad de agua					
6. De cómo modelos de Planeación (ejemplo: SWIM) considera el cambio climático, la tecnología y el uso humano					
7. De la importancia de diversificar fuentes de agua para las regiones agrícolas					
8. De la necesidad de considerar los cultivos tradicionales y otros cultivos de la región que sean tolerantes a la salinidad					
9. De la necesidad de entender el balance del agua para mejorar el uso eficiente en la irrigación de cultivos como el nogal					
10. De la necesidad de mejora el manejo de irrigación y el uso eficiente del agua					

11. ¿Qué otros temas relacionados con el agua en la región le gustarían saber más? ____
12. Cuéntenos tres (3) cosas que le gustaron de la exposición
    a) ____
    b) ____
    c) ____
13. Cuéntenos tres (3) cosas que podemos hacer de manera diferente en futuras exposiciones
    a) ____
    b) ____
    c) ____
14. ¿Prefiere este formato de "feria de ciencias" o algún otro formato como clase o formato de taller para recibir información sobre el proyecto?
15. Díganos cómo prefiere recibir información/resultados. ____

B. Analyzed Responses

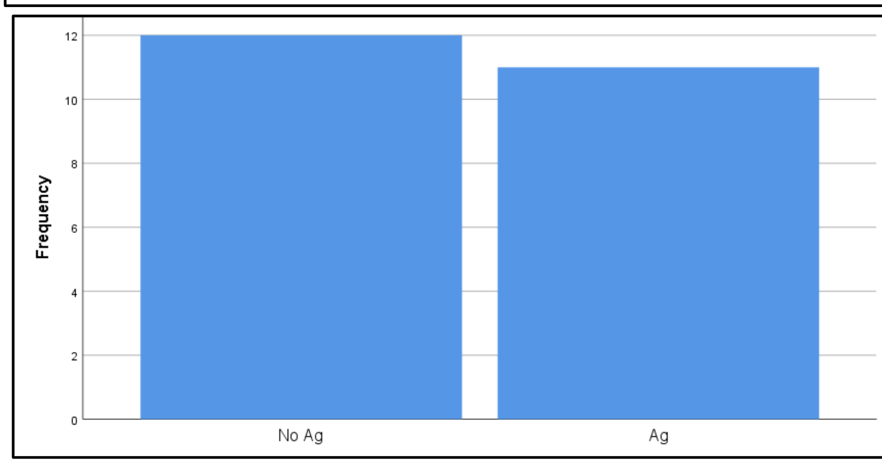
Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	20	87.0	87.0	87.0
	Female	3	13.0	13.0	100.0
	Total	23	100.0	100.0	

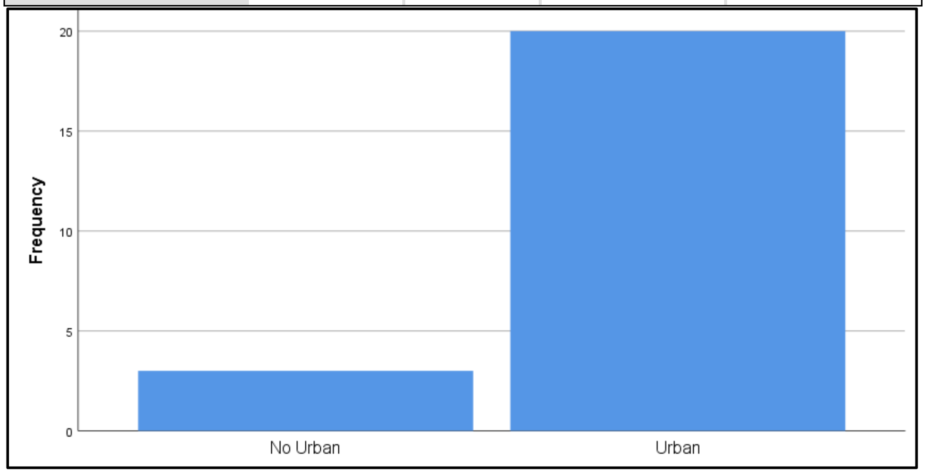


Ag

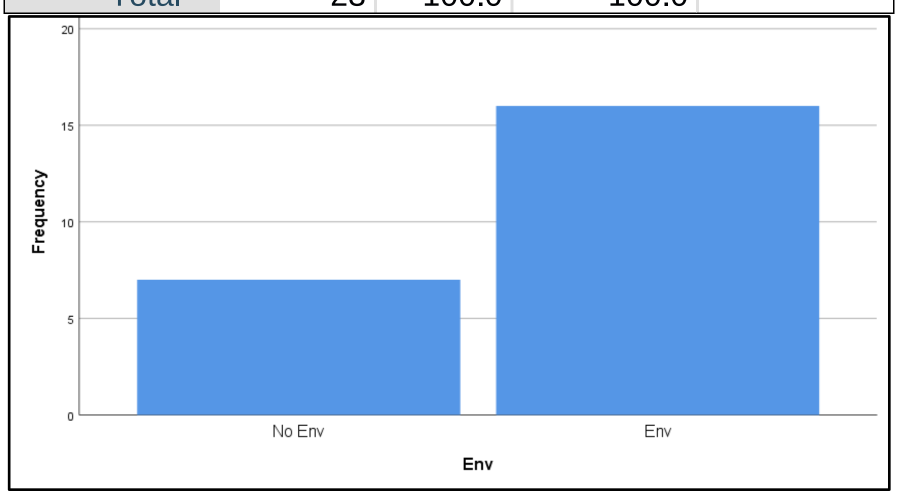
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No Ag	12	52.2	52.2	52.2
	Ag	11	47.8	47.8	100.0
	Total	23	100.0	100.0	



Urban					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No Urban	3	13.0	13.0	13.0
	Urban	20	87.0	87.0	100.0
	Total	23	100.0	100.0	

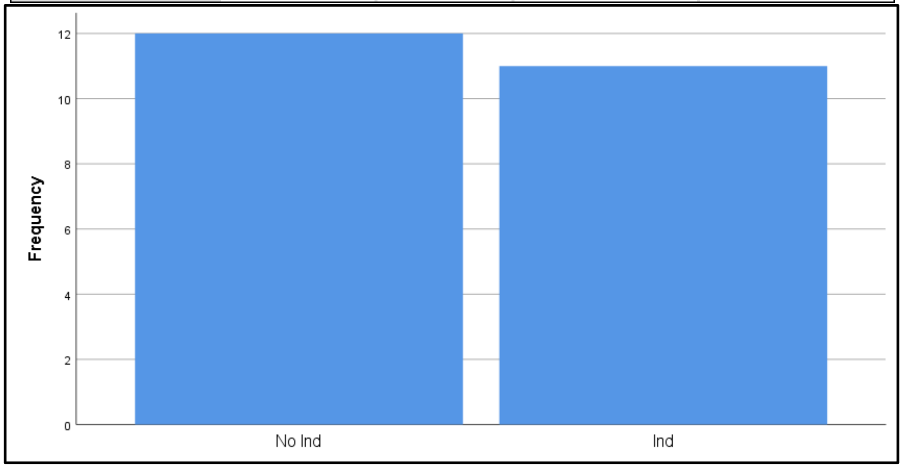


Environment					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No Env	7	30.4	30.4	30.4
	Env	16	69.6	69.6	100.0
	Total	23	100.0	100.0	



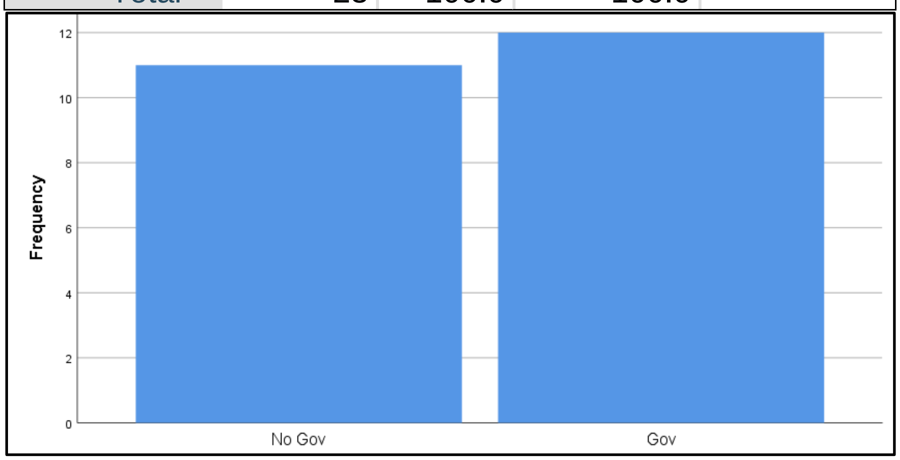
Industry

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No Ind	12	52.2	52.2	52.2
	Ind	11	47.8	47.8	100.0
	Total	23	100.0	100.0	

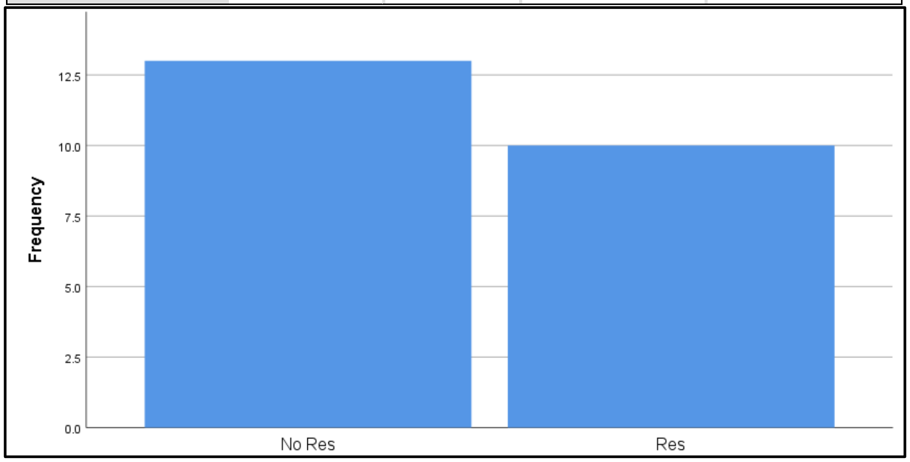


Government

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No Gov	11	47.8	47.8	47.8
	Gov	12	52.2	52.2	100.0
	Total	23	100.0	100.0	



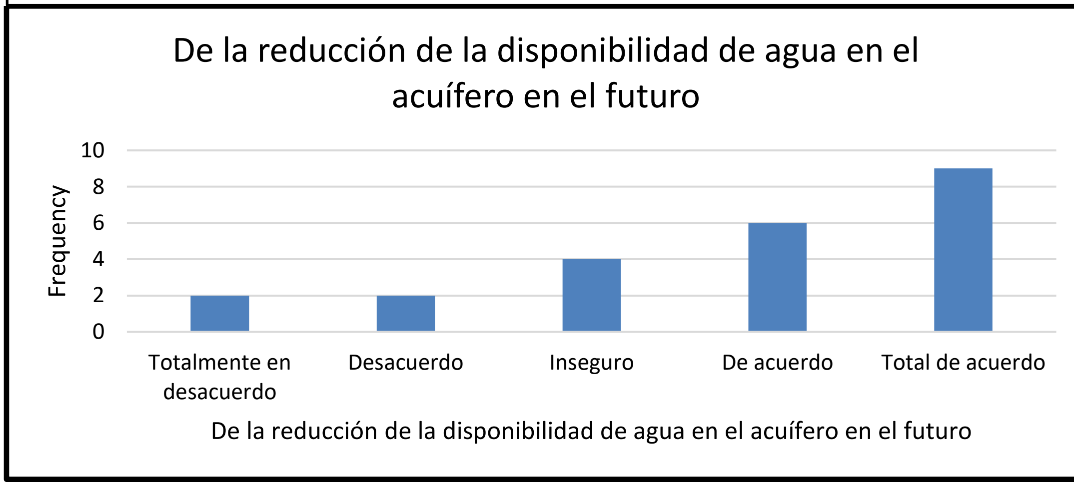
Research					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No Res	13	56.5	56.5	56.5
	Res	10	43.5	43.5	100.0
	Total	23	100.0	100.0	



1. **Of the reduction of water availability from the aquifer**

De la reducción de la disponibilidad de agua en el acuífero en el futuro

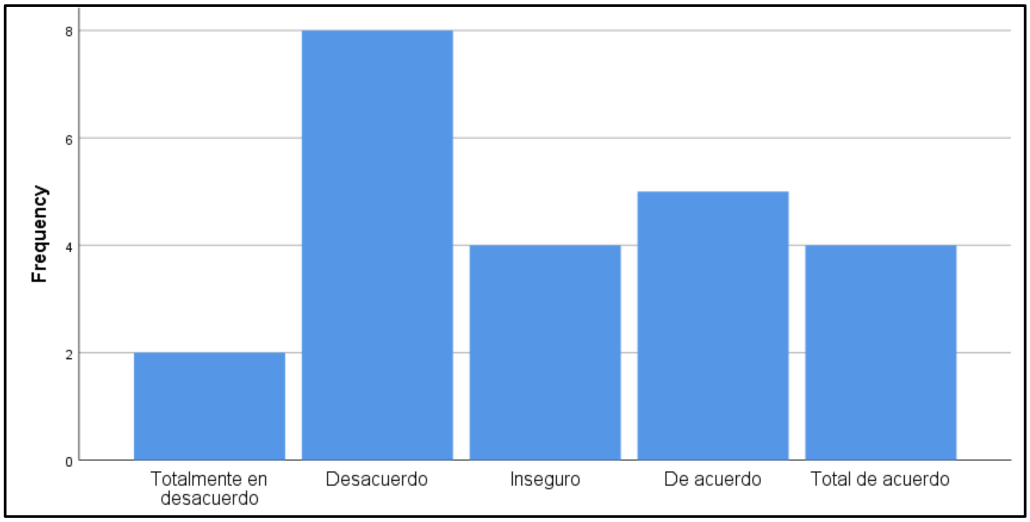
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Totalmente en desacuerdo	2	8.7	8.7	8.7
	Desacuerdo	2	8.7	8.7	17.4
	Inseguro	4	17.4	17.4	34.8
	De acuerdo	6	26.1	26.1	60.9
	Total de acuerdo	9	39.1	39.1	100.0
	Total	23	100.0	100.0	



2. **Of the need to pump more groundwater because of reduced surface water**

De la necesidad de bombear más agua subterránea debido a la reducción de agua superficial

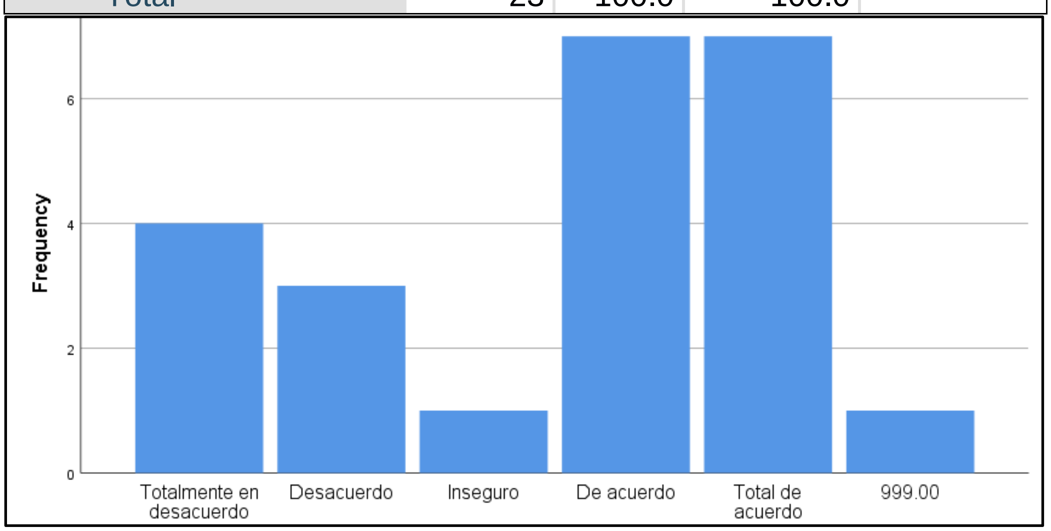
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Totalmente en desacuerdo	2	8.7	8.7	8.7
	Desacuerdo	8	34.8	34.8	43.5
	Inseguro	4	17.4	17.4	60.9
	De acuerdo	5	21.7	21.7	82.6
	Total de acuerdo	4	17.4	17.4	100.0
	Total	23	100.0	100.0	



3. **Of the differences in urban water use between El Paso, Las Cruces, and Ciudad Juárez**

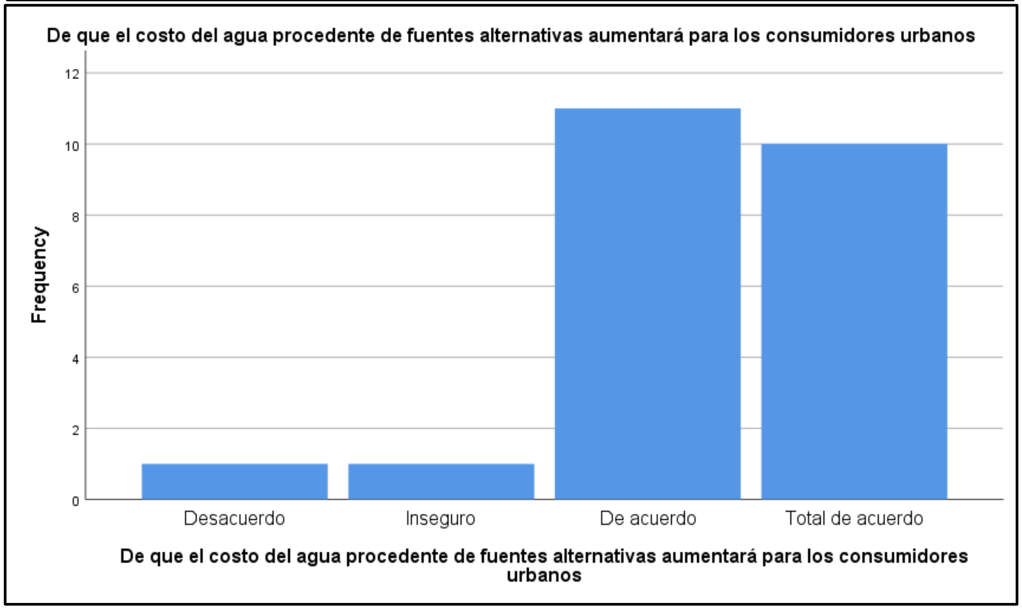
De las diferencias del uso del agua urbana entre El Paso, Las Cruces y Ciudad Juárez

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Totalmente en desacuerdo	4	17.4	17.4	17.4
	Desacuerdo	3	13.0	13.0	30.4
	Inseguro	1	4.3	4.3	34.8
	De acuerdo	7	30.4	30.4	65.2
	Total de acuerdo	7	30.4	30.4	95.7
	999.00	1	4.3	4.3	100.0
	Total	23	100.0	100.0	



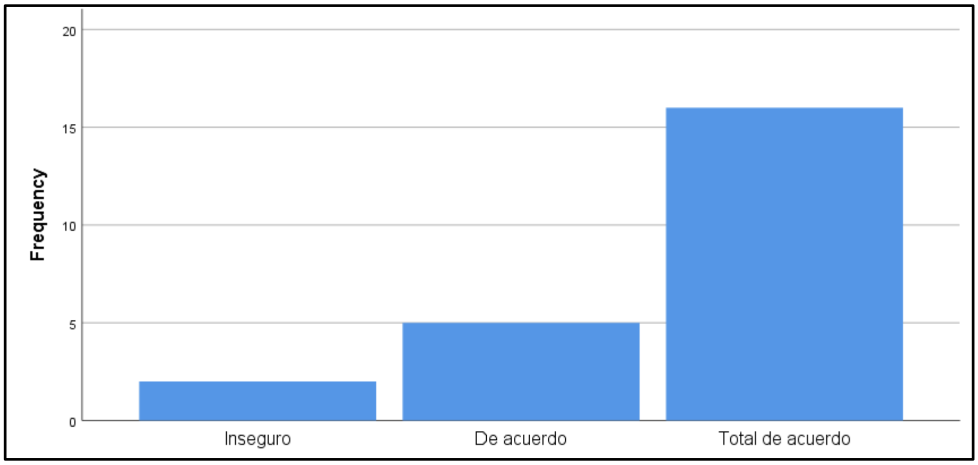
4. **Of that the cost of water from alternative sources will rise for urban consumers**

De que el costo del agua procedente de fuentes alternativas aumentará para los consumidores urbanos					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Desacuerdo	1	4.3	4.3	4.3
	Inseguro	1	4.3	4.3	8.7
	De acuerdo	11	47.8	47.8	56.5
	Total de acuerdo	10	43.5	43.5	100.0
	Total	23	100.0	100.0	



5. **Of how the SWIM model allows stakeholders to explore future water availability impact**

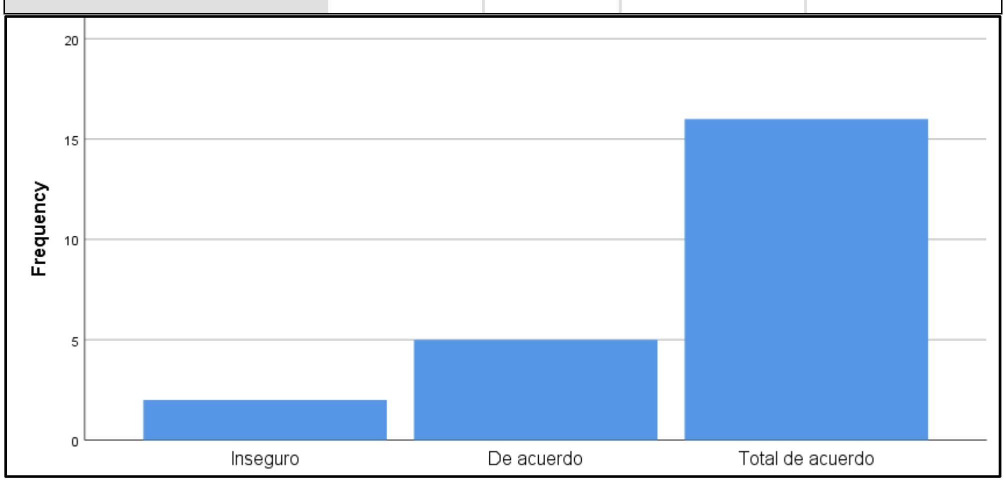
De cómo modelos de planeación (ejemplo: SWIM) permiten a las partes interesadas explorar el impacto futuro de la disponibilidad de agua					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Inseguro	2	8.7	8.7	8.7
	De acuerdo	5	21.7	21.7	30.4
	Total de acuerdo	16	69.6	69.6	100.0
	Total	23	100.0	100.0	



6. **Of how the SWIM model allows stakeholders to explore future water availability impact**

De cómo modelos de Planeación (ejemplo: SWIM) considera el cambio climático, la tecnología y el uso humano

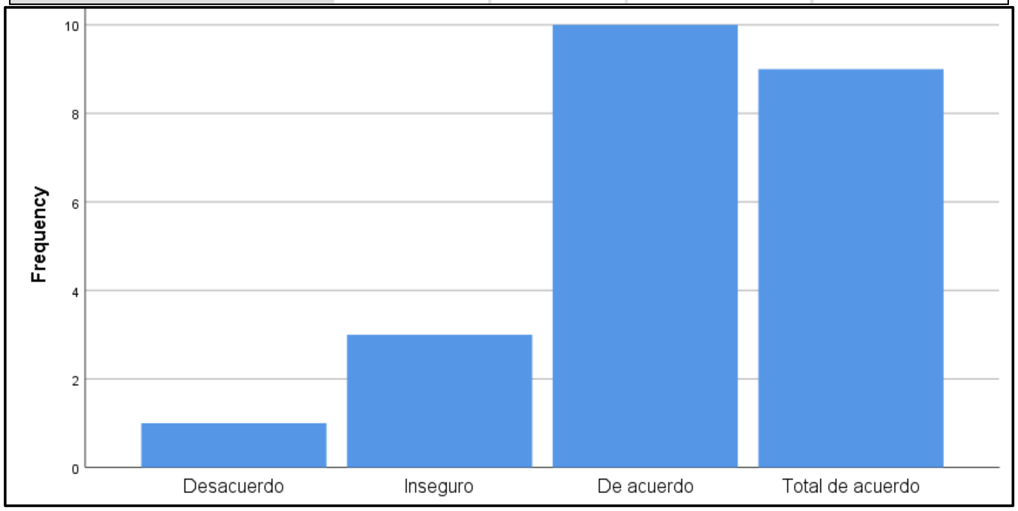
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Desacuerdo	1	4.3	4.3	4.3
	Inseguro	1	4.3	4.3	8.7
	De acuerdo	9	39.1	39.1	47.8
	Total de acuerdo	12	52.2	52.2	100.0
	Total	23	100.0	100.0	



7. **Of the importance of diversifying sources of water for agriculture in the region**

De la importancia de diversificar fuentes de agua para las regiones agrícolas

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Desacuerdo	1	4.3	4.3	4.3
	Inseguro	3	13.0	13.0	17.4
	De acuerdo	10	43.5	43.5	60.9
	Total de acuerdo	9	39.1	39.1	100.0
	Total	23	100.0	100.0	

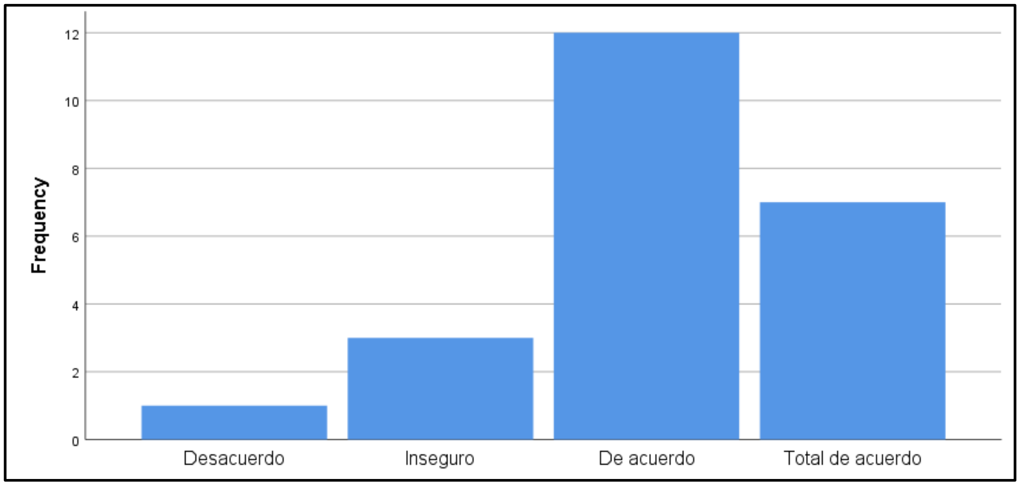


8. **Of the need to consider traditional and other crops in the region that are salt-tolerant**

De la necesidad de considerar los cultivos tradicionales y otros cultivos de la región que sean tolerantes a la salinidad

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Desacuerdo	1	4.3	4.3	4.3
	Inseguro	3	13.0	13.0	17.4
	De acuerdo	12	52.2	52.2	69.6
	Total de acuerdo	7	30.4	30.4	100.0

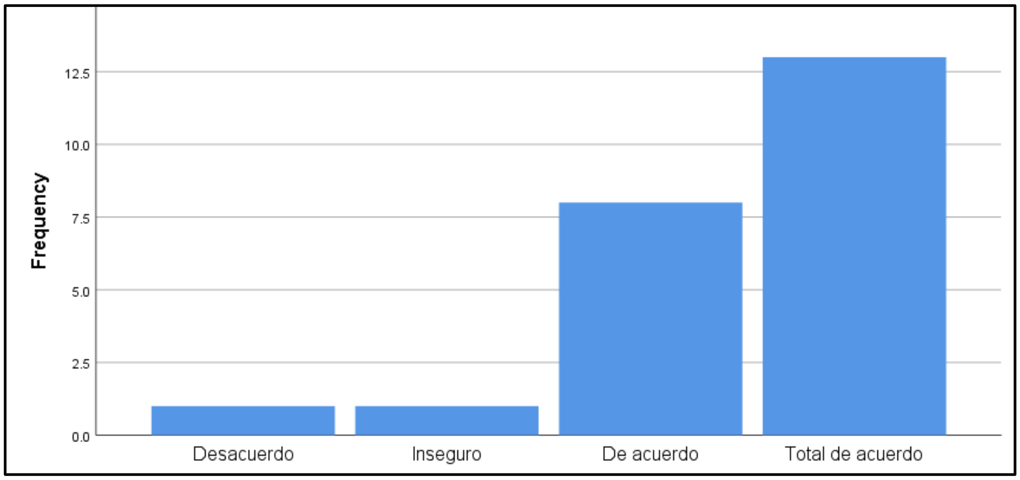
	Total	23	100.0	100.0	



9. Of aware of the need to understand water balance to improve water use efficiency in irrigated crops such as pecans

De la necesidad de entender el balance del agua para mejorar el uso eficiente en la irrigación de cultivos como el nogal

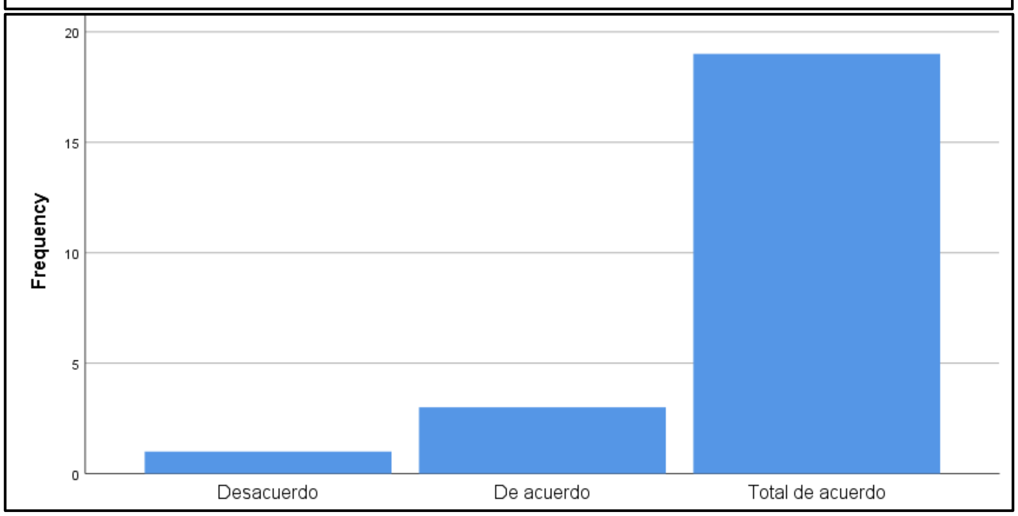
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Desacuerdo	1	4.3	4.3	4.3
	Inseguro	1	4.3	4.3	8.7
	De acuerdo	8	34.8	34.8	43.5
	Total de acuerdo	13	56.5	56.5	100.0
	Total	23	100.0	100.0	



10. Of the need to improve irrigation management and water use efficiency

De la necesidad de mejora el manejo de irrigación y el uso eficiente del agua

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Desacuerdo	1	4.3	4.3	4.3
	De acuerdo	3	13.0	13.0	17.4
	Total de acuerdo	19	82.6	82.6	100.0
	Total	23	100.0	100.0	



Attachment C. Responses to open-ended questions

11. ¿Qué otros temas relacionados con el agua en la región le gustarían saber más? ***(What other topics related to water in the region would you like to know more about?)***

Theme: About aquifer recharge and agriculture-related issues (23.3%)
1. Nivel de recarga
2. Recargas al acuífero
3. Manejo de agua pluvial
4. Sistema integra de drenaje pluvial
5. Agua en pozos agrícolas
6. Eficiencia sistema de riego zona agrícola
7. La manera en que una vez utilizada el agua para riego es tratada y/o programas para tratamiento e inyección a los acuíferos

Theme: About water leakage and waste (16.7%)
1. Fugas
2. ¿Cuáles son las actividades principales de malgasto de agua y como se pueden reducir?
3. Perdidas en redes de distribución
4. Destinos de las aguas que se desperdician
5. Del manejo de las fugas por infraestructura

Theme: About desalination and residual water recovery (16.7%)
1. Proyectos de desalinización
2. Salinidad, costos e extracciones
3. La potabilización de agua residual
4. Proyectos para el uso de agua recuperada
5. Que pasa con las filtraciones y que se hace para evitarlas

Theme: About water laws and legislation (16.7%)
1. Gobernanza del agua
2. Legislación y políticas publicas
3. Derechos de la ciudadanía y el público consumidor
4. Límites permisibles para el uso agrícola y urbana
5. De donde piensa aumentar su disponibilidad el organismo operador para satisfacer la creciente demanda

Theme: About bi-national and region-wide water issues (16.7%)
1. Uso residual en ambas ciudades
2. Balance hídrico de los usos de la región
3. La exposición de al agua compartida binacionalmente
4. Infraestructura y proyectos de conservación en ambas ciudades fronterizas (Posibles resultados con su implementación)

Theme: About climate change (10.0%)
1. Cambio climático
2. Relación con el cambio climático
3. Impactos ambientales de ganadería (sea para carne o lácteos)

12. Cuéntenos tres (3) cosas que le gustaron de la exposición *(Tell us three (3) things you liked about the exhibition)*

Theme: The professionalism of project and presenters (22.2%)
1. Postura
2. Formato
3. Plataforma
4. Puntualidad
5. Puntualísimo
6. Organización
7. El planteamiento
8. Profesionalismo
9. Ambiente de respeto
10. Apertura de expositores
11. Programa abierto al publico
12. Consistencia de los encargados respeto al tema

Theme: The content and applicability of presentations (22.2%)
1. Diversidad
2. Contenido
3. El balance hídrico
4. Ejercicio práctico, entendible
5. Herramientas útiles para usuario
6. Análisis de consumo en la ciudad
7. La información otorgada físicamente
8. La relación de datos de acuerdo a la realidad
9. Entrega de artículo en papel previo a la presentación
10. Tecnología aplicada al entendimiento del manejo de agua
11. El uso de ejemplos prácticos pare explicar los problemas expuestos
12. La aportación de varias fuentes de información para hacer una base de datos

Theme: The nature and intent of event (18.5%)
1. Investigación
2. Informe técnico
3. Dentro del tema
4. Compartir datos
5. Cercanía al usuario

6. Resolver escenarios
7. La planeación al futuro
8. Coordinación entre los países
9. Actualización de la plataforma
10. Motivación en cambio de cultura

Theme: The openness of presentations (16.7%)
1. Actualidad
2. Transparencia
3. Dinámica sencilla
4. Tiempo de cada tema
5. El tema explicado sobre el proyecto
6. Oportunidad de expresar inquietudes
7. Los temas son explicados puntualmente
8. Abierto a todas las preguntas y comentarios
9. Presentaron la información precisa, sin muchos rodeos

Theme: The clarity of presentations (13.0%)
1. Claridad
2. Claridad sencilla
3. Respuestas y preguntas claras
4. La claridad en las exposiciones
5. La claridad de la información dada
6. Claridad de los puntos que se tocaron
7. Información clara sobre la plataforma

Theme: The SWIM model (7.4%)
1. Explicación del modelo SWIM
2. La modelación SWIM
3. El uso del modelo SWIM
4. Las proyecciones que hace SWIM

13. Cuéntenos tres (3) cosas que podemos hacer de manera diferente en futuras exposiciones. *(Tell us three (3) things we can do differently in future exhibitions).*

Theme: Improve use of audio visuals (37.1%
1. Proyector
2. Proyector
3. Quizá proyector
4. Apoyo visual
5. Ayuda visual a color
6. Exposiciones gralícales
7. Diapositivas (proyectores)
8. Imágenes dedicadas al tema
9. Colocación de presentación visual
10. Elementos tecnológicos para la presentación

11. Presentación de resultados de manera gráfica, no solo hablando (cerca de expositor)
12. Micrófono o alta voz
13. Algún tipo de sonido que ayude a que la exposición sea escuchada en toda el área

Theme: Improve conference meeting room (22.9%)
1. Epacio
2. Mejor lugar
3. Lugar más amplio
4. Área o salón más amplio
5. Un lugar con menos ruido
6. El espacio es del todo inadecuado
7. Distracción ruidos de la planta alta, ____ eso
8. Un espacio donde todos podamos ____, tal vez otro acomodo de sillas

Theme: Improve participation (20.0%)
1. Ampliar más el foro
2. Mayor participación de las comunidades
3. Abrir un poco más el público – en general
4. Tener contactos que apoyen el uso del agua
5. Mejorar la participación de los tomadores de decisiones
6. Muchos sectores involucrados (stakeholders) están del todo ausentes
7. Nula difusión. Incluso busque información sin éxito. De no ser una profesora, no hubiera sabido.

Theme: Improve content of presentations (20.0%)
1. Hacer predicciones
2. Interactuar con la plataforma
3. Manipulación de los modelos en vivo
4. Presentación de resultados de forma tipica
5. Verificar información real para tener resultados reales
6. Hacer cambios de acuerdo a modificaciones que se presentan
7. Hablar más de números (con cuánta agua contamos y para qué es utilizada, % de cada una de las actividades

14. **¿Prefiere este formato de "feria de ciencias" o algún otro formato como clase o formato de taller para recibir información sobre el proyecto? *(Do you prefer this "science fair" format or some other format like classroom lecture or workshop format for receiving information about the project?)***

Theme: Mixed responses
1. Si
2. Me gusto el formato
3. Depende de los objetivos
4. Prefiero talleres prácticos
5. Este formato de feria de ciencias

15. **Díganos cómo prefiere recibir información/resultados. *(Tell us how you prefer to receive information/results.)***

Theme: Via email (32.3%)
1. Email
2. Correo electrónico
3. Correo electrónico
4. Correo electrónico
5. Por correo electrónico
6. Por correo electrónico
7. Por correo electrónico
8. Por correo electrónico
9. Email de participantes
10. Notificaciones mediante correo electrónico de las actualizaciones y resultados de programa

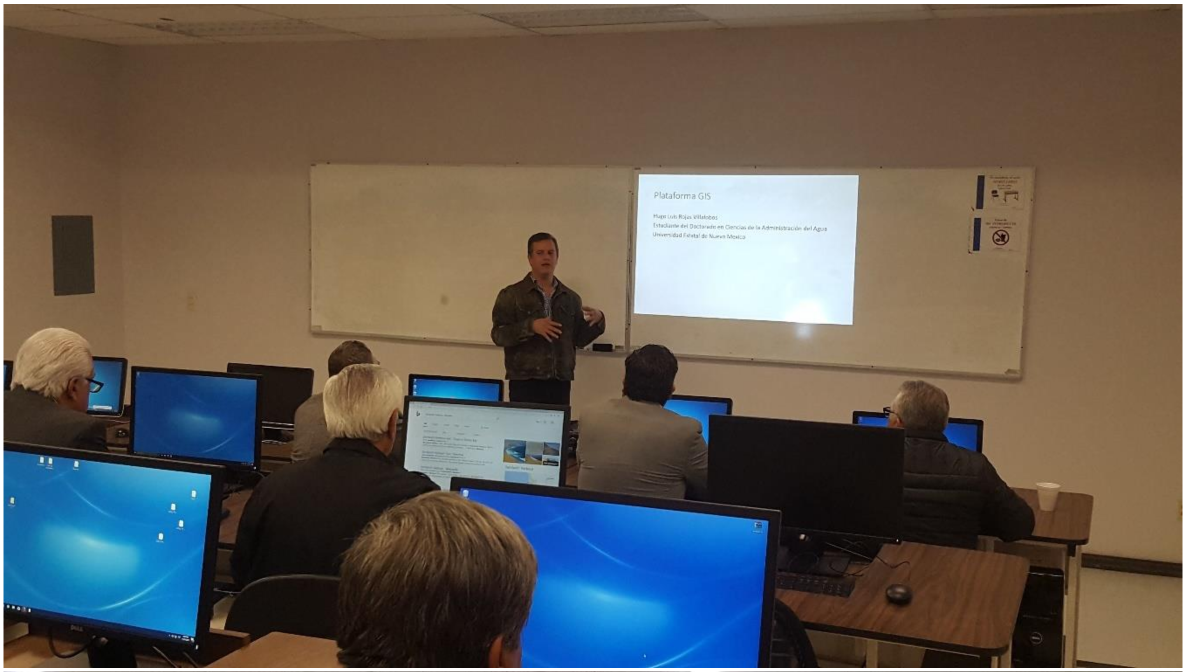
Theme: Via hands-on workshops
1. Taller
2. Taller
3. Talleres
4. Taller participativo
5. Así con asistencia personal
6. Conferencias con resultados
7. plataformas fáciles de manejar

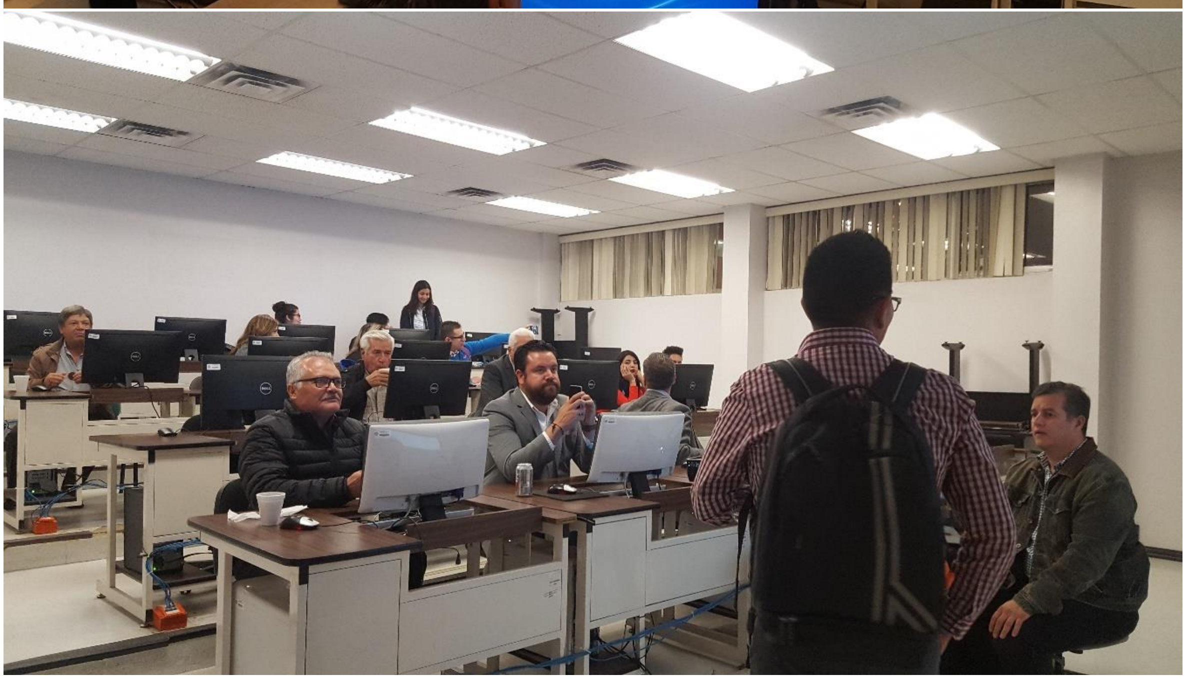
Theme: Via social media and internet (22.6%)
1. Redes sociales
2. Redes sociales
3. Vía electrónica
4. En la nube o vía internet
5. Por medio de aplicaciones fáciles de descargar

Theme: Via mail and printed material (12.9%)
1. Correo
2. Correo
3. Como informe impreso
4. Revistas especializadas

Theme: Via web sites (9.7%)
1. Página web
2. Página de internet
3. distintas páginas web

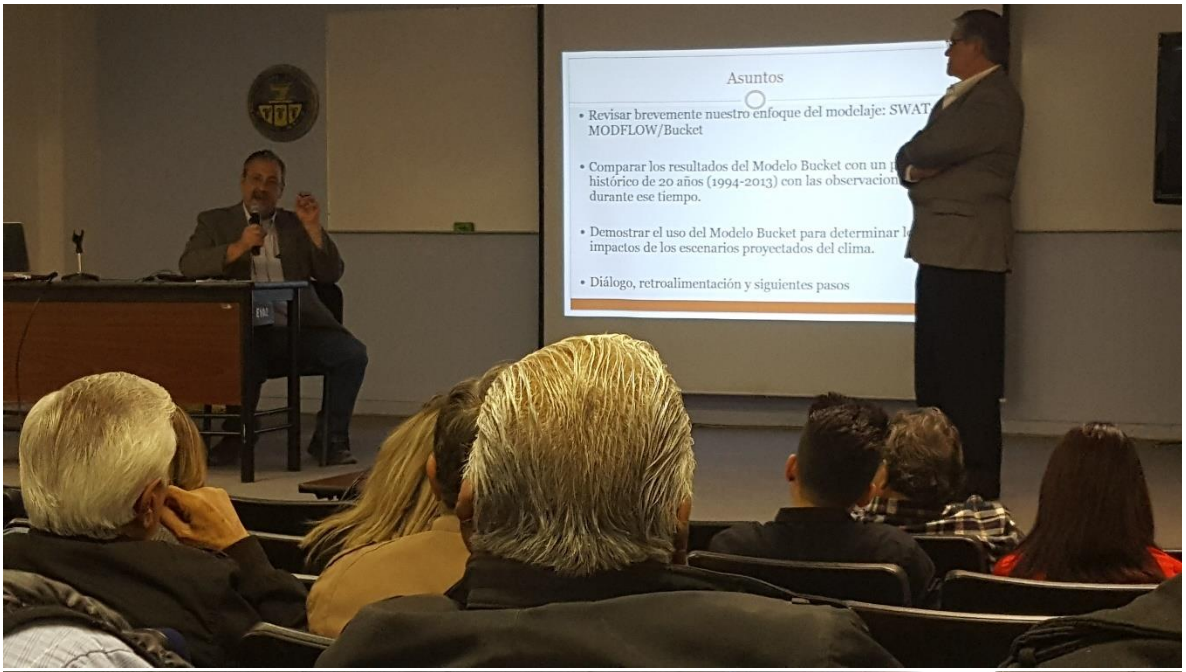
COMPENDIO DE FOTOS DE DIFERENTES EVENTOS EN DONDE SE PARTICIPO CON LA REPRESENTACION INSTITUCIONAL


Plataforma GIS
Hugo Luis Rojas Villalobos
Estudiante del Doctorado en Ciencias de la Administración del Agua
Universidad Estatal de Nuevo Mexico




UACJ
PROCESO DE CLASIFICACIÓN
SUPERVISADA PARA COBERTURA
Y USO DE SUELO


Asuntos
Revisar brevemente nuestro
Componentes
Entrada de datos


Asuntos
• Revisar brevemente nuestro enfoque del modelaje: SWAT
MODFLOW/Bucket
• Comparar los resultados del Modelo Bucket con un
histórico de 20 años (1994-2013) con las
durante ese tiempo.
• Demostrar el uso del Modelo Bucket para determinar
impactos de los escenarios proyectados del clima.
• Diálogo, retroalimentación y siguientes pasos


PROTECCION CIVIL


PROTECCION CIVIL


PROTECCION CIVIL


PROTECCION CIVIL


PROTECCION CIVIL

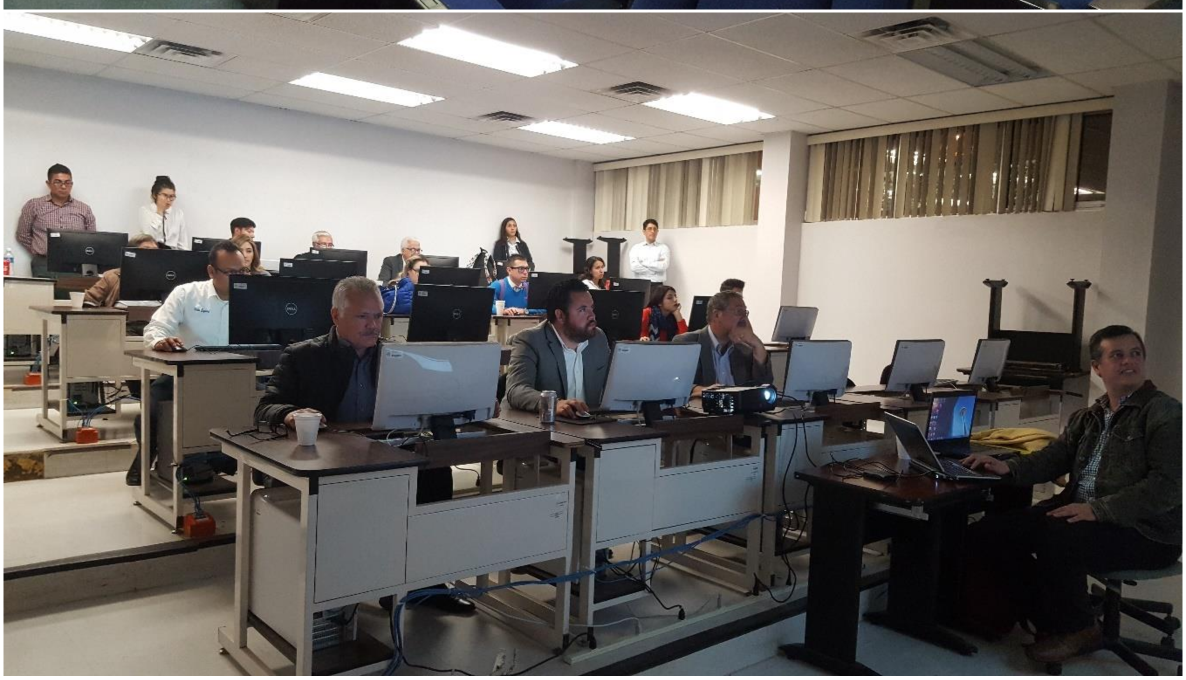

PROTECCION CIVIL

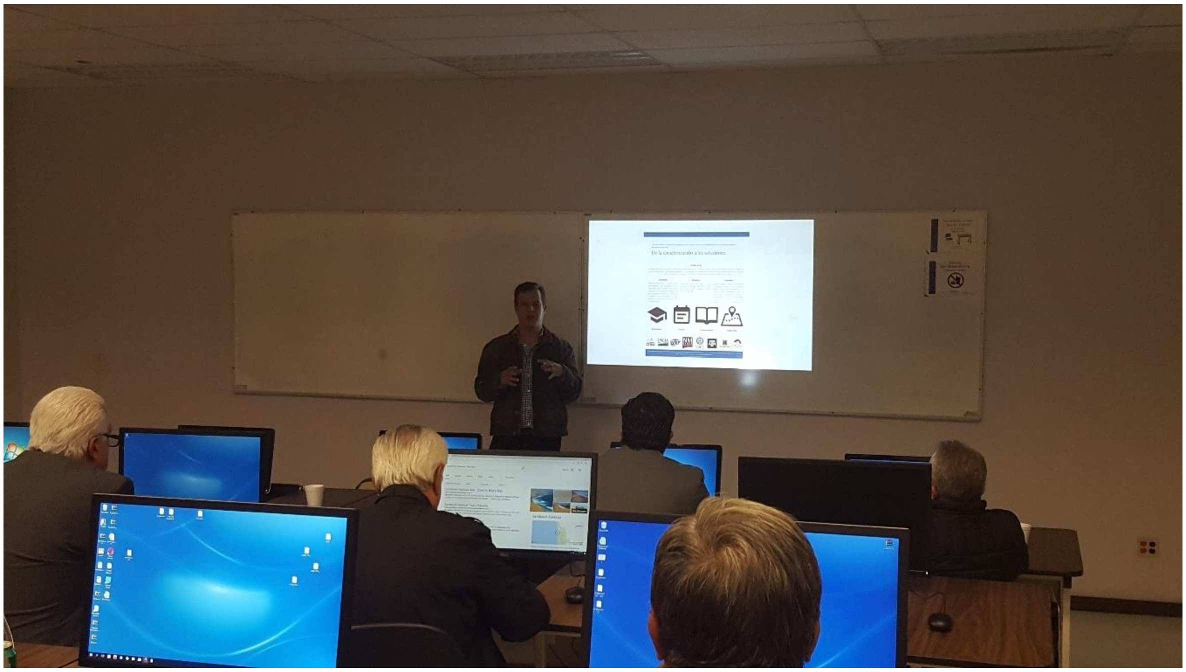

Plataforma GIS
PROTECCION CIVIL


PROTECCION CIVIL


Productos
Hidrología
Transporte de sedimentos
Crecimiento promedio de plantas


Ecuación de balance hídrico
Donde:
UACJ

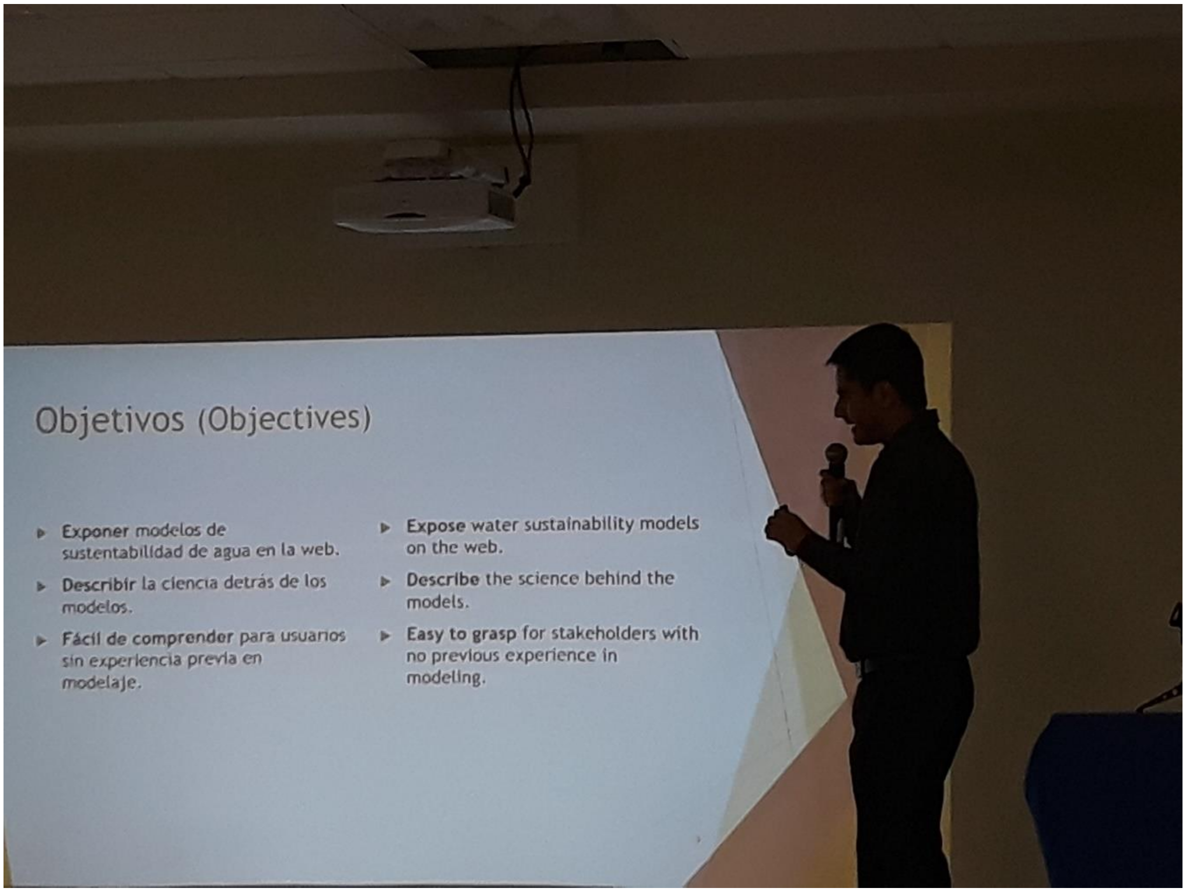





SIGLO XX
1941 ÉPOCA DE ORO
1956 ÉPOCA DE ORO


③1941 ÉPOCA DE ORO
④1956 ÉPOCA DE ORO


③1941 ÉPOCA DE ORO
⑥1956 ÉPOCA DE ORO


Objetivos (Objectives)
Exponer modelos de sustentabilidad de agua en la web.
Describir la ciencia detrás de los modelos.
Fácil de comprender para usuarios sin experiencia previa en modelaje.
Expose water sustainability models on the web.
Describe the science behind the models.
Easy to grasp for stakeholders with no previous experience in modeling.


ustainable Water Res
a Desert River Basin
Demands: From
3er Talle
INSTITUTO DE INGENIERÍA Y TECNOLOG


INSTITUTO DE INGENIERÍA Y TECNOLOGÍA


② SIGLO XX
③ 1941 ÉPOCA DE ORO
1956 ÉPOCA DE ORO


UADHE
"Informe de Avances del Programa Educativo de la
Hermanos Escobar: Innovacion/Retos/
en la Educacion Superior
Dr. Alfredo Granados Olivas
Rector UADHE
TALLER DE CAPACITACION
Abril, 2018


Hydrogeologic section of Lower Mesilla
alley-Paso del Norte-Hueco Bolson reach,
howing SFG Aquifer-System pinch out over
edrock units (white). River Alluvium (yellow)
Courchesne
Bridge


GEO
¿Qué es la Gobernanza
del Agua y porqué es
importante para mí?
Universidad Autónoma de
Ciudad Juárez
IADA
UACJ
Cuauhtémoc, Chihuahua
13 de marzo de 2020


Universidad Autónoma de
Ciudad Juárez
IADA
UACJ
¿Qué es la Gobernanza
del Agua y porqué es
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, Chihuahua
13 de marzo de 2020