Ingeniería y Agrimensura

Dimensión

Revista del Colegio de Ingenieros y Agrimensores de Puerto Rico
Año 33, Vol. 2, 2019 Disponible en el internet: www.ciapr.org

Rebuilding Puerto Rico's Bridges Using Innovative Composite Technology

Requirements for an Economical and Effective Bridge Program

Conceptual Design to Produce Drinking Water for Small Rural Communities

Ian Poellet

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Ingeniería y Agrimensura

Dimensión

Año 33, Vol. 2

Dimension (Online)
ISSN 2167-7832

Dimension (Print)
ISSN 2155-1618

Contenido

Mensaje del Presidente del CIAPR 5

Mensaje del Presidente de la Junta Editora 6

Rebuilding Puerto Rico's Bridges Using Innovative Composite Technology 9
Ken Sweeney, PE and Victor Méndez, PE

Requirements for an Economical And Effective Bridge Program 13
Richard D. Rogovin, J.D

Conceptual Design to Produce Drinking Water for Small Rural Communities 15
Aluisio C. O. Pimenta, PE, Eileen M. Cruz-Pastrana, Johel Padilla

Diccionario Zurdo 22

Cover Photo by Ian Poellet
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Año 33, Vol. 2, 2019
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La revista Dimensión es producida por: Publishing Resources, Inc.: Ronald J. Chevako, Presidente y Principal Oficial Ejecutivo. Para información sobre ventas de anuncios comuníquese con Ronald Chevako (787) 647-9342.

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Mensaje del Presidente

Estimados lectores de Dimensión:

Reciban un cordial saludo del Colegio de Ingenieros y Agrimensores de Puerto Rico. Me complace mucho poder presentarles lo que será la última edición de la Revista durante mi incumbencia como Presidente del CIAPR.

Ciertamente ha sido para mí un privilegio colaborar con nuestro equipo editor de la Revista Dimensión, liderado por el Dr. Benjamín Colucci Rios y el productor de la misma, el Sr. Ron Chevako. A tales efectos, comienzo por agradecer a este grupo de excelentes y comprometidos profesionales por el gran apoyo recibido durante este espacio de dos años de mi vida, sobre el cual siempre habré de sentirme sumamente honrado y orgulloso.

Los artículos seleccionados en este volumen de la revista son de alta pertinencia ante el proceso de reconstrucción que esperamos se pueda realizar durante varios años en Puerto Rico. Tocamos temas relacionados a materiales con propiedades especiales en términos de capacidad y sostenibilidad para elementos de infraestructura y a procesos para asegurar la integridad de esa infraestructura. Además hablamos de sistemas para la producción de agua potable en comunidades aisladas de nuestra isla. Sin duda alguna, son temas de sumo interés en este particular momento histórico. Espero que disfruten los tres artículos incluidos en esta edición.

Finalmente, expreso mi más profunda gratitud a todos los lectores de la Revista Dimensión por el continuo interés en los temas que atañen a nuestras honrosas profesiones de ingeniería y agrimensura. Espero que nuestra revista continúe aportando al desarrollo de nuestros profesionales a través de las contribuciones técnicas de los profesionales que comparten su pericia y talento en los artículos de Dimensión. Igualmente agradecemos a todos los auspiciados que hacen posible el trabajo de producción de la Revista Dimensión.

Un abrazo colegial y continuemos todos ***Unidos Transformando el Colegio,*** y a Puerto Rico.

Cordialmente,

Pablo Vázquez Ruiz, PE, MBA
Presidente

MENSAJE DEL PRESIDENTE DE LA JUNTA EDITORA

Un cordial saludo a todos los ingenieros y agrimensores del CIAPR. Esta segunda edición del año 2019 contiene tres artículos de interés a nuestra matrícula, el "Diccionario zurdo" y el mensaje de nuestro Presidente, Ing. Pablo Vázquez Ruiz.

En el primer artículo titulado *Rebuilding Puerto Rico's Bridges Using Innovative Composite Technology,* los autores Ken Sweeney y Víctor Méndez representando la compañía *AIT Bridges* nos presentan los beneficios potenciales asociados a la utilización de materiales compuestos en el proceso de reconstrucción de puentes, específicamente como un método costo efectivo para reparación de puentes a raíz del paso del huracán María sobre Puerto Rico. Los beneficios de estos materiales conocidos como *Fiber Reinforced Polymers (FRP),* específicamente en términos de sus propiedades ingenieriles aplicables a puentes y los siete (7) atributos principales asociados a resistencia, sostenibilidad y costo de ciclo de vida, entre otros están descritos en el artículo. Finalmente, se presenta una descripción de un puente compuesto en forma arco.

En el segundo artículo denominado *Requirements for an Economical and Effective Bridge Program,* el autor Richard D. Rogovin, J.D., el presidente de la compañía *U.S. Bridge* nos presenta inicialmente la pertinencia de reconocer puentes seguros vs. no-seguros y la importancia de tener un programa de inspección de puentes que cumpla con los requerimientos federales. Nos presenta además los retos de financiamiento de los programas de puentes en los Estados Unidos y territorios, y finalmente, nos presenta los requisitos en su opinión para un programa económico y efectivo para puentes aclarando la diferencia entre puentes permanentes y temporeros y sus implicaciones.

En el tercer artículo, titulado *Conceptual Design to Produce Drinking Water for Small Rural Communities,* los autores Aluisio C. O. Pimenta, Eileen M. Cruz-Pastrana y Johel Padilla proponen un diseño conceptual para producir agua potable para las comunidades rurales localizadas en las regiones montañosas de Puerto Rico incorporando un filtro de arena por gravedad/filtración y desinfección química. Los beneficios de este sistema son descritos en el artículo y, al igual que recomendaciones para considerarlo como un modelo viable para comunidades similares en la región montañosa de Puerto Rico.

Agradezco la aportación de los profesionales que colaboraron en esta edición de la Revista Dimensión y un especial agradecimiento a la estudiante Natalia A. Alzate Pérez y a Irmalí Franco del Centro de Transferencia de Tecnología en Transportación por su asistencia y asuntos administrativos asociados a esta edición. Espero que la selección de artículos técnicos en esta segunda edición del 2019 de la Revista Dimensión sea de utilidad y beneficio para los lectores y profesionales de la ingeniería y agrimensura de Puerto Rico. Les exhorto a que también disfruten nuestra sección el Diccionario Zurdo y que accedan a la página electrónica del CIAPR, **www.ciapr.org** para que tengan acceso a las demás ediciones electrónicas de la Revista Dimensión. Los invito a contactarnos (benjamín.colucci1@upr.edu) con sus comentarios, o si conocen de algún recurso que desee someter un artículo que sea de interés a la matrícula de ingenieros y agrimensores de Puerto Rico.

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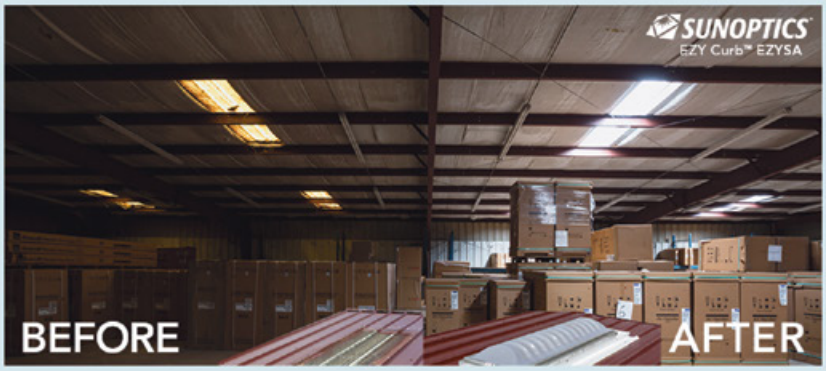

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REBUILDING PUERTO RICO'S BRIDGES USING INNOVATIVE COMPOSITE TECHNOLOGY

Ken Sweeney, PE and Victor Méndez, PE

After the damage to bridges throughout Puerto Rico from hurricanes Irma and María, there continues to a pressing need to replace damaged and temporary bridges to keep the traveling public on the road to recovery. Swift, creative, and innovative solutions are imperative. To make bridges better than they were before demands the use of materials that are better than before. In today's world of limited resources and public demand for solutions now rather than years from now, composite materials provide an affordable, innovative and superior solution to meet this need.

Composite materials, also known as Fiber Reinforced Polymers (FRP), have been used safely and extensively in the aerospace, automotive, marine and energy sectors for many years. FRP has a long documented history of success in highly corrosive environments requiring high strength, durability and long lasting materials.

FRP Properties Applicable to Bridge Engineering

The three (3) fundamental materials used to manufacture structural components for bridges are:

- E-glass fabric
- Carbon fabric
- Vinyl-Ester Epoxy Polymer Matrix

These basic materials used to manufacture composite materials are combined into structural shapes either by pultrusion or vacuum infusion processes. The resultant material has significant advantages over steel and other traditional construction materials. For example, steel weighs 490 lb./ft^2 and composites are as much as 50% to 60% lighter.

Composites have high strength-to-weight and stiffness-to-weight ratios which is a good measure of structural efficiency. Other important attributes are high corrosion and fatigue resistance, and low thermal expansion. Steel on the other hand is limited by high weight resulting in very high transportation costs, and its susceptibility to corrosion in areas of salt exposure results in high maintenance costs.

Attributes of Composite Materials

Seven (7) attributes associated with composite materials applicable to bridge systems are described below:

- Impact Resistance: Composites have superior impact properties by using long continuous fibers.
- Lower Life Cycle Costs: Composites need little maintenance and have longevity of more than 100 years.
- Corrosion Resistance: Composites are virtually corrosion-free when exposed to high concentrations of salt and moisture because the outer surface is formed by impermeable polymers.
- Seismic Resistance: Composites are designed to meet, and many times exceed the requirements for seismic design including racking and ovaling required by tunnel designs. Composites generally damper vibrations.
- Sustainability: The manufacturing, transportation and installation significantly reduces carbon footprint compared to conventional construction materials.
- High Strength and Stiffness: Carbon fiber has strengths between 500 ksi to 800 ksi, and a stiffness of 35 Msi with a unit weight of 110 lb/ft^2 providing high reserve structural capacity and safety.
- Fatigue Resistance: Composites are designed to sustain infinite fatigue resistance and for bridges tested to 6 million cycles following AASHTO standard.

Because of these attributes associated with composite bridges, structural bridge engineers can now specify materials which reduce weight and improve lifespan at reduced cost both initially and with minimal maintenance. Composite bridge systems are now available that have been extensively tested, put in service, and are performing very well.

Description of the Composite Arch Bridge System

The Composite Arch Bridge System provided by AIT Bridges is a cost-effective solution to medium span (30' – 80') overfill bridges. The system consists of composite FRP tubular elements and FRP decking supported on standard or precast foundations. The system spans up to 80 feet and can also be used in multiple spans increasing the overall bridge lengths. Tubular elements can be cut for efficient transport and then spliced on site. This is system is highly customizable, can be sized and shaped to many configurations, and can also be manufactured locally. When a skewed bridge is appropriate for a project, the arches can be installed on a skew thereby requiring a smaller bridge and resulting in cost savings.

Due to the lightweight structural components, no heavy lifting equipment is required and utility relocations can be avoided. This solution is ideal for remote and compact locations as demonstrated by the 30 AIT composite arch bridges constructed in nine states from Maine to Michigan, plus Trinidad.

Figure 1: Representative Composite Tub Girder System (CT Girder™) Manufactured by AIT Bridges

The Composite Tub Girder System (CT Girder™) provided by AIT Bridges is a long life alternative solution to steel and other traditional medium span girder bridges with spans up to 100 feet (See Figure 1). The system consists of lightweight FRP tub girders that can be simply supported, or use of continuous over supports topped with a precast or cast-in-place reinforced concrete deck. The CT Girder™ will be the lowest life-cycle cost in the industry, and in many cases the lowest initial cost when compared to similar steel and other traditional materials used in bridge construction. The CT Girder™ is stackable for transportation and weighs 50% less than steel and 75% less than concrete, requiring lighter equipment for installation and smaller foundations.

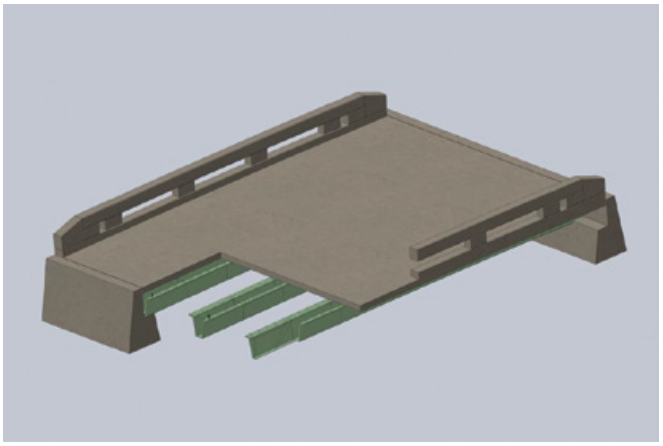
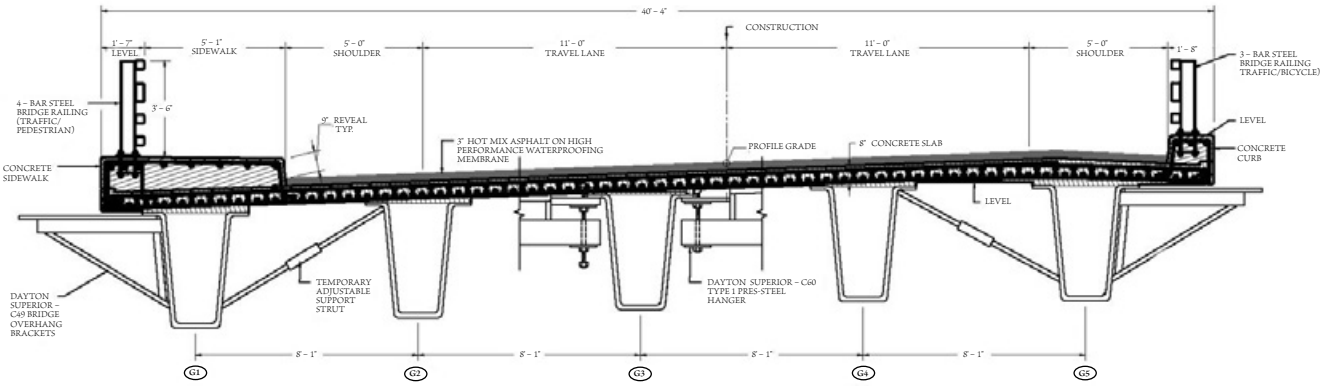


Figure 2: Stackable CT Girder™



Transverse Section

Figure 3: Cast-in-Place Deck

These systems offered as solutions by AIT Bridges provide the benefits above and also meet the following standards:

- AASHTO LRFD Bridge Code.
- Seismic Codes.
- Live Loads exceeding HL-93, 110,000 Puerto Rico Truck, easily achievable in design.
- Durability standards including fire, ultraviolet, and salt.

Both systems can be manufactured locally with equipment, materials, and local labor with training supplied by AIT Bridges.

Conclusions

The AIT Composite Bridges Technology is a cost-effective solution that meets the AASHTO LRFD Bridge as well as seismic codes exceeding HL-93 live loads of 110,000 lbs. required by the Puerto Rico Truck Size and Weight Regulations on Public Highways.

In summary, the AIT Bridge Systems are:

- Safe- The system benefits from a high structural reserve capacity and redundancy well above the regulatory standards and codes.
- Sustainable- Composites are manufactured with very low energy production. The bridge provides a 100+ year life span with minimal maintenance during its life. By eliminating 50-year replacement and significantly reducing maintenance costs, AIT's system reduces the overall bridge cost significantly.
- Environmentally friendly- The system provides for a natural stream bottom and low impacts on the surrounding environment during construction and its

life cycle. It provides an excellent habitat for wildlife and aquatic organisms.

- Cost-effective/Non-corrosive/Longer-lasting- The system has the lowest life cycle cost in the industry. The system is not susceptible to environmental deterioration as is traditional steel and concrete structures.
- Aesthetically pleasing- Arch structures are naturally fitting and well received in the built environment around the world in both urban and rural settings.

Composite technologies have been used in other sectors for many years, but we have only just begun to tap the potential of composite materials in bridge construction. AIT Bridges' Composite Arch Bridge System and CT Girder™ are the result of more than two decades of composites research by the University of Maine Advanced Structures and Composites Center (ASCC), led by its founder Dr. Habib Dagher. The ASCC is a world-leading, interdisciplinary center for research, education, and economic development encompassing material sciences, manufacturing, and the engineering of composites and structures. Cutting-edge research programs have been instrumental in the continued development of composites within the bridge building sector, as evidenced by research studies conducted by the University of Maine, University of Massachusetts, and the Vermont Agency of Transportation [1, 2, 3].

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Biographical Notes

Ken Sweeney, PE is a former chief engineer of the Maine Department of Transportation (Maine DOT) and president, AIT Bridges. For additional information regarding composite bridge technology, please visit aitbridges.com or email Ken Sweeney at Ken@aitbridges.com.

Victor Méndez, PE, is a former deputy secretary of the U.S. Department of Transportation and a former administrator of the Federal Highway Administration. He is a member of the Board of Advisors of Infrastructure Ventures LLC, Strategic Advisor to AIT Bridges

REQUIREMENTS FOR AN ECONOMICAL AND EFFECTIVE BRIDGE PROGRAM

Richard D. Rogovin, J.D

Every government agency that owns its roads and bridges and depends on public funds to maintain them is highly responsible to the public for both safety and economy. After the emergency services of fire, police and medical, the proper maintenance of roads and bridges is the most important service a government agency can perform.

The need for safe roads is obvious: potholes, washed-out pavement, or missing guard rails cause accidents resulting in property damage, personal injuries, and deaths. In the State of Ohio alone, motorists file claims of millions of dollars a year for damage to their cars from broken pavement. However, it is necessary to remember that broken roads can also delay emergency vehicles needed for fires or hospital runs or police protection.

Safe vs. Unsafe Bridges

There are two important differences between unsafe roads and unsafe bridges. Defects in roads usually do not become dangerous until the danger is visible, and repairs can be made by skilled or unskilled labor. Defects in bridges, on the other hand, usually become dangerous before they are visible, and repairs require technical knowledge and replacement parts. Bridge repairs for any given surface area are much more expensive than road repairs, and are therefore more likely to be neglected. For this reason the federal government requires that bridges be professionally inspected at regular intervals and assigned ratings so that their maintenance and replacement costs can be predicted and budgeted.

Funding Challenges for Bridge Programs in the US

The duty owed to the public of maintaining safe roads and bridges is impossible to perform without adequate funds, usually provided, directly or indirectly through taxes. However, no state or local entity in the United States has funds adequate to meet the need for bridge repair or replacement. Congress is reluctant to increase any tax; the federal gas tax has not been increased for 30 years. The Ohio gas tax was recently increased after a battle among the Governor, who wanted an 18.4 cent increase, the House which was willing to accept 10.5 cents and the Senate which voted only 6.5 cents. The parties compromised in a Conference Committee at 10.5 cents, which will leave half of needed repairs unfinished.

Part of the problem of inadequate funds is the government's own negligence in its bridge design program. Neither the state nor the federal governments have performed the public duty to economize when repairing and replacing bridges. The very human cause is that everyone has less interest in conserving funds coming from someone else than they have in conserving their own funds. Examples in public works are numerous.

A few years ago, a state Department of Transportation finished the replacement for the principal bridge leading into a major city. Like the bridge it replaced, it was a steel deck truss bridge with painted steel. Like the old bridge, it will suffer corrosive attack from ice-melting salt spread on its pavement and distributed throughout its steel structure below by heavy daily traffic. Like the old bridge, it will not be properly repainted every few years and will require replacement after only 30-40 years. Had the steel been hot—dip galvanized, the service life for the bridge would have been doubled, without interim maintenance. However, given the fact that the state was spending federal money, the $500 million in construction cost was considered to be acceptable and the state expects federal support for any repainting required.

Another disaster in bridge design was the monumental bridge built in China for the replacement of the Eastern span of the Oakland Bay Bridge in California to satisfy local demand for a "gateway" project, at a final cost in excess of $16 billion. The steel tubing is corroding from the inside because it leaks water in several places.

In Miami, Florida, the Florida International University also demanded a "gateway" bridge, a faux cable-stayed design of post-stressed concrete at twice the cost of a steel truss bridge. During erection, it collapsed on several cars, killing six drivers and passengers.

The government of a South American country is another offender of prudent management. It purchases large quantities of temporary bridges every few years, installs them to replace washed-out concrete bridges, fails to keep track of the cycles of traffic using these bridges or to frequently inspect them, and assumes that funds will exist to replace them with concrete bridges one day in the future.

Last year a private consulting firm was retained by a bridge company to perform a traffic study of a new, heavily used temporary bridge. It reported that after only six months in service, the bridge's design life of 1,000,000 cycles had been exhausted, and that it would be too dangerous to leave in place. (This country does not maintain weigh stations to prevent overloads). Nothing was done, and very likely each level of bureaucracy prepared a memorandum which was passed to the next level, ultimately reaching the director's office where it was filed away. When the bridge collapses, which is inevitable, this memorandum will be conveniently lost.

Requirements for Economical and Effective Bridge Program

What, then, is required for an economical and effective bridge program?

1. A commitment on the part of each government employee to consider public funds as if they were his own, and to resolve that any permanent bridge replacement for which he is responsible will not be a monument, but the most simple and practical design that is consistent with a long service life without expensive maintenance.
2. An understanding that if a permanent bridge can be produced in the time it would take to obtain a temporary one. It is better to inconvenience the public with detours than to waste scarce funds needed for future bridge work.
3. A realization that temporary bridges are only advertised as "permanent" outside the United States; that in the United States they are never purchased but only leased, and if this is required while the permanent bridge is being produced, leasing is the most economical way to proceed.
4. An understanding that concrete superstructures require more piers, heavier abutments and deliver a shorter service life than galvanized steel superstructures, and that to be assured of quality it is necessary to have daily compressive tests performed on the concrete by an on-site laboratory. (The porosity of concrete requires Teflon-coated or stainless steel reinforcing.)

Engineering is a noble profession and engineers deserve much more credit and recognition that than they receive. For this writer, there is no higher achievement for government engineers than the creation and operation of a truly economical and effective bridge program.

Biographical Note:

Richard D. Rogovin, J.D., is chairman of U.S. Bridge, 5001 Pine Creek Drive, Westerville, Oh. 43081. Email: dickrogo@gmail.com, Mobile: (614) 209-5010

CONCEPTUAL DESIGN TO PRODUCE DRINKING WATER FOR SMALL RURAL COMMUNITIES

Aluisio C. O. Pimenta, PE, Eileen M. Cruz-Pastrana, Johel Padilla

ABSTRACT

Presented herein is a conceptual design proposed to produce drinking water for small rural communities located in mountain regions, using gravity-fed slow sand filtration and chemical disinfection. One benefit of the proposed system is the small electricity footprint achieved using alternative energy sources. A case study is presented for a community aqueduct located in the Juan Asencio neighborhood in the municipality of Aguas Buenas, Puerto Rico. To provide information for the basic design, a Digital Elevation Map (DEM) was obtained in Raster format for Juan Asencio, and maps were developed containing topographic contours, local watersheds, and creeks. The maps were used to establish the feasibility of using surface water resources and the treatment system proposed. The treatment system consists of water extraction, gravity filtration, chemical disinfection, and a solar power-driven pump to convey water to the distribution tank; the system complies with current SDWA regulations for small systems.

RESUMEN

El diseño conceptual para la producción de agua potable en áreas rurales y montañosas, incorporando filtración y desinfección es presentado en este artículo. Beneficios del sistema propuesto incluyen la reducción en consumo de electricidad y el uso de fuentes alternas de energía. Se presenta un estudio de caso para un acueducto comunitario localizado en el barrio Juan Asencio, Aguas Buenas, Puerto Rico. Para lograr el diseño básico, se obtuvo un mapa digital de elevaciones para la región en formato Ráster, posibilitando el desarrollo de mapas con contornos topográficos, y la ubicación de cuencas y quebradas. Los mapas posibilitaron el estudio de viabilidad de recursos de agua superficial disponibles y del sistema de tratamiento propuesto. Este incluye extracción de agua, filtración por gravedad, desinfección química, y una bomba accionada por energía solar para elevar el agua al tanque de distribución; el sistema cumple con las regulaciones requeridas para sistemas de agua potable pequeños.

KEYWORDS: Community aqueducts design, pollution prevention, drinking water, slow filtration, Raster, GIS, energy conservation, solar power pumping.

INTRODUCTION

The aftermath of category 4 Hurricane Maria over Puerto Rico on September 20, 2017 revealed limitations in the energy supply chain for both electricity and fuels. Consequently, the supply of drinking water was affected, given the dependency on pumping to distribute water, often against steep gradients in the mountain regions, requiring high demand of electrical power.

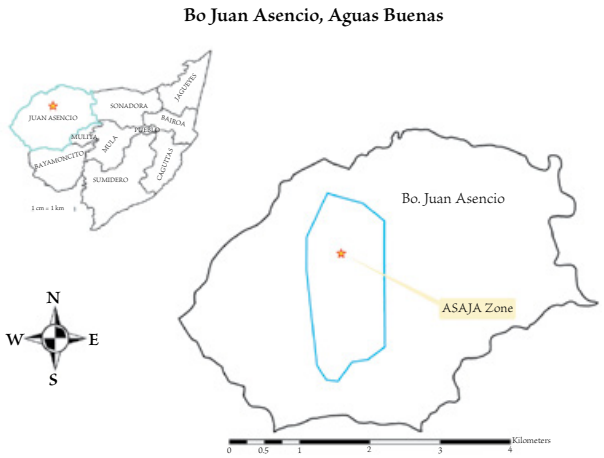


Figure 1. Juan Asencio in Aguas Buenas

However, Hurricane Maria produced public awareness in Puerto Rico regarding the need to conserve energy. It also deepened the realization of the serious need for alternative and more resilient sources of energy such as solar, wind, tidal, and gravitational. To contribute to energy savings, alternative systems for water extraction, treatment, and distribution are needed, that are less dependent on pumping and public electricity supply. In October of 2016, the United States Environmental Protection Agency (EPA) awarded funds to the University of Puerto Rico, to implement Pollution Prevention (P2) methods and protocols in a community aqueduct, in Juan Asencio, Aguas Buenas, a municipality located in the eastern extreme of the central mountain range of Puerto Rico (Figure 1). Project objectives included, among others, obtaining measurable reductions in the use of water and energy.

The Juan Asencio Community Aqueduct (ASAJA, for its Spanish acronym) system is composed of a deep water well, a well pump and appurtenances, its discharge pipeline, an elevated storage tank, and a distribution system that serves approximately 250 residences. The well and pump are located at geographical coordinates 18o 15' 39" N and 66o 9' 56" W, (green symbol in Figure 2).

The area where the well is located belongs to the municipality of Aguas Buenas, and it is in the process of transfer of ownership to ASAJA.

The initial project tasks consisted of replacing the well pump and the pump discharge piping. The original pump was operating with low efficiency (~30%), and the well piping had signs of deterioration, causing water loss at the pump discharge. The new pump operates with a much higher efficiency (~60%), representing a 50% savings in electricity

per gallon of water pumped. In addition, by replacing the deteriorated pipes, the well production was increased from 22 to 32 gpm, a 45% increase in water supply capacity. Both actions combined contributed to the achievement of project goals, since the electricity cost for the aqueduct was reduced 20% on average, corresponding to savings of $3,000 a year, approximately.

COMMUNITY WATER SUPPLY AND ENERGY CONSERVATION

During the project period (in September of 2017) Hurricane Maria passed over Puerto Rico, and Juan Asencio was almost in the trajectory of the hurricane's eye. Despite the overall devastation, the community was able to energize the well pump 5 days after the hurricane, when they obtained fuel to connect a diesel generator to power the water pump, fill the elevated water tank, and distribute water by gravity to the residents. This achievement demonstrates the relevance and resilience of community aqueducts in mountain rural areas, where public drinking water services are not available to all communities.

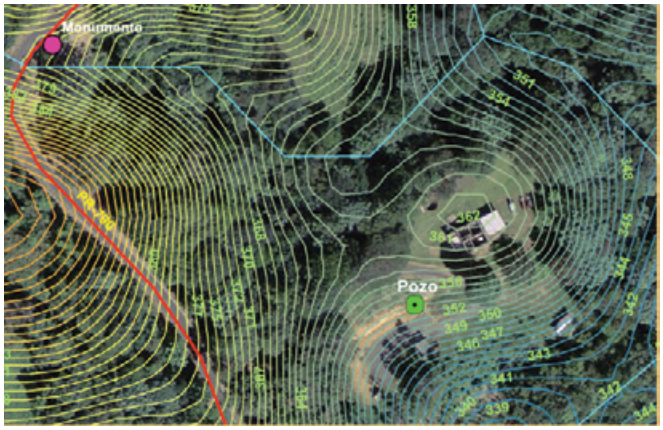


Figure 2. Well and Pump Location

Energy conservation, and its application to communal aqueducts calls attention to alternatives for water supply which these rural communities might consider, and the possibility of cost savings associated with reductions in energy requirements for water pumping. The total static head for the ASAJA well pump is close to 720 feet, 32% representing the elevation from the well water level to the surface. Therefore, energy savings may be obtained if surface water sources are used instead of wells, especially if the water treatment is gravity-fed. Additional savings are possible if intermediate storage tanks are used to avoid pumping all water to be distributed to the elevated storage tank, the highest point in the system, especially since many residences in Juan Asencio are located at relatively lower elevations, compared to the storage tank.

PROJECT LOCATION AND MAPPING

Remote Sensing Tools

The area comprising ASAJA was modeled using remote sensing tools to develop maps for the watersheds, including topography and location of surface water resources.

From the USGS web page, a Digital Elevation Map (DEM) in Raster format was obtained for Juan Asencio [1]. Using the DEM Raster, maps for specific zones of Juan Asencio were developed, containing topographic contours. Watersheds in the area were located using the hydrologic tools of ArcGIS version 10.4 (Figures 3 a and b). In addition, maps with three-dimension contour lines (Figure 3c) were used to provide a unique perspective of the study area. To achieve these final images, an orthophoto obtained from USGS [2] was superimposed on the DEM file in order to integrate DEM information with visible images of the areas.

The maps developed, based on information gathered in Raster format, were combined with GIS information, geographic coordinates, and the orthophotos to create other layers of images containing existing buildings and roads, using the OpenStreetMap program [3].

Surface Water Resources

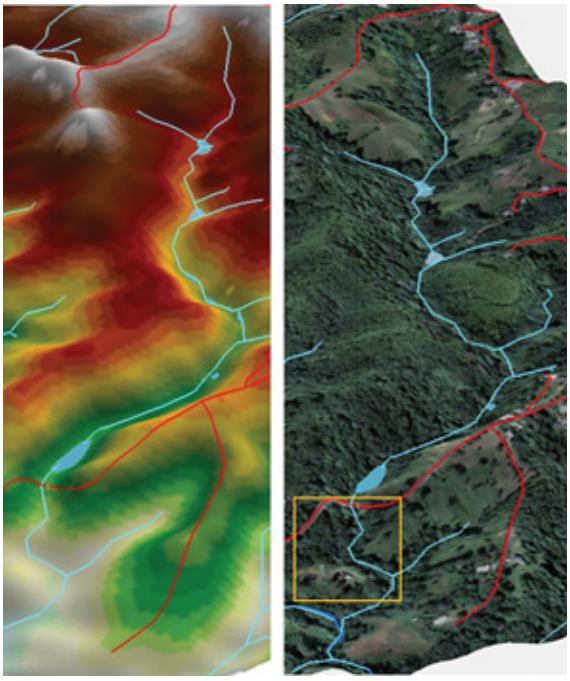
Using the information previously described, and the ArcMap program (version 10.4), the watersheds within the Juan Asencio area were characterized.

The 3D images presented in Figures 3 b and c show a typical surface water body and its watershed contained mostly within the Juan Asencio community. It also shows that the watershed is sparsely populated, which is adequate for the preservation of source water quality.

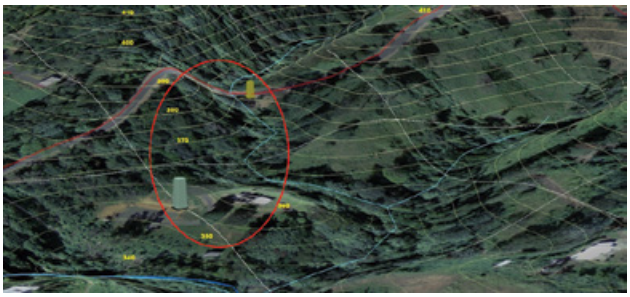
Therefore, the creek represented in Figures 3 a and b by the blue lines was selected for this study. The areas within the orange square and the red ellipse in Figures 3 b and c, respectively, represent the area selected to implement the water extraction and treatment system proposed in this work.

Topography

Information collected for the Juan Asencio area in Raster format was used to characterize the topography of the area, to establish the feasibility of water extraction and gravity-fed treatment. Topographic contours were also used to locate critical points of the aqueduct such as the water well, the water distribution tank, and households located at higher elevations in the aqueduct system. Examples of topographic contours are presented in Figure 2 and Figure 3c for the study area.



(a) (b)



(c)

Figure 3. Raster and Satellite Images, and Topographic Contours of Selected Watershed and Area for Implementation of Alternative Water Supply

WATER DEMAND AND SUPPLY

The population served by ASAJA averages close to 1,000 people. Based on a typical demand of 200 liters per capta per day [4], a daily supply of 200,000 liters (~53,000 gallons) is required to properly serve the ASAJA community.

The well serving ASAJA currently produces 32 gpm, which based on 16 hours of operation per day results in a daily production of 30,720 gallons, leaving a deficit of 22,190 gallons per day. Operation 16 hours per day is the maximum recommended for the preservation of well water level and for extended lifetime of the pump.

Alternative Supply Sources for Expansion

ASAJA has considered expanding its capacity, by incorporating a new well and pumping system to operate as a mirror of the existing system. The advantage of a well is the simplicity of the system, which does not require water treatment. However, water wells are uncertain with respect to water quantity, which depends on recharge and the influence of multiple wells located in the same aquifer, and with respect to quality (sanitary surveys and influence of surface water may require water treatment). In addition, the head required to elevate water to the surface imposes an additional energy burden on the system.

The Juan Asencio area is rich in surface water bodies. Upon close inspection of the maps developed for the area, a creek was identified (blue lines shown in Figure 3b), located within the Juan Asencio community. The creek was considered favorable for water extraction, because of its potential for gravity-fed treatment, and adequate capacity (see next section). Figure 3b also shows that the distances between households and the creek are safe for water quality preservation, if proper sanitary septic tanks are used to dispose of wastewaters. In addition, inspection of the watershed revealed that it is not negatively impacted by sediments from run-off, keeping raw water turbidity at low levels. The disadvantages of surface water sources are the need for filtration and disinfection of the raw water, and additional monitoring for both source and treated water, as explained in section 6 below.

Costs for Additional Water Supply Systems

A typical water well for ASAJA, would cost around $60,000, including well, pump and appurtenances, and initial tests for pumping capacity and water quality tests. Capital costs for electricity supply might cost from $50,000, to over $100,000 depending on distances from existing power lines and the well location. The cost for an alternative solar system with batteries would exceed $100,000. The capital cost for a surface water system using slow filtration would not exceed $100,000, including source water monitoring for coliform species, if solar driven pumping is used.

The great advantage of the surface water system is the lower operational costs, if gravity-fed treatment is used, combined with a DC pump (driven by solar power) to elevate the treated water to the storage tank. The pump could operate eight (8) hours a day (daylight period), without the need for batteries. The electricity savings for ASAJA might total between $10,000 and $15,000 a year.

Water Flows for the Surface Water Source

Watershed surface areas were calculated, using the ArcMap tool, to estimate total precipitation in the watershed. The watershed surface areas calculated combined with area precipitation for critical periods (5% lows for one-year average recurrence), provide safe estimates for a water balance in the watershed.

The surface area calculated by ArcMap for this watershed is 635,700 m2. The lower bound (p = 5%) for 30-day accumulation of precipitation in the area is 83 mm, which occurs usually during the dryer months of February and March [7]. The result is a minimum of 52,800 m3 per month or 465,600 gallons per day of precipitation on the watershed, for dry periods. If an extraction of 25,000 gallons per day is proposed for the alternative system, it would correspond to 5.4% of the total precipitation on the watershed, which is practical.

SURFACE WATER EXTRACTION AND TREATMENT

Groundwater extraction in the Juan Asencio region is a common practice. A big concern for groundwater systems in the region is the high energy expenditure for water pumping due to the high elevation profiles. On the contrary, the use of surface water is not a common practice in the Juan Asencio communities. However, due to its high potential and given the availability of surface water sources in the region, a basic design is presented for a system to extract, treat, and distribute water for the ASAJA customers.

Flow Sheet and Hydraulic Profile of the Treatment System

The surface water system for water extraction and treatment proposed for Juan Asencio is presented in Figure 4, consisting of the water extraction reservoir, the water filtration system, the water disinfection tank, and the pump used to convey water to the distribution tank. Figure 4 also presents a hydraulic profile for the system, indicating that enough head between the water extraction point and the outlet of the disinfection tank is available for gravity-fed treatment.

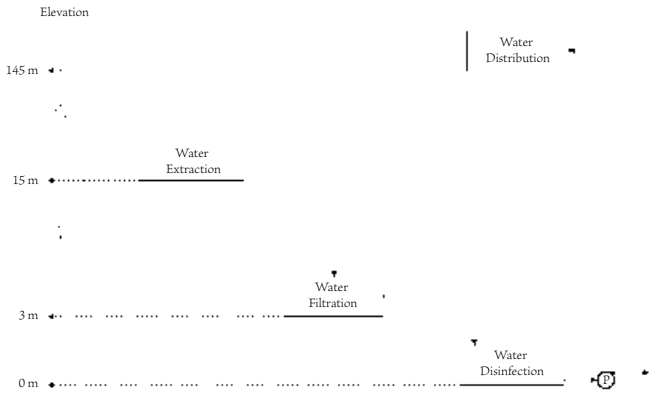


Figure 4. Flow Sheet and Hydraulic Profile of Treatment System

The figure also illustrates the high static head between the water disinfection tank, where water pumping is conducted, and the elevated water tank.

The design area, including topographic contours, water extraction location (pink circle), and the water well (green symbol), is presented in Figure 2. The filters and the disinfection tank should be located adjacent to the well, as indicated by the red box in Figure 9.

Water Extraction

The extraction of water for the proposed system would occur by gravity, at a point below an existing bridge located where the road (red line) crosses the creek (blue line), on top in the orange square shown in Figure 3b.

A water extraction tank must be built at a location below the bridge that crosses the creek. A structure, as shown in Figure 5 (top view and front view), is proposed. The drawings are not to scale. The features of the system are the V-notch overflow weir, which may be used for surface water flow measurements, and the water extraction pipe located at the bottom of the tank to prevent floating material in the extracted water.

To improve the availability of surface water to supply the system, a 2.5-feet high dam can be built at the small pond shown above the orange square in Figure 3 (b). This dam could accumulate at least 480,000 gallons of water, which corresponds to close to 20 days of water supply for the surface water system proposed.

Surface Water Treatment

As required by the Surface Water Treatment Rule (SWTR) of the Safe Drinking Water Act (SDWA), water from surface sources must be filtered and disinfected to be distributed as drinking water. The treatment configuration proposed in this study is a combination of slow sand filtration and chemical disinfection using chlorine, as shown in Figure 6. Ten filter units are proposed, to facilitate filter cleaning. Filtered water flows by gravity to the disinfection chamber. The system would be constructed adjacent to the existing well as shown in the red box of Figure 9.

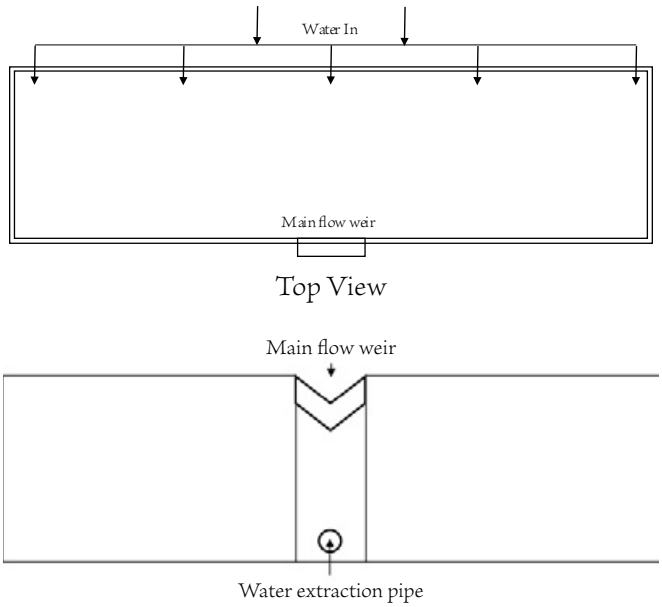


Figure 5: Flow Sheet and Hydraulic Profile

Slow Sand Filtration

Slow sand filtration is an adequate treatment technology for small rural systems. The major advantages are the simplicity of construction and operation, adequate for small communities. Slow sand filters operate by gravity and do not require backwash for cleaning of the filter medium. Since the removal of solids occurs mostly at the surface of the bed (shmutzdecke), periodic replacement (3 to 4 times per year) of the top layer of the sand bed (2 to 3 inches) is conducted to clean the filter, whenever the water head over the filter

exceeds a threshold determined during filter start-up. Slow sand filters guarantee excellent water quality, without the use of chemical coagulants. The disadvantage is the high surface area required for adequate filtration, which limits its use to small systems (usually 1,000 consumers or less) that have space available. Slow sand filters are also inadequate for source waters with turbidity that exceeds 50 NTU.

A typical slow sand filtration unit is presented in Figure 7, consisting of a sand bed, having a depth of 1 m approximately, supported on a bed of gravel, typically 0.5 m deep. The raw water is fed from the top of the filter, through a V-notch weir that can be used to control the flow of water to the filter unit.

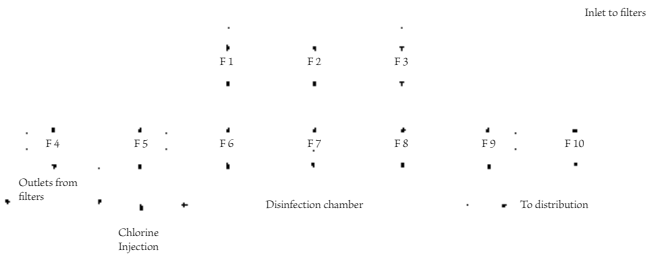


Figure 6. Flow Sheet for Filtration and Disinfection

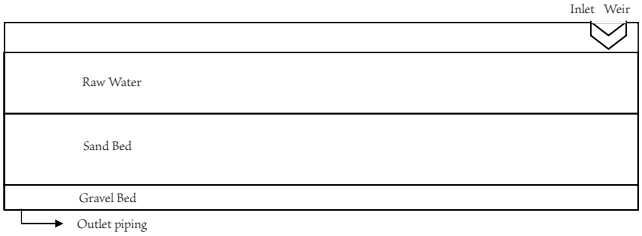


Figure 7: Typical Slow Sand Filtration Unit

The perforated pipes used for the collection of filtered water are installed at the bottom of the filter, within the bed of gravel.

Filtration rates for slow filters vary from 1 to 5 m3/m2/day, typically 2 m3/m2/day [7]. For the ASAJA proposed filtration system, where the water demand for expansion has been estimated at 25,000 gallons per day, the typical result would be 48 m2 of total filter area for operation 24 hours a day, or 144 m2 for operation 8 hours a day. Operation 8 hours per day is convenient to reduce monitoring for filtered water turbidity. The proposed filter units will provide 15 m2 of surface area each, approximately. Multiple filter units allow for easier cleaning of sand beds when required, without interruption of water production.

The filtration system does not have to be covered, according to current regulation, but may be covered for sanitary purposes.

Chemical Disinfection

A typical chemical disinfection chamber configuration is presented in Figure 8, where disinfection is always conducted at constant volume, since the treated water has to overflow the chamber exit baffle to reach the pumping pit. Chlorine is proposed as the chemical disinfectant since it is readily available, and is currently used by ASAJA in the existing system. The disadvantage of chlorine is the potential formation of Disinfection Byproducts, (DBP) which must be monitored in the distribution system.

However, DBP monitoring is already required for the ASAJA aqueduct since chlorine is currently applied prior to the water storage tank.

The required volume for the disinfection chamber was calculated using the Ct factor for chlorine combined with Giardia lamblia as the controlling pathogen. For the critical environmental conditions in Juan Asencio, water with pH equal to 8 and a temperature of 15o C, using chlorine at 1 mg/L residual concentration, the Ct factor obtained is 108 min·mg/L [8], for the selected chlorine residual, which results in 108 minutes of disinfection contact time. The 25,000 gallons per day to be treated in 8 hours yields a disinfection flow rate of 62.5 gallons per minute, which multiplied by 108 minutes of contact time results in 6,750 gallons or 25.5 m3 for the disinfection chamber volume.

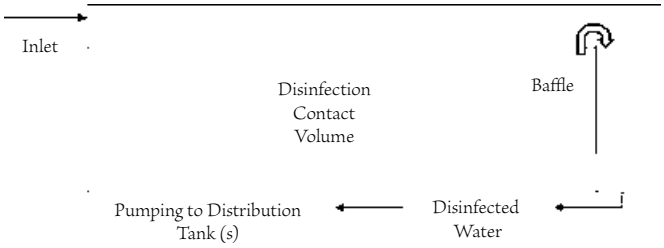


Figure 8: Typical Disinfection Chamber

Water distribution

Figure 9 shows the location of the existing ASAJA water well. The blue line represents the pipeline that conveys water to the storage tank. The new pump, driven by solar power and operating 8 hours per day, would initially connect to this existing line, to elevate water to the storage tank. From the storage tank, the water would be distributed by gravity, similarly to current practice.

MONITORING AND COMPLIANCE

The Juan Asencio community aqueduct serves approximately 250 residencies and 1,000 people, and is considered a small public water distribution system under SDWA regulations.

In comparison the groundwater sources, the use of surface water for drinking water supply requires additional monitoring: source water monitoring, combined filter effluent monitoring for turbidity (every four hours), and disinfection residual measurement at the exit from the disinfection chamber (once a day), all according to the SWTR [9]. For systems serving less than 10,000 people, source water monitoring may be conducted initially for E coli instead of Cryptosporidium parvum [10]. Furthermore, the turbidity standard for monthly measurements for slow filters is 1.0 NTU (for at least 95% of the samples), instead of the 0.3 NTU required for rapid filters.

CONCLUSIONS AND RECOMMENDATIONS

This proposed model for drinking water supply for rural areas located in mountain regions may be considered as a feasible model for Puerto Rico, given the potential for implementation in hundreds of similar communities that could be benefitted by the system, and the energy conservation that results in cost reductions.

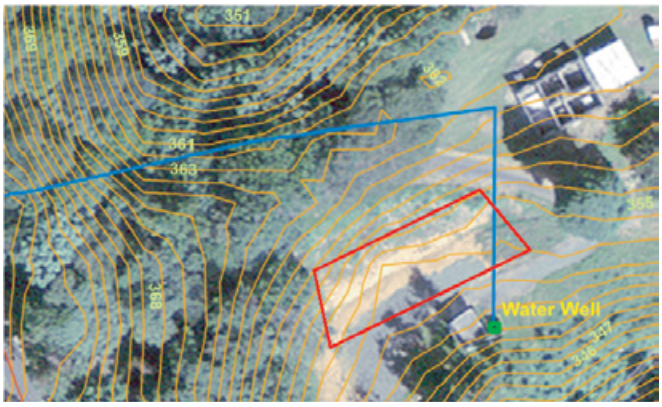


Figure 9. Existing Water Well and Design Area

The use of remote sensing and GIS tools for system design is extremely helpful, allowing the identification of potential water sources and the feasibility of systems operated by gravity.

Slow sand filtration is an efficient technology for producing drinking water for small rural communities, in compliance with current regulations, using surface water sources with low turbidity (≤ 50 NTU). The filters are easy to build, operate, and monitor, and require limited maintenance. Slow sand filtration may be complemented by constant volume disinfection using chlorine tablets, again providing an efficient and easy process to control and monitor for regulatory requirements.

Gravity-fed water treatment coupled with water conveyance by solar powered pumping is an effective way to conserve energy and to reduce operation costs for drinking water production in small communities.

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[7] Crittenden, et al. *MWH's Water Treatment: Principles and Design*, 3rd Edition; Table 11.1 pp 731.

[8] EPA Guidance Manual LT1ESWTR Disinfection Profiling and Benchmarking; Appendix B. CT Tables

[9] Comprehensive Surface Water Treatment Rules Quick Reference Guide: Systems Using Slow Sand, Diatomaceous Earth, or Alternative Filtration; August 2004; EPA 816-F-04-002.

[10] Long Term 2 Enhanced Surface Water Treatment Rule: A Quick Reference Guide For Schedule 4 Systems; June 2006; EPA 816-F-06-008

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We wish to thank the Colegio de Ingenieros y Agrimensores for the privilege of producing your technical peer review publication DIMENSIÓN for the past thirty (30) years without publication costs to the CIAPR. Thank you to all the presidents, editors, and CIAPR staff people who worked hard alongside us. Great thanks to all who worked hard to submit articles. We wish we could have published even more of them.

We could not have done it without the incredible support of our advertisers throughout this long period of time. We are particularly grateful to those that participated in the first mega edition after Hurricanes Irma and Maria.

Finally special thanks to two people who have been critical during these last two rather difficult years, President Pablo Vázquez Ruiz, PE, MBA and President of the Editorial Board, Benjamin Colucci Rios, PhD, PE, PTOE, FITE, API, JD.

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DICCIONARIO ZURDO

por Don Poco Sabe

¡Cuidado con las falsas analogías!

Hace un tiempo **don Poco** (en su alter ego) tuvo una conversación con un **dimensionario** que había publicado en las redes sociales una noticia negativa falsa —y, por cierto, muy dañina— sobre una compañía internacional, sin corroborarla. Don Poco afirmaba que la ética, tanto profesional como personal, obliga a corroborar este tipo de publicaciones antes de seguirlas diseminando. La respuesta de esta persona fue "Ya yo me retiré, así que no tengo que seguir los Cánones de Ética." ¿Acaso existe este pensar entre nuestros profesionales de forma general, o fue un caso aislado? Parecería que los **grandes cocorocos** de la **Orden Dimensionaria** deberían aumentar sus esfuerzos en educar a los miembros de la **Orden** sobre sus obligaciones éticas, tanto profesionales como personales, aun después de retirados.

En otra ocasión **don Poco** (también en su alter ego) abordó a otro **dimensionario** que comparaba atrocidades de los nazis con situaciones actuales que en ninguna forma se asemejan en propósito ni magnitud con aquellas acciones. La respuesta fue que la similitud era que en ambas situaciones "había crueldad"… Sorprendente respuesta, pues había tantas características diferentes —incluyendo lo que esa persona veía como "crueldad"— que la analogía era a todas luces falsa.

En esa tónica, **don Poco** quiere hoy contribuir en aclarar lo que es una **falsa analogía**, para evitar, especialmente entre nuestros **dimensionarios,** la caída (inadvertida o intencional) en errores que faltan a los más básicos principios de ética. Comencemos con algunas definiciones.

Falsa analogía: Para definir una falsa analogía es necesario saber qué es una **analogía**. He aquí lo que dice el **Mataburros** de la Real Academia **Cervantina** (la cita no es completa – se puede ver la definición completa aquí[1]):

analogía

Del lat. *analogĭa,* y este del gr. *ἀναλογία analogía.*

1. f. Relación de semejanza entre cosas distintas.

2. f. Razonamiento basado en la existencia de atributos semejantes en seres o cosas diferentes.

…

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falsa analogía

Una falsa se usa con propósito de engaño, comparando eventos o circunstancias que tienen cierto parecido con eventos o circunstancias a los que se quiere desacreditar (o acreditar), a sabiendas de que se implica que otras características dejadas fuera intencionalmente de los eventos, no tienen ningún parecido. Citamos un artículo sobre filosofía de Esteban Galisteo Gómez (el original puede leerse aquí[2]) que hace una muy clara definición de los que es una **falsa analogía:**

"**La falsa analogía es un tipo de falacia**. En este caso, la falacia está en apoyar una conclusión sobre la base de una analogía que parece evidente. Se comparan dos hechos, poniendo de relieve las semejanzas entre ellos. Sin embargo, se dan de lado diferencias importantes, ocultándose el hecho de que esa comparación es incorrecta desde un punto de vista lógico. Y, de igual manera, la conclusión obtenida a partir de una falsa analogía es también incorrecta desde este punto de vista.

De forma esquemática, una falsa analogía tiene esta forma: **puesto que A y B son similares, si A es P entonces B también lo es. El argumento es falaz porque del hecho de que A y B sean similares no se sigue que compartan todas sus propiedades o que sean similares en todos los aspectos.**"

Aquí citamos una vez más el **Mataburros:**

falacia

Del lat. *fallacia.*

1. f. Engaño, fraude o mentira con que se intenta dañar a alguien.

2. f. Hábito de emplear falsedades en daño ajeno.

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1 Por si estás leyendo el artículo en papel, el enlace es: https://dle.rae.es/?id=2Vt6TRt

2 Por si estás leyendo el articulo en papel: https://filosofia.laguia2000.com/logica/falsa-analogia

La mejor forma de describir algunas ideas es dando ejemplos de las mismas. Aquí un ejemplo que **don Poco** ha encontrado en la internet:

> *Editado y corregido para claridad* (ver el original aquí[3]).
>
> "A los estudiantes se les debería permitir consultar sus libros en los exámenes. ya que los cirujanos tienen rayos X para guiarlos durante una operación y los carpinteros tienen planos para guiarlos cuando construyen una casa.
> Veamos, el argumento implica que, puesto que A y B son similares, si A es P, entonces B también lo es. El argumento es falaz porque del hecho que A y B sean similares no quiere decir que compartan todas sus propiedades. En la premisa se comparan y destacan las semejanzas de dos hechos, pero, sin embargo, se dejan fuera algunas diferencias importantes, haciendo que la comparación sea incorrecta. Eso lleva a que la conclusión también sea incorrecta.
> El argumento es falaz, porque los cirujanos y los carpinteros no están haciendo exámenes para probar cuánto saben, pero los estudiantes sí. Las situaciones son completamente diferentes y no se puede establecer una relación entre ellas.

Aquí hay unos ejemplos más de un blog de José Carlos Vicente (la cita tiene algunas correcciones - se puede leer el artículo completo aquí[4]):

"**Falsa Analogía**
- A dice que B es igual a X
- X es igual a Y (según A). - Luego B es igual a Y.
"Si él puede hacer eso yo también puedo hacer esto otro"
El secreto de esta falacia es comparar datos, hechos o situaciones que no son comparables.
Es decir, se realiza una afirmación mediante una comparación de hechos que, si bien pueden parecer similares, en realidad distan mucho de serlo.
Estas falacias se utilizan habitualmente y se aceptan sin más, pese a que son fácilmente rebatibles de tres modos:

- Porque son absurdas.
  - "¿Cómo va a ser mal tipo alguien que juega tan bien al fútbol?".
- Por existir factores que impiden la comparación.
  - "Un mecánico que no está trabajando en ese momento no tiene por qué ponerse a arreglar un coche sólo porque pasa por ahí. Pues un médico igual".
- Porque se puede realizar la misma comparación en sentido contrario
  - "Como es del país vecino de nuestros clientes es el adecuado para dirigir el proyecto".
  - "Como es del país vecino de nuestros clientes quizá no es el adecuado dirigir el proyecto" (las tensiones de vecindad suceden en todas partes)."

Así pues, mis compañeros **dimensionarios**, en esta época de continua expresión política en los medios y en las redes sociales, no nos dejemos llevar por emociones o ideologías. Nuestra responsabilidad ética no desaparece cuando hablamos sobre política, religión o cualquier otro asunto controversial. Tampoco desaparece cuando nos retiramos o dejamos de practicar la profesión. Los principios éticos son los mismos, nuestras circunstancias solamente cambian el modo de aplicación de los mismos, no nos liberan de esos principios como personas, como seres humanos obligados moralmente a promover el bien común.

3 Ibid.: https://prezi.com/minp1mshb9ks/falacia-de-falsa-analogia/

4 Por si estás leyendo el artículo en papel: http://sharingideas-josecavd.blogspot.com/2017/02/falacias-falsa-analogia-peticion-de-principio-ad-baculum.html

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