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Database on coastal vulnerability and exposure

COAST project

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1 Introduction

The coastal zone is an area of high interest, characterized by increased population density, hosting important commercial activities and constituting habitats of high socioeconomic value (Costanza, 1999). Nearshore areas also support diverse ecosystems that provide important habitats and sources of food. One third of the EU population lives within 50 km of the coast. Globally about 120 million people are exposed annually to tropical cyclone hazards, which killed 250,000 people from 1980 to 2000. The EU Strategy on Adaptation to Climate Change stresses that coastal zones are particularly vulnerable to the effects of climate change. This is due to the combined effects of sea level rise and potential changes in the frequency and/or intensity of storms. In recent years, substantial research effort has focused on several aspects of coastal hazard and risk in view of climate change (Church and White, 2011; Hinkel et al., 2014; Hogarth, 2014; Hoggart et al., 2014; Jevrejeva et al., 2014; Losada et al., 2013).

In this document, we report progress on the development of European layers on exposure and vulnerability. This involves the collection and cataloguing of relevant exposure factors (e.g., land use, population, settlements, infrastructures) and vulnerability indicators (coastal flood protection, damage functions) as well as the development and application of tools for the logging, spatial interpolation, statistical analysis and validation of the collected information. All data are available through the *The Risk Data hub database* the aim of which is to improve the accessibility and dissemination of EU-wide curated risk data for fostering Disaster Risk Management (DRM).

2 Exposure

Exposure refers to the capital and human assets exposed to the hazard. These are typically expressed by statistics on population, socio-economic data on sectorial activities and infrastructure, and information about environmental variables. To assess impacts in coastal zones in Europe the following exposure information has been collected:

Geographical data

SRTM Digital Elevation Model - NASA provides the Shuttle Radar Topographic Mission (SRTM) digital elevation model (DEM) version 4.1 freely to the public in efforts to increase the use of geospatial science for sustainable development and analysis in developing countries. For a good overview of the data please visit the webpage: http://srtm.csi.cgiar.org/index.asp.

Land Cover

Corine Land Cover is a compilation of national land cover inventories, which are integrated into a seamless land cover map of Europe. For a good overview of the data please visit the webpage:http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-2006-raster-2

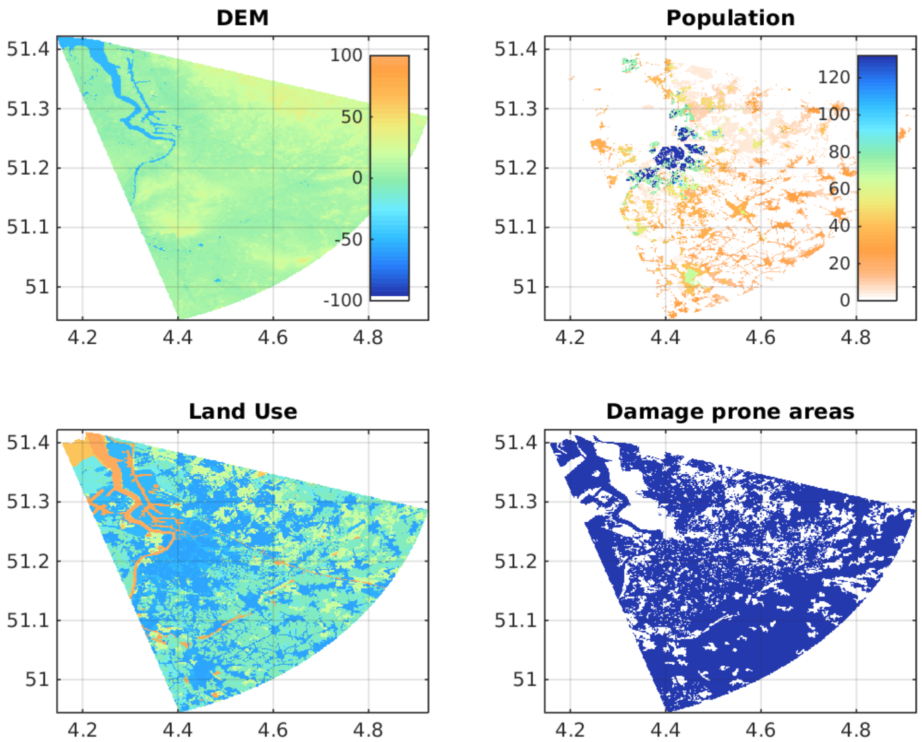

Figure 1. Example of coastal segment data: Digital Elevation Model, Population, Land Use and Damage Prone areas according to the land use and the depth damage functions.

Current population

A 100 m resolution population grid map for Europe has been derived for the year 2006 based on a refined version of Corine Land Cover 2006 (with a minimum mapping unit of one hectare for artificial surfaces (Batista e Silva et al., 2013), combined with information on the soil sealing degree.

Current land use

A refined version of the Corine Land Cover 2006 map with an improved minimum mapping unit of 1 hectare for all types of artificial surfaces and inland waters has been generated by incorporating land use/cover information present in finer thematic maps available for Europe. These include the CLC change map, Soil Sealing Layer, TeleAtlas® Spatial Database, Urban Atlas, and SRTM Water Bodies Data. Relevant data from these datasets were extracted and prepared to be combined with CLC in a stepwise approach. Each step increased the level of modifications to the original CLC. The spatial resolution of the map is 100 x 100 m (Batista e Silva et al., 2013).

Critical infrastructures

A wide range of existing infrastructures and key economic assets in the EU have been mapped, including the following:

a. Energy assets (e.g., nuclear and thermal power plants, renewable energy infrastructure)
b. Transport assets (e.g., roads, railways, ports)
c. Social infrastructure (e.g., education, health)
d. Industry (e.g., chemical, metals, waste treatment)
e. Nature protection (e.g., NATURA sites)

These exposure layers are currently being collected at European scale and integrated in a GIS environment (also in view of the AA "Resilience of large investments in Europe to climate change (CCMFF)" between JRC and DG CLIMA). An effort is currently under way to extract only the information relevant to the coastal zone from the pan-European datasets, thus reducing substantially the amount of data and the computational times. These layers can then be combined with the inundation maps generated in the previous step and information on the vulnerability of the exposed assets.

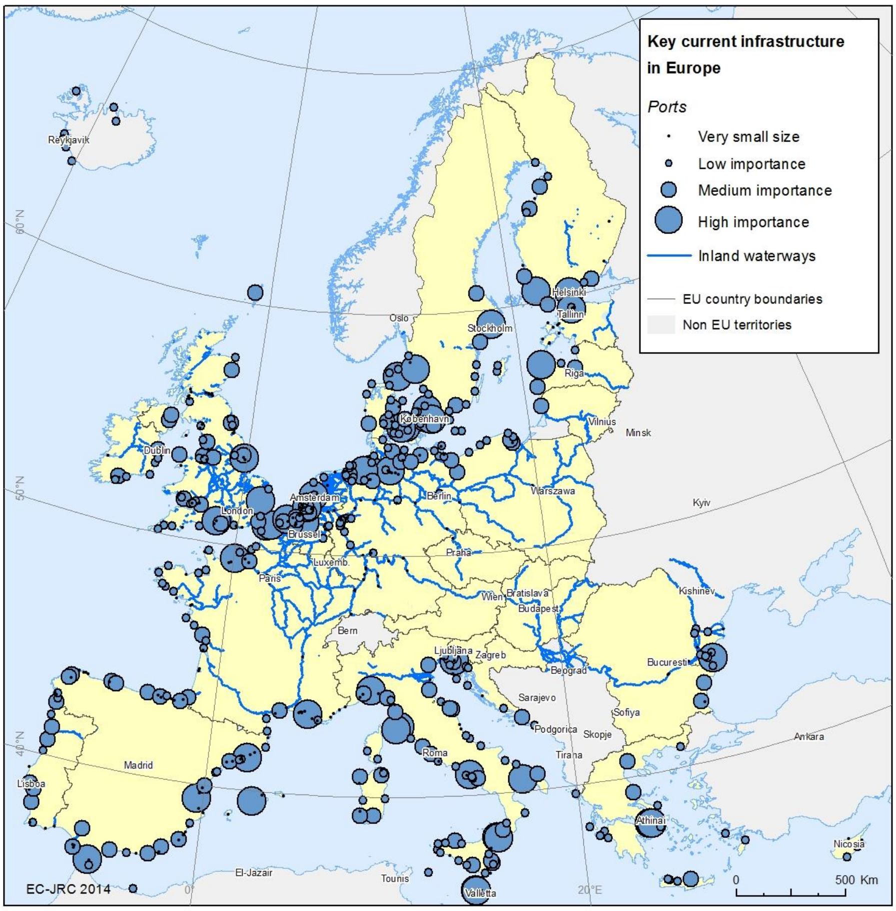

Figure 2. Example of key infrastructures in Europe at potential risk from coastal hazards: Ports.

3 Vulnerability

Depth Damage Functions: Vulnerability refers here to the susceptibility of the receptor to be adversely affected by the coastal flood hazard and can be seen as an internal characteristic of the affected element. This includes the capacity to anticipate, cope with, resist, and recover from the adverse effects of the physical event. The vulnerability to coastal flooding of coastal infrastructure, societies and ecosystems is expressed in this work through depth-damage functions (Ciscar et al., 2014; Rojas et al., 2013). JRC has an extensive database of country-specific depth-damage functions (DDFs) that relate water depth with exposed assets and the resulting economic damage. The country based DDFs are piece-wise linear functions from 0 to 6 meters flood depth, defined for each of the 45 land use classes included in the refined CORINE Land Cover (e.g. see; Figure 3). To account for differences in the distribution of wealth within countries, national DDFs were further rescaled to NUTS3 level on the grounds of GDP per capita.

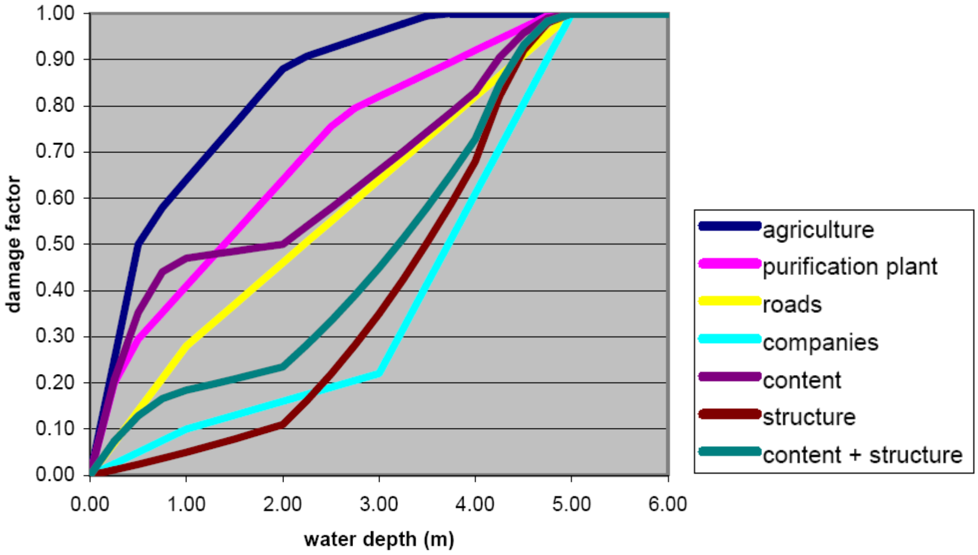

Figure 3. Example depth-damage functions showing relationship between flood water depth and damage factor per land use class (note that damage factors are normalized and need to be rescaled with maximum damages per land use class prior to their application).

Coastal protection: Starting with the FLOPROS database (Scussolini et al., 2015), all available data on coastal protection in Europe were compiled from open databases and national authorities (https://www.gov.uk/government/organisations/environment-agency; Vafeidis et al., 2008; www.ahn.nl). For several countries baseline inundation maps and losses for different return periods were also available from national reports and datasets (BRGM, 2009; Paprotny and Terefenko, 2017; Portuguese Environment Agency, 2014; Prefet de la region Centre, 2014; Rijkswaterstaat, 2012; UK Environmental Agency, 2015; Verwaest et al., 2012). The compiled information allowed carrying out a regional or country-level calibration of the protection standards; which were adjusted in order to reproduce the reported present day impacts as in Jongman et al (Jongman et al., 2014) using the LISCOAST tool (Vousdoukas et al., submitted).

4 The Risk Data Hub database conceptual model

The DRMKC RiskData Hub will host various geospatial data, technologies and methodologies coming from different sources (projects, organisations and scientists). In order to share all these resources, the platform will promote data sharing on the concept of open data and open technologies. Moreover, a set of standards will be adopted as a strategy for rendering the spatial data and associated technologies easily accessible and to support a seamless interaction between users and the resources hosted on the platform. Furthermore, DRMKC RiskData Hub will provide technology where the users will not only be able to access the database but also will become the main participants for producing and updating the required data.

4.1 Standards

Standards are technical specifications that clarifies the interaction between users and data. These standards pertain to data (data capture, encoding, data quality, data delivery, metadata) as well as to services and tools used to communicate it. All together the identified standards related to spatial data and communication protocols of the web-based platform, enhance the interoperability of the system.

Standards that allow access to integrated spatial data or metadata through a HTTP protocol defined by Open Geospatial Consortium (OGC; http//:www.opengeospatial.org):

- Web Feature Service (WFS) specifications gives access to data sets
- Web Coverage Service (WCS) specifications gives access to raster data
- Web Map Service (WMS) offers the ability of accessing georeferenced images of vectors and raster data

Standards that allow to document data and related services through metadata using International Organisation of Standardization (ISO; http://www.iso.org):

- ISO 19115 for resource metadata
- ISO 19139 for metadata encoding
- ISO 19119 for service metadata

In addition, the INSPIRE directive, adopted for DRMKC RiskData Hub provides the basis for the interoperability of spatial data by establishing harmonised conditions of access by public, EU institutions and organisations to spatial data and services.

4.2 Community of Users

Various communities covering research, policy and operational actors, which have their own specificities but also present a common goal of overall risk management will form the community of users for Risk Data hub database. The diversity and cross-discipline disseminated data and results, render the community users as both data providers and also end-users. Therefore, Risk Data hub database intends to create conditions to enhance a network for information transfer among various involved communities.

The data providers are mainly the research groups from the EU's Joint Research Centres which are also collaborating centres of DRMKC - European Flood Awareness System (EFAS), European Forest Fires Information System(EFIS), Global Disasters Alerts and Coordination System (GDACS), Major Accident Reporting System (eMARS), Global Informal Tsunami Monitoring System (GTIMS-2), European Reference Network for Critical

Infrastructure Protection (ERNCIP), - and also EU-funded research projects developed through programmes such as Horizon 2020 and the Framework Programme for Research and Technological Development (FP7).

Complementary to data providers the end-users represent a complex and ambitious challenge as they include a wide variety of stakeholders. The user community of the DRMKC are multinational, cross-discipline scientists, policy-makers and practitioners. They are dispersed into different disciplines and sectors and often they are working independently on overlapping crisis situations. They can be divided in five main categories of users:

Policy Makers

At EU level, the main policy DGs concerned with Disaster Risk Management are DGs, ECHO, ENTR, ENV, ENER, MOVE etc.

At Member State's level, Ministries of Defence, Interior, Foreign Affairs, Civil Protection, Industry, Agencies as well as Regional Authorities all benefit from research outputs.

Benefits:

- Use of curated and scientifically based data needed for policy implementations.
- Compare implementation development among countries and regions.
- Get an overview of research results in disaster risk management.

Scientists

Disaster risk assessment research involves a wide range of scientific disciplines which have to interact, ensuring complementarity and building interdisciplinary networks. Different types of scientists are considered (University, Research Institutes, research units linked to Defence/Interior ministries or agencies);

Benefits:

- Publish and share EU and regional data to turn their research into operational services and policy advice;
- Identify cross-border platform and data commonly used by Policy-Makers and Practitioners;
- Participate in multi-disciplinary, cross-border scientific partnerships and offer expertise to civil protection and disaster risk management authorities.

Private Sector

Various industry branches and stakeholders in the areas of infrastructure, energy, defence, civil protection etc.
Benefits:

- Access tested innovative solutions for crisis management and practical advice on adoption of new research and technology.
- Be aware of curated and updated data and initiatives from EU organisations;

General public

Various NGOs, public at large and users form the Education (schools) and training bodies.
Benefits:

- Get situation awareness and general information on disaster risk from regional to global disasters;
- Join a Community of Users, collaborating to share data, and even help in developing database on losses and damages

5 Implementing the pilot Risk Data hub database

DRMKC RiskData Hub is a web-based application that aims to offer a technological solution for freely visualize access, download and link to geospatial data on disaster risk and determinants of risk at EU-wide scale.

5.1 Data Storage - general aspects

Two types of implementation are considered for the data storage: the file system and the database.

File system – is the simplest form of storage for a web GIS that is usually used when the amount of data is relatively small. The advantage of this type of storage comes from the fast, secure manner it can be handled and maintained. However, the server needs to be able to examine the changes that are brought to the content of the file which sometimes is done by many concurrent users.
Database – is a collection of data and the structures used to represent that data - most commonly used are tables. Each row of the table is depicting an object and each column defines the attributes. Using a database to store spatial data has some advantages:

- Attributes and geometry of features are stored together.
- Spatial databases allow you to perform spatial queries and manipulate geometry with functions.
- Multiuser-support: share data among users and manage rights to access data.

5.2 Data distribution – general aspects

The communication between the client and the server needs to be performed in a standardized way. The standardized HTTP communication protocol and OGC web Services, which are standardized HTTP interfaces for exchange of spatial data between client and server are the processes chosen for data distribution.

Hypertext Transfer Protocol (HTTP) is a standardized communication protocol for the World Wide Web (WWW). It uses Uniform Resource Identifiers (URI) to identify the path to the resource (W3 2016a).

OGC Web Services refers to a set of standards defined for publishing raster and vector data over the web (OGC 2016b). These standards define on how to request or send spatial data over a network, considering the format of the data, the extent and in what coordinate system the extent is defined. The most commonly used operations that ensure spatial data distribution are:

- Web Map Service (WMS) defines an interface that allows a client to retrieve georeferenced images/data (raster or vector data)
- The Web Feature Service (WFS) used for exchanging vector data
- The Web Coverage Service (WCS) used for retrieving the raw raster data
- The Web Processing Service (WPS) provides a standard for geospatial processes implemented as web services.

5.3 Risk Data Hub database development

The DRMKC database is currently accessible at the following link: https://disastergeonode.jrc.ec.europa.eu/ and it is supported on the following architecture:

- ***PostgresSQL and PostGIS*** is an open source Database Management System (DMS);
- ***GeoNode*** open-source software that will enable share of disaster risk datasets and enhance public access.
- ***GeoServer*** is an open source software server;

5.4 System architecture

The Risk Data hub database is currently implemented following the software architecture as shown in the figure below. GeoNode is a geographic Content Management System (CMS), mainly aimed at collaborative sharing and editing of geographic layers and maps and it is composed by:

- A Database Management System and its spatial extension: PostgreSQL and PostGIS
- A server-side software which can provide standard Web Map Services: GeoServer;
- A CSM framework: Django;
- Client-side libraries for building WebGIS applications: OpenLayers, GeoExt and LeafletJs.

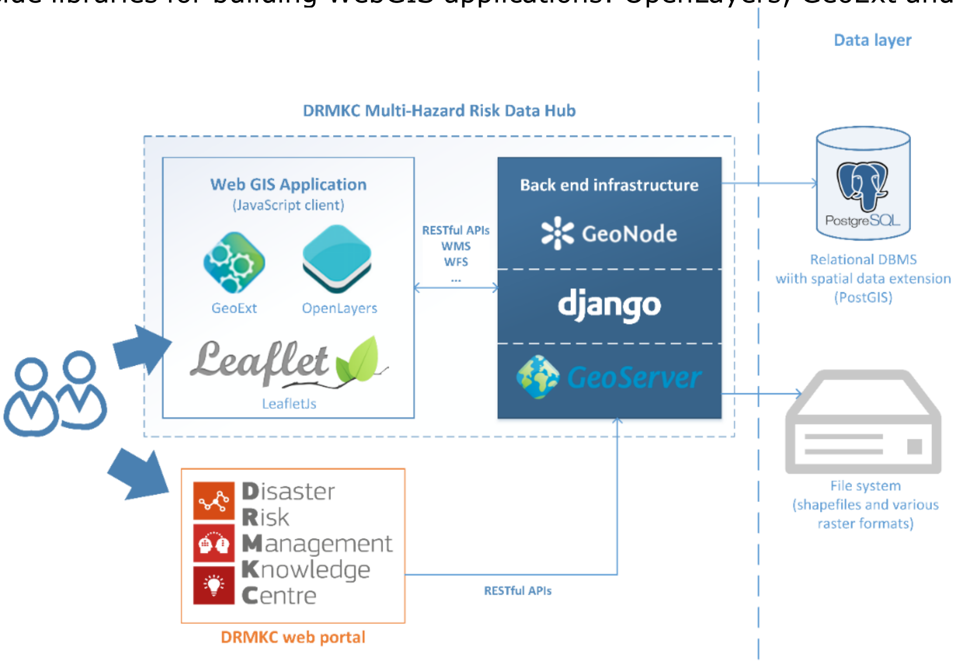

Figure 4. Schema of the Multi-Hazard Risk Data Hub architecture, based on the Geonode technology stack. The hub will be also integrated with the DRMKC web portal (e.g. for displaying the latest published layers) through the RESTul web services made available by GeoNode.

PostgresSQL and PostGIS is an open source Database Management System (DMS) that combines a relational database model and an object-oriented database model, which is commonly used in GIS and is called Object-Relational database (PostgresSQL, 2016). This model structures data in tables and provides all the functionality of a relational database.

For the RiskData Hub, the GeoNode/PostgresSQL has a double function: first it works in support of the GeoNode website, being the place where all the information about the users, groups and instruments is stored. Secondly it works as a data repository for geospatial data using the PostGIs extension. For the DRMKC database the geospatial data is stored both as vector (.shp) and gridded data (.tif).

GeoServer is an open source software server written in Java that allows users to publish geospatial data. It performs 3 main activities: stores, renders and transforms geographical content showed by the GeoNode in a graphic format. GeoServer is able to serve map data in a variety of formats and is fully OGC compliant (GeoServer, 2016)

Django is a framework for building web applications and in particular Content Management Systems (Django, 2016). It provides the foundation to GeoNode logic components, in particular in relation to modelling, classification, querying and navigation, as well as user and group-based permission management for viewing and editing data.

OpenLayers, GeoExt and **LefletJs** are all javascript libraries especially aimed at the management of GIS information. In particular, GeoExt (GeoExt, 2016) relies on OpenLayers for displaying geographical information retrieved from standard OGC web services. In addition, it uses the ExtJS UI framework for enabling desktop-like GIS functionalities such as advanced querying of features and style editing. However, the *GeoExt*/*ExtJs* (OpenLayers, 2016) version currently used by GeoNode is not aligned with the latest implementation of these software tools.

LeafletJs is an alternative, lightweight map client which has become increasingly popular in the community of web GIS developers. It has a plugin-based architecture and offers better responsiveness on mobile devices.

5.5 Data storage

The main datasets stored in the DRMKC databases are:

- Spatial Data, both raw and aggregated (at administration units) representing risk and determinants of risk data (exposure, vulnerability, hazard).
- Geospatial data: layers of administration boundaries, Geophysical features, Digital Elevation Model, etc.)
- Metadata: in accordance with INSPIRE recommendations and stored in the Database Management System (PostgresSQL and PostGIS).

5.6 Data access

The database is accessible only by the server. Access rules are set to strict, meaning that there exists no public URL pointing to the folder and the DBMS endpoint.

User access to data is therefore managed only by the web application, either via the GeoNode-enabled web pages and RESTful APIs or via the OGS-compliant web services provided by GeoServer.

The permission structure in GeoNode permits the restriction of access and editing right of certain layers either to specific users, or to all those belonging to a certain group.

5.7 Data representation

Data is represented in a variety of formats depending on the specific purpose and user requirements. In particular, raw, continuous data is represented as raster layers (.tif) and served via WMS tiled services, while information aggregated at level of NUTS administrative level is represented as vector feature classes, and is later available to the client both via WMS and WFS services. WFS enable for better interactivity on the client side. To allow for faster loading of data, GeoJSON data format is an option. However, the GeoNode/GeoServer architecture still enables access to resources using standard OGC formats for INSPIRE compliant interoperability with future third-party applications.

The main entities included for aggregated vector layers are: NUTS_ID, Nuts_name, their coordinates system, statistical indicators names (for hazard, risk, vulnerability and exposure) with their value.

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