Papillion Creek and Tributaries Lakes, Nebraska

General Reevaluation Report

US Army Corps of Engineers®

Appendix G
Nonstructural Analysis and Floodplain Management

June 2021

Omaha District
Northwestern Division

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

AEP – Annual Exceedance Probability
BCR – Benefit-to-cost ratio
BFE - Base flood elevation
CFR – Code of Federal Regulations
CMU – Concrete Masonry Unit
EAD – Expected annual damage
DFE – Design flood elevation
EAP – Emergency Action Plan
FEMA – Federal Emergency Management Agency
FIRM – Flood Insurance Rate Map
FIS – Flood Insurance Study
FPMP – Floodplain Management Plan
HEC-FDA – Hydrologic Engineering Center – Flood Damage Analysis
HMGP – Hazard Mitigation Grant Program
HMP – Hazard Mitigation Plan
LiDAR – Light Detection and Ranging
NFIP – National Flood Insurance Program
NRD – Natural Resource District
OMRR&R – Operation, Maintenance, Repair, Rehabilitation, and Replacement
PED – Preconstruction Engineering & Design
PPA – Project Partnership Agreement
SFHA – Special Flood Hazard Area
USACE – U.S. Army Corps of Engineers
WRDA – Water Resources Development Act

1.0 Introduction

This nonstructural flood risk management assessment has been conducted by the U.S. Army Corps of Engineers (USACE), Omaha District. The intent of the assessment is to analyze and develop nonstructural measures for at risk properties within the Papillion Creek Watershed. This assessment focuses on at-risk buildings and contains the technical methodology used for investigating the feasibility of incorporating nonstructural flood risk management measures within the project area. The area of focus for nonstructural mitigation is Douglas and Sarpy counties in eastern Nebraska as shown in Figure 1.

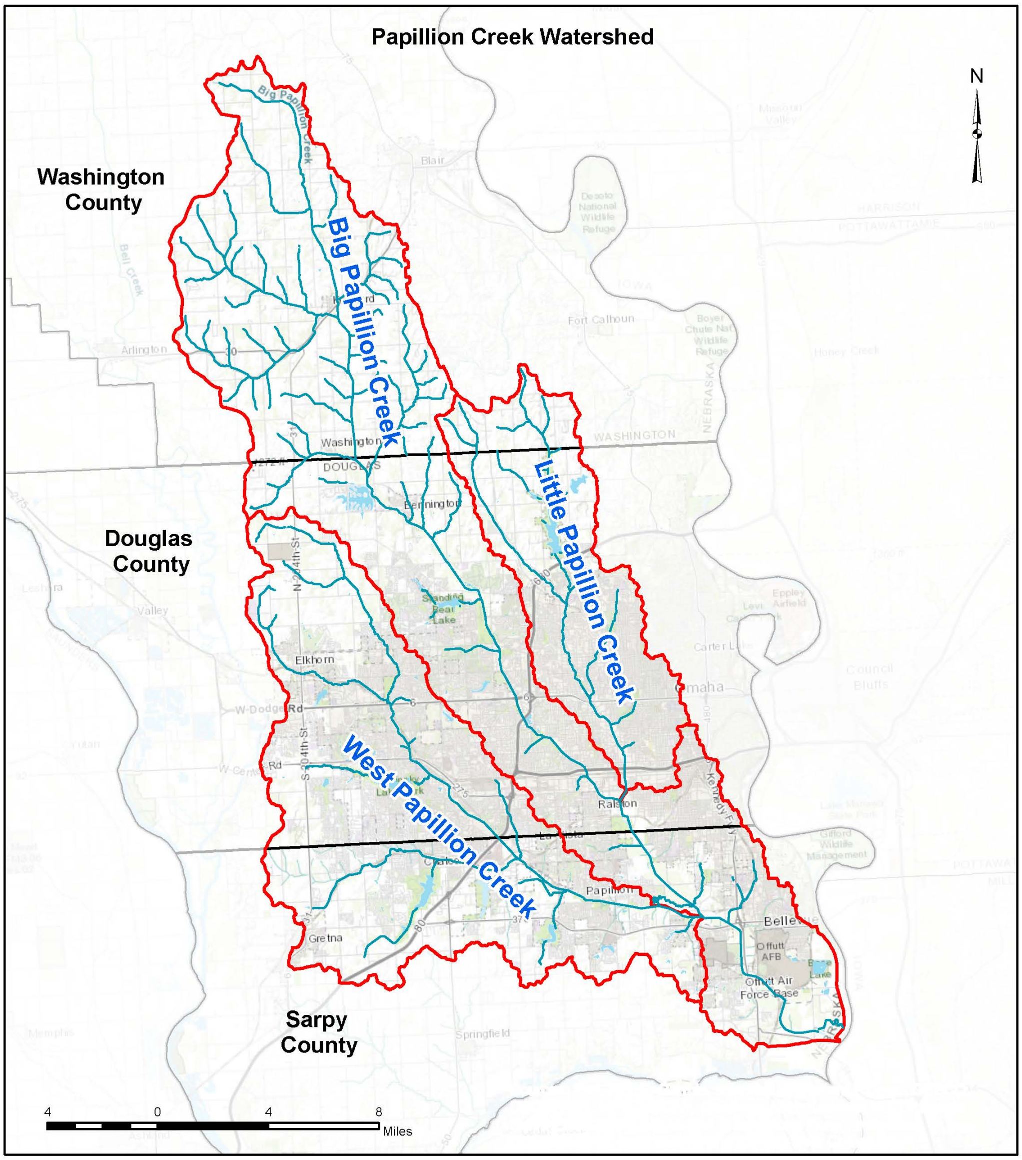

Figure 1. Nonstructural Assessment Study Areas

The Papillion Creek Watershed covers approximately 402 square miles in parts of Douglas, Sarpy and Washington Counties – including the Omaha Metropolitan Area. There are three primary tributaries that form the Papillion Creek system – Little Papillion Creek, Big Papillion Creek and West Branch Papillion Creek. Once joined, they form the Papillion Creek that empties into the Missouri River near

Bellevue. The watershed is highly urbanized in Douglas and Sarpy counties. There are 4,296 structures in or near the 0.2% annual exceedance probability (AEP) floodplain based on the updated USACE modeling for this study. Of these, approximately 1,300 structures incur damages from the 1% AEP flood event and were assessed for nonstructural measures.

Nonstructural measures are dependent upon specific building characteristics for each structure. Therefore, the objective of this nonstructural assessment is to determine a strategy for incorporating a range of nonstructural measures which are economically feasible, socially acceptable, and environmentally acceptable that will reduce the cumulative risk of damages from flooding. Typical nonstructural measures include elevation, filling the basement, relocation, acquisition, and wet or dry floodproofing of the structure. Each structure assessed may require a different nonstructural technique. While this nonstructural assessment relies heavily upon an inventory of data collected in the field, during design and implementation each building would need to be inspected by a team consisting of a floodplain engineer, structural engineer, cost engineer, civil engineer or architect, and real estate specialist in order to verify the mitigation details relative to the type of nonstructural technique recommended. Nonstructural implementation mitigation agreements must be entered into with each individual structure owner. The Papillion Creek Watershed nonstructural assessment assumes that participation would be voluntary.

With implementation of any flood risk/flood damage reduction project, the ability of the project to achieve the objectives must be considered for both the short and long term. Nonstructural measures may be advantageous over structural measures with respect to operation, maintenance, repair, rehabilitation, and replacement (OMRR&R) costs, not just for the perceived economic life of the project (50 years), but for the ability of the project to provide the desired level of flood risk management for as long as the damage source exists. Nonstructural measures can be implemented in very small increments with each increment producing flood risk reduction benefits. Nonstructural measures typically have no, or minimal, environmental impacts.

2.0 Flood Risk and Floodplain Management

Floodplain regulation and floodplain management are effective tools in reducing flood risk and flood damage. The basic principles of these tools are codified nationally in the National Flood Insurance Program (NFIP) which establishes minimum standards of floodplain management and floodplain regulation for those communities that participate in the NFIP. Standards that exceed the minimum required by the NFIP may be enacted by the states and communities to provide greater flood risk management.

Flood risk can generally be considered a function that considers both statistical probabilities of flood occurring and the consequences of those events. It is sometimes represented as mathematical formula as:

$$\textbf{Risk} = \boldsymbol{f}\,\textbf{(Probability, Consequence)}$$

Probability of Flooding is the frequency of flooding or how often flooding occur in a particular location.

Consequences are the potential life loss or damages associated with flooding. Structures (residential, commercial, critical, public, and industrial), land use (agricultural, urban, public), and infrastructure (highways, roads, rail, utilities) are the potentially damageable assets. Residents, travelers, and workers are the populations that may be at risk for life loss due to flooding. Reduce the consequences of flooding and risk is reduced.

Flood Risk Management is taking actions (physical, operational, or administrative) that could reduce the probability, the consequences, or both.

2.1 Floodplain and Flood Risk Characteristics

Flooding in the Papillion Creek Watershed normally occurs from heavy rainfall which can be widespread or localized in various parts of the basin. Flooding can be flashy in nature with the Big Papillion Creek and West Papillion Creek tributaries exhibiting somewhat longer warning times than South Papillion Creek, Little Papillion Creek, and other smaller tributaries (FEMA, 2010). The development in the floodplain throughout the Papillion Creek Watershed is highly urbanized and consists of residential, commercial, industrial, and governmental buildings or facilities. Basements exist in some of the building types, most predominantly residential.

2.2 Executive Order 11988; Floodplain Management

Executive Order 11988 (EO 11988) was issued by President Carter on 24 May 1977. In issuing the Executive Order the President stated "in order to avoid to the extent possible the long and short term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative, it is hereby ordered that each agency shall provide leadership and shall take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health and welfare, and to restore and preserve the natural and beneficial values served by floodplains in carrying out its responsibilities…".

USACE guidance for implementation of EO 11988 is contained in ER 1165-2-26. Compliance with EO 11988 is documented in the Environmental Appendix H. The EO 11988 objective is to avoid long and short-term adverse impacts in the base floodplain.

2.3 Floodplain Mapping

Floodplain mapping provides the identification of flood risk, whether in the form of a map which portrays flood boundaries, or as an inundation map illustrating the depth of flooding. This measure is a significant tool when addressing flood risk. The initial countywide Flood Insurance Study (FIS) report for Sarpy County, Nebraska and Incorporated Areas, number 31153CV001B was initially effective January 19, 1995. The countywide FIS incorporated the communities of Bellevue (1977), La Vista (1977), Sarpy County Unincorporated areas (1979), and Springfield (1976) into one comprehensive FIS. The current effective FIS Report is dated May 3, 2010. The initial countywide FIS report for Douglas County, Nebraska and Incorporated Areas, number 31055CV001D was initially effective December 2, 2005. The countywide FIS incorporated the communities of Bennington (1978), Douglas County Unincorporated areas (1978), Elkhorn (1977), Omaha (1988), Ralston (1978), Valley (1978), and Waterloo (1978) into one comprehensive FIS. The current effective FIS report is dated May 19, 2014. Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM) Panels exist for the entirety of the Papillion Creek Watershed (Table 1). Both floodplain and floodway delineations are shown in Figure 2.

Table 1. FEMA FIRM Panels in the Papillion Creek Watershed

Douglas County	Douglas County	Sarpy County	Washington County
31055C0329J	31055C0327H	31153C0210G	31177C0260D
31055C0328J	31055C0186J	31153C0036H	31177C0280D
31055C0212H	31055C0238H	31153C0041H	31177C0285D
31055C0353H	31055C0217H	31153C0044H	31177C0145D
31055C0334H	31055C0208H	31153C0043H	31177C0165D
31055C0075H	31055C0180H	31153C0062H	31177C0168D
31055C0204H	31055C0302J	31153C0042H	31177C0270D
31055C0333H	31055C0184H	31153C0037H	31177C0320D
31055C0354H	31055C0183J	31153C0069H	31177C0290D
31055C0309J	31055C0179J	31153C0039H	31177C0295D
31055C0308J	31055C0216H	31153C0070H	31177C0315D
31055C0177J	31055C0325H	31153C0068H	
31055C0351H	31055C0301H	31153C0093G	
31055C0332H	31055C0093H	31153C0038H	
31055C0219H	31055C0089H	31153C0061H	
31055C0188J	31055C0206H	31153C0090H	
31055C0331H	31055C0211H	31153C0064H	
31055C0326J	31055C0192H	31153C0063H	
31055C0307J	31055C0191J		
31055C0306J	31055C0187J		
31055C0202H	31055C0218H		
31055C0201H	31055C0214H		
31055C0088H	31055C0213K		
31055C0182H	31055C0194J		
31055C0181H	31055C0193J		
31055C0203H	31055C0189J		

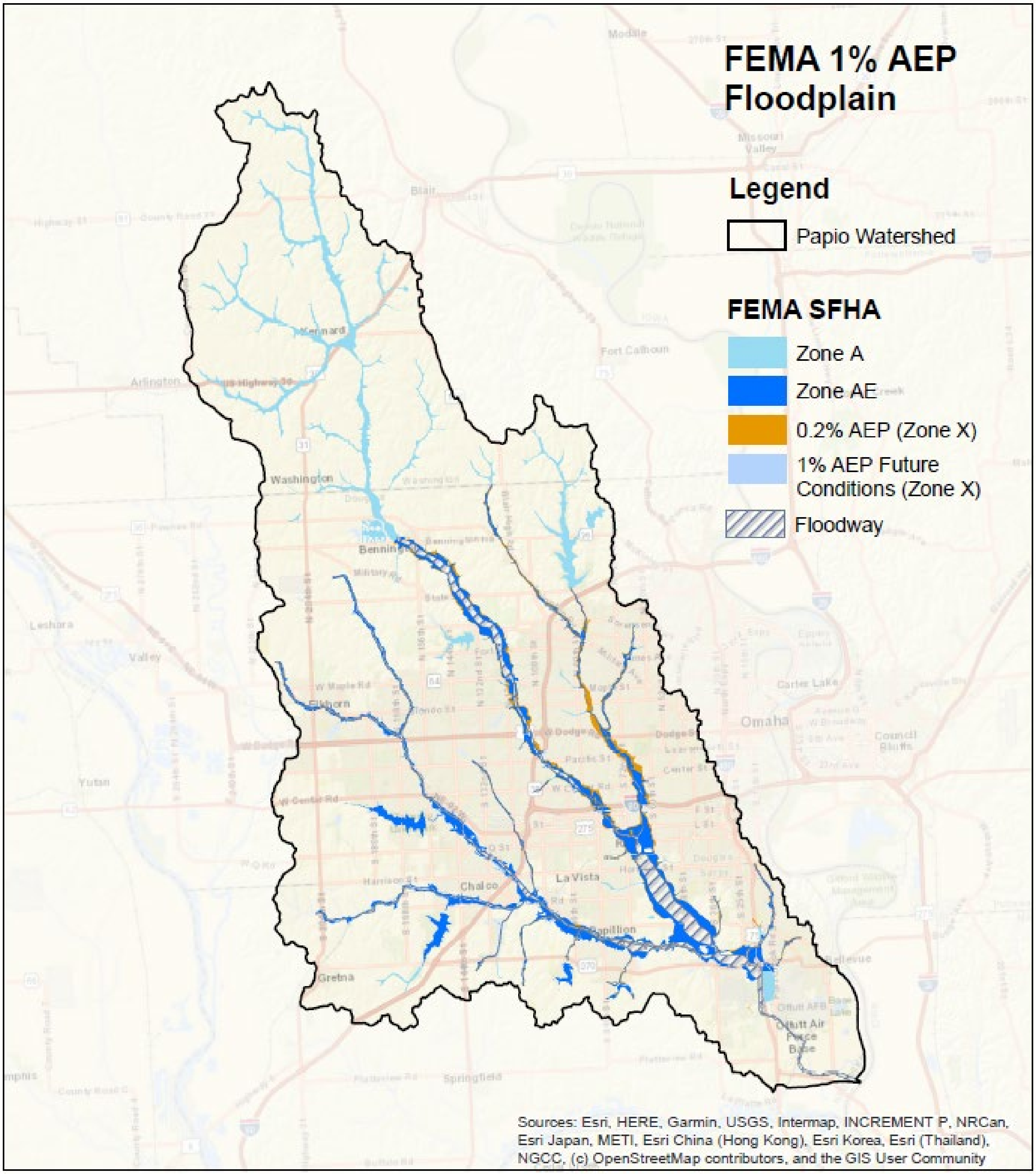

Figure 2. FEMA Floodplain Map of Douglas, Sarpy, and Washington County

2.4 Floodplain Regulation and Floodplain Management

The State of Nebraska has adopted floodplain regulations that are more restrictive than the NFIP minimum standards through Nebraska Administrative Code Title 455, Chapter 1. Nebraska's minimum standards for floodplain management require that all new construction and substantial improvements of residential structures shall have the lowest floor (including basements) elevated to or above one foot above the base flood elevation (BFE). The national standard is that new or substantially improved structures shall have the lowest floor elevated to or above the BFE. Additionally, Nebraska does not allow new structures for human habitation to be built in the floodway. The more stringent requirements for the State of Nebraska will help reduce flood risk by requiring a one additional foot above the BFE to allow for known flood hazards. This requirement for Nebraska also results in lower premiums for those participating in the NFIP. (P-MRNRD 2016)

The Papio-Missouri River Natural Resources District (P-MRNRD) and the City of Omaha have adopted the 2016 Multi-Jurisdictional Hazard Mitigation Plan (HMP). An HMP is a community-guided document that identifies both vulnerability to natural and man-made hazards, and mitigation measures to reduce or eliminate this vulnerability. Local communities should carefully consider potential flood risk mitigation strategies for inclusion in their local HMP. Following a presidentially declared disaster, federal funds may be available to pursue projects and advanced planning will help communities to effectively utilize funds.

Floodplain management authorities are exercised through floodplain ordinances (or alternatively zoning ordinances; see Section 2.5) adopted by local jurisdictions. All jurisdictions located within the Papillion Creek Watershed require all new construction or substantial improvement to be one foot above the BFE. No new or substantially approved buildings for human occupancy are allowed within the floodway (44 CFR 60.3). Communities with adopted floodplain ordinances (separate from zoning ordinances) include the following:

- The City of Omaha Floodplain Ordinance Number 39946, which is part of the Omaha Municipal Code.
- Washington County Floodplain Management Resolution No. 2013

2.5 Zoning

Zoning is an important land use tool that local jurisdictions exercise. Indeed, the state's statutes grant municipalities and counties the power to consider flood hazards in the formulation of zoning regulations. A community may determine that certain areas are hazardous for human habitation and restrict or limit development by amending zoning ordinances. Establishing good zoning regulations for flood risk can help reduce the long-term risk that a community faces from flooding. Communities located within the Papillion Creek Watershed with adopted zoning ordinances include the following:

- City of Bellevue Zoning Ordinance (Ordinance 3619) - Effective August 8, 2011.
- City of Bennington Zoning Ordinance (Ordinance 460) - Effective June 9, 2019.
- Douglas County Zoning Regulations by Article https://www.dceservices.org/mobile-landuse/zoning-regulations accessed August 15, 2019.
- City of Gretna Zoning Ordinance (Ordinance 2000) - Effective July 5, 2017, Modified July 3, 2018.

- City of LaVista Zoning Ordinance (Ordinance 848) - Effective November 20, 2001.

- The City of Omaha exercises zoning authorities through the Omaha Master Plan.

- City of Papillion Zoning Ordinance (Ordinance 1200) - Effective September 19, 1995.

- City of Ralston Zoning Ordinance by Article http://www.cityofralston.com/zoning.html accessed August 15, 2019.

- Sarpy County Building Codes - Effective January 1, 2017.

- Washington County Zoning Resolution (Resolution 2005-19) - Effective June 14, 2005.

2.6 Restoring Natural and Beneficial Floodplain Functions

Within the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (P&G), which guide Federal involvement in water resources issues, three primary objectives are identified. The objectives are: 1) maximizing sustainable economic development, 2) avoiding the unwise use of floodplains and minimizing adverse impacts, and 3) protecting and restoring the functions of natural systems.

The natural and beneficial functions of floodplains are numerous and the ability of a natural floodplain to reduce flood damages is now being emphasized to a greater degree than it has in the past. The P&G requires that full consideration and reporting on nonstructural alternative actions or plans are an integral part in the evaluation process of Federal investments in water resources. As a nonstructural measure to reduce flood risk, undeveloped floodplains (whether natural or manmade non-development) not only reduce flood risk because damageable property is not located in a floodplain, but also reduce downstream flood stages by providing natural floodplain storage for flood water.

2.7 Critical Facilities

Any facility which could become inoperable during a flood event and result in increased complexity during the emergency response or recovery is considered critical. Critical facilities are essential during a flood to provide human safety, health, and welfare. Critical facilities are generally those services required during the flood such as police and fire protection, emergency operations, evacuation sites, and medical services. Facilities which house the elderly, disabled, or requiring medical assistance, require extensive evacuation time would also be considered critical. Any facilities that could, if flooded, add to the severity of the disaster such as petroleum terminals, wastewater treatment plants, toxic material storage sites, are considered critical. In order to comply with the guidelines of the EO 11988, critical facilities should be located at a minimum above the 0.2% AEP flood elevation.

2.8 Flood Warning Systems and Flood Emergency Action Plans

All nonstructural measures, with the exception of acquisition and relocation to a completely flood free site, should be combined with the development and implementation of flood warning and preparedness planning. This relies upon stream gages, rain gages, and hydrologic computer modeling to determine the impacts of flooding for areas of potential flood risk. A flood warning system, when properly installed and calibrated, is able to identify the amount of time available for residents to implement emergency measures to protect valuables or to evacuate the area during serious flood events. Local officials are encouraged to develop and maintain a flood emergency action plan (EAP) that identifies hazards, risks and vulnerabilities, and encourages the development of local flood risk mitigation. The EAP should include the community's response to flooding, location of evacuation centers, evacuation routes, and flood recovery processes.

A Flood Warning System for the Papillion Creek Watershed was installed in 1994 by the USACE to better monitor rainfall and high water in the Big, Little and West Papillion Creeks. Up to the minute readings along streams are monitored by the National Weather Service and aid in flood detection and early warning. The system has been recently upgraded and is maintained by the US Geological Survey.

2.9 Floodplain Management Plans

Section 202 of the Water Resources Development Act of 1996 (WRDA 1996), requires the development of a Floodplain Management Plan (FPMP) for federally constructed flood risk management projects. This plan is to be developed and in-place within one year after signing the Project Partnership Agreement (PPA). The FPMP is a document developed by the non-Federal sponsor, with input and guidance from the Federal agency. The FPMP assures that the integrity of the Federal project will not be diminished during the life of the project and that impacts of future flood events in the project area have been reduced. The FPMP will address potential measures, practices, and policies to reduce loss of life, injuries, damages to property and facilities, public expenditures, and other adverse impacts associated with flooding and to preserve and enhance natural floodplain values. The FPMP is required for either a structural or nonstructural project. A FPMP for a feasible, selected alternative would be developed once a flood reduction project is approved.

3.0 Nonstructural Flood Risk Management Measures

Nonstructural measures reduce flood risk by modifying the characteristics of the buildings that are subject to flooding and/or modifying the behavior of people living in or near floodplains. Nonstructural measures differ from structural measures because they do not modify the characteristics of floods (stage, velocity, duration) or induce development in a flood risk area. Nonstructural measures can be incorporated into existing or new properties to mitigate for potential future flood damages. Each measure must meet specific criteria that would make it acceptable to the flood characteristics and site conditions. Nonstructural measures can be formulated into nonstructural alternatives include removing buildings from floodplains by relocation or acquisition, floodproofing buildings, or elevating buildings.

3.1 Elevation on Extended Foundation

This nonstructural technique elevates the existing building from its original foundation to the design flood elevation. This measure is recommended for residential buildings, with or without basements. In the Papillion Creek Watershed, it is required that the lowest floor be elevated at least one foot above the BFE to be in compliance with local and state codes. Therefore, the design flood event (DFE) for this study is the 1% AEP based on the USACE updated modeling plus one foot. When the design flood event is exceeded on an elevated building, flood damages gradually increase; but will be less than the damages in existing conditions. The maximum raise considered for any residential building is 13 feet above ground level. Flood depths in excess of 6 feet only occur at those structures located in the FEMA regulatory floodway. Since flood depths did not exceed 6 feet elsewhere, all residential buildings with significant flood damages for flood events less than the 0.2% AEP flood event were evaluated. Figure 3 illustrates an example of a residential building without a basement before and after incorporation of this nonstructural technique.

Elevation can be performed using fill material, extended foundation walls, piers, posts, piles or columns. Elevation is also a very successful technique for reinforced slab-on-grade structures. If the elevated foundation below the first floor is an enclosed masonry perimeter, then appropriately sized flood vents must be included. The flood vents allow flooding of the space below the first floor to balance static water pressures. The total vent opening size must be at least one square inch of total vent opening per one square foot of enclosed space and the vents cannot be blocked, per floodplain management regulations. Appropriate access to the elevated first floor, including handicapped access if needed, should be provided and all utilities including floor furnaces and electrical panels will be elevated at least 1.0 foot above the BFE to meet local floodplain requirements. In many elevation scenarios, the cost of elevating a structure an extra foot or two is less expensive than the first foot, due to the cost incurred for mobilizing equipment.

In communities that participate in the NFIP, any replacement or substantial improvements (improvements greater than 50% of the building value) to properties located in the Special Flood Hazard Area (SFHA) must be in compliance with local community floodplain management regulations that meet the minimum standards of the NFIP. The local floodplain regulations state that new or substantially improved residences must have the lowest floor, and all associated machinery and equipment, elevated at least to the DFE. For many residential buildings, elevation for flood risk management may have notable costs and may qualify as substantial improvement.

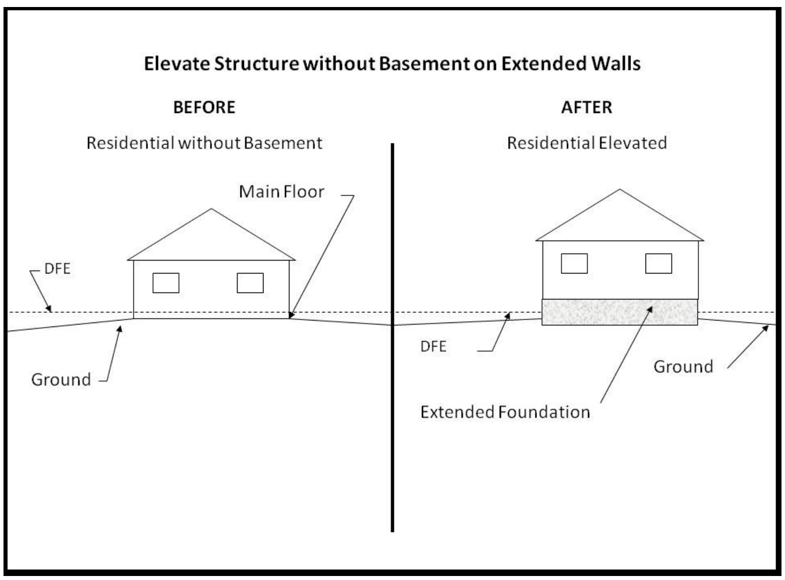

Figure 3. Elevation of Structure on Extended Foundation

The cost to elevate residential buildings was calculated by utilizing equations based upon building square footage, floodproofing height, and foundation type. The equation for computing residential elevation costs was developed by the Omaha District Cost Engineering Office from a cost estimate procedure developed for FEMA's Hazard Mitigation Grant Program (HMGP) (Elevation Cost Guide, 2013).

The Omaha District Cost Engineering formula for determining costs based on the HMGP cost estimate procedure of a residential building for flood risk management is:

Elevation Cost = (**HCF** + **AUC** + **SRC**) x **ACF** x **SF**

Where: **HCF =** FEMA HMGP cost per square foot, based on foundation type and height of raise, see Table 2
AUC = Additional utility cost per square foot = 1.50
SRC = Site restoration cost per square foot = 3.50
ACF = Area cost factor = 0.99
SF = Footprint of residence to be raised, square feet

Table 2. HMGP Residential Elevation Cost Factors

Costs per Square Foot Based on Foundation Type			
Raise (ft)	**Open Foundation**	**Slab Separation**	**Slab Raise**
1.50-2.49	$50.53	$60.53	$70.53
2.50-3.49	$51.58	$61.58	$71.58
3.50-4.49	$52.63	$62.63	$72.63
4.50-5.49	$55.63	$65.63	$75.63
5.50-6.49	$58.63	$68.63	$78.63
6.50-7.49	$61.63	$71.63	$81.63
7.50-8.49	$64.63	$74.63	$84.63

Open foundation elevation costs are applicable to buildings on basement walls or on foundation walls with a crawl space. Slab separation is a technique for raising a slab-on-grade residence by separating the building superstructure from the foundation slab. A slab raise involves raising the foundation slab and the superstructure as one unit. If a building foundation requires significant repair prior to building elevation, there would be additional costs.

Residential buildings with basements would require the basements to be filled and an addition for any relocated utilities added to the raised first floor. These items are described in the following section and the costs are calculated outside the elevation cost formula.

3.2 Removal of Basement and Main Floor Utility Addition

This nonstructural technique consists of filling in the existing basement with sand or gravel and the top of the fill is covered with a vapor barrier. This measure could occur without elevating the structure if the first floor is located above the BFE. Filling in the basement is required when elevating residential buildings which have basements or dry floodproofing commercial buildings that have basements. The filled basement resists damage to the building foundation from hydrostatic forces and raises the threshold of flood damages to the main floor elevation, whether existing or elevated. To compensate for a portion of the lost basement area and provide a location for relocation of the utilities (i.e. electrical panel, furnace, water heater, water softener, washer and dryer) which may be located in the basement, an above ground addition may be constructed onto the building at the DFE. Relocation of the furnace and water heater provides the property owner an opportunity, at their expense, to replace those items with new units that are more efficient. In that situation, the estimated cost of relocating the existing furnace and water heater would be applied to the cost of installing the replacement units. For purposes of this analysis, an addition size of 50 square feet was used. Figure 4 illustrates a simplified example of removing a basement by adding fill material and constructing an addition to the residence to house utilities. Cost estimates for the fill, flood vents, and addition are summarized in Table 3.

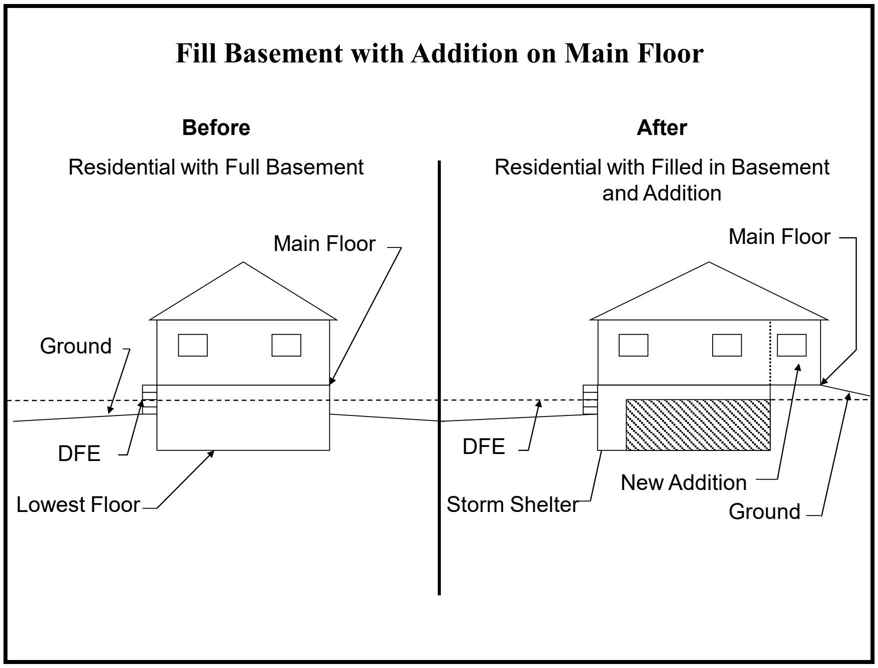

Figure 4. Filled Basement with Main Floor Addition

Table 3. Cost Parameter for Filling Residential Basement

Item	Cost/Units	Quantity Calculation
Sand Fill	$1.40/cubic foot	Basement Area x 6 feet
Flood Vents	$200 per vent	Basement Area / 200
Addition	$150/sqft	50 Square Feet

3.3 Dry Floodproofing Commercial Buildings

Dry floodproofing of commercial and other non-residential buildings involves implementing techniques that prevent floodwaters from entering the building. Applying a water-resistant sealant around the building is used to prevent flood water from entering. The sealant layer is then protected with a brick veneer or similar material. Closure panels are used at building openings and a sump pump and drain system must be installed as part of the measure to control seepage through closure devices. A back-up power supply for the pump may be necessary. Backflow prevention devices must be installed on sanitary sewer lines. A schematic of the dry floodproofing technique is shown in Figure 5.

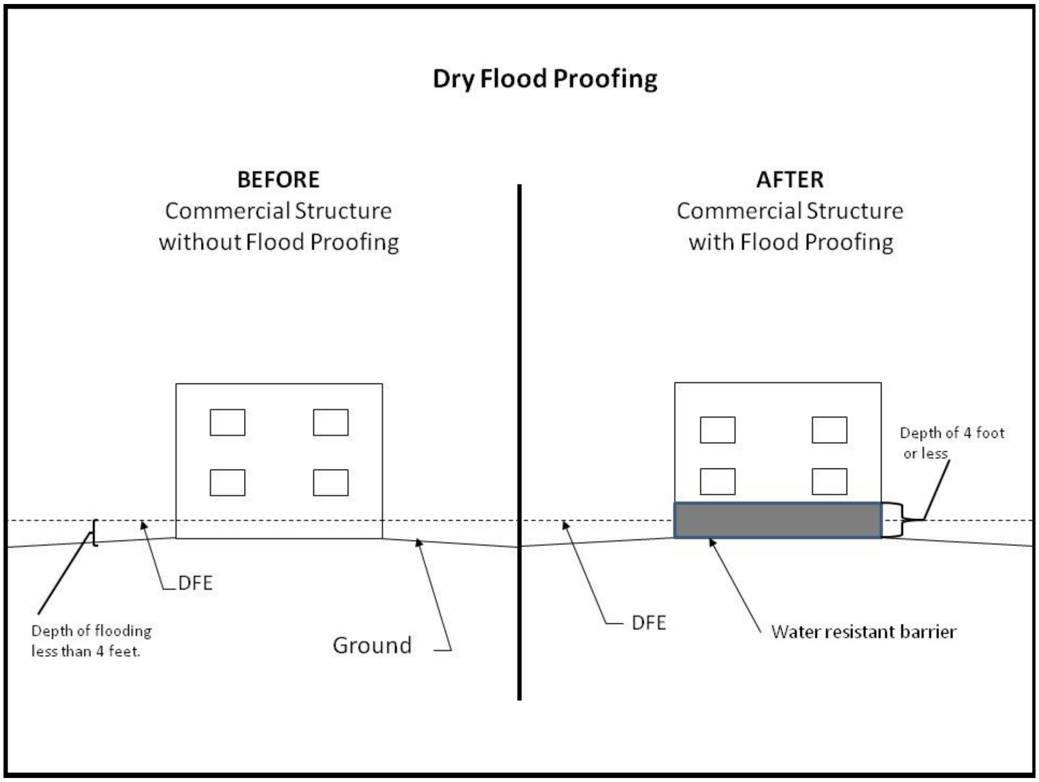

Figure 5. Commercial Dry Floodproofing

Testing sponsored by the National Nonstructural Committee at the USACE Engineering Research and Design Center indicated that a masonry or concrete commercial building can generally be dry floodproofed up to design depth of 3 feet. Higher floodproofing may require modifications to the building to support greater water depths. (USACE, 1988). A structural analysis of the wall strength is required if it is desired to achieve higher protection. Buildings constructed of poured concrete, concrete masonry, or brick are most suitable for dry floodproofing. The floodplain building inventory of the study area found a number of non-residential buildings with walls of prefabricated steel panels. Since these panels may not be of sufficient strength to resist the hydrostatic load and may leak through the joints between the steel panels, an alternate method of dry floodproofing was proposed for metal buildings. To provide sufficient wall strength, new short walls of concrete masonry units (CMU) with interiors of the masonry blocks filled with waterproof grout and with steel reinforcements would be built on a new foundation footing immediately outside of the existing steel walls. The waterproof sealant and brick veneer are applied to the CMU wall. Closures for openings into the building are also built into the CMU wall.

Another available dry floodproofing component for commercial buildings is raising the interior first floor above the design flood elevation. This is done by placing fill on the original floor slab and constructing a new floor slab at the DFE. New interior or exterior stairs or ramps would be constructed to access the raised first floor. Electrical service, plumbing, and heating, ventilation and air conditioning (HVAC) systems would be elevated. This method requires the building construction be resistant to water damage (masonry, concrete or metal), not have a basement or that the basement be completely filled, and that the first-floor ceilings be high enough to provide sufficient clearance above the elevated floor.

With the elevated interior first floor, the walls are supported from hydrostatic forces by new interior walls supporting the raised floor and containing the fill on the dry (interior) side so the floodproofing level may be higher than usual for dry floodproofing. An alternative to raising the first floor on fill is for the new floor slab to be elevated on piers or other structural members. Flood vents would be installed in the exterior walls below the floor to equalize the hydrostatic forces. If floodwaters are allowed in part of the building this method should be considered as dry/wet floodproofing. This method provides greater flood risk management than waterproofing the building envelope since it is not vulnerable to catastrophic failure from leakage or if the floodproofing elevation is exceeded. If the design flood elevation is exceeded, flood depths on the elevated first floor will be less than the existing conditions.

Buildings could also be partially dry floodproofed and partially wet floodproofed. Normally, this technique occurs in a warehouse or similar structure where the interior office area is dry floodproofed and the rest of the structures is wet floodproofed. In this situation, the interior walls of the dry floodproofed area need to be waterproofed as well as the exterior walls. In this analysis, structures were only assessed for one measure or the other. A more detailed analysis of the interior construction would be required to if multiple measures to one structure were to be assessed.

Cost estimates were developed for commercial buildings with design flood depths up to 4 feet and removal of basement if necessary. A structural engineer will be required to thoroughly review the adequacy of the building to withstand hydrostatic and dynamic floodwater loading on the walls and uplift forces on the foundation prior to implementation. The various costs used in the dry floodproofing estimate are summarized in Table 4. The perimeter was estimated by taking the square root of the area and then multiplying by four. The number and size of closure panels needed were estimated from the Google Earth Street View map application. The floodproofing height was calculated by subtracting the foundation elevation from the design flood elevation. Dry floodproofing achieves flood insurance premium reduction for commercial structures but is not recognized by the NFIP for flood insurance premium reduction if applied to a residential structure. Residential buildings cannot be removed from insurance or floodplain management requirements by dry floodproofing. An individual homeowner may choose to floodproof their home (provided not a substantial improvement), but the lowest floor will not change for insurance or permitting.

Table 4. Cost Parameters for Dry Floodproofing

Item	Unit of Measure	Unit Cost
Waterproofing Sealant	SF	$2.48
Masonry Veneer	SF	$18.58
3 ft Floodproof Door	1 unit	$3,000
6 ft Floodproof Door	1 unit	$6,000
Closure Panels	1 panel	$1220
CMU Wall	SF	$21.78
Wall Foundation	LF	$97.97
Skimmer Pumps	1 unit	$188.56
Sewer Backflow Valve	1 unit	$1622.24

3.4 Wet Floodproofing Commercial Buildings

This nonstructural technique is applicable as either a standalone measure or as a measure combined with other measures such as elevation. In accordance with the NFIP, application of wet floodproofing techniques may require a variance from local floodplain management regulations, see FEMA Technical Bulletin 7-93 for more information. As a standalone measure, floodwaters are allowed to enter a structure, thereby requiring that all construction materials be flood damage-resistant in accordance with FEMA Technical Bulletin 2, and all utilities must be elevated above the design flood elevation. Flood vents are installed in the walls to allow floodwaters into the building and equalize the hydrostatic forces. It is required that there be a minimum of two vents with a minimum one square inch of flood vent area for each square foot of the wet floodproofing area, as specified in 44 CFR Section 60.3(c)(5). All utilities, such as heating, lighting, electrical panels and outlets must be elevated above the DFE or be located inside flood resistant closures.

Since wet floodproofing allows floodwaters into a building, it is not allowed for finished residential buildings. Wet floodproofing may be applicable to commercial and industrial buildings when combined with a flood warning, preparedness and response plan. To protect the contents during flooding, damageable items would be elevated permanently above the DFE. This measure is not applicable in areas with large flood depths and high velocity flows. A wet floodproofing proposal should be discussed with the local floodplain manager prior to implementation and may require a variance from floodplain management regulations.

The various costs used in the wet floodproofing estimate are summarized in Table 5. The total structure square footage was used along with the unit cost information to determine cost. These costs could vary significantly from structure to structure and depend on the structure's functional purpose. For estimating purposes, the structure perimeter was used to estimate the length of electrical utilities that would need to be relocated. The floodproofing height was calculated by subtracting the foundation elevation from the design flood elevation.

Table 5. Cost Parameters for Wet Floodproofing

Item	Unit of Measure	Unit Cost
Demo interior wall	SF	$1.79
Insulation and wains coat	SF	$10.70
Raise electric utilities	LF	$15.52
Flood vents	1 unit	$390.04
Sewer backflow valve	1 unit	$1622.24

3.5 Relocation of Buildings

This nonstructural technique requires physically moving the at-risk structure out of the floodplain and buying the land upon which the structure was located. This measure achieves a high level of flood risk reduction when structures can be relocated from a high flood hazard area to an area that is located completely out of the floodplain. Development of relocation sites where structures could be moved to achieve the planning objectives and retain such aspects as community tax base, neighborhood cohesion, or cultural and historic significance can be part of any relocation project.

3.6 Acquisition

This nonstructural technique consists of buying the structure and the associated land. The building is either demolished or is sold to others and relocated to a location external to the floodplain. Land acquisition can be in the form of fee title or permanent easement with fee title. After acquisition, the land must be maintained as open space through deed restriction that prohibits any type of development that can sustain flood damages or restrict flood flows. Land acquired as part of a nonstructural project can be converted to a new use such as ecosystem restoration and/or recreation that is consistent with open space restrictions, such as trails, parks, golf courses, shoreline access, and interpretive markers. Existing infrastructure, including utilities, streets, and sidewalks, can be removed as part of the project when previously developed land is converted to open space. By incorporating new uses of the permanently evacuated floodplains into the nonstructural flood risk reduction project, economic feasibility of the acquisition or relocation projects is enhanced by adding the benefits of ecosystem restoration and recreation.

3.7 Maintenance and Operations of Nonstructural Measures

The regular maintenance required for elevated residential buildings would be similar to normal building maintenance. The increased maintenance related to the added height of the foundation and steps would be minimal. If elevated on a crawlspace, periodic inspection and maintenance of the building flood vents is needed, which would be a minor activity compared to normal building maintenance. Elevated residential buildings have no flood risk management features that require operation therefore there are no operational considerations. Residents of all buildings in a flood hazard area within the Papillion Creek Watershed should be encouraged to develop an individual flood preparedness plan.

The maintenance of commercial buildings with wet floodproofing consists primarily of periodic inspection and maintenance of the building flood vents, which would be a minor activity compared to normal building maintenance. Operations for wet floodproofed buildings when flooding is imminent would be limited to elevating or removing the building contents that are not permanently located above the design flood elevation. The property should have a building flood preparedness plan that is regularly updated by the owners/managers and communicated to the employees.

Buildings with dry floodproofing would require periodic (at least annual) inspection and maintenance, per manufacturer recommendations. Closure panels need to be checked periodically to make sure they fit properly and that gaskets remain watertight. Drainage systems and pumps need regular maintenance. The owner should prepare a formal inspection and maintenance plan for the dry floodproofing components.

Owners/managers should prepare and regularly update a detailed EAP for the installation of the closures, operation of the floodproofing measures, and to identify responsibilities and procedures when flooding is imminent. All employees should be familiarized with the plan. The owners/managers should provide annual training and flood emergency exercise, including additional training for new employees.

While the local sponsor will not directly operate or maintain the nonstructural measures, the sponsor should take the lead in providing flood preparedness information to the community and in dissemination of flood warnings. The owner, or appropriate person assigned in the EAP, is responsible for monitoring weather and flood alerts and enacting the EAP. The sponsor should also specifically monitor properties where nonstructural measures have been installed and through the permitting and inspection process to prohibit alterations to the nonstructural measures that would degrade the flood risk reduction provided.

4.0 Nonstructural Measures Economic Feasibility

For the purposes of determining the Federal interest in nonstructural flood risk management measures for this assessment, the economic feasibility of nonstructural flood mitigation measures was determined for individual buildings.

4.1 Structure Inventory

Structures located near and within the 0.2% AEP floodplain were identified. There were approximately 4,296 structures identified within or near the 0.2% AEP floodplain. LiDAR was used to identify the ground elevation at each structure. The study area contains two types of buildings: residential and non-residential (commercial or public) buildings.

A nonstructural analysis requires that each building be examined based on building type, where the building is located within the floodplain, foundation type, and previous flooding characteristics of the area for purposes of determining the nonstructural measure is most the appropriate. The structure inventory data requirements are ground elevation, first floor elevation, structure occupancy type, numbers of stories, structure footprint, foundation type, perimeter distance, exterior wall construction, basement square feet, height of low openings, and openings on commercial buildings. The majority of this data can be collected from the county assessor.

4.2 Nonstructural Measures Evaluated

This nonstructural assessment considered nonstructural flood risk management measures for residential and commercial buildings damaged by the 1% AEP flood event. Each building shown to be damaged analyzed based upon data collected via desk audit and available community records. To be considered economically feasible, benefits of a flood risk management measure must exceed the costs of the measure. This is also expressed in terms of a benefit-cost ratio (BCR) greater than one.

As discussed in the Economics Appendix F, the economic analysis conducted in this study utilized HEC-FDA. The model was used to calculate expected flood damages on a reach by reach basis at various flood events. This data was then used to develop expected annual damages (EAD) for each of the reaches. Benefits and costs were then used to determine the potential economic feasibility of nonstructural measures.

The methods that were most appropriate were selected for structures in the inventory based on whether the buildings were residential or non-residential, the individual characteristics of each building, and the Flood Damage Reduction Matrix created by the USACE Nonstructural Committee shown in Figure 6. The nonstructural measures considered for residential buildings during this assessment were elevation on extended foundation walls, filling in the basements and constructing a main floor addition. Encroachments are prohibited in the regulatory floodway (44 CFR 60.3), therefore the appropriate nonstructural measures for structures located in the floodway are acquisition or relocation.

US Army Corps of Engineers®

Nonstructural Flood Risk Management

National Nonstructural Committee

May 2019		PHYSICAL NONSTRUCTURAL MITIGATION MEASURES									
NONSTRUCTURAL FLOOD RISK MANAGEMENT MATRIX		Elevation									
		Extend Foundation	Piers	Posts	Columns	Piles	Fill (Compacted)	Relocation	Acquisition	Dry Flood Proofing	Wet Flood Proofing
Flooding Characteristics	**Flood Depth**										
	Shallow (less than 3 ft)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Moderate (3 to 6 feet)	Y	Y	Y	Y	Y	Y	Y	Y	N	Y
	Deep (6 to 12 feet)	Y	Y	Y	Y	Y	Y	Y	Y	N	Y
	Very Deep (more than 12 feet)	N	N	N	N	N	N	Y	Y	N	N
	Flood Velocity										
	Low (less than 3 feet per second)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Moderate (3 to 6 feet per second)	N	Y	Y	Y	Y	Y	Y	Y	N	N
	High (more than 6 feet per second)	N	Y	N	N	Y	N	Y	Y	N	N
	Flash Flooding										
	Yes (less than 1 hour warning)	Y	Y	Y	Y	Y	Y	Y	Y	N	N
	No (more than 1 hour warning)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Debris / Ice Flow										
	Yes	N	Y	N	N	Y	Y	Y	Y	N	N
	No	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Site Characteristics	**Site Location**										
	Coastal Beach Front	N	N	N	N	Y	N	Y	Y	N	N
	Coastal Interior (Low Velocity)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Riverine Flood Plain	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Soil Type										
	Permeable	Y	Y	Y	Y	Y	Y	Y	Y	N	Y
	Impermeable	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Building Characteristics	**Structure Foundation**										
	Slab on Grade (reinforced)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Crawl Space	N	N	N	N	N	Y	Y	Y	N	Y
	Basement	N	N	N	N	N	Y	Y	Y	N	Y
	Abandonment of Crawlspace / Basement	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Structure Construction										
	Concrete, Stone, or Masonry	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Metal	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Wood	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Overall Structure Condition										
	Excellent to Fair	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Fair to Poor	N	N	N	N	N	N	N	Y	N	N
Community (Project Area) Benefits	**Economics**										
	Insurance Premium Reduction (Residential)	Y	Y	Y	Y	Y	Y	Y	Y	N	N
	Insurance Premium Reduction (Non-Residential)	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
	Avoids Adverse Impact on Adjacent Property	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
	Reduction in Admin Costs of NFIP	N	N	N	N	N	Y	Y	Y	N	N
	Reduction in Emergency Costs	N	N	N	N	N	N	Y	Y	N	N
	Public Infrastructure Damage Reduced	N	N	N	N	N	N	Y	Y	N	N
	Intangible Benefits										
	Ecosystem Restoration Potential	N	N	N	N	N	N	Y	Y	N	N
	Recreation Potential	N	N	N	N	N	N	Y	Y	N	N
	Community (Project Are) Cohesion	Y	Y	Y	Y	Y	Y	N	N	Y	Y
	Flood Risk Eliminated	N	N	N	N	N	N	Y	Y	N	N

The US Army Corps of Engineers National Nonstructural Committee [NNC] is available to assist in any aspect of formulating and implementing nonstructural flood damage reduction measures and realizing the opportunities that exist with nonstructural.

For more information, please contact the NNC Chairman and committee members at: nnc@usace.army.mil
or visit the NNC website at: http://www.usace.army.mil/Missions/CivilWorks/ProjectPlanning/nnc/

US Army Corps of Engineers
National Nonstructural Committee

Figure 6. Flood Damage Reduction Matrix

5.0 Tentatively Selected Plan Nonstructural Alternatives

Nonstructural measures were considered for structures with the lowest floor below the 1% AEP flood event in the 1% AEP floodplain boundary based on the updated modeling for this study. At the time of TSP, the hydraulic modeling only considered existing conditions, it did not incorporate future without-project hydrology. Existing conditions modeling does not include any of the proposed structural alternatives. The design flood event (DFE) is the 1% AEP flood elevation based on the existing conditions models plus an additional one foot. This formulation is based on EO 11988 and the NFIP standards for the 1% AEP flood event and the local requirements. Based on structure type, depth of flooding at the structure, and other considerations, the appropriate nonstructural measures was selected for each structure and cost estimates were developed based on floodproofing that structure to the DFE.

Damages were determined for the without-project conditions with the HEC-FDA model. A modified with-project conditions HEC-FDA structure inventory file was created for the project area which modified the structures identified for nonstructural measures to limit the computation of flood damages until the DFE was exceeded. The input data was modeled in HEC-FDA to determine damages for the with-project conditions. The difference between the without-project and with-project represents the project benefits which are computed on an annualized basis. An interest rate of 2.75% (FY20) over 50 years was used to annualize to total project costs for comparison with the annualized project benefits.

Quantities for nonstructural mitigation cost estimates were developed for each building that was evaluated for nonstructural measures in detail based on a visual assessment from the outside of the building and the assessor's database. Prior to implementing a nonstructural measure, additional detailed inspection of the structure for design data and costs will be required (See Section 6).

The benefits and costs were analyzed and used to compute the net benefits and BCR for each reach. If this calculation was positive it meant that the proposed nonstructural measures had positive net benefits and a BCR greater than 1.0. If negative, it meant that the recommended nonstructural measure's cost exceeded the benefits and resulted in a BCR less than 1.0. The annual costs include additional costs above the construction costs including 8% for engineering and design, 10% for supervision and administration, and a 25% contingency. The computation of the annual benefits and uncertainty is described in detail in the Economics Appendix F.

5.1 Standalone Nonstructural Alternative

The standalone nonstructural alternative includes nonstructural mitigation measures for all structures with computed expected damages from the 1% AEP flood event whose lowest floor is below the 1% AEP flood elevation. The breakdown of the nonstructural measure selected in each reach as shown in Table 6. Table 7 shows the annualized project benefits, costs, overall net benefits and BCR for each stream within the nonstructural standalone alternative.

There are 36 structures located in the floodway. These structures would either have to be acquired or relocated to a flood-free site. These 36 structures were preliminarily evaluated and determined the economic justification of this measure was negative. Therefore, acquisition and relocation were dropped from further consideration. The structures in the floodway were not included in any nonstructural alternative due to extremely high costs and feedback received from the sponsor and during scoping meetings that mandatory buyouts would not be supported. The 1% AEP floodplain nonstructural standalone alternative is shown in Figure 7.

Table 6. Number of Structures Tentatively Selected for the Standalone Alternative

Stream	Number of Structures Mitigated	Basement Fill	Elevation	Dry Floodproof
Big Papillion	422	73	108	241
Cole Creek	4	0	4	0
Little Papillion	489	43	298	148
Papillion	39	0	0	39
Saddle Creek	54	2	3	49
South Papillion	85	12	24	49
Thomas Creek	12	2	6	4
West Papillion	193	28	69	96
Total	1,298	160	512	626

Table 7. Standalone Nonstructural Alternative Costs and Benefits

Stream	Structures Mitigated	Estimated Floodproofing Costs	Average Annual Costs	Average Annual Benefits	Net Benefits	BCR
Big Papillion Creek	422	43,093,980	$1,596,230	$513,890	-$1,082,340	0.32
Cole Creek	4	$433,140	$16,040	$4,250	-$11,790	0.26
Little Papillion Creek	489	44,760,440	$1,657,960	$720,820	-$937,140	0.43
Papillion Creek	39	$2,473,960	$91,640	$118,040	$26,400	1.29
Saddle Creek	54	$3,770,670	$139,700	$216,000	$76,330	1.55
South Papillion Creek	85	12,824,780	$475,040	$214,300	-$260,740	0.45
Thomas Creek	12	$1,298,360	$48,090	$14,870	-$33,220	0.31
West Papillion Creek	193	$15,921,690	$589,760	$98,420	-$491,340	0.17
Total	1,298	$124,577,020	$4,614,460	$1,900,590	-$2,713,870	0.41

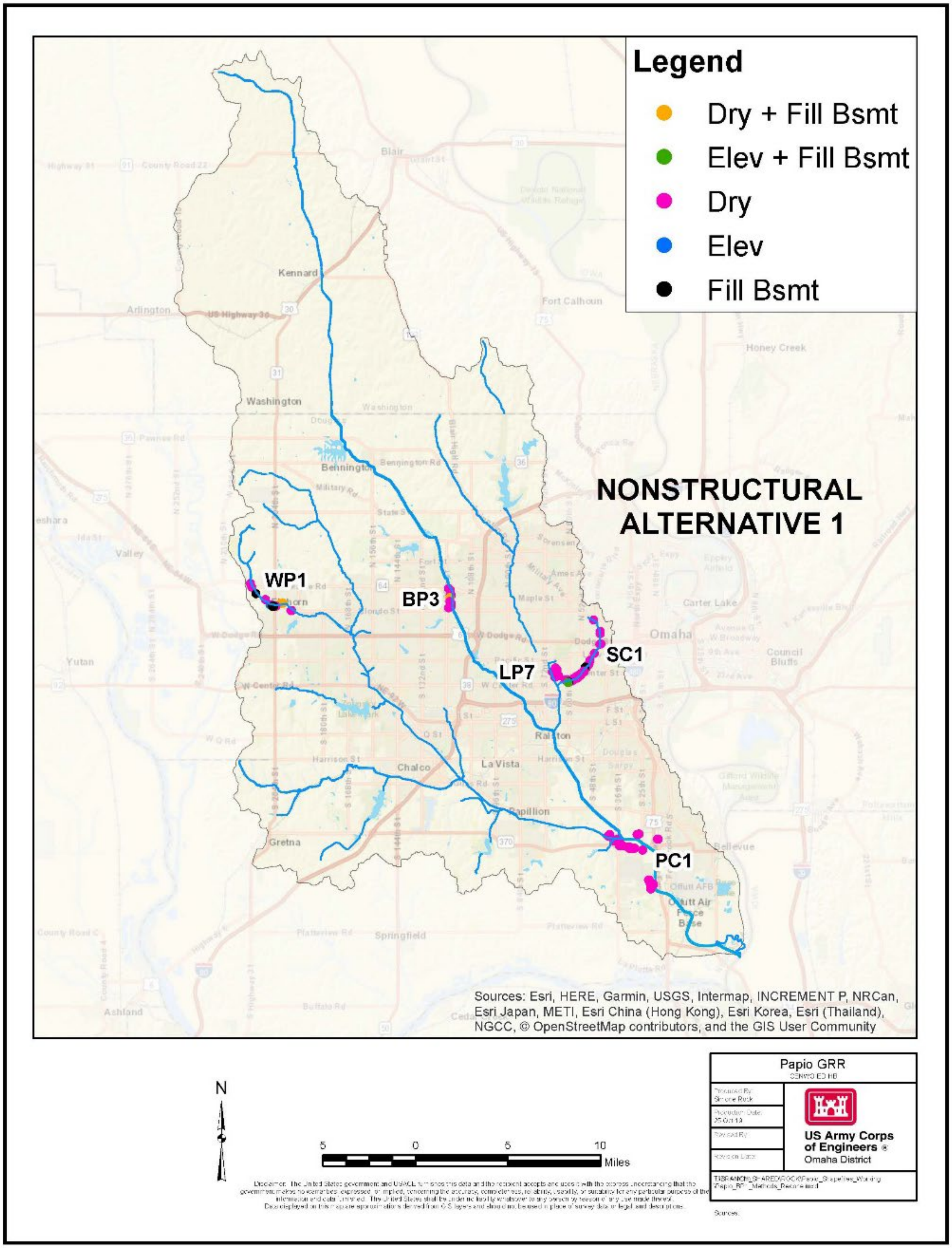

Figure 7. Nonstructural Standalone Alternative

5.2 2% AEP Floodplain Nonstructural Alternative

Following the standalone nonstructural alternative analysis, further nonstructural analysis was conducted focusing on high risk areas. This additional alternative does not protect all of the structures damaged in the 1% AEP flood event like the standalone alternative. Instead, this alternative uses a smaller floodplain boundary aggregation as an agile approach to identify and mitigate greater flood risk where possible.

The 2% AEP floodplain alternative was considered for reaches that where the all-inclusive standalone nonstructural plan was not economically viable, and instead focused on floodproofing the higher risk structures within the 2% AEP floodplain boundary. This alternative considered 51 structures (Table 8). The economically viable reaches from the 1% AEP floodplain standalone plan remained unchanged. Table 9 shows the resulting annualized project benefits, costs, overall net benefits and BCR for each reach within 2% AEP floodplain nonstructural alternative. The 2% AEP floodplain alternative is shown in Figure 8.

Table 8. Structures for Nonstructural Mitigation in the 2% AEP Floodplain Alternative

Stream	Number of Structures Mitigated	Basement Fill	Elevation	Dry Floodproofing
Big Papillion Creek	10	1	4	5
Cole Creek	2	0	2	0
Little Papillion Creek	2	0	0	2
South Papillion Creek	37	10	15	12
Total	51	11	21	19

Table 9. 2% AEP Floodplain Nonstructural Alternative

Stream	Structures Mitigated	Estimated Floodproofing Costs	Average Annual Costs	Average Annual Benefits	Net Benefits	BCR
Big Papillion Creek	10	$1,048,740	$38,840	$37,910	-$930	0.98
Cole Creek	2	$110,190	$4,080	$1,790	-$2,290	0.44
Little Papillion Creek	2	$62,960	$2,330	$3,070	$740	1.32
South Papillion Creek	37	$5,408,560	$200,340	$13,800	-$186,540	0.07
Total	51	$6,630,450	$245,590	$56,570	-$189,020	0.23

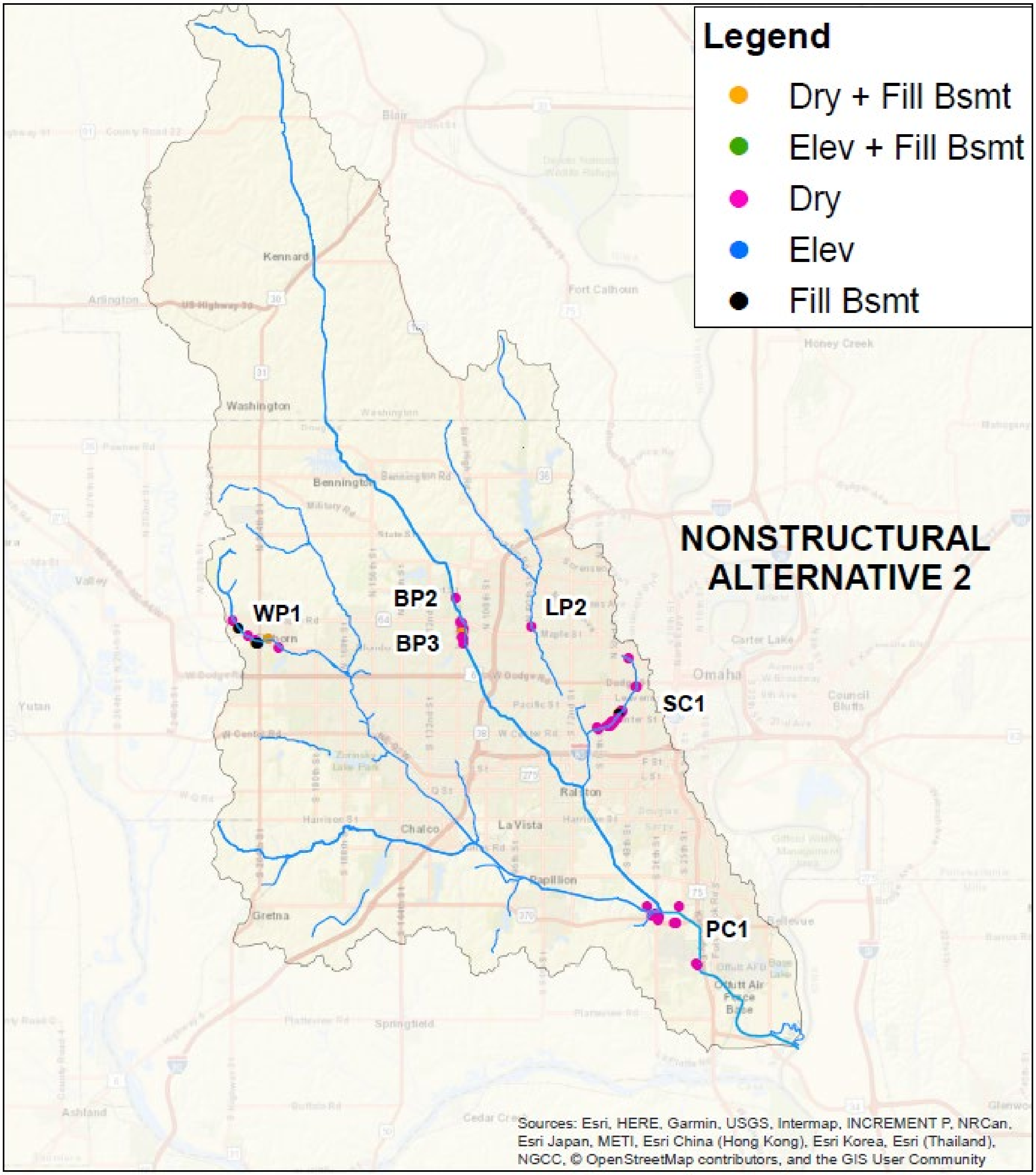

Figure 8. 2% AEP Floodplain Nonstructural Alternative

5.3 Nonstructural Tentatively Selected Plan

The tentatively selected plan includes those reaches that were economically justified in standalone alternative and adds those reaches that were economically justified in the 2% AEP floodplain alternative. These include reaches BP1, BP2, BP3, and BP4 on the Big Papillion Creek with a combined BCR of 1.25; reaches LP2, LP6 and LP7 on the Little Papillion Creek with a combined BCR of 2.02; and reaches PC1, SC1 and WP1 on the Papillion, Saddle Creek, and West Papillion Creeks (Table 10). The tentatively selected plan for nonstructural measures is shown in Figure 9.

Table 10. Tentatively Selected Plan Nonstructural Measures Costs and Benefits

Stream	Structures Mitigated	Estimated Floodproofing Costs	Average Annual Cost	Average Annual Benefits	Net Benefits	BCR
Big Papillion	55	$5,159,150	$191,100	$239,170	$48,290	1.25
Little Papillion	72	$6,848,160	$253,660	$511,280	257,620	2.02
Papillion Creek	39	$2,473,960	$91,640	$118,040	$26,400	1.29
Saddle Creek	54	$3,770,670	$139,670	$216,000	$76,330	1.55
West Papillion	22	$1,549,870	$57,410	$84,800	$27,390	1.48
Total	242	$19,801,810	$733,480	$1,169,290	$435,810	1.59

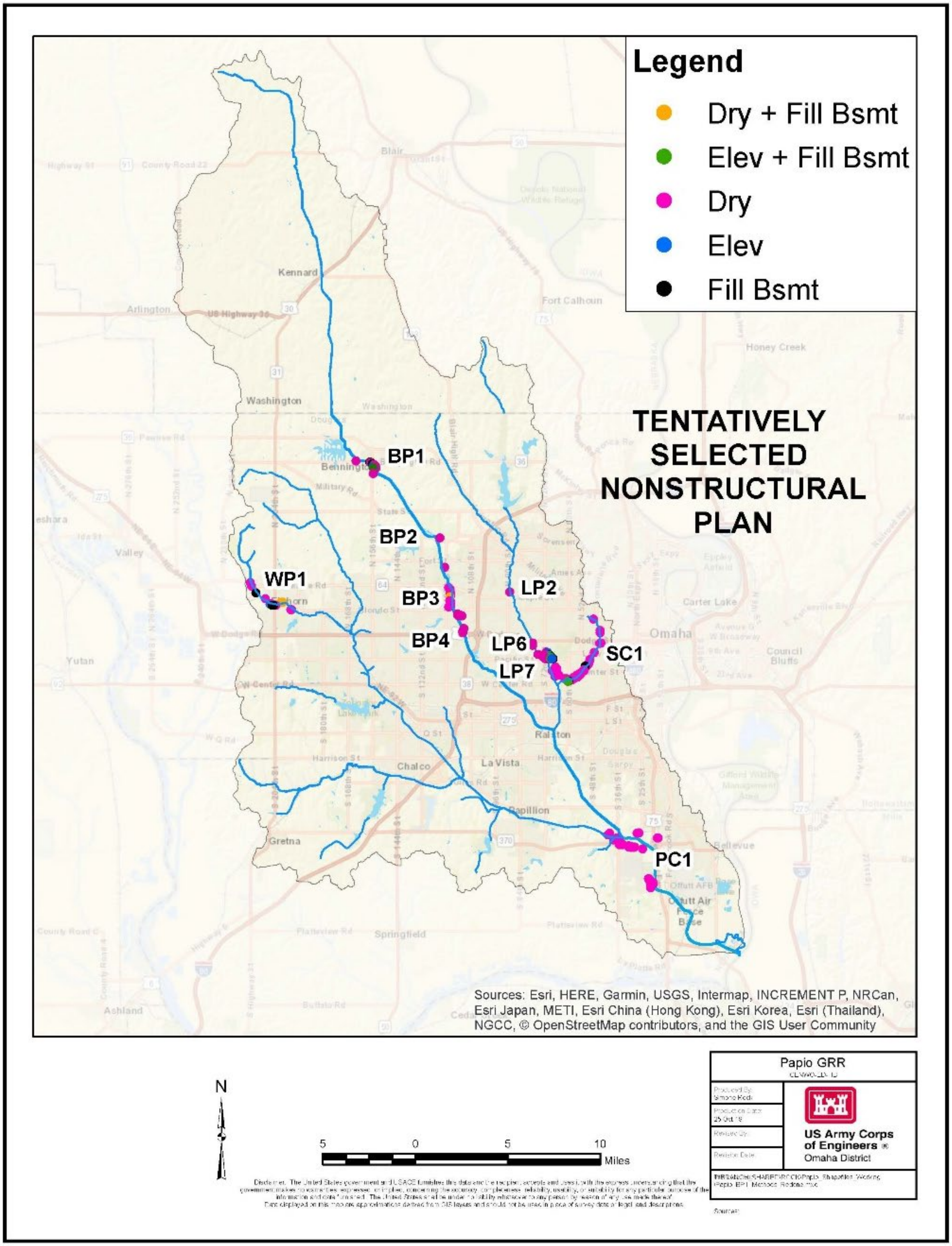

Figure 9. Tentatively Selected Plan for Nonstructural Measures

6.0 Update of the Nonstructural Alternatives

After TSP, there were several refinements incorporated into the nonstructural analysis. These refinements include identifying critical facilities and incorporating future without-project hydrology. These updates typically increased the estimated flood depths assessed during TSP, and the following nonstructural alternatives were updated to incorporate these refinements. Nonstructural measures were considered for structures with the lowest floor below the 1% AEP flood event based on the updated modeling incorporating the future without-project hydrology. There are 693 structures meeting these requirements (Table 11).

Critical facilities in the study area include buildings such as fire stations, law enforcement facilities, schools, and medical facilities. None of these facilities are damaged at the 1% AEP flood event before or after implementation of the structural alternatives and therefore were not selected for nonstructural mitigation.

During the refinements, the economic discount rate was also updated to the FY21 rate of 2.5% for a 50-year period analysis. The annual costs of 8% for engineering and design, 10% for supervision and administration, and a 25% contingency did not change from TSP.

The updated standalone nonstructural alternative shows 693 structures that incur expected flood damages from the 1% AEP flood event and whose first floor elevation of the structure is below the 1% AEP flood elevation. Updated results showed that the 1% AEP standalone plan is economically viable for all streams except Thomas Creek, however this plan does not incorporate the implementation of the structural alternative affecting the water surface elevations within the basin (Table 12). Therefore, an additional analysis was performed to determine the structures still at flood risk after the structural plan would be implemented.

Table 11. Updated Standalone Nonstructural Alternative Structure Mitigation Measure

Stream	Total Structures Mitigated	Basement Fill	Elevation	Dry Floodproofing	Flood Vent
Big Papillion Creek	252	57	40	155	0
Cole Creek	1	0	0	1	0
Little Papillion Creek	259	37	120	74	28
Papillion Creek	12	0	0	12	0
Saddle Creek	56	0	5	51	0
South Papillion Creek	63	13	14	36	0
Thomas Creek	7	1	4	1	1
West Papillion Creek	43	5	9	29	0
Total	693	113	192	359	29

Table 12. Updated Standalone Nonstructural Alternative Costs and Benefits

Stream	Structures Mitigated	Estimated Floodproofing Costs	Average Annual Costs	Average Annual Benefits	Net Benefits	BCR
Big Papillion Creek	252	$24,130,500	$850,800	$1,406,610	$555,820	1.65
Cole Creek	1	$18,370	$650	$1,120	$470	1.73
Little Papillion Creek	259	$21,518,170	$758,690	$1,681,100	$922,410	2.22
Papillion Creek	12	$1,043,940	$36,810	$139,360	$102,550	3.79
Saddle Creek	56	$4,369,550	$154,060	$751,530	$597,470	4.88
South Papillion Creek	63	$8,080,840	$284,920	$653,840	$368,930	2.29
Thomas Creek	7	$551,700	$19,450	$9,050	-$10,400	0.47
West Papillion Creek	43	$3,648,690	$128,650	$155,590	$26,940	1.21
Total	**693**	**$63,361,760**	**$2,234,010**	**$4,798,200**	**$2,564,190**	**2.15**

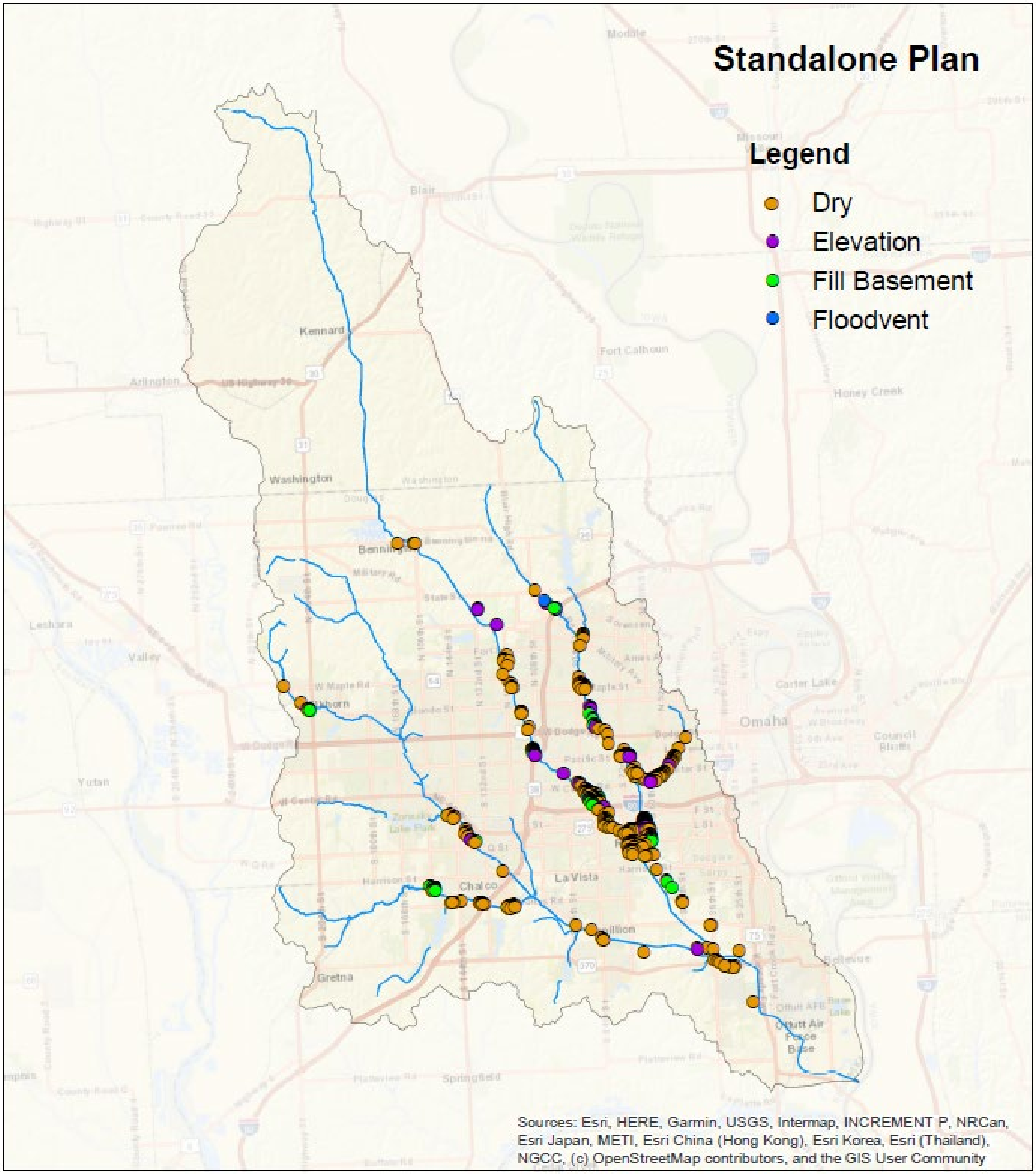

Figure 10. Updated Standalone Nonstructural Alternative

6.1 Updated Nonstructural Plan Combining with the Structural Recommend Plan

The nonstructural plan was developed using the updated WSE for the 1% AEP floodplain boundary with the optimized structural plan implemented. Nonstructural plans were developed by stream and cost estimates were completed for the updated floodproofing height incorporating from the structural alternatives.

The nonstructural plan was developed with the following planning criteria:

- Within the updated 1% AEP floodplain from the optimized structural plan
- Lowest floor below the 1% AEP flood elevation

From the above planning criteria, a nonstructural plan was developed to complement the structural plan based on initially investigated potential floodproofing of 554 structures (Figure 11). This plan covered all of the structures in the updated 1% AEP floodplain boundary incorporating the optimized structural plan. However, USACE policy requires that each added increment should (within reason) contribute positive net NED benefits and have a BCR of greater than 1.0, but based on the initial iteration, only the Big Papillion Creek, Papillion Creek, Saddle Creek, and South Papillion Creek tributaries individually showed economic viability for the all-inclusive 1% AEP standalone plan when combined with the optimized structural plan (Table 13). Therefore, further optimization of the nonstructural plan was investigated in the next section to include a portion of the remaining streams with negative net benefits for the standalone alternative.

Table 13. Updated Standalone Nonstructural Alternative Incorporating the Structural Alternative WSE Costs and Benefits

Stream	Structures Mitigated	Estimated Floodproofing Costs	Average Annual Costs	Average Annual Benefits	Net Benefits	BCR
Big Papillion Creek	255	$27,397,240	$965,970	$1,245,920	$279,950	1.29
Cole Creek	1	$18,870	$670	$660	-$5	0.99
Little Papillion Creek	160	$14,702,440	$518,380	$269,160	-$249,220	0.52
Papillion Creek	9	$763,670	$26,930	$124,680	$97,750	4.63
Saddle Creek	56	$4,399,740	$155,130	$744,260	$589,130	4.80
South Papillion Creek	31	$4,420,300	$155,850	$353,290	$197,440	2.27
Thomas Creek	2	$74,410	$2,620	$900	-$1,720	0.34
West Papillion Creek	40	$3,543,420	$124,930	$121,310	-$3,620	0.97
Total	**554**	**$55,320,100**	**$1,950,480**	**$2,860,180**	**$909,700**	**1.47**

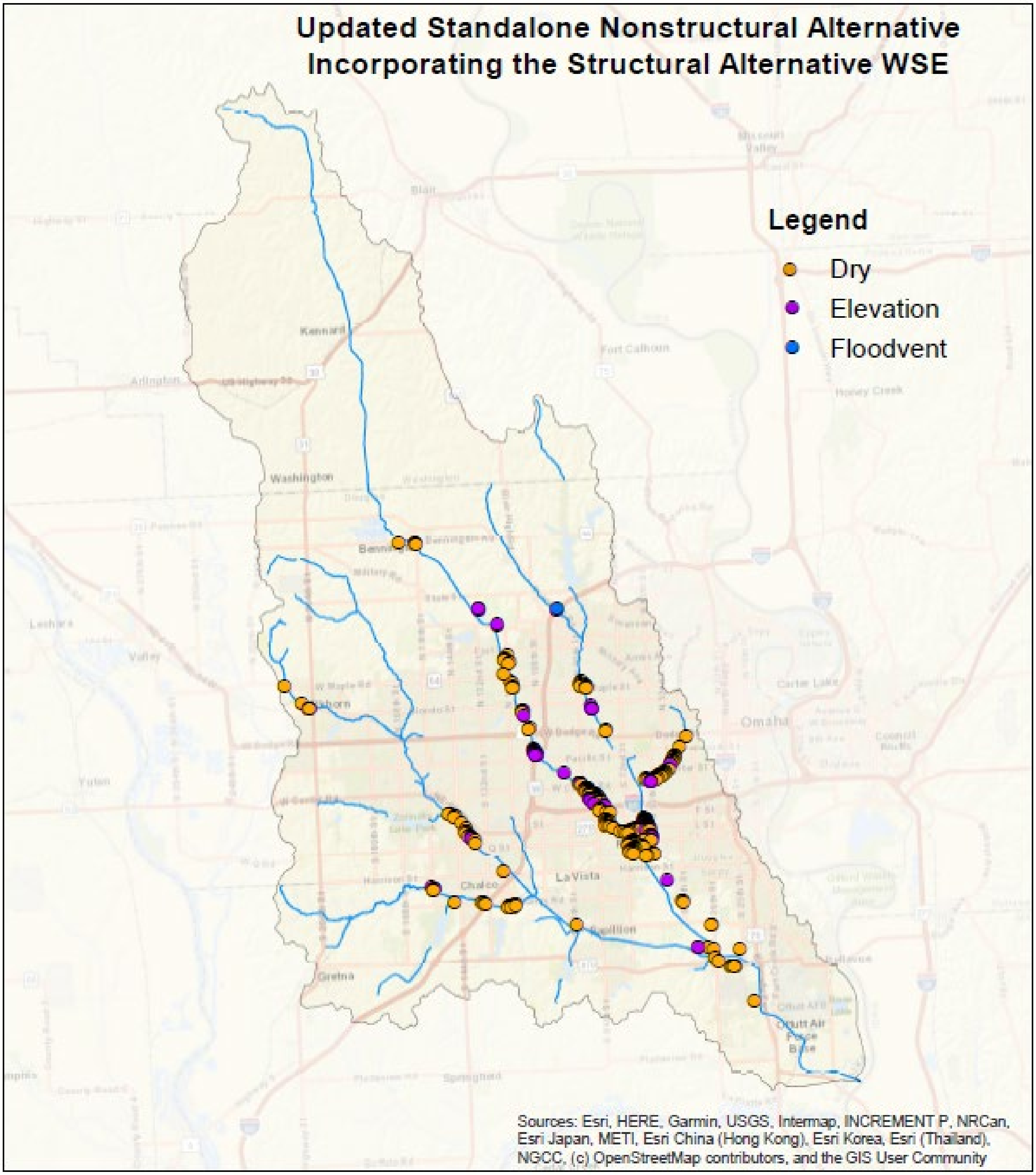

Figure 11. Updated Standalone Nonstructural Alternative Incorporating the Structural Alternative WSE

7.0 Nonstructural Optimization and Recommended Plan

Following the evaluation of the initial updated nonstructural plan, in Section 6.1, optimization of the nonstructural plan was performed to determine if a more economically viable plan could be identified in the 1% AEP floodplain boundary that produced more comprehensive flood risk management throughout the basin. Nonstructural alternatives, while justified on the basis of NED net benefits, are also supposed to give consideration to grouping plans around logical boundaries to provide community cohesiveness. Therefore, the optimized nonstructural plan was evaluated based on evaluating the initial plan, removing outlier reaches, and re-grouping the remaining reaches in the 1% AEP floodplain boundary to provide a plan that balances maximizing NED Benefits and providing a community-focused flood risk management Thomas Creek was removed from the plan due to the very small number of structures, none of which were economically viable. Little Papillion Creek was also removed because none of the individual reaches were economically viable. For the remaining streams individual reaches were investigated by reach to develop community-based groupings of structures and then re-evaluated. This optimized nonstructural plan is also the recommended nonstructural plan with results summarized in Table 14, Table 15, and Figures 12-23. The plan includes 71 basement fills, 59 elevation of residential structures, and 256 dry floodproofing of commercial structures for a total of 386 structures in the plan which produced net benefits of $1,137,860 and has a BCR of 1.79 and an increased contingency of 28%.

Table 14. Recommended Nonstructural Plan Costs and Benefits

Stream	Structures Mitigated	Estimated Floodproofing Costs	Average Annual Cost	Average Annual Benefits	Net Benefits	BCR
Big Papillion Creek	255	$27,968,260	$989,160	$1,245,920	$256,760	1.26
Papillion Creek	9	$779,590	$27,570	$124,680	$97,110	4.52
Saddle Creek	56	$4,491,440	$158,850	$744,260	$585,410	4.69
South Papillion Creek	31	$4,512,420	$159,590	$353,290	$193,700	2.21
West Papillion Creek	35	$3,179.240	$112,440	$117,320	$4,880	1.03
Total	**386**	**$40,930,950**	**$1,447,610**	**$2,585,470**	**$1,137,860**	**1.79**

Table 15. Recommended Plan Nonstructural Measures Breakdown

Nonstructural Measure Type	Number of Structures
Fill Basement	71
Elevate Residential Structure	59
Dry Floodproof Commercial Structure	256
Total	**386**

7.1 Nonstructural Participation Rate Sensitivity Analysis

Planning Bulletin 2019-03 recommends the use of participation rate sensitivity analysis for voluntary nonstructural measures. Since there was no clear evidence from the non-Federal sponsor on the success of a large number of nonstructural measures implemented in the past, the participation rate sensitivity analysis was conducted on feedback received from the non-Federal sponsor and the public during public meetings. The nonstructural measure of filling basements was the least supported measure, therefore the recommended nonstructural plan was evaluated without this measure. The recommended plan included 386 structures total, when the fill basement measure was removed from the plan, there remained 315 structures for elevations and dry floodproofing which is about 82% participation. The new total cost of this plan would be $38,197,060 (Table 16), which is just under two million dollars cheaper than the recommended plan (100% participation). Because fill basement measures address structures with lower flood depths, the benefits realized are typically smaller than measures such as elevation and dry floodproofing. Based on this assumption, the costs are expected to decrease at a faster rate than the benefits decrease with removing the fill basement measure, therefore net benefits are expected to increase with this change.

Table 16. Participation Rate Analysis Costs and Benefits

Stream	Structures Mitigated	Estimated Floodproofing Costs	Average Annual Cost	Average Annual Benefits	Net Benefits	BCR
Big Papillion Creek	197	$25,875,267	$912,312	$1,210,590	$298,278	1.33
Papillion Creek	9	$763,671	$26,926	$124,680	$97,754	4.63
Saddle Creek	55	$4,384,810	$154,600	$743,460	$588,860	4.81
South Papillion Creek	24	$4,206,275	$148,305	$348,170	$199,865	2.35
West Papillion Creek	30	$2,967,038	$104,612	$113,470	$8,858	1.08
Total	**315**	**$38,197,061**	**$1,346,754**	**$2,540,370**	**$1,193,616**	**1.89**

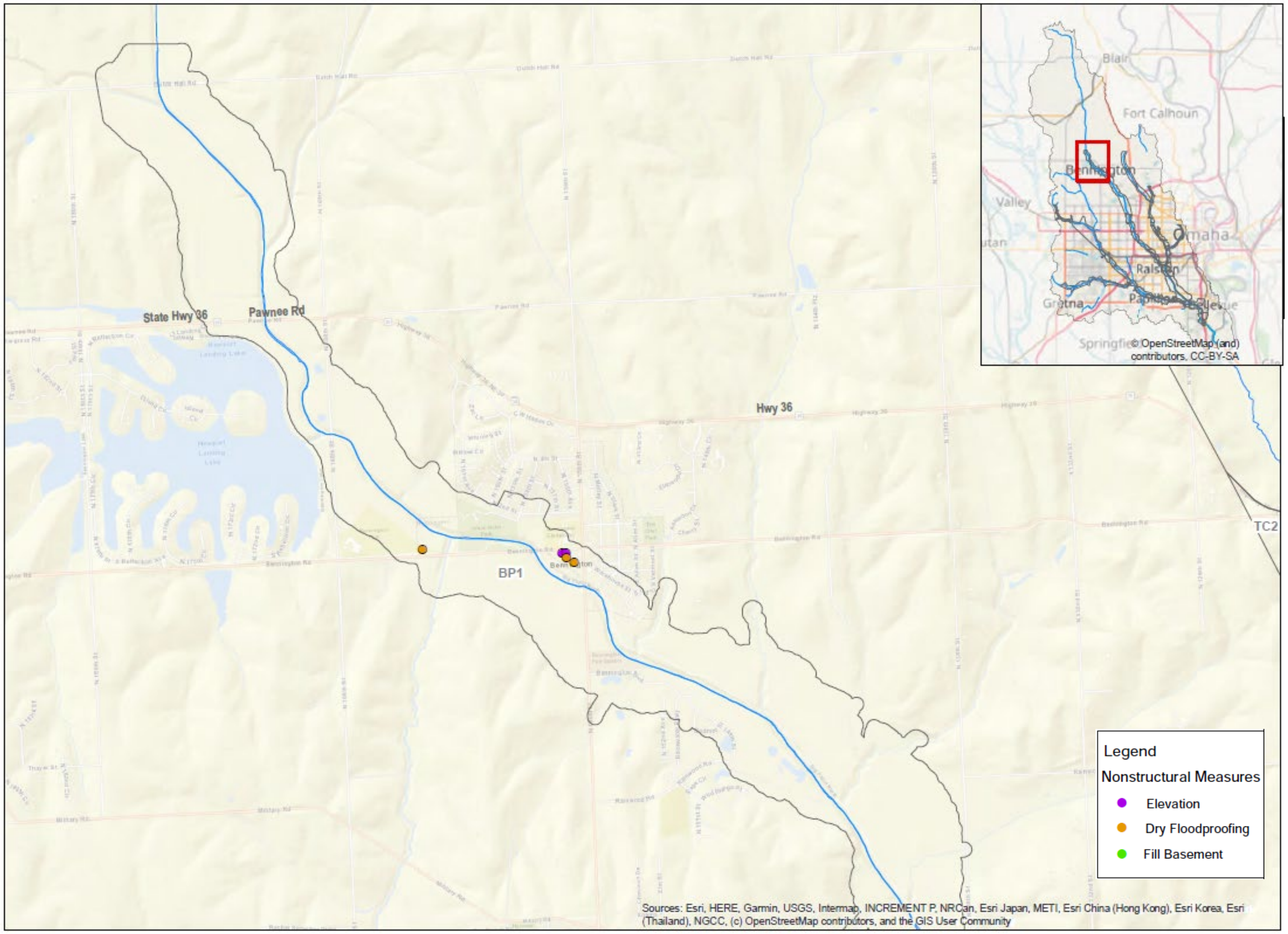

Figure 12. Recommended Plan for Nonstructural Measures: Big Papillion Creek Reach 1

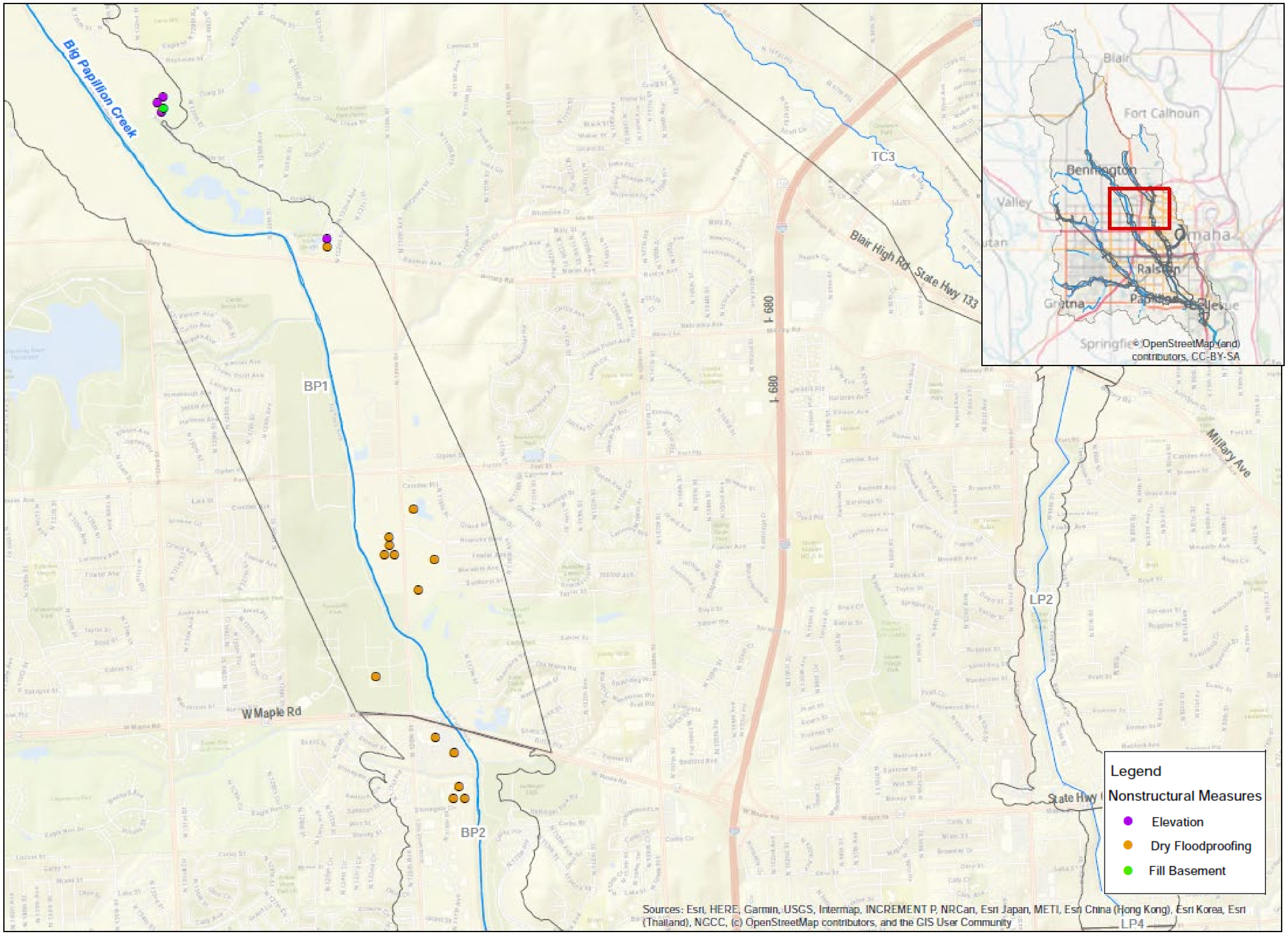

Figure 13. Recommended Plan for Nonstructural Measures: Big Papillion Creek Reach 1 and 2

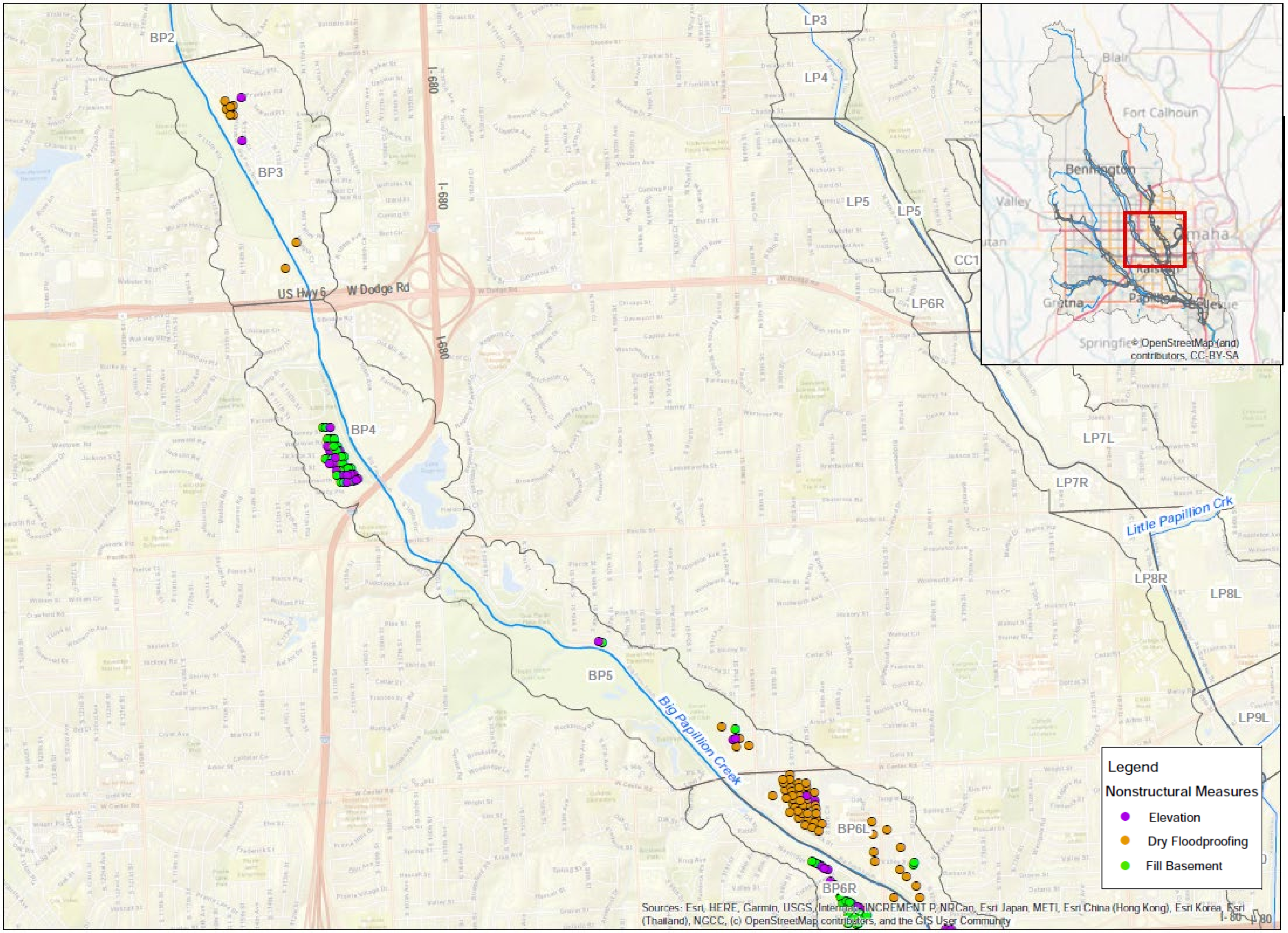

Figure 14. Recommended Plan for Nonstructural Measures: Big Papillion Creek Reach 3, 4, 5, 6L, and 6R

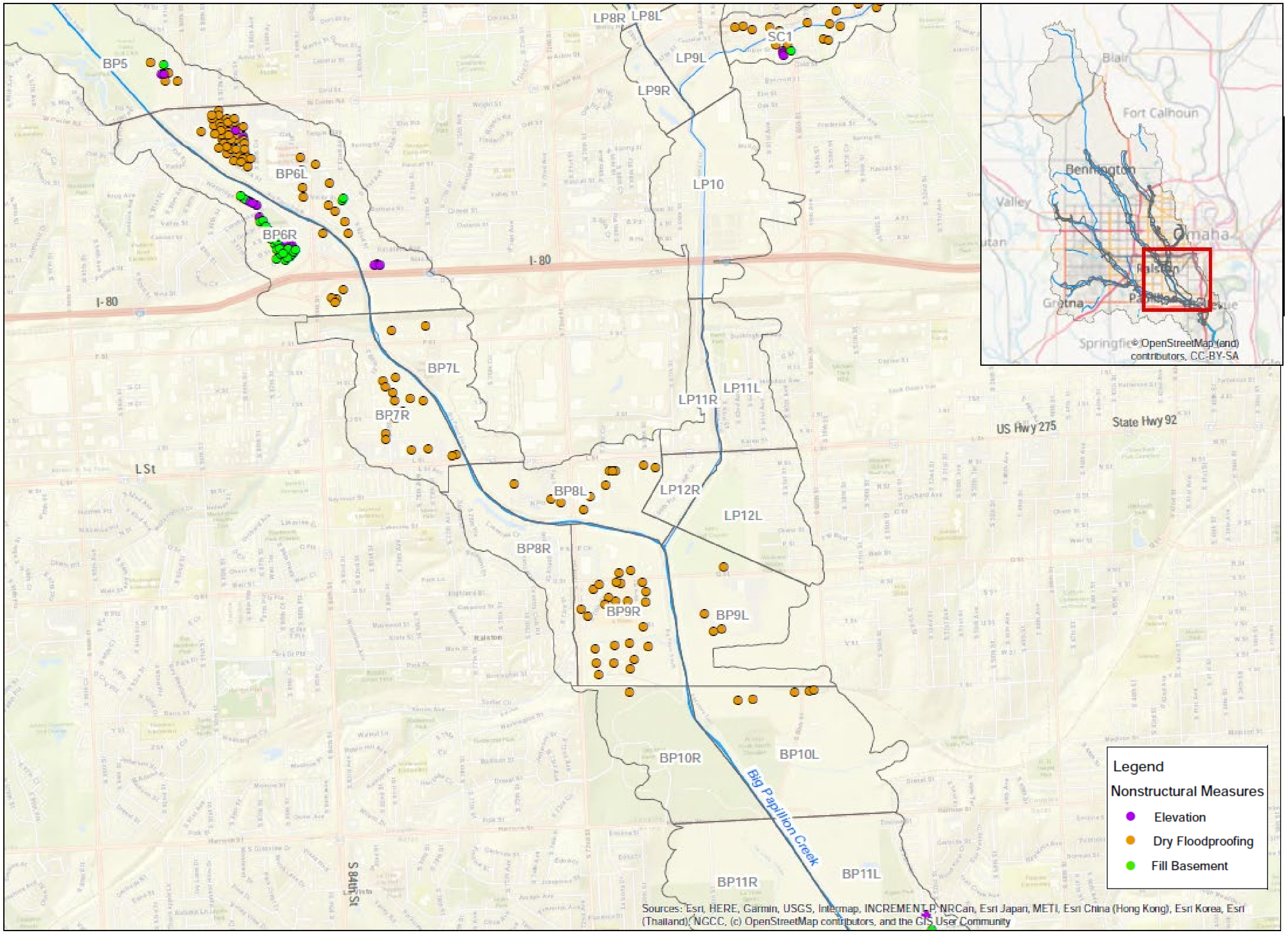

Figure 15. Recommended Plan for Nonstructural Measures: Big Papillion Creek Reach 6L, 6R, 7L, 7R, 8L, 8R, 9L, 9R, 10L, and 10R

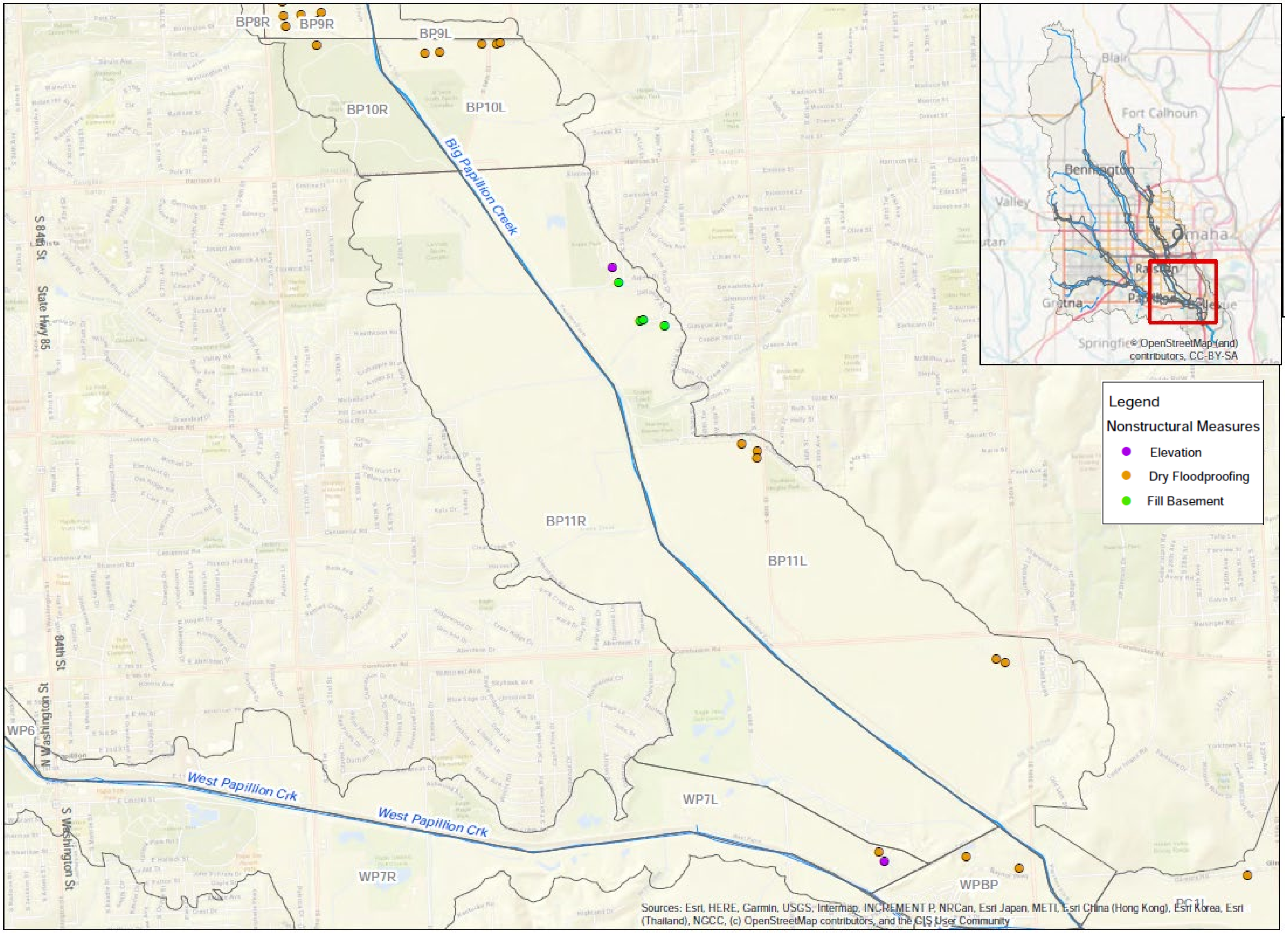

Figure 16. Recommended Plan for Nonstructural Measures: Big Papillion Creek Reach 11R and 11L

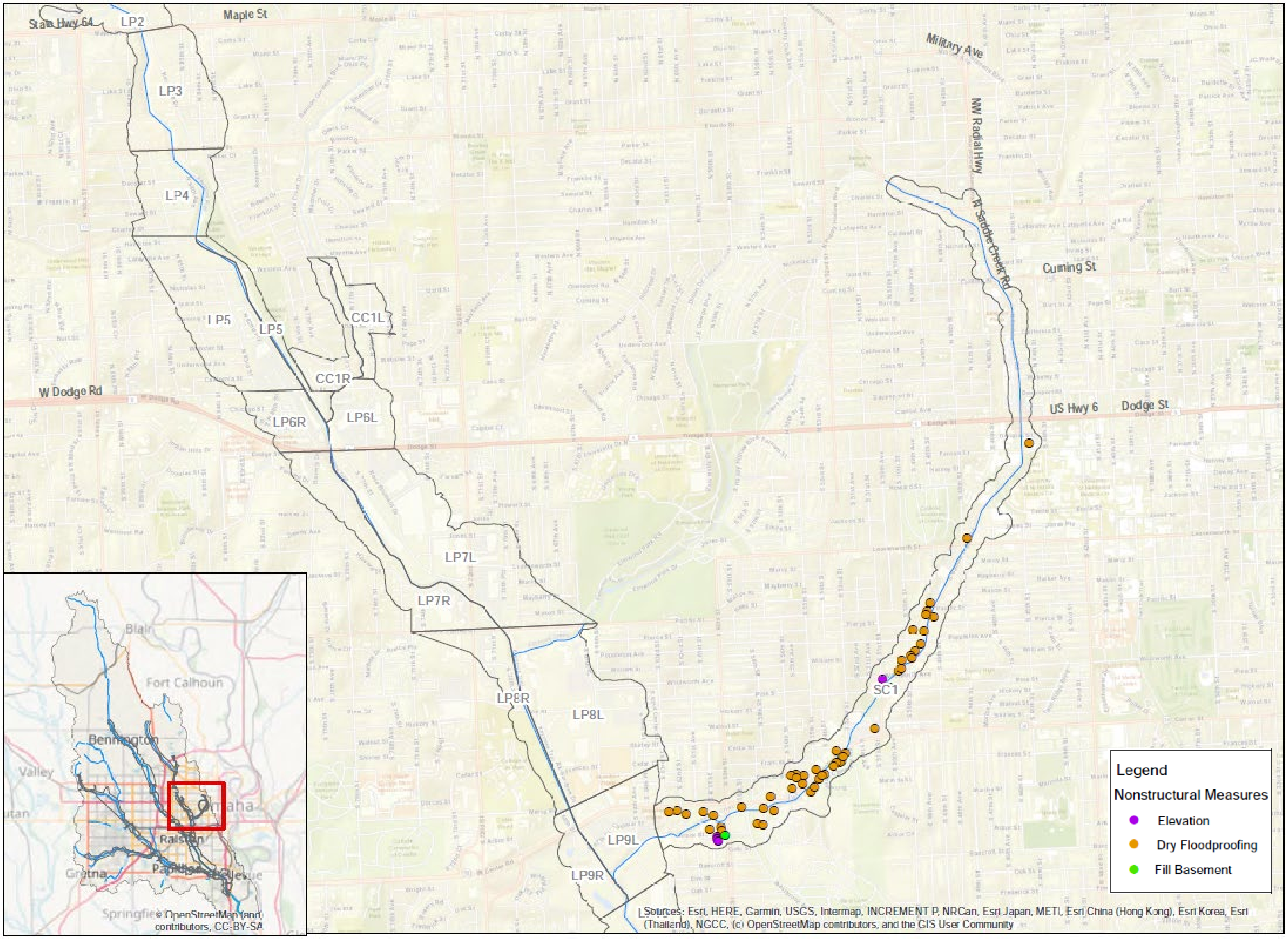

Figure 17. Recommended Plan for Nonstructural Measures: Saddle Creek

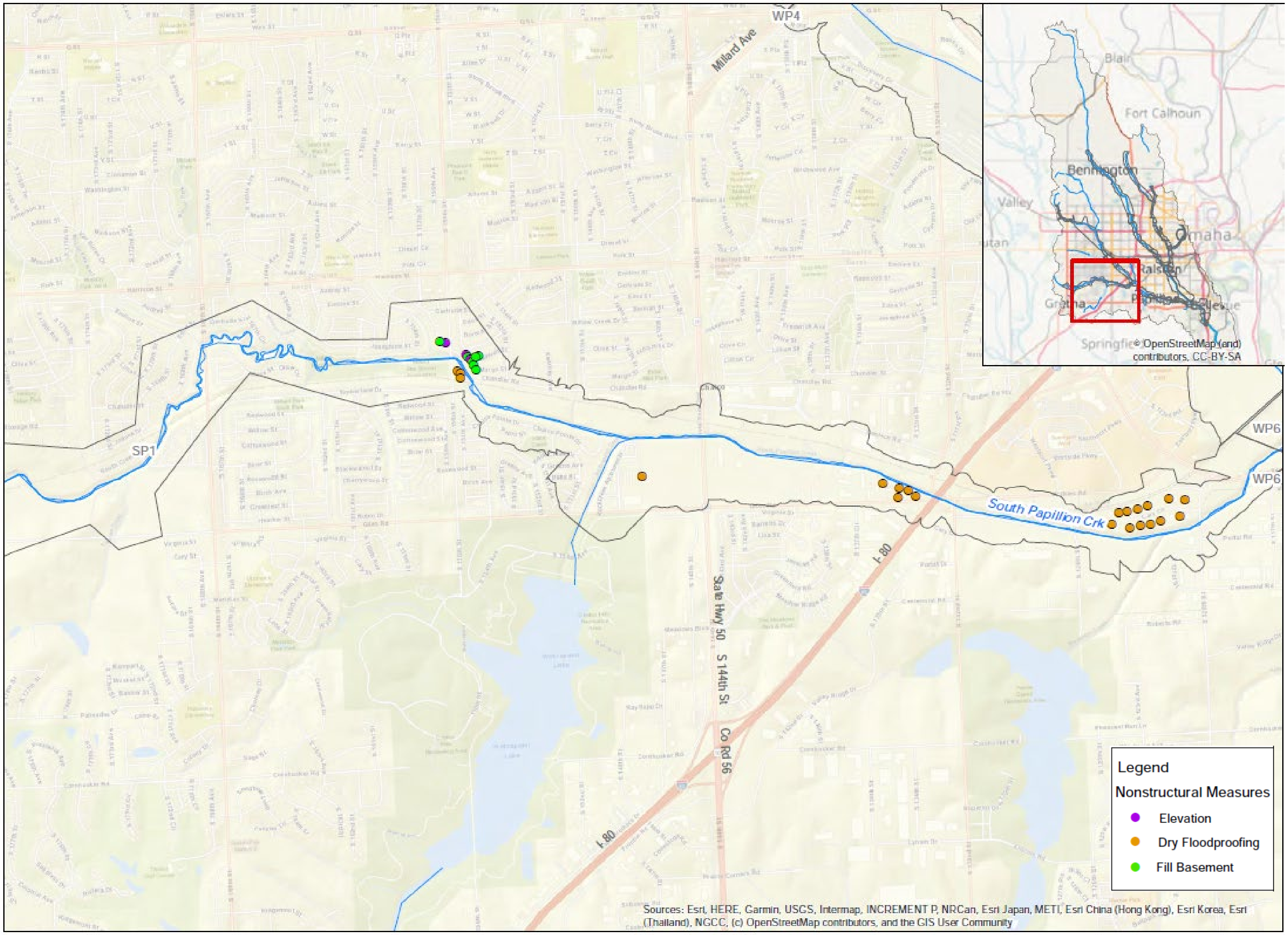

Figure 18. Recommended Plan for Nonstructural Measures: South Papillion Creek

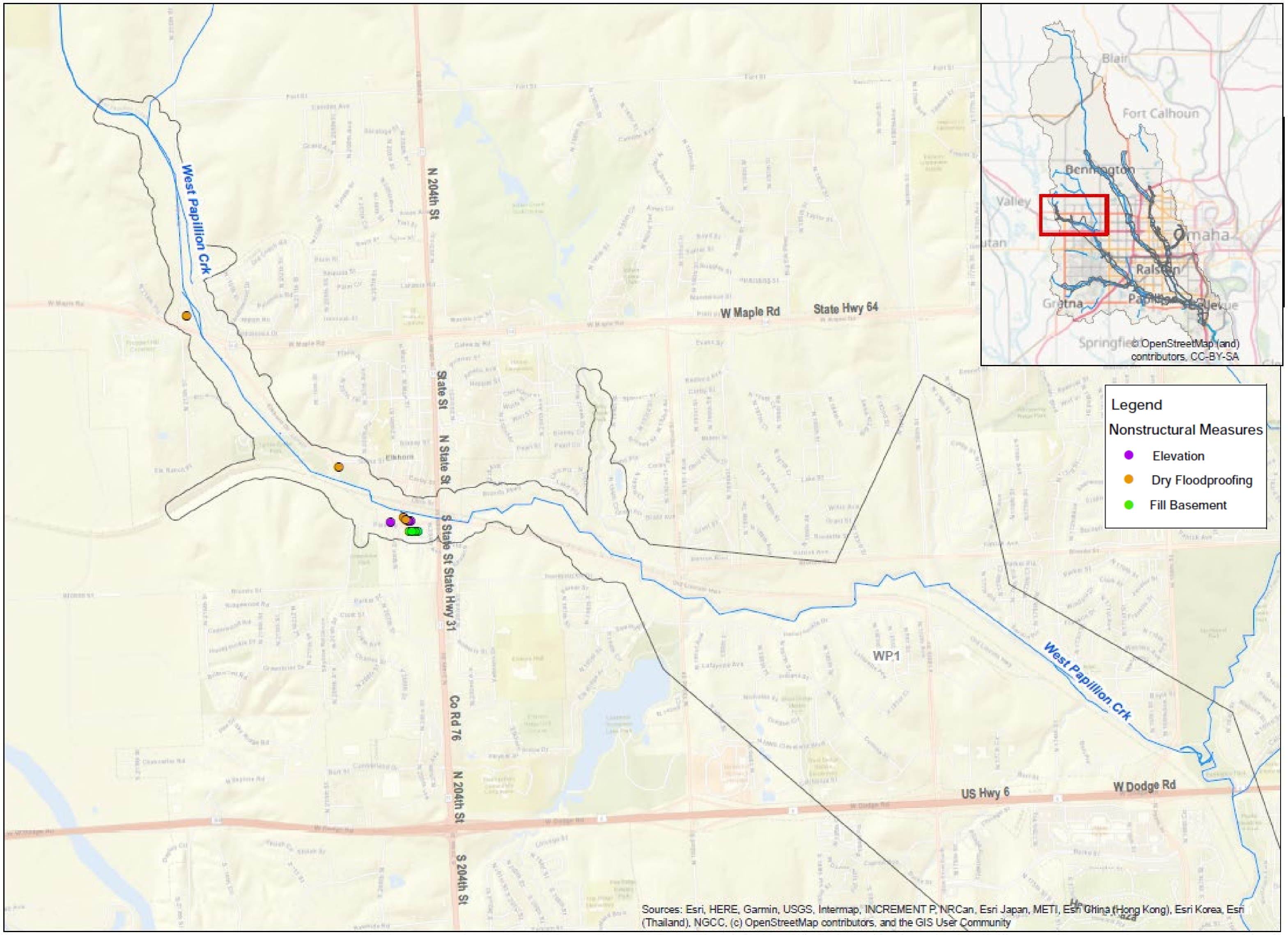

Figure 19. Recommended Plan for Nonstructural Measures: West Papillion Creek Reach 1

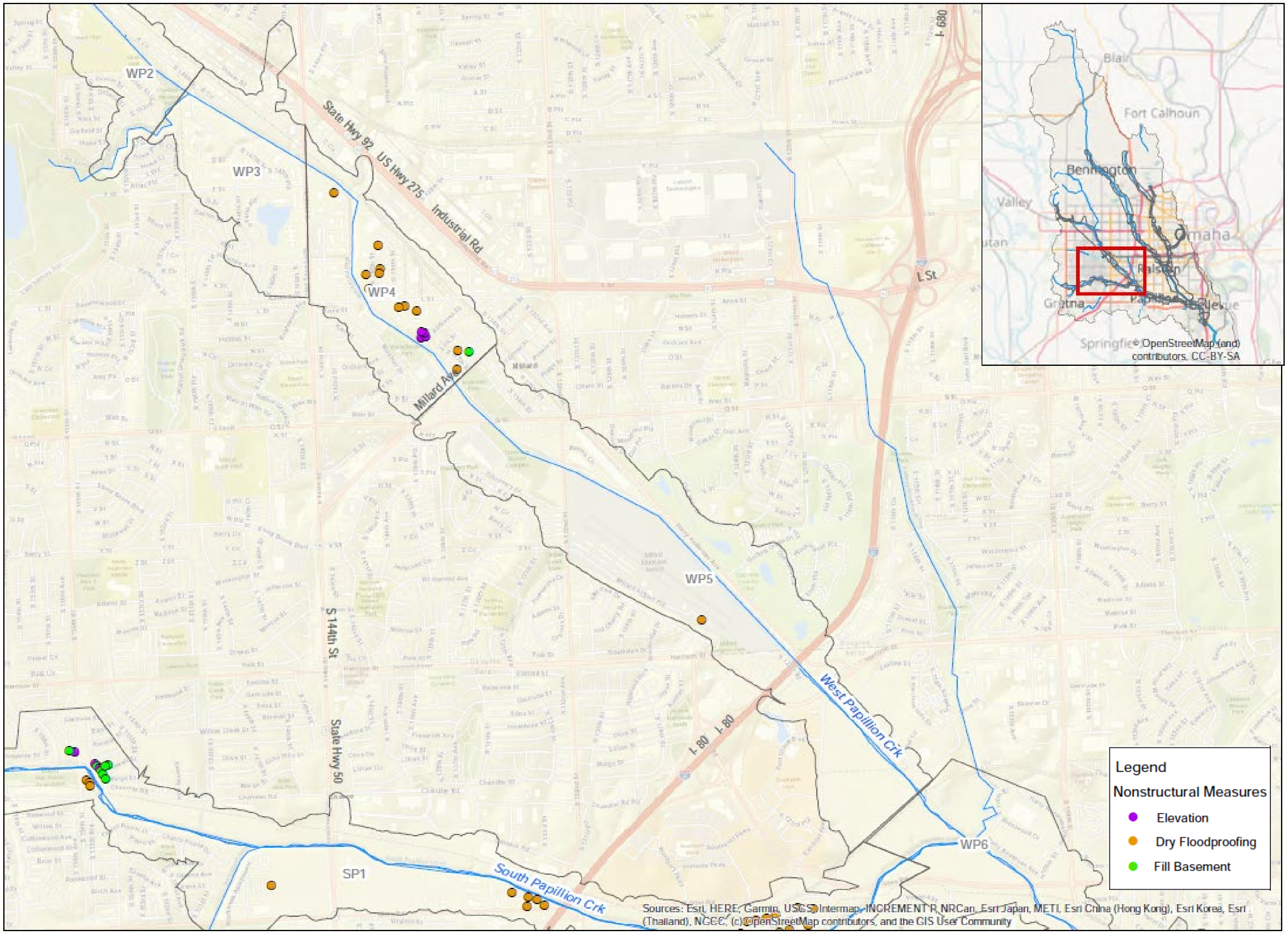

Figure 20. Recommended Plan for Nonstructural Measures: West Papillion Creek Reach 4 and 5

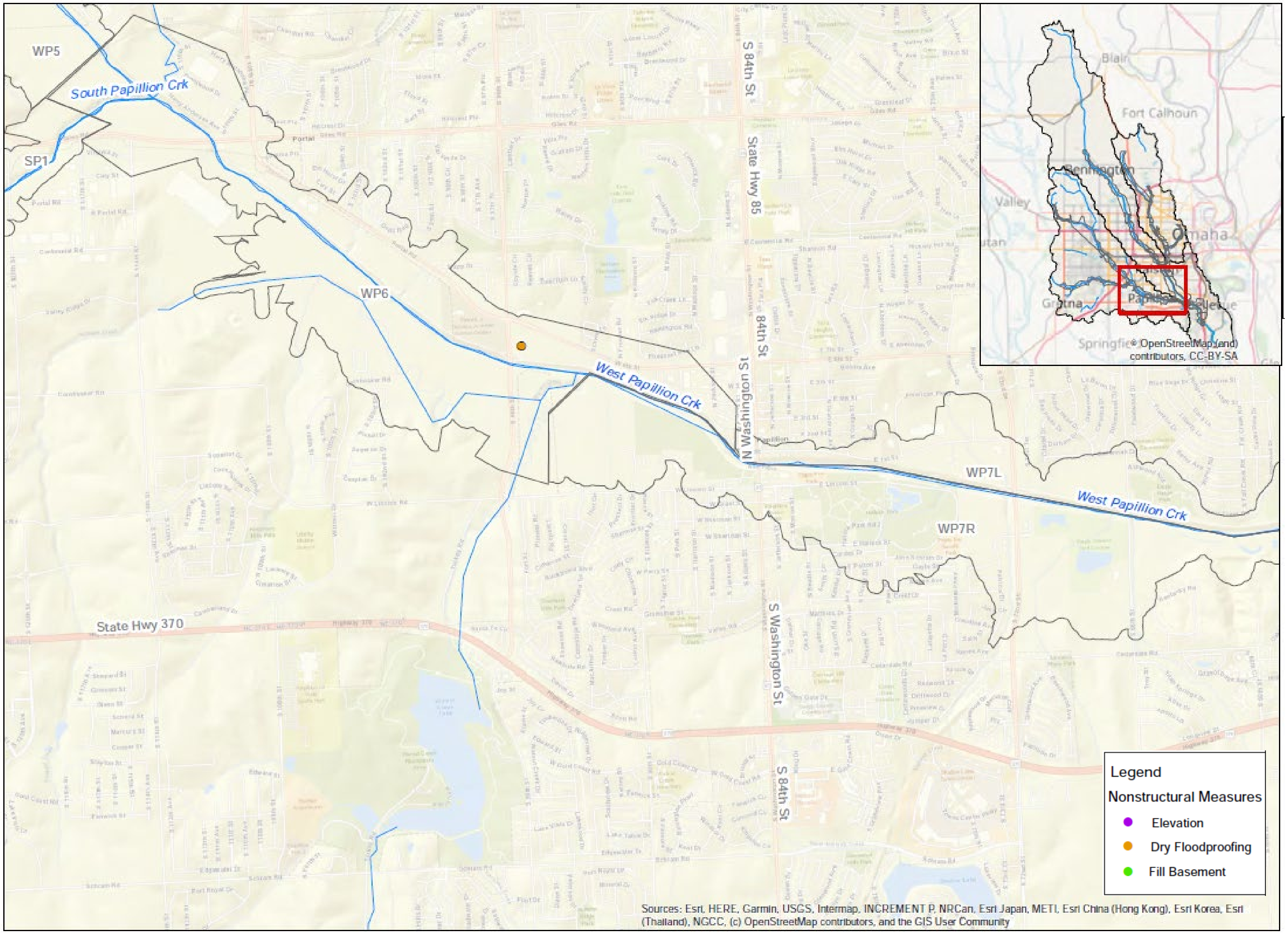

Figure 21. Recommended Plan for Nonstructural Measures: West Papillion Creek Reach 6

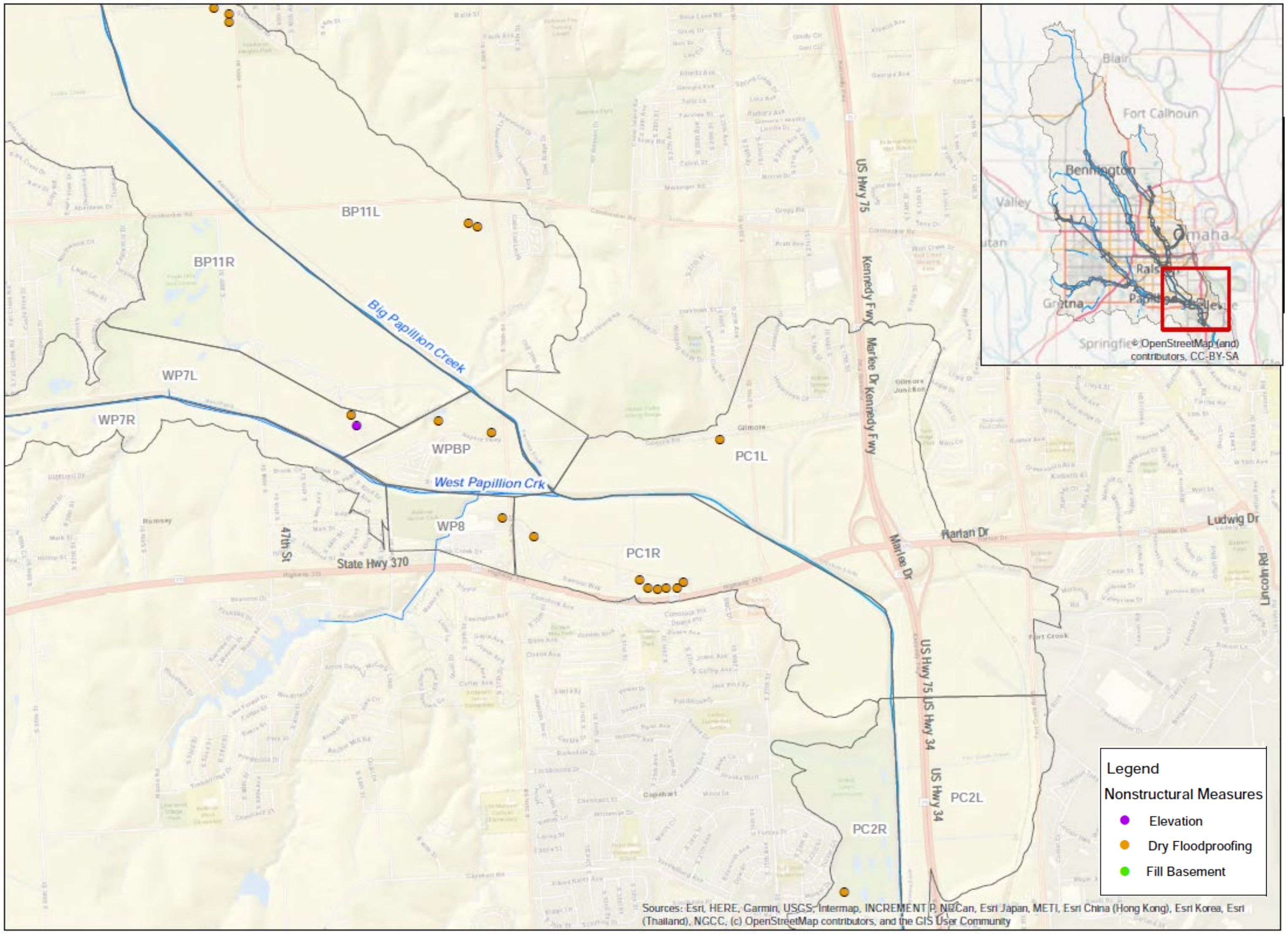

Figure 22. Recommended Plan for Nonstructural Measures: Papillion Creek

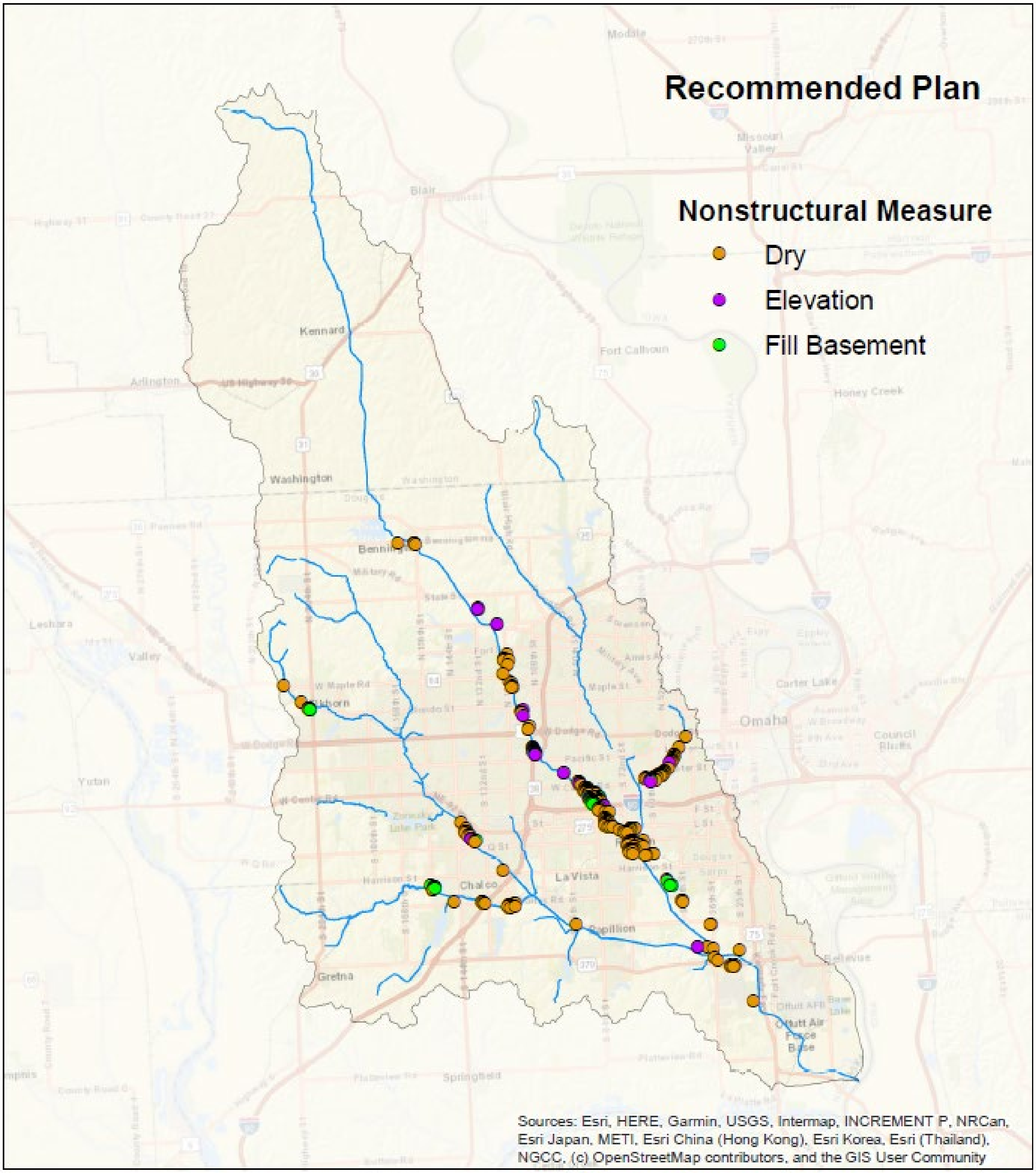

Figure 23. Recommended Plan for Nonstructural Measures: Overall Map

8.0 Implementation of Nonstructural Measures

The jurisdictions within the Papillion Creek Watershed require Floodplain Development Permits for any construction within the SFHA. The permits ensure the construction is meeting the requirements of the NFIP and the local floodplain management ordinances.

None of the nonstructural measures evaluated would allow the buildings to be safely occupied during flooding. Community outreach initiatives, such as providing flood information flyers and updating the flood warning system, can increase the awareness of flood risk among residents, which can lead to better response time in the event of a flood. Implementation of the project would include the development of a flood preparedness and evacuation plan paired with the existing flood warning system, and encourage residents to sign up for the wireless emergency alert system that Omaha uses, this system will send alerts directly to people's cellphones in the vicinity of the hazard.

During preconstruction engineering and design (PED) more detailed evaluations will be conducted for each building that may qualify for nonstructural measure implementation. Site inspections will verify that the technical assumptions used for selecting the nonstructural measure for each building were appropriate or may determine a more appropriate nonstructural measure. A preliminary design for the nonstructural measure for each building will be developed and an analysis of the elevation heights will be optimized. Participation in nonstructural mitigation measures is voluntary and would be confirmed during this time.

The selected nonstructural plan consists of the following nonstructural measures:

1. Elevation and basement fill of eligible residential structures to the 1% AEP flood elevation plus one foot.
2. Dry or wet floodproofing of eligible non-residential structures to the 1% AEP flood elevation plus one foot or a maximum floodproofing height of 4 feet.

Interested property owners will be informed of the details of implementation of the nonstructural measures of the project, including eligibility criteria and related US Army Corps of Engineers (USACE) engineering and management requirements by written notice. It is anticipated that implementation of the tentatively selected nonstructural plan will occur over a phased implementation period of approximately 5-10 years. However, the scale of the project is highly dependent upon the participation rate for implementation and the amount of allocated funding in any given year. If a structure owner does not want to participate in the project, USACE and the non-Federal Sponsor would defer any further action on that structure until such time as the structure owner elects to participate or until the period of eligibility ends. However, USACE reserves the right to determine whether or not a structure may be included in the nonstructural implementation after a structure owner has previously declined participation, and if allowed to participate, the timing and scheduling of such participation will not adversely impact the project.

9.0 References

Code of Federal Regulations, Emergency Management and Assistance, Title 44, 2011.

City of Bellevue Zoning Ordinance (Ordinance 3619) - Effective August 8, 2011.

City of Bennington Zoning Ordinance (Ordinance 460) - Effective June 9, 2019.

City of Gretna Zoning Ordinance (Ordinance 2000) - Effective July 5, 2017, Modified July 3, 2018.

City of LaVista Zoning Ordinance (Ordinance 848) - Effective November 20, 2001.

City of Omaha Floodplain Ordinance (Ordinance 39946) - Amended March 18, 2014, Effective May 19, 2014.

City of Omaha Municipal Code, codified through Ordinance No. 41868, enacted June 25, 2019. (Supp. No. 80, update 3).

City of Papillion Zoning Ordinance (Ordinance 1200) - Effective September 19, 1995.

City of Ralston Zoning Ordinance by Article http://www.cityofralston.com/zoning.html accessed August 15, 2019.

Douglas County Zoning Regulations by Article https://www.dceservices.org/mobile-landuse/zoning-regulations accessed August 15, 2019.

Federal Emergency Management Agency; Floodproofing Non-Residential Buildings; FEMA P-936; June 2013.

Federal Emergency Management Agency, Office of Community Development, Disaster Recovery Unity, Hazard Mitigation Program; Procedure Number 1, Revision Number 11; "Elevation Cost Guide", January 15, 2013.

Papio-Missouri River Natural Resources District (P-MRNRD), Multi-Jurisdictional Hazard Mitigation Plan, February 2016.

Sarpy County Building Codes - Effective January 1, 2017.

U.S. Army Corps of Engineers, National Nonstructural Flood Proofing Committee; Flood Proofing Tests, Tests of Materials and Systems for Flood Proofing Structures; August 1988.

U.S. Army Corps of Engineers, Engineering Regulation (ER) 1100-2-100, Planning Guidance Notebook. U.S. Army Corps of Engineers, 10 October 2003.

U.S. Army Corps of Engineers, National Nonstructural Flood Proofing Committee; Raising and Moving the Slab on Grade House with the Slab Attached; 1990.

Washington County Zoning Resolution (Resolution 2005-19) - Effective June 14, 2005.