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Journal of Research and Development

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The works must be unpublished and refer to topics of industrial development, project model, computer application, research production, systems development, research networks, application design, programming and development proposals and other topics related to Humanities and Behavioral Sciences.

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In the first article we present, *Analysis of wear for a base Steel 5% Cr, applying 392 N of load and variable speed of 0.18 m/s, 0.36 m/s and 0.54 m/s, using the T05 Block-on-ring wear tester machine*, by OROZCO-GARCÍA, Calvin Jacob, SERVIN-CASTAÑEDA, Rumualdo, SAN MIGUEL-IZA, Sandra María and GONZÁLEZ-ZARAZUA, Roberto Aldo, with ascription in the UAdeC and Universidad Tecnológica de la Región Centro de Coahuila, as the next article we present, *Monitoring of cities with tectonic and volcanic activity, Jocotepec and Ciudad Guzmán, Jalisco: Case studies*, by PEÑA-GARCÍA, Laura Elizabeth, GARAVITO-ESPINOZA, Daniel Alejandro, MACIEL-FLORES, Roberto and ROSAS-ELGUERA, José, with ascription in the Universidad de Guadalajara, as the next article we present, *Methodological proposal for monitoring basins that drain into the Pacific Ocean. Case study Tomatlán - Tecuán basin (RH15Ca)*, by RAMIREZ-RAMIREZ, Lizbeth Citlaly & PLASCENCIA-ORTEGA, Amairani del Refugio, with ascription in the Universidad de Guadalajara, as the last article we present, *Preliminary assessment of the risk of river overflow in the presence of a bridge using HEC-RAS and LiDAR topography*, by CHÁVEZ-CÁRDENAS, Xavier, ARROYO-CHAVEZ, Hiram, GUTIERREZ-VILLALOBOS, José Marcelino and MORALEZ-GARIBAY, María Cristina with ascription in the Universidad de Guanajuato.

Content

Article **Journal of Research and Development**
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Thermogravimetric study of 316L steel coated by physical deposit in vapor deposition phase (PVD)

Estudio termogravimétrico de acero 316L recubierto por deposito físico en fase vapor (PVD)

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Abstract

Catastrophic carburization (metal dusting) is one of the problems with the greatest impact on the petrochemical and direct iron reduction industry. This work shows the synthesis of chromium oxide (Cr2O3) coatings on 316L steel as a protective layer to prevent and/or delay material degradation. In this work, the Physical Vapor Deposition (PVD) method will be used, since it is a technique that allows the control of the atmosphere in which the deposition is being carried out, forming high quality thin films, with excellent adherence to the substrate, thus improving its surface properties. Thin films with thicknesses less than one micrometer were obtained, which were subjected to corrosion tests by thermogravimetry in an atmosphere of CH4 at 800°C for 15 minutes and 20 hours, scanning electron microscopy and elemental quantification. The coatings obtained showed an improvement in their resistance to corrosion in critical atmospheric conditions according to the graphs obtained in the thermogravimetry test, observing a lower weight gain compared to the uncoated sample.

Catastrophic carburization, Reduction, Deposition

Resumen

La carburización catastrófica (metal dusting) es una de las problemáticas con mayor repercusión en la industria petroquímica y de reducción directa de hierro. El presente trabajo muestra la síntesis de recubrimientos de óxido de cromo (Cr2O3) sobre acero 316L como capa protectora para prevenir y/o demorar la degradación del material. En este trabajo se empleará el método de Deposición Física de Vapor (PVD), ya que es una técnica que permite el control de la atmosfera en la cual se está realizando la deposición, formando películas delgadas de alta calidad, con una excelente adherencia al sustrato, mejorando así sus propiedades superficiales. Se obtuvieron películas delgadas de espesores inferiores a un micrómetro, que fueron sometidas a pruebas de corrosión por termogravimetría en una atmosfera de CH4 a 800°C por tiempos de 15 minutos y 20 horas, microscopia electrónica de barrido y cuantificación elemental. Los recubrimientos obtenidos presentaron una mejora en su resistencia a la corrosión en condiciones atmosféricas críticas de acuerdo con los gráficos obtenidos en la prueba de termogravimetría observando una ganancia en peso menor en comparación con la muestra no recubierta.

Carburización catastrófica, Reducción, Depósito

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Introduction

Corrosion is the deterioration of a substance or its properties due to reaction with its environment; If the environment is at high temperatures, the phenomenon is called catastrophic carburization (metal dusting). When in contact with highly carburizing atmospheres, vulnerable metals begin a disintegration process generating carbon that will supersaturate the surface when dissolved in the metallic phase, this will cause the destruction of the material by eroding it, mainly affecting the performance of the material in the chemical industries, electrical, energy and transportation (Grabke, 2003).

One of the solutions that have been proposed to delay catastrophic carburization (metal dusting) is to perform a coating using the physical vapor deposition (PVD) technique, this will help preserve and extend the useful life of the materials. One of the candidates with the greatest potential to be deposited is chromium oxide (Cr_2O_3) due to its protective properties against corrosion.

The chrome oxide coating acts as a protective layer, improving the resistance to corrosion of the steel as it modifies the properties of the surface. Some steels such as stainless steels (especially austenitic stainless steels (Y. L. G, 1990)) present this element in their composition, showing resistance to corrosion by themselves because they tend to form a passive oxide layer (T Michler, 2016).

Physical Vapor Deposition Method (PVD)

Being one of the techniques that does not generate contaminants, physical vapor deposition (PVD) is used to transfer material from an atomic level through evaporation, which will later condense on the surface of the substrate, thus forming a thin film (A. V. Rane, 2018) (Ghader Faraji, 2018). This process is carried out in a controlled atmosphere where an inert gas is used to transport the evaporated ions; smooth surfaces with good adhesion, excellent tribological and mechanical properties are produced (Makhlouf, 2011).

The use of the physical vapor deposition (PVD) technique allows deposits of elements, alloys or compounds free of contamination, with good quality and increased adhesion (Baptista, Silva, Porteiro, Míguez, & Pinto, 2018).

Metal dusting

The degradation of both alloys and metals due to the presence of carbon in the environment is known as carburization, this type of corrosion causes failures in different industrial components (D. J. Young, 2011). A consequence of the formation of metallic powders on surfaces is the severe loss of material. At elevated temperatures between 400-700°C carbon dioxide (CO) acts as a reducing gas releasing carbon destroying alloys at an exuberant rate compared to oxygen (Zhang, 2012).

Thin Film Cr/Cr_2O_3

Chromium oxide has high hardness, which allows it to have high resistance to wear, obtaining a low coefficient of friction. These characteristics make it a potential candidate for coating parts or components that are exposed to critical environmental conditions. In the final phase, chrome oxidation changes the microstructure of the surface, increasing the properties of the material on which it is deposited (Laura Dimate Castellanos, 2017).

Methodology

Through roughing and polishing, 316L steel samples were prepared to be processed with the physical vapor deposition technique. Chromium oxide was synthesized on the substrates using a chromium blank and constant oxygen flow. A 20-minute ion wash is performed before adding the pure chrome bond coat for 5 minutes. Once the oxygen is added, the process lasts 30 minutes. The samples obtained are characterized by thermogravimetry (TGA) at different times: 0 and 15 min. and 20 hours; Finally, the characterization was carried out by scanning electron microscopy and an analysis of energy dispersion and mapping by elements.

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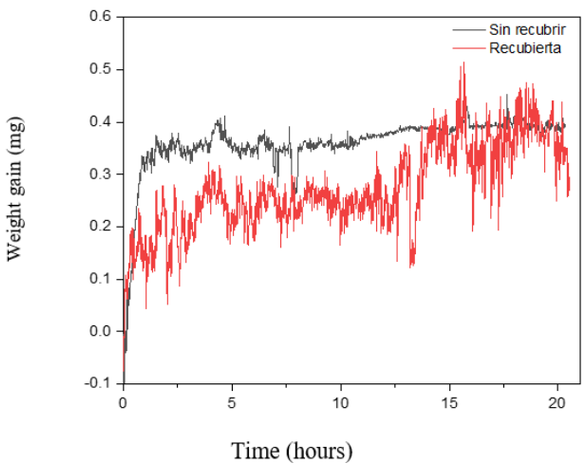
Results and discussion

Thermogravimetry tests were performed at 15 minutes and 20 hours without coating, then a 20-hour test with Cr/Cr_2O_3 coating; Figure 1 shows the graph obtained when performing the thermogravimetry test, the comparison of the samples exposed to corrosion for 20 hours with and without coating is presented.

It can be seen that the coated sample has a lower weight gain compared to the uncoated sample; At approximately 14 hours, both samples show a very close weight gain between both cases, however, in the case of the coated one it is slightly lower.



Graphic 1 Comparative TGA of samples subjected to corrosion for 20 hours

Figure 1 presents the images obtained by scanning electron microscopy, showing the surface of the uncoated 316L substrate, and treated by thermogravimetry at different times. The oxide formation process is observed; before being subjected to corrosion tests, 0 minutes (figure 1a) there is little presence of oxides compared to the sample that was processed for 15 minutes (figure 1b), in which the oxides are more noticeable and begin to form agglomerations; the 20-hour sample (figure 1c), which in the thermogravimetry graph shows an increase in mass, demonstrating that this is due to the formation of oxide on its surface; the figure shows grain boundaries and oxide deposits.

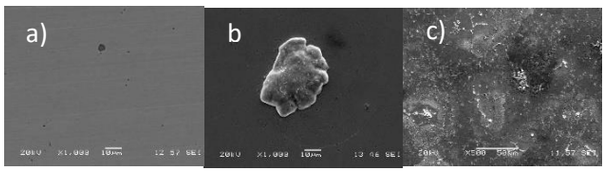


Figure 2 Uncoated 316L steel characterized by thermogravimetry: a) 0 minutes, b) 15 minutes and c) 20 hours

Figure 2 shows the surface of the Cr/Cr_2O_3 coating that was deposited on a 316L steel and subsequently subjected to a 20-hour corrosion test by thermogravimetry. The coating showed a decrease in the formation of oxides; image 3a was obtained by scanning secondary electrons, bright regions were observed so a scan with backscattered electrons was performed (figure 2b) to make these formations visible by atomic contrast.

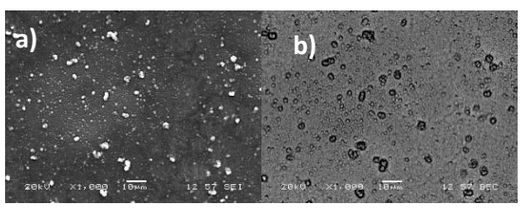


Figure 2 Chromium/chromium oxide coating on a 316L steel characterized by thermogravimetry for 20 hours

Figures 3, 4 and 5 show the element identification analyzes for each of the samples processed by thermogravimetry at 0, 15 minutes and 20 hours that were not coated. Figure 4c shows the amount of chromium present in the substrate while figure 3b gives the amount of oxygen present in the sample.

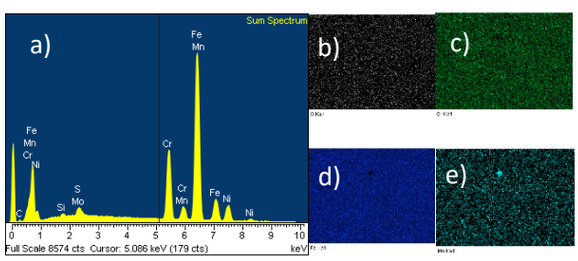


Figure 3 Elemental analysis of uncoated 316L sample with minutes in thermogravimetry. a) Mapping of oxygen in the sample, b) Mapping of chromium in the sample, c) Mapping of iron in the sample and d) Mapping of manganese in the sample

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The region presented in figure 4 has a small accumulation of oxide, this is observed in figure 4b where it is shown that oxygen is present in this region, in the same way there is the presence of chromium in the sample according to figure 4c.

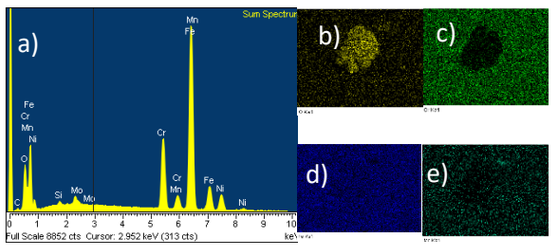

Figure 4 Elemental analysis of the uncoated 316L sample with 15 minutes in thermogravimetry. a) Mapping of oxygen in the sample, b) Mapping of chromium in the sample, c) Mapping of iron in the sample and d) Mapping of manganese in the sample

In figure 5, the analysis by energy dispersion and the mapping by elements of the sample subjected to 20 hours of uncoated corrosion, regions where oxygen (figure 5b) and chromium (figure 5c) are concentrated can be observed, denoting the formation of oxides in these areas.

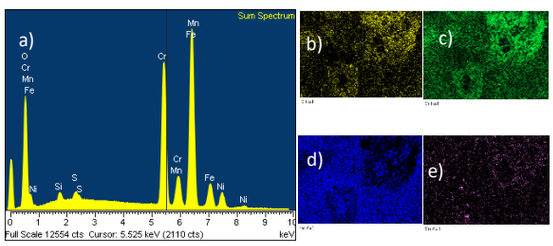

Figure 5 Element analysis of uncoated 316L sample with 20 hours in thermogravimetry. a) Mapping of oxygen in the sample, b) Mapping of chromium in the sample, c) Mapping of iron in the sample and d) Mapping of manganese in the sample

In comparison with the previous images, figure 6 shows the analysis of the sample coated and subjected to corrosion for 20 hours, the energy dispersion analysis shows a higher peak of chromium present in the thin film, it is observed that oxygen figure 6b and the chromium figure 6c are homogeneous throughout the analyzed surface, the iron of the base substrate figure 6d is practically imperceptible due to the layer formed of Cr/Cr_2O_3, this indicates the protective nature of the thin film, which after being subjected to corrosion even is attached to the substrate.

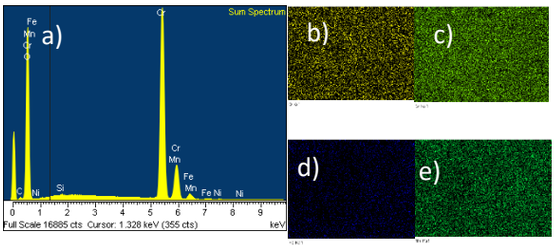

Figure 6 Energy dispersive analysis and element mapping of the 20-hour coated 316L sample in thermogravimetry. a) energy dispersion analysis showing the presence of chromium in the thin film, b) Mapping of chromium in the sample, c) Mapping of iron in the sample and d) Mapping of manganese in the sample

Conclusion

Catastrophic carburization occurs frequently in the industry, so the method of protection by adding thin films on the surface increases the useful life of the material by delaying its degradation.

Cr/Cr_2O_3 coatings created by the PVD process on 316L steel substrates have shown an improvement in resistance to gas corrosion at high temperatures, considerably reducing it.

The results obtained in the present work show that the proposed coating (Cr/Cr_2O_3) generates a protection barrier for the substrate, obtaining a lower weight gain during the thermogravimetry test than the uncoated material, longer corrosion tests are necessary to continue with the study of thin films as corrosion barriers.

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Article **Journal of Research and Development**
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Monitoring of cities with tectonic and volcanic activity, Jocotepec and Ciudad Guzmán, Jalisco: Case studies

Vigilancia de zonas tectónica y volcánica activas con población. Estudios de caso, Jocotepec y Ciudad Guzmán Jalisco

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Abstract

Jalisco is located in the contact of tectonic plates that have generated earthquakes along the coast and within the continent, its limits include several geological provinces: Central Table, Jalisco Block, Sierra Madre del Sur, Sierra Madre Occidental and Mexican Volcanic Belt, the latter, characterized by its recent volcanic and tectonic activity, within it there are various towns such as Jocotepec and Ciudad Guzmán that, recently, have been affected in their infrastructure by landslides and differential settlements of the land, of which it is unknown for sure. its origin and even when the movement has been reported, it has not been measured as a whole to define if it is a sunken block (which can be associated with tectonism) or it is only a subsidence (extraction of water or decomposition of organic matter). Due to the deformation of the soil in several towns in Jalisco, as is the case of Jocotepec and Cd. Guzmán, it is proposed to implement a methodology that includes the measurement of the deformations that have occurred considering milestones outside the graben, monitoring possible gas emissions (methane and radon) in the cracks, install geophysical equipment to determine if the Curie point is affected and detect punctual seismicity. Keywords; Tectonic trenches, gases, active volcanism, ground deformation.

Tectonic trenches, Active volcanism, Ground deformation

Resumen

Jalisco se ubica en el contacto de placas tectónicas que han generado sismos a lo largo de la costa y dentro del continente, sus límites incluyen varias provincias geológicas: Mesa Central, Bloque Jalisco, Sierra Madre del Sur, Sierra Madre Occidental y Faja Volcánica Mexicana, esta última, caracterizada por su actividad volcánica y tectónica reciente, dentro de ella existen diversas poblaciones como Jocotepec y Ciudad Guzmán que, en fechas recientes, han sido afectadas en su infraestructura por deslizamientos y asentamientos diferenciales del terreno, de los cuales se desconoce con seguridad su origen y aun cuando se ha reportado el movimiento, no se ha medido en su conjunto para definir si es un bloque hundido (que pueda asociarse a tectonismo) o solo es un hundimiento (extracción del agua o descomposición de materia orgánica). Por la deformación del suelo en varias poblaciones de Jalisco, como es el caso de Jocotepec y Cd. Guzmán, se propone implementar una metodología que incluye la medición de las deformaciones ocurridas considerando mojoneras fuera del graben, vigilar las posibles emanaciones de gases (metano y radón) en las grietas, instalar equipo de geofísica para detectar sismicidad puntual.

Fosas tectónicas, Dolcanismo activo, deformación del terreno

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Introduction

The decade of the nineties was decreed by the United Nations (UN) as the decade for disaster prevention. During this decade, the University of Guadalajara (UdG) carried out the first Risk Atlas for the Guadalajara Metropolitan Area (UdG, 1994). The UN made an account of the disasters that have occurred worldwide and stated that.

The objectives set to prevent disasters were not achieved, so they propose to continue with the necessary actions for an indefinite period of time to achieve the reduction of disasters worldwide. Among these actions were courses (now taught at the undergraduate and graduate levels), dissemination of information resulting from research on hazards and risks, through various publications and through web pages.

The General Law of Ecological Balance and Environmental Protection was created, State Law on Ecological Balance and Environmental Protection and the Law on Civil Protection were created. In addition, the definitions of Risks, Threats and Vulnerability were introduced.

In addition, institutions such as the National Center for Disaster Prevention (CENAPRED) and, at the state and municipal level, Civil Protection Units were created and strengthened.

Five geological provinces converge in Jalisco; Sierra Madre del Sur, Jalisco Block, Sierra Madre Occidental, Mesa Central and Mexican Volcanic Belt, whose ages are 200 million years old to date, besides having a patrimonial sea (where the greatest number of epicenters are registered), islands and marine platform of interest, but little studied, geologically speaking.

Jalisco according to the General Secretariat of the Government of the State of Jalisco - Directorate of Municipal Studies (2022) is located in the central western part of the Mexican Republic (approximate coordinates 20º 34'00" N and 103º40¨35" W), bordered to the west by the Pacific Ocean, to the north by Nayarit, Zacatecas and Aguascalientes, to the northeast by San Luis Potosí, to the east by Guanajuato, to the south by Michoacán and Colima. Jalisco is divided into 125 municipalities, nine of which form the Guadalajara Metropolitan Area, and twelve administrative regions.

Its morphology is varied, starting with the coast of the Pacific Ocean and highlighting some elevations such as; El Nevado de Colima (4,260 meters above sea level), Colima Volcano (3,820 meters above sea level), Sierra de Tapalpa (2,940 meters above sea level), Tequila Volcano (2,940 meters above sea level), Cerro Viejo (2,880 meters above sea level), Sierra el Tigre (2,840 masl), Sierra de Manantlán (2,840 masl), Sierra Alta (2,850 masl), Sierra Huichola (2,860 masl) and Cerro Gordo (2,670 masl).

The main urban and industrial settlements compete for space and water resources in the valleys of La Barca, Ocotlán, Ameca and Guadalajara, which are located within the Chapala, Colima and Tepic-Chapala tectonic basins.

Among the main active tectonic zones are the Chapala graben (including the Cítala graben), Tepic-Chapala and Colima grabens, which converge in the Triple Union located in the Zacoalco de Torres - San Marcos region. Within the Chapala graben there are volcanoes dissected by faults or associated to regional faults of E-W direction.

The aforementioned grabens have been filled by sediments throughout their history. Geothermal wells drilled in San Marcos report 750 m thick sediments, which have intercalations of organic matter and sediments. In the south of Lake Chapala, organic matter has generated chapopotera and methane gas emanation.

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The region is tectonically active as evidenced by historical and current seismicity in different parts of Jalisco. On March 25, 1806, a strong earthquake collapsed the vaults of the main temple, burying approximately 2,000 people, Government of Jalisco (2022). In 1568, there was an earthquake with an estimated magnitude of 7.6 that affected the communities of Ameca to Sayula (Suter, 2015). In Cd. Guzmán, on March 25, 1806, a strong earthquake collapsed the vaults of the main temple, burying approximately 2,000 people where there have been strong earthquakes, which have caused the death of thousands of inhabitants (Gobierno de Jalisco (2022)).

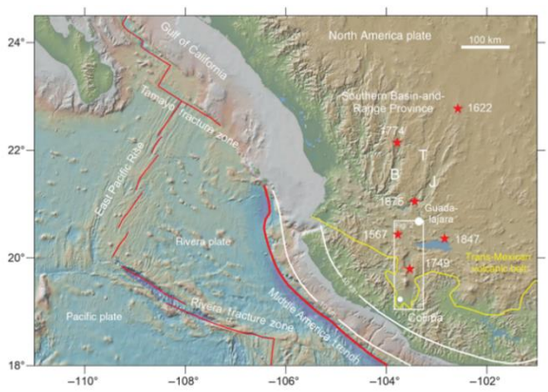

Figure 1 In 1847, in Ocotlán, east of Jocotepec, a 5.7 magnitude earthquake occurred where at least 58 people died
Source: (Suter, 2018)

We present a detailed review in two localities that evidence ground subsidence: Jocotepec and Ciudad Guzmán. The available information is found in scientific journals, popularization, congress abstracts, laws.

Our purpose is to present a proposal to monitor ground subsidence in populations or localities vulnerable to aquifer overexploitation and/or seismic activity.

The identified sites of interest were located using the Google Earth program and periodic feedback was obtained through the Mendeley program, Dianet fins, ScienceDirect Messa, Academia.edu and ResearchGate. From the above, papers associated with the topic and the area of study were selected and are cited as references. The literature review shows that Jocotepec and Ciudad Guzman are located near regional faults such as graben or semi-graben, but also where recent volcanic activity has developed, as in Ciudad Guzman.

Ciudad Guzmán and Jocotepec: Geologic Locations

The western part of the Transmexican Volcanic Belt is characterized by the presence of three tectonic trenches (Figure 1). Jocotepec is located at the western end of the Chapala graben, which had been considered a seismically inactive tectonic depression. However, 1847 a 5.7 earthquake was recorded that caused heavy damage in Ocotlán due to ground motion (Suter, 2018).

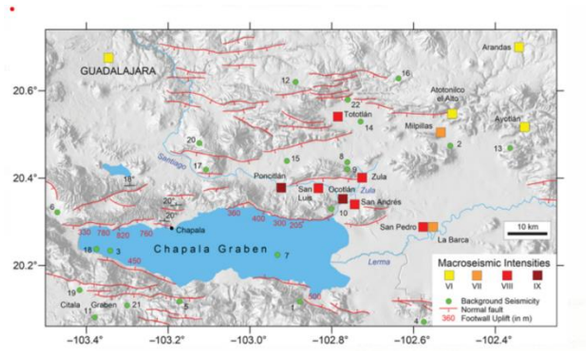

Figure 2 Seismotectonic map of the Chapala graben region showing the macroseismic intensity distribution for the Chapala graben earthquake of October 2, 1847
Source: (Suter, 2018)

The position of the light on this shaded relief map is in the west (Figure 2). Fault traces and the amount of uplift of the footwall are based on interpretation of the topographic relief. Floor wall dips are from Garduño-Monroy et al. (1993) Taken from Suter 2018.

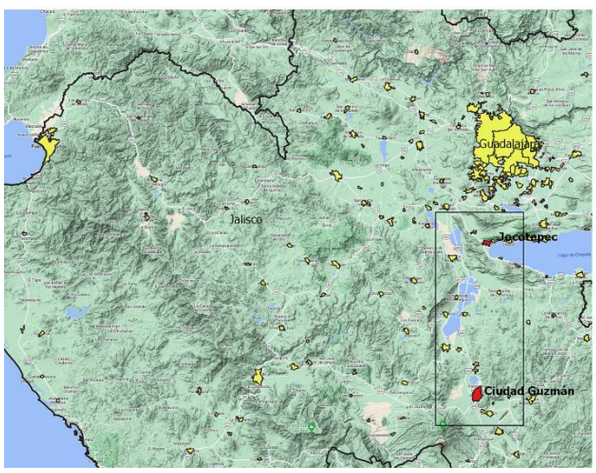

Figure 3 Ciudad Guzmán, located in the Colima graben. On October 22, 1749, there was an earthquake with a magnitude of 5.8 that caused severe damage to the communities of Amacueca, Sayula and Ciudad Guzmán
Source: (Suter, 2019)

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Both Ciudad Guzmán and Jocotepec are located in the Transmexican Volcanic Belt whose characteristic is the recentness of its volcanism and seismic activity. This last province, the FVM, in its western section near the Guadalajara Metropolitan area, stops having an E-W orientation and splits to partially have a NW-SE orientation (from Tepic to Guadalajara) associated with the Tepic Chapala graben and another has an almost N-S direction (from Colima to San Marcos), forming part of the Colima graben.

Figure 4 On March 25, 1806, a strong earthquake collapsed the towers and vaults of the main temple, burying approximately 2,000 people (Government of Jalisco (2022)

During the field work carried out, it was observed that the localities identified with recent and continuous affectations are the following: Guadalajara Jocotepec Highway (Mex. 15), between the beltway and the intersection with the junction to Jocotepec, the constant settling of the road causes continuous maintenance. Figure 5 shows the locations with damage).

Current damage

The damage in Ciudad Guzmán today is evident, Figures 5 and 6 is a dramatic example of this. To the south of Ciudad Guzmán there are "abras" (Figure 6), a term coined in the locality to define cracks or deformations of the soil that occur in different parts of the city, following a preferential direction of N45E.

Figure 5 Damaged houses in Cd. Guzmán
Source: (Photo from Maciel-Flores archive)

Figure 6 Abrasions formed in Cd. Guzmán
Source: (Photograph from the Maciel-Flores archive).

As in Ciudad Guzmán, in Jocotepec there are damaged houses that make them uninhabitable, as well as roads with drops close to one meter, such as those illustrated in Figure 7.

Figure 7 Road and houses damaged by a settlement in Jocotepec (Photograph from the Maciel-Flores archive).
Guadalajara - Colima Highway (Mex. 54), kilometer 6 approximately, there is a constant settlement near the intersection with the railroad

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Discussion

Aquifer Monitoring

Basically, land subsidence can be related to massive groundwater extraction or tectonic activity. In recent years, in Jalisco, there has been an increase in the cultivation of berries in large greenhouses, as is the case in Jocotepec and Ciudad Guzmán, which is predominantly used in highly developed greenhouses in the municipalities of Jocotepec, Sayula, Ciudad Guzmán, and Tapalpa.

Some researchers, especially in this southern region of Jalisco, have worked to identify the environmental costs that have been generated by the agricultural sector, in the Sayula region for example, the agricultural sector has generated some impacting actions such as the increase in the depth of the water table (Macias-Macias, 2008). The abundance of water in the valley caused a change in land cover and land use between 2000 and 2015 which represents an increase in the extension of protected agriculture or greenhouses in Sayula (Ezzahra et al., 2015). In the regions of Cd. Guzmán, Sayula and Jocotepec, the production of grains and other commodities has been shifted away from the production of grains and other commodities to promote the export of berries.

Macias-Macias and Sevilla (2020) cite that berries "Consume a large amount of water, the scarcest natural resource in our country. Almost 70% of the available fresh water is used in the agricultural sector, although this varies from region to region.

If we analyze Tables 1 and 2, we can see that water use in Jalisco is mainly in the agricultural sector. Table 1, elaborated with data from 2016, and Table 2, elaborated with data from 2019, show the increase of groundwater use in general in the state of Jalisco. This is the reason why several countries have opted to grow their products abroad, in order to conserve the water resource and also in soil, declaring this resource as strategic".

Use of water in Jalisco			
By type of use and source (Hm^3/year), 2016			
Use	Underground	Superficial	Total
Agricultural	1,990	1,729	3,719
Public supply	365	699	1,064
Self-sufficient industry	203	8	211
Total	2,558	2,436	4,994
Source, National Water Information System (SINA-CONAGUA, 2016)			

Table 1 Water use in Jalisco in 2016
Source: (SINA-CONAGUA, 2016)

Use of water in Jalisco			
By type of use and source (Hm^3/year), 2019			
Use	Underground	Superficial	Total
Agricultural	2,007	1,726	3,733
Public supply	371	699	1,070
Self-sufficient industry	211	9	221
Total	2,590	2,435	5,024

Table 2 Water use in Jalisco in 2019
Source: (CONAGUA. 2019. Subdirección General de Administración del Agua)

Table 3 shows the pressure exerted on the water resource in the municipality of Ciudad Guzmán.

Millions of cubic meters per year				
Year	Average annual recharge	Extraction	Average annual availability	Deficit
2007	266	130.92	135.08	0
2009	266.1	163.26	102.84	0
2015	266.1	287.05	0	-20.95
2018	266.1	293.02	0	-26.92

Table 3 Water statistics in the Ciudad Guzmán Aquifer
Source: (Prepared based on data from Diario Oficial de la Federación, August 13, 2007; August 28, 2009; April 20, 2015; January 4, 2018. Macias- Macias and Sevilla (2020)

In a first approximation we underline that the increase in water demand associated with berry crops and population increase requires a higher water extraction that may cause soil settlement.

In a preliminary study, the water table depths of existing wells and wells in the Zapotlán basin were taken. This information was modeled in 3D, the result of which is shown in Figure 4. The geometry of the water table is apparently associated with geological structures oriented N45E and which cause slopes in the aquifer.

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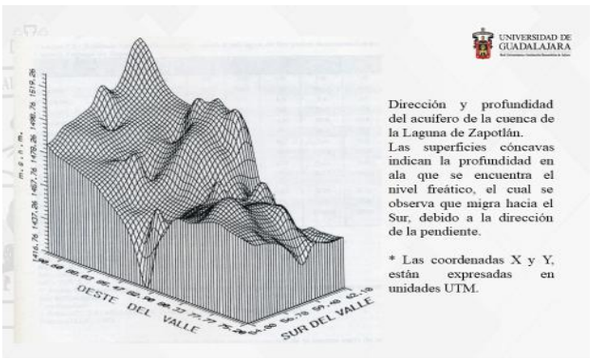

Figure 8 Modeling of the Zapotlán Lagoon aquifer

Seismic Monitoring

Jocotepec and Ciudad Guzmán are localities whose geological history is associated with extensional stresses (Rosas-Elguera, 1996) that formed the Chapala and Colima gabbens. Recent seismic activity has been documented in both cases (Suter, 2018 and 2019).

Figure 9 Proposed location of seismic equipment and accelerographs for Ciudad Guzmán Jal.

Figure 10. Proposed location of seismic equipment and accelerographs for Jocotepec Jal.

In Figures 9 and 10 we present a first approximation of two local seismic/accelerographic networks, one in Jocotepec and the other in Ciudad Guzmán. The purpose in both cases is to determine the ground accelerations, this information can be used to regulate the construction criteria and avoid severe damages that can be translated into human lives.

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Methodological proposal for monitoring basins that drain into the Pacific Ocean. Case study Tomatlán - Tecuán basin (RH15Ca)

Propuesta metodológica para la vigilancia de las cuencas que drenan al Océano Pacifico. Estudio de caso cuenca Tomatlán - Tecuán (RH15Ca)

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Abstract

In this article it is proposed to assess the state of the RH15Ca basin and the use that its population gives to the water, to finally see what state it is in when it empties into the Pacific Ocean. Through the realization of maps of the location of rural and urban populations, climatology, vegetation and land use, ggeology and bathymetry, it is intended to understand the conditions of the water resource and whether or not it is suitable for its waters to flow into the Ocean. This methodology can be applied to the study of other basins in the state of Jalisco or the Mexican Republic.

Basin, Ocean, Flow

Resumen

En el siguiente artículo se propone valorar el estado de la cuenca RH15Ca y el uso que su población le da al agua, para finalmente ver en que estado se encuentra al desembocar al Océano Pacifico. A través de la realización de mapas de ubicación de poblaciones rurales y urbanas, climatología, vegetación y uso de suelo, geología y batimetría se pretende entender en que condiciones se encuentra el recurso hídrico y si es apto o no que sus aguas desemboquen al Océano. Esta metodología puede ser aplicada para el estudio de otras cuencas en el estado de Jalisco o la República Mexicana.

Cuenca, Océano, Desembocar

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Introduction

Society is constantly growing and, above all, requires more and more satisfiers, such as food, water, and various supplies, which, once used, are disposed of in liquid or solid form, and many of these end up on the coasts; part of the population living in the interior of the continent spends their free time vacationing on the beaches, To satisfy the growing demand for water for the agricultural, industrial or recreational sector, the rivers that feed the beaches have been dammed, impacting aquatic ecosystems by modifying the physical and chemical characteristics of the water and draining the coasts, fish, waste disposal and the use of these areas for transportation. Consequently, the deterioration of the coastal environment has become a critical problem and recent reports indicate that the deterioration of an important source of protein, the sea, is on the rise (National Research Council 2000).

More than half of the world's population is located within this region and this proportion is growing due to both population growth and migration to coastal regions (Dennison, W. C. 2008). Approximately 19 million people reside within 1 km of the coast in the American United States (IAI 2010).

Coastal regions of the United States are economically vital areas that support a diverse range of industries and large tourism and population centers. This increase in part is due to recreational use, coupled with the impact of large year-round populations, demonstrates the great importance people place on the environmental quality of coastal areas but people place increasing pressure on coastal ecosystems and make management of these areas increasingly challenging (NRC, 2000).

The infamous plastic islands of the sea is a reflection of the tons of garbage that people from different nations dump into the seas. It is a problem that is expected to grow due to the increasing population growth in coastal areas, which, according to Aranda 2004, causes habitat modification, degradation of water resources, pollution, as well as the introduction of exotic species, which together are causing changes in the coasts that range from greater erosion and vulnerability to the deterioration of the environmental health of a coastal area. The deterioration of the environmental health of an ecosystem directly impacts the health of the population. This type of pollution that alters the quality of coastal water is known as eutrophication (Aranda, N., 2004).

Eutrophication is the process of organic enrichment of an ecosystem where the increased supply of organic matter causes changes in that system. In coastal ecosystems, eutrophication can lead to excessive, and sometimes toxic, production of algal biomass; loss of important nearshore habitats; changes in marine biodiversity and species distribution; increased sedimentation of organic particles; and reduction of the reach of sunlight and depletion of dissolved oxygen (NRC 2000). Most of the organic matter comes from sewage generated both onshore and upstream. The proportion that is discharged into the environment without being collected or treated beforehand is considerable. This is especially true in low-income nations where only 8% of domestic and industrial wastewater is treated, a very low percentage compared to 70% in high-income countries. Due to this lack of treatment, in many regions of the world, wastewater contaminated by bacteria, nitrates, phosphates and solvents is discharged into lakes and rivers and ends up in the sea, with consequent negative environmental and public health impacts (UNESCO 2017).

Mexico is a country with a fortunate geographic location as it is located in the middle of two oceanic slopes, which largely explains the enormous biological and ecosystemic diversity it gathers, having a wide range of marine resources and ecosystems. Seventeen of the 32 states of the Mexican Republic have a total of 11 122 km of coastline (Secretaría de Medio Ambiente y Recursos Naturales, 2018).

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Within the continental territory, Mexico has lakes, lagoons, rivers among other bodies of water that were grouped into hydrological regions. According to the National Water Commission (CONAGUA) hydrological regions are territorial areas conformed according to their morphological, orographic and hydrological characteristics, in which the hydrological basin is considered the basic unit for the management of water resources. Its purpose is the grouping and systematization of information, analysis, diagnoses, programs and actions related to the occurrence of water in quantity and quality, as well as its exploitation, use or exploitation. Mexico has 37 of these regions, within which more than one hydrological basin can be found. These basins could be defined as a surface morphographic unit delimited by the course of a river and its tributaries as secondary rivers that feed the main river. It covers from the area where the river originates to the place where it flows into the sea (lakes, lagoons and/or sea) (SEMARNAT, sf). Unfortunately, overexploitation and misuse of water resources have led to serious contamination problems, not only of the water body but also of the watershed itself.

Location

The RH15Ca sub-basin is located in the central western part of the Mexican Republic in the state of Jalisco, located in the Administrative Hydrological Region VII Lerma-Santiago-Pacific, covering part of the territory of 3 municipalities, Cabo corrientes, Tapalpa de Allende and Tomatlán (Fig. 1). Two of the three municipalities are coastal municipalities. It is located between the coordinates 19.967125, -105.237420. It has an area of 2,706 km2, and its elevation ranges from 0 to 2,578 meters above sea level.

The territorial occupation of the basins in the municipalities is 32.23% of Talpa de Allende, in Cabo Corriente it covers 7.18% of the total area of the municipality and in the municipality of Tomatlán it has the largest territorial occupation of the basin with 52.2%. This sub-basin belongs to the RH15C basin complex, which corresponds to the Tomatlán-Tecuán rivers.

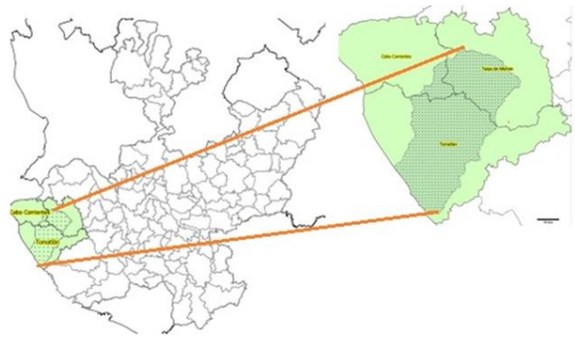

Figure 1 Location of the RH15Ca watershed, Digital Map of Mexico, Data taken from INEGI.

Objective

To assess the RH15Ca watershed and its anthropogenic use in order to describe the state of eutrophication in which it is found.

Specific objectives

- Qualitative assessment of the environmental health of the RH15Ca watershed.
-
- Delimit the watershed used for the case study.
- Define the size of the population living within the watershed.
- Analyze the environmental services that exist in the watershed among its different treatment plants and landfills.
- Review current legislation regarding water quality in a watershed.
- Identify the industrial activity carried out in the watershed.
- Review the analysis of SEMARNAT's clean beaches program to observe its changes. Development of Sections and Sections of the Article with subsequent numbering.

Methodology

In order to carry out the present work, an extensive bibliographic search of diverse topics related to the current state of the RH15Ca watershed was carried out, in addition to the creation of a series of maps with the use of the Digital Map of Mexico.

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All the integrated information was prioritized in Table 4 and percentages were assigned to define the value of the positive and negative parameters.

RH15Ca Watershed

The RH15Ca watershed is drained by numerous streams and rivers (Fig. 2), one of the main ones being the Tomatlán River, which is divided into two sections: Tomatlán A, which runs from the municipality of Tapalpa de Allende to the Cajón de Peñas dam, and Tomatlán B, which runs from the Cajón de Peñas dam to the Pacific Ocean coast. The Cajón de Peñas dam has an operating capacity of 510.56 m3. Water from this basin is mainly used for urban public use, agriculture, livestock, and a hydroelectric plant, which consists of a power generation plant that takes advantage of the existing irrigation infrastructure of the Tule canal (SINAT, sf).

Most of the water used by the urban and rural communities in the watershed is not treated in treatment plants because some of the existing plants are in disuse; in Cabo Corrientes there is one plant out of operation capable of treating 6 liters of wastewater per second and in Tomatlán there are a total of 5 plants out of operation with the capacity to treat a total of 49 liters of water per second. The municipality of Talpa de Allende is the only municipality that has a wastewater treatment plant. Basin Name and description Cp Ar Uc (a) R Ex Ev Av Av Ab Rxy Ab-Rxy D Classification 1504 Rio Tomatlán A: From its headwaters to the Cajón de Peña dam 854.83 0 995.65 533.4 0 26.73 2.49 363.35 267.9 95.45 95.43 Available 1505 Tomatlan River B: From where Cajon de Peña Dam is located, to the mouth of the Tomatlan River in the Pacific Ocean. 316.28 363.35 155.94 493.98 212.4 0 0 0 805.2 496.9 308.3 308.3 Available has a wastewater treatment plant in operation, which sanitizes 30 liters of sewage per second (CEA, 2015).

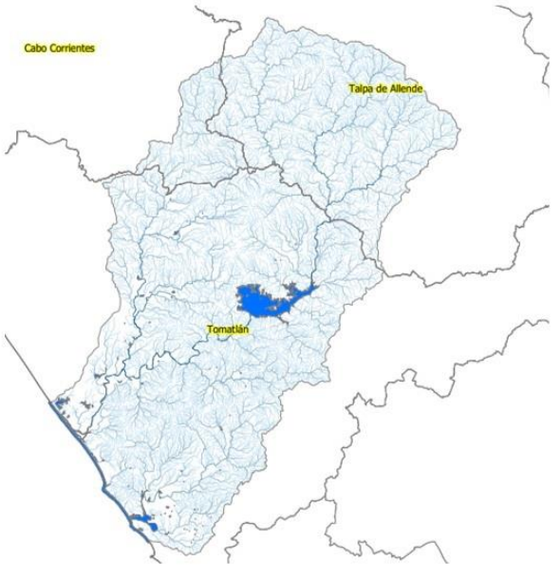

Figure 2 Hydrology of the RH15Ca watershed, Digital Map of Mexico, data taken from INEGI

Water use and management in the basin is monitored every three years by the National Water Commission (CONAGUA) in order to make an update of the basin's surface water use. According to the Official Gazette of the Federation (DOF, 2020) considering that Article 22 of the National Water Law, states that, in order to grant concessions or allocations, the average annual water availability must be considered, which will be published by the National Water Commission, making public the availability of national surface waters by hydrological basin, hydrological region or locality Table .1.

Article 15 of said Law updates the average annual availability of national surface waters of the hydrological basins that integrate the Hydrological Region number 15 Coast of Jalisco to be as follows:

1504.- Tomatlán river hydrological basin A: volume available at the outlet of 95.453 million cubic meters. Classification: (availability).

1505.- Tomatlan river basin B: available volume at the outlet of 308.306 million cubic meters. Ranking: (availability) (DOf, 2020).

Symbology

Cp.- Average annual volume of natural runoff.

Ar.- Average annual volume of runoff from the upstream basin.

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Uc(a).- Annual volume of surface water withdrawal through titles currently registered/assigned in REPDA.

R.- Annual volume of returns.

Ex.- Annual volume of exports.

Ev.- Average annual volume of evaporation in reservoirs.

Av.- Average annual volume of storage variation in reservoirs.

Ab.- Average annual volume of runoff from the basin downstream.

Rxy.- Current annual volume committed downstream, volumes corresponding to reserves, environmental use, regulations and programming.

reserves, environmental use, regulations and water programming.

Watershed	Name and description	Cp	Ar	Uc (a)	R	Ex	Ev	Av	Ab	Rxy	Ab-Rxy	D	Classification
1504	Tomatlán River A: From its source to Cajón de Peña dam	354.83	0	995.65	533.4	0	26.73	2.49	363.35	267.9	95.45	95.43	Available
1505	Tomatlán B River: From the Cajón de Peña dam to the mouth of the Tomatlán River in the Pacific Ocean.	316.28	363.35	155.94	493.98	212.4	0	0	805.2	496.9	308.3	308.3	Available

Table 1 Hydrological Region number 15 Coast of Jalisco. Summary of values of the terms involved in the calculation of surface availability. *Values in millions of cubic meters DOF, 2020

D.- Average annual surface water availability in the hydrological basin.

EH. - Hydrometric station.

EC.- Climatological station.

The equations used for the calculation of surface water availability are the following:

Ab = Cp + Ar + R + Im - (Uc(a) + Uc(b) + Uc(c) + Ev + Ex + Av)

D = Ab – Rxy

After calculating the surface water availability in the basin, it was concluded that its current status is AVAILABLE, referring to those basins where there is an available volume of surface water to grant new concessions by the CONAGUA (CEA, 2015).

Following this series of results the Official Journal of the Federation decreed that the closed areas previously in force in the hydrological basins Río Tomatlán A and Río Tomatlán B, belonging to the Hydrological Region Number 15 Coast of Jalisco, were abolished and established as a partial reserve zone of national surface waters for environmental use or ecological conservation in the hydrological basins published on June 6, 2018.

RH15Ca watershed Rural populations

Along the basin are settled rural populations, in the populations inhabit between 1-1000 people. As can be seen in the map (Fig. 3) the vast majority of the populations are located near the different bodies of water along the basin. As is well known, water is an indispensable resource for human use and consumption; in these regions it is mainly used as drinking water and for irrigation in the agricultural and livestock sector.

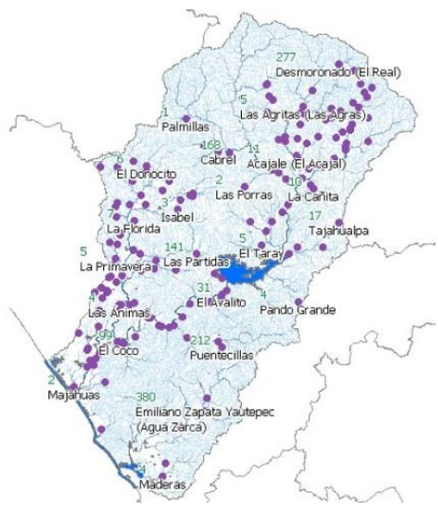

Figure 3 Rural populations of watershed RH15Ca, Digital Map of Mexico, data taken from INEGI.

Watershed RH15Ca urban populations

In the RH15Ca watershed, there are few urban population centers, the main cities being Tomatlán with 9,030 inhabitants, Campo Acosta with 2,638 and José Maria Pino Suárez (Nuevo Nahuapa) with 2,554 (Fig. 4).

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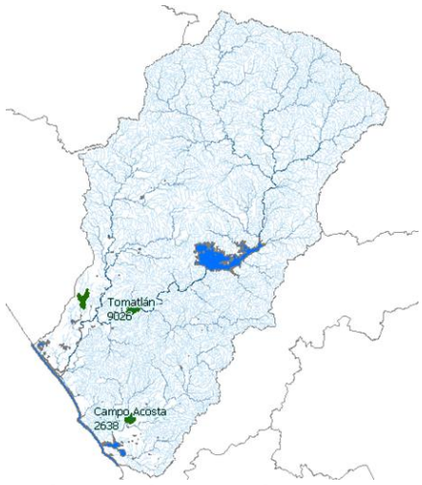

Figure 4 Urban populations in the RH15Ca watershed, Digital Map of Mexico, data taken from INEGI.

Climatology

The watershed has 3 types of climate; Temperate sub-humid, Warm sub-humid and Dry very warm (Fig. 5), with 1,124 mm of average annual precipitation and an average annual temperature of 23.2°C while its average maximum and minimum temperatures range between 36.0°C and 14.5°C respectively, being in the month of June when the highest temperatures are recorded and the month of January the coldest. (CEA, 2015).

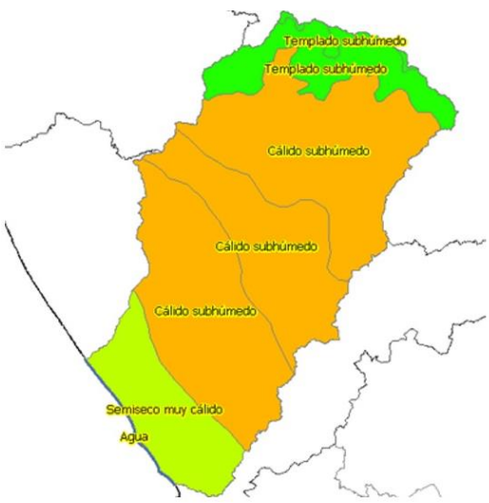

Figure 5 Climatology of the RH15Ca basin, Digital Map of Mexico, Data taken from INEGI.

Geology and rock types

Most of the basin is composed of intrusive igneous rock (Fig. 6). This type of rock is formed when the solidification of magma occurs within the lithosphere, i.e. it is formed within the earth's crust and reach the earth's surface through orogenic processes (tectonic deformations) or through external processes of erosion (Servicio Geológico Mexicano, 2017). It is observed is that the main flows of Rio Tomatlán run over alluvial rock, these are soils of materials transported or deposited in the coastal plains and inland valleys. They are recent or recently deposited soils (Fig. 7).

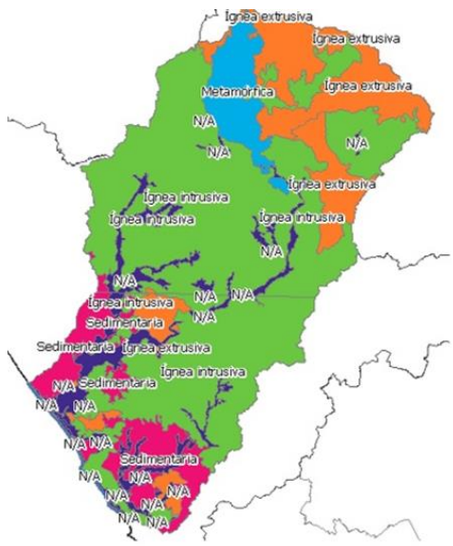

Figure 6 Geology and rock type of the RH15Ca basin, Rock class, Digital Map of Mexico, data taken from INEGI

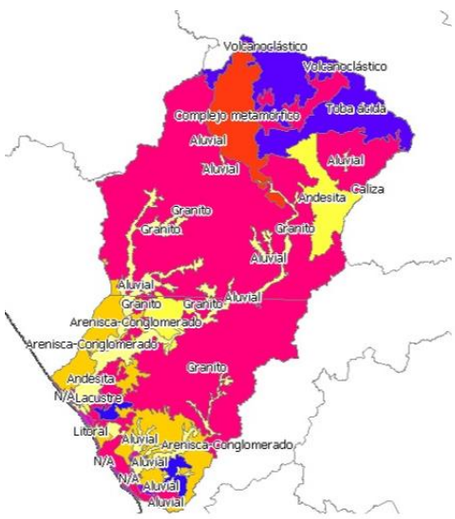

Figure 7 Geology and rock type of the RH15Ca basin Rock subclass, Digital Map of Mexico, data taken from INEGI

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Vegetation cover and land use

Part of the watershed is located in the southern Sierra Madre, so its main vegetation is pine-oak forests, grasslands and jungles. Irrigated agriculture covers a notable part of the basin, as Tomatlan is an important producer of mango in the state of Jalisco (Fig. 8).

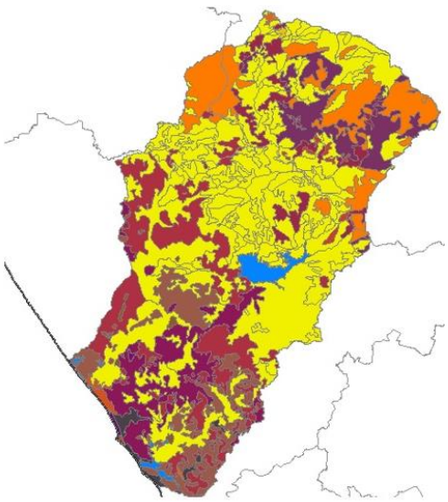

Figure 8 Land cover and land use in the RH15Ca watershed, Digital Map of Mexico, data taken from INEGI

Coasts of Jalisco

On the coasts of the Mexican Pacific Ocean the waters, especially those of the state of Jalisco, are very productive waters thanks to the different hydrophysical and chemical variables of the area. Knowing all these variables helps us to know the dynamics of the oceanic waters and the influence that the continental waters have on the coast.

The coasts are mainly formed by rocky coastline, sandy beaches, bays and inlets of different dimensions. The continental shelf off the coast of Jalisco is very narrow, its width at 200 m from the coast can be as little as 7 to 10 km (Fig. 8). The dynamics of the waters in this region on average flow in a northwesterly direction during the summer and in the opposite direction in the winter months creating small marine currents along the coasts of Jalisco. In this part of the continental shelf there are internal tides of diurnal and semi-diurnal period, causing them to propagate from the continental slope to the coast in the form of solitary waves which cause the deformation of the thermocline generating orbital currents.

These currents cause water submergence of up to 25 m, changing the dynamics of the water with variations in temperature and salinity (Filonov,

A.E.et all, 2000). This whole series of events demonstrates the dynamics of the ocean along the coast of Jalisco, and consequently what happens to the water of the basins that flow into the Mexican Pacific and how they end up mixing with everything they carry upstream.

In Jalisco, most of the state's registered fishing comes from inland waters and is obtained using rustic techniques. In this case the fishermen, depending on their own skills and resources, build their own fishing gear and in most cases, their own boats, which are small. In fact, only 10% of the boats in the state are larger, and most of the time the deep-sea fishing in the state is carried out by fleets belonging to other states. In the state's fishing activity in localities located between Puerto Vallarta and Barra de Navidad, around 136 species have been identified in the commercial catch of which 89% were fish, 8% crustaceans, 6% mollusks and 1% echinoderms (Dagostino, R. & Lemus, J. 2014). Because the continental shelf off the coast of Jalisco is narrow, fishery production tends to be lower compared to northern coastal states, as these have an extensive continental shelf on which they have the capacity to host a greater amount of marine life and fishery resources.

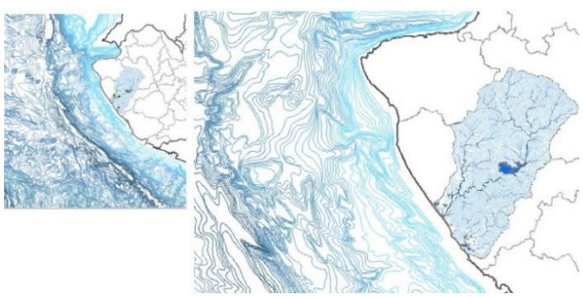

Figure 8 Bathymetry of the coasts of Jalisco, Digital Map of Mexico, data taken from INEGI

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BACTERIOLOGICAL QUALITY OF SEAWATER 2022 (NMP ENTEROCOCCI/100ML)					
Beach	Sampling site	Coordinates	Sampling date	NMP/100ml	Ranking
Yelapa Beach	Yelapa	20° 29' 24.8" 105° 26'34.8" Coordenadas	March 15 -24	23	APTA
	Yelapa		17-18 de julio	181	APTA

BACTERIOLOGICAL QUALITY OF SEAWATER 2021 (NMP ENTEROCOCCI/100ML)					
Beach	Sampling site	Coordinates	Sampling date	NMP/100ml	Ranking
Yelapa Beach	Yelapa	20° 29' 24.8" 105° 26'34.8" Coordenadas	2 y 10 de marzo	106	APTA
	Yelapa		29 de nov- 9 de dic	17	APTA

BACTERIOLOGICAL QUALITY OF SEAWATER 2019 (NMP ENTEROCOCCI/100ML)					
Beach	Sampling site	Coordinates	Sampling date	NMP/100ml	Ranking
Yelapa Beach	Yelapa	20° 29' 24.8" 105° 26'34.8"	19-27 de marzo	10	APTA
	Yelapa		10-19 de junio	29	APTA
	Yelapa		29 de nov- 10 de dic	19	APTA

Table 2 Data was collected from the Clean Beaches Program by SEMARNAT to review the bacteriological quality of the beaches surrounding the RH15Ca watershed to estimate water quality

MPN Enterococci /100ml	Beach classification
De 0 a 200	APTA
Greater than 200	NO APTA

Table 3 Classification criteria for seawater quality, Secretary of Environment and Natural Resources, 2019

Results

The analysis of this basin, according to Table 4, indicates that it has more favorable parameters for draining rainwater to the sea than unfavorable parameters, among the most important parameters is the presence of sanitary landfills and treatment plants.

Tomatlán-Tecuán sub-basin (RH15Ca)		
Parameters to assess	Valores	
	Favourable	Unfavourable
	State	Federal
Size of the sub-basin	10	0
Total population of the sub-basin	Distributed throughout the basin	Concentrated in the lower part
	9	1
5t Natural vegetation cover	In full	Partial
	8	2
Land use	Forestry	Agriculture
	8	2
Lithology type	Permeable	Waterproof
	2	8
Precipitation	Greater than 1000 mm	Less than 1000 mm
	10	
Treatment plants	10	
Landfills	10	
Total	47	13

Table 4 Analysis of the favorable or unfavorable parameters for a basin to drain water of good or bad quality to the coasts of Jalisco

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Conclusion

It is considered necessary to apply this methodological analysis in the rest of the watersheds in Jalisco that drain to the sea and if possible in the coasts of the Mexican Republic, prioritizing the watersheds that need to be studied in greater detail due to their evident pollution problems.

Moving to a phase of qualitative methodological analysis, installing sensors and making a periodic systematic monitoring of the watersheds would be an interesting proposal to implement as a second phase of analysis of the state of eutrophication of the watersheds.

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Preliminary assessment of the risk of river overflow in the presence of a bridge using HEC-RAS and LiDAR topography

Evaluación preliminar del riesgo de desbordamiento de ríos en presencia de un puente mediante HEC-RAS y topografía LiDAR

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Abstract

The objective of this study is to evaluate the risk of flooding due to the overflowing of the Laja River around the bridge located on the Santa Catarina de Peña-Perico de Cornejo Road section in the municipality of Salamanca, Guanajuato, Mexico. The evaluation is carried out through modeling and computational simulation under normal and extreme flow conditions. The software used is HEC-RAS under steady flow and establishing uniform flow as the boundary condition for the inflow and outflow in the domain. The modeling is performed entirely with open-access information available in databases of governmental agencies on the Internet. The methodology used is proposed as an important support in the monitoring and/or forecasting of river hydrodynamics in areas of interest such as the location of bridges, allowing the identification of risk areas and scenarios quickly and economically, so that efforts and resources can be focused on these critical scenarios with more extensive studies, including sediment transport, updated and more accurate topographic data, as well as extending the projection of hydrological variables. In the case study presented, the flooding problem was identified, and it is recommended to gather information in the field to complement the study and establish adequate solutions.

Flood, Hydrodynamics, Computational simulation

Resumen

El objetivo del presente estudio es evaluar el riesgo de inundación por desbordamiento del Río Laja en la zona del puente ubicado sobre el tramo carretero Santa Catarina de Peña-Perico de Cornejo en el municipio de Salamanca, Guanajuato, México. La evaluación se realiza a través de modelado y simulación computacional bajo condiciones normales y extremas del caudal. El programa utilizado es HEC-RAS bajo condiciones de flujo permanente y estableciendo flujo uniforme como condición de frontera de entrada y salida del flujo en el dominio. El modelado se realiza totalmente con información de acceso libre disponible en bases de datos de dependencias gubernamentales en Internet. La metodología empleada se propone como un apoyo importante en el monitoreo y/o pronóstico de la hidrodinámica de ríos en zonas de interés como lo pueden ser la ubicación de puentes, permitiendo identificar zonas y escenarios de riesgo de forma rápida y económica, de esta forma tanto los esfuerzos como los recursos se pueden centrar en estos escenarios críticos mediante estudios más extensos, en los que se incluyan transporte de sedimento, datos topográficos actualizados y de mayor precisión, así como, ampliar la proyección de variables hidrológicas. En el caso del estudio presentado se identificó la problemática de inundación, donde se recomienda recabar información en campo para complementar el estudio y establecer soluciones adecuadas.

Inundación, Hidrodinámica, Simulación Computacional

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Introduction

This article addresses two fundamental aspects in urban development planning, floods and bridges. According to Hernández-Uribe *et al*. (2016) UNESCO (United Nations Educational, Scientific and Cultural Organization) points out that floods account for 50% of water-related disasters worldwide, even above famines, droughts and epidemics. In economic terms, it is estimated that floods are responsible for 20% of total losses in Asia in the last 30 years (Dutta, 2003).

Douben (2006) notes that, on a global scale, the frequency of floods is increasing, although the reliability of flood data tends to overestimate this trend. This global increase is mainly due to relatively large floods with a recurrence interval of between 10 and 20 years.

Thus, floods are a sensitive issue that requires global efforts to estimate the areas at risk and to assess both hazard and vulnerability to flooding. Recent studies show that Latin America is no exception (Segura-Gutiérrez and Vargas-García, 2022; Curay-Casaverde, 2022; Calvo-Siles, 2022; Pinto-Argel, 2022; Cieza-Guerrero, 2022; Hernández-Uribe *et al*., 2016).

In the state of Guanajuato, the issue of floods has also been closely followed, from the social and hydrological perspective (Woitrin-Bibot *et al*., 2015) and punctual analyses of extreme events (Matías-Ramírez *et al*., 2007).

On the other hand, bridges with crucial elements in the land communication network that catalyze urban development. However, a negative point is pointed out by Pregnolato *et a*l. (2022): Bridges act as bottlenecks for surrounding roads and, therefore, any service disruptions can disrupt community access and connections, impair emergency planning and evacuation routes, and impact economies and businesses.

Because of the importance of bridges and the impact they suffer from flooding, many efforts are focused on estimating flood risk analysis.

The present work aims to implement a methodology based on the use of freely available information in databases on the Internet to perform preliminary assessments of the probability of flooding in the vicinity of bridges quickly and inexpensively. The results of the assessments will allow efficient use of available resources, prioritizing high-risk regions.

The research is presented under the following scheme. The Study Area section describes the location, selection criteria and characteristics of the chosen region. The software used, the calculation methods, the boundary conditions and the selection of model tuning parameters are presented in the Modeling section. The flow rates that define the simulated scenarios are presented in the Simulations section, while the resulting water level and its corresponding analysis are included in the Results and Analysis section. Finally, in Conclusions, the most relevant results are summarized and opportunities for improvement are defined.

Study area

The study area corresponds to a stretch of the Laja River where the bridge that connects the communities of Santa Catarina de Peña and Perico de Cornejo is located (14 Q, 282162.00 m E, 2270615.00 m N), see Figure 1. The area is located in the municipality of Salamanca, Guanajuato, Mexico; the bridge provides a quick connection between a region dedicated mainly to agriculture and the Querétaro-Irapuato highway, which integrates the industrial corridor of Guanajuato, one of the most active trade routes in the central region of the country.

Figure 1 Location of the study area

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The runoff area associated with the selected bridge is 11,945.40 km^2, this area is approximate to that of the R. Laja watershed (key RH12H) of 12,093.83 km^2, the difference is due to the fact that the bridge is located slightly before the outlet of the watershed as shown in Figure 2.

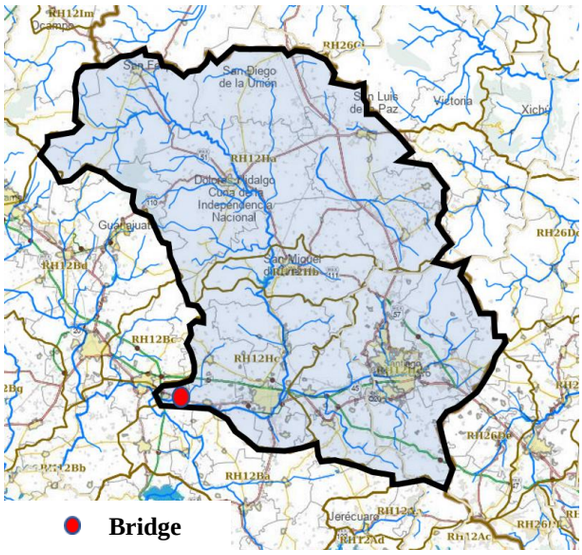

Figure 2 R. Laja watershed and location of the bridge

The climate of the area is semi-warm sub-humid with summer rains of lower humidity. The temperature range is 14 to 20°C and precipitation is 600 to 900 mm. In terms of geology, the area is composed of alluvial soil and in edaphological terms corresponds to a vertisol. Land use is agricultural (INEGI, 2010).

Modeling

HEC - RAS (Hydrologic Engineering Centers River Analysis System) is a hydraulic modeling software that, through the one-dimensional steady flow computation component, determines water surface profiles for steady and gradually varying flow. The system can handle a complete channel network, a dendritic system or a single river reach. The steady flow component is capable of modeling flow surface profiles in subcritical, supercritical and mixed regimes. The basic computational procedure is based on the solution of the one-dimensional energy equation (US Army Corps of Engineers, 2022).

This software also allows simulating flows in natural or artificial channels, as well as determining the water level, so it is also used in flood studies.

The basic requirements for calculating one-dimensional flow within HEC-RAS: flow data and geometry, are described below.

Flow

The type of flow used is permanent, since we worked with constant flows and not with hydrographs.

With the help of the Simulador de Flujos de Agua de Cuencas Hidrográficas (SIATL), the nearest hydrometric station to the study area, station 12238 (see Figure 3), was identified and the record of the maximum annual discharge was extracted from the Banco Nacional de Datos de Aguas Superficiales (BANDAS).

Figure 3 Location of hydrometric station 12238

The record of station 12238 contains the maximum annual discharge from the year 1929 to 2014.

Regarding the boundary condition, since we did not have information on the water level in the study area, we started with the normal discharge, so the section of the channel to be evaluated was extended upstream considering the beginning in a relatively straight section to reduce the initial error and avoid a significant affectation in the area of interest, the bridge area (Figure 5).

Geometry

The geometry data, for the present study, consists of the delimitation and configuration of the channel through its length, cross sections and energy loss coefficients (friction, expansion and contraction).

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The geometry of the model was established with the help of HEC-GEORAS software from the LiDAR data obtained from the F14C63F3 chart provided by INEGI (National Institute of Statistics and Geography), see Figure 4.

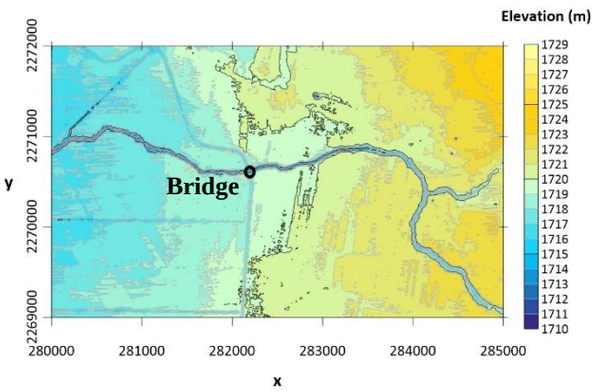

Figure 4 Contour map of terrain elevations, UTM coordinates

The model domain is shown in Figure 5 and was established considering the channel configuration (length) and floodplains in the study area (width). The length of the river was approximately 1600 m, while the width of the domain was approximately 450 m (200 m in both flood plains, right and left, and 50 m from the main channel, approximately).

On the other hand, cross sections were set at every 100 m by defining the Mannng roughness coefficient based on information from the HEC-RAS manual. The main channel was assigned a coefficient of 0.045, since it was considered a clean channel with little vegetation and stones, with some pools and shallows; while the flood plains were assigned a coefficient of 0.040, since they were plains with mature crops in rows.

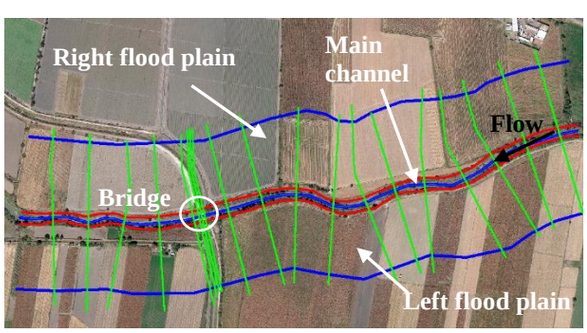

Figure 5 Domain. Main channel, flood plains and cross sections

For the modeling of the bridge, the four mandatory sections were established for the correct hydraulic calculation. The contraction and expansion lengths were estimated at 15 and 30 m, respectively. Since it is a bridge with a span of 22 m, a deck width of 3.5 m, with 3 oval piers separated by 6.5 m and abutments with straight walls, as shown in Figure 6, the moment balance method was chosen for the hydraulic analysis of the bridge. The drag coefficient (Cd) was assigned 0.32 and the pier shape coefficient K was 0.9.

Figure 6 Bridge
Source: (Google Earth) Simulations

The 84 annual peak discharges, corresponding to the 84 years of the record of hydrometric station 12238, were analyzed to obtain the associated return periods using equation 1 according to Aparicio-Mijares (2008). The results are presented in Graph 1.

$$Tr = \frac{n+1}{m} \quad (1)$$

where:

Tr =Return period

n =Number of data

m =Number of order in a list from largest to smallest

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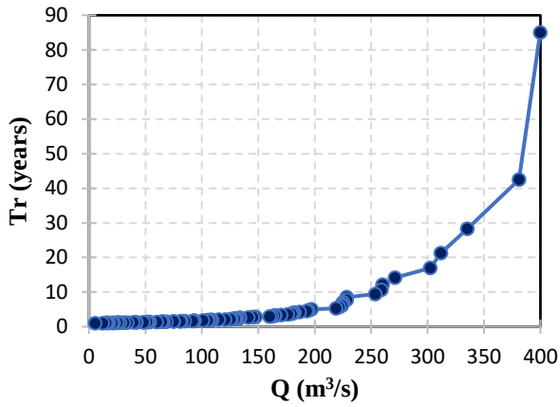

Graphic 1 Return period of the maximum annual expenditure (Q)

The selected simulation scenarios are presented in the following table.

Simulation	Tr (Years)	Q (m^3/s)
1	1	15
2	2	100
3	10	250
4	50	390

Table 1 Simulation scenarios

Results and Analysis

The results presented below correspond to the free water surface elevation (WS), the ground elevation (Ground) is used as a reference and the banks of the main channel (Bank Sta) are indicated.

For each simulation, the calculated water elevation is shown for the bridge cross section and the entire domain with a 3D view to locate flood zones. For the first simulation, corresponding to a 1-year return period and an associated flow of 15 m^3/s, the water level in the bridge section presents an elevation of 1714.8 m, and a discharge of 2.20 m as shown in Figure 7. On the other hand, Figure 8 shows that the flow is contained entirely within the main channel.

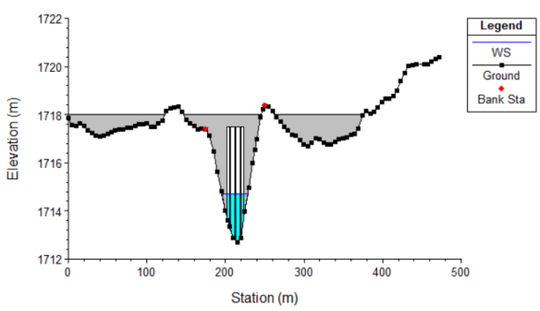

Figure 7 Water elevation in the bridge section. Q=15 m^3/s

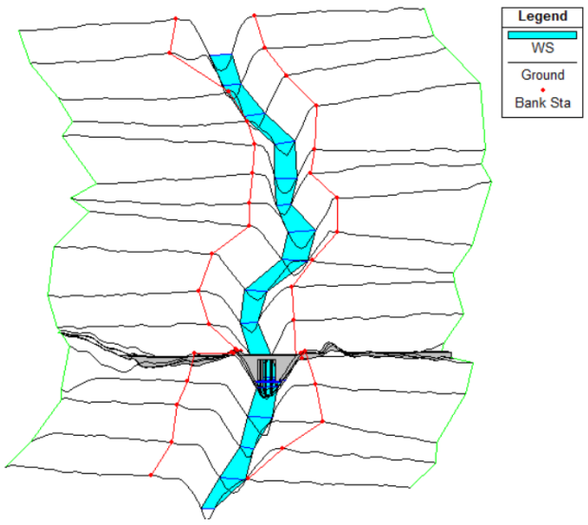

Figure 8 Water elevation in the domain. Q=15 m^3/s

When evaluating the flow of 100 m^3/s corresponding to the return period of 2 years, the increase in the water surface is notorious, registering an elevation of 1716.8 m with an associated 4 m of water flow; however, there is still 0.8 m to reach the bridge deck (see Figure 9).

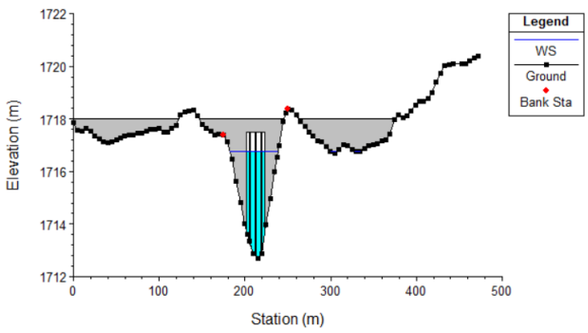

Figure 9 Water elevation in the bridge section. Q=100 m^3/s

The obstacle that the bridge represents to the flow is already noticeable upstream of the bridge with a slight increase in the width of the free surface associated with the backwater caused, but without being very significant as shown in Figure 10. Also, immediately downstream of the bridge there is flooding in a part of the right plain, which is only associated with the increase in the water surface and the low elevation of the land in that area.

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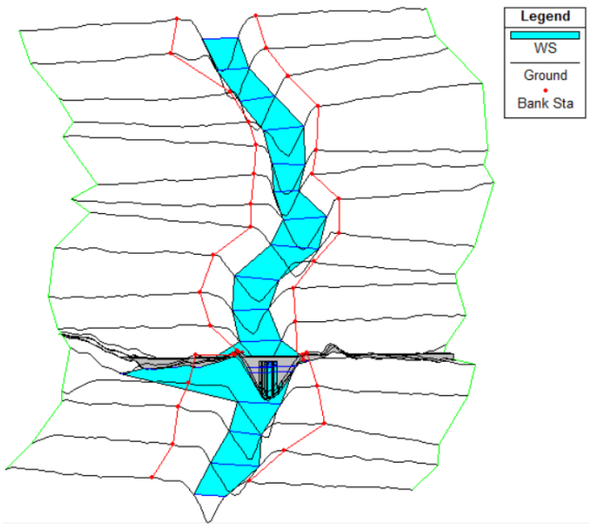

Figure 10 Water elevation in the domain. Q=100 m^3/s

Figure 11 indicates that the bridge deck, 1718 m elevation, is exceeded by the water surface which reached 1718.6 m in the third simulation (T =10 years and Q = 250 m^3/s).

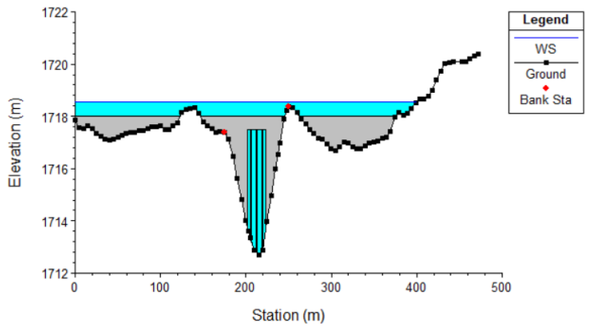

Figure 11 Water elevation in the bridge section. Q=250 m^3/s

The substantial increase in flow and the effect of the bridge on the flow are reflected in increased flooding of the plains mainly in the vicinity of the bridge (see Figure 12).

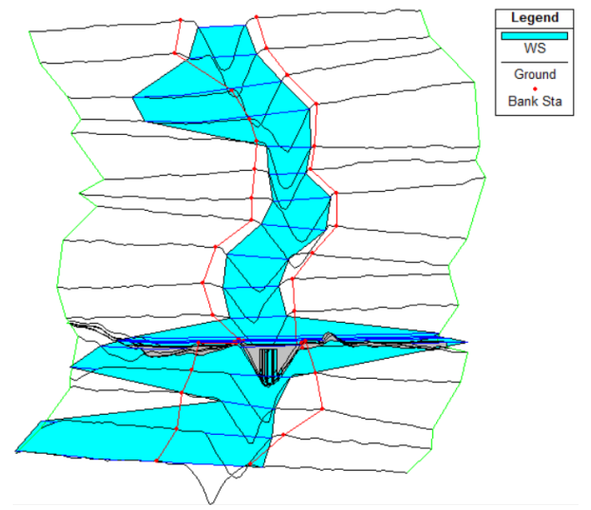

Figure 12 Water elevation in the domain. Q=250 m^3/s

Finally, for simulation 4 (Tr =50 years and Q = 390 m^3/s), the bridge deck is 1.2 m submerged as clearly shown in Figure 13. The main channel is completely overtopped, the right plain is completely flooded, while the left plain has little dry area (see Figure 14).

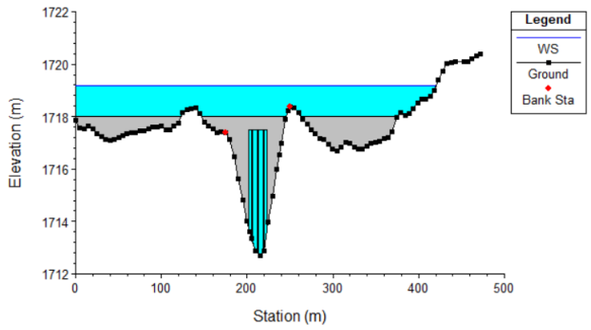

Figure 13 Water elevation in the bridge section. Q=390 m^3/s

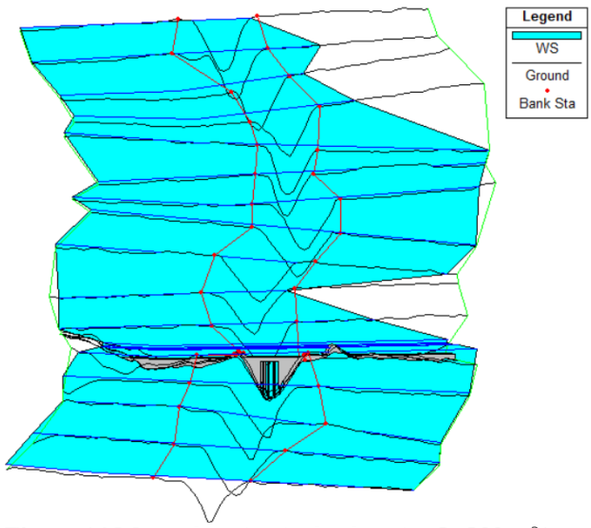

Figure 14 Water elevation in the domain. Q=390 m^3/s.

Conclusions

According to the results and the curve of return periods and maximum annual expenditures, the bridge is subject to flooding conditions with a frequency close to 10 years.

The frequency of flooding is short, but it should be considered that the bridge is small and its affectation does not represent significant losses.

For the case study, the established flood plains were insufficient to map the flooding. However, the objective of the work was achieved by demonstrating the practicality of the assessment methodology.

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The usefulness of the proposed methodology to perform a preliminary assessment of the probability of flooding in bridges, based on information available in databases, is demonstrated by monitoring the variation of the free surface with different flows in the vicinity of the bridge.

This methodology can be improved by calibrating the model by region by performing a characterization of the roughness coefficients and of the bridges (sizing).

After identifying the risk scenarios and prioritizing them, the exercise of the economic resource can be carried out efficiently.

The usefulness of the information available in databases is also evident and it is recommended to continue investing in the acquisition of terrain elevations through LiDAR technology.

Acknowledgements

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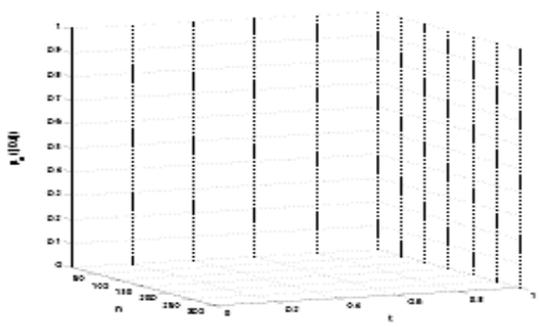

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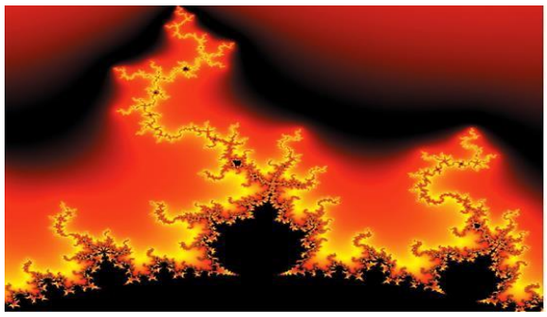

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