

**Paraguayan Space Agency
Republic of Paraguay**

Project Completion Report

Project for Management of Space Program Applied to the Socioeconomic Development in the Republic of Paraguay

October 2025

**Japan International Cooperation Agency
(JICA)**

**Japan Space Systems
PASCO CORPORATION
Japan Space Forum**

GP
JR
25-025

1 USD = 147.077000 JPY
1 PYG = 0.020540 JPY

(September 2025)

List of Abbreviations

#	Abbreviation	Japanese	English	Spanish
1	AEP	パラグアイ国宇宙機構	Paraguayan Space Agency	Agencia Espacial del Paraguay
2	DMH	国立気象水文総局	Director of Meteorology and Hydrology	Dirección de Meteorología e Hidrología
3	EM	エンジニアリングモデル	Engineering Model	-
4	INE	国家統計局	National Institute of Statistics	Instituto Nacional de Estadística
5	INDERT	土地開発局	National Institute of Rural and Land Development	Instituto Nacional de Desarrollo Rural y de la Tierra
6	INFONA	国家森林局	National Forestry Institute	Instituto Forestal Nacional
7	IPTA	パラグアイ農業技術機構	Paraguayan Institute of Agricultural Technology	Instituto Paraguayo de Tecnología Agraria
8	ISS	国際宇宙ステーション	International Space Station	-
9	JAXA	宇宙航空研究開発機構	Japan Aerospace Exploration Agency	-
10	JCC	合同調整委員会	Joint Coordination Committee	-
11	JICA	国際協力機構	Japan International Cooperation Agency	Agencia de Cooperación Internacional del Japón
12	Kyutech	九州工業大学	Kyushu Institute of Technology	-
13	MADES	環境持続開発省	Ministry of Environment and Sustainable Development	Ministerio del Ambiente y Desarrollo Sostenible
14	MAG	農牧省	Ministry of Agriculture and Livestock	Ministerio de Agricultura y Ganadería
15	MEF	経済開発省	Vice-Ministry of Economy and Planning	Ministerio de Economía y Finanzas
16	MOPC	公共事業通信省	Ministry of Public Works and Communication	Ministerio de Obras Públicas y Comunicaciones
17	PEI	制度的戦略計画 2018-2023	Plan of Institutional Strategy 2018 - 2023	Plan Estratégico Institucional 2018-2023
18	SDGs	持続可能な開発目標	Sustainable Development Goals	Objetivos de Desarrollo Sostenible
19	SEN	国家緊急事態庁	National Emergency Secretary	Secretaría de Emergencia Nacional
20	SENAVE	国家植物種子品質研究所	National Plant, Seed Quality and Health Service	Servicio Nacional de Calidad y Sanidad Vegetal y de Semillas
21	UCA	カトリカ大学	Catholic University	Universidad Católica
22	UNA	アスンシオン国立大学	National University of Asuncion	Universidad Nacional de Asunción
23	WG	協議体	Working Group	

List of Figures

Fig. 1.5-1.	Sites of AEP Headquarters/GEOLab, SPACELab and Pilot Project Site (Disaster)	5
Fig. 1.5-2.	Sites of AEP Headquarters and Pilot Project (Agriculture-livestock)	5
Fig. 1.8-1.	Period and Implementation Plan of the Project	8
Fig. 1.9-1.	Implementation Structure	9
Fig. 1.10-1.	Goals of SDGs Which the Project Aimed	10
Fig. 2.1-1.	Structure of AEP (as of July 2025)	12
Fig. 2.1-2.	Structure of AEP (Expected in 2028)	13
Fig. 2.2-1.	AEP's Role as Space Tech Hub by Public-Private-Academia Space Cooperation with Japan	15
Fig. 3.3.6-1.	Pre-Field Survey before Pilot Project (Disaster)	36
Fig. 3.3.6-2.	Pre-Field Survey before Pilot Project (Agriculture-livestock)	37
Fig. 3.3.7-1.	Field Survey Location	50
Fig. 3.3.7-2.	Photo of Field Survey (Left: Building of residence, Right: Wetland)	50
Fig. 3.3.7-3.	Pilot Project Schedule for Disaster Prevention Field	51
Fig. 3.3.7-4.	Pilot Project Flowchart for Disaster Prevention Field	51
Fig. 3.3.7-5.	Certificate for Training	53
Fig. 3.3.7-6.	Flood Hazard Map (Left: Norte Area, Right: Sur Area)	55
Fig. 3.3.7-7.	Manual and Flood Hazard Map Dashboard	55
Fig. 3.3.7-8.	Photo of Disaster Prevention in the Workshop	56
Fig. 3.3.8-1.	Location Map and Overview of the Target Area	60
Fig. 3.3.8-2.	Example of Growth Maps Created by AEP	62
Fig. 3.3.8-3.	Scenes from Field Surveys	63
Fig. 3.3.8-4.	Prototype Crop Classification Map Predicted Using Google Earth Engine (GEE)	63
Fig. 3.3.8-5.	Overview of the Satellite Data Utilization Manual for the Agriculture and Livestock Sector	64
Fig. 3.3.8-6.	Scenes from the Workshop	64

List of Tables

Table 1.3-1.	Overall Goal and Project Purpose	4
Table 1.4-1.	Outputs of the Project	4
Table 1.5-1.	Sites of the Project	4
Table 1.7-1.	Working Group for Disaster Management	6
Table 1.7-2.	Working Group for Agriculture-livestock	6
Table 1.7-3.	Derived Projects	7
Table 2.2-1.	Purposes of the Strategic Plan 2024-2033	14
Table 3.1.1-1.	Experts	16
Table 3.1.1-2.	Equipment Procured in the Project	17
Table 3.1.1-3.	Satellite Data for Agriculture-livestock: PlanetScope	17
Table 3.1.1-4.	Satellite Data Procured for Agriculture-livestock: GRUS	25
Table 3.2-1.	PDM (First Version)	27
Table 3.2-2.	Revisions of PDM	29
Table 3.3.2-1.	List of Reports	30
Table 3.3.3-1.	Schedule of Baseline Survey	31
Table 3.3.3-2.	Schedule of Endline Survey	31
Table 3.3.4-1.	Overviews of Meetings of JCC	32
Table 3.3.5-1.	List of Monitoring Sheet	32
Table 3.3.6-1.	Overview of results from the government ministries, universities, and institutions' interview	34
Table 3.3.6-2.	Evaluation for Space System Utilizations by Endline Survey	35
Table 3.3.6-3.	KCCP (Upstream Training Schedule) (1st Batch)	38
Table 3.3.6-4.	KCCP (Upstream Training Schedule) (2nd Batch)	40
Table 3.3.6-5.	KCCP (Downstream Training Schedule)	42
Table 3.3.6-6.	KCCP (unit objectives)	44
Table 3.3.6-7.	Companies, academia and government organizations collaborated in KCCP	45
Table 3.3.7-1.	Disaster Prevention Field: Candidate Organizations for the Working Group	47
Table 3.3.7-2.	WG Meeting for Disaster Prevention Field	47
Table 3.3.7-3.	Results of the Interview Survey on the Application of Space-Related Technologies in the Disaster Prevention Field	48
Table 3.3.7-4.	Data Requirement for Flood Inundation Analysis	52
Table 3.3.7-5.	1st Online Training	53
Table 3.3.7-6.	2nd Online Training	54
Table 3.3.7-7.	List of Acquired Data	54
Table 3.3.8-1.	Candidate Institutions for the Agriculture and Livestock WG	56
Table 3.3.8-2.	Summary of WG Meetings	57
Table 3.3.8-3.	Summary of Interview Results from Ministries, Universities, and Institutions Related to the Agriculture and Livestock Sector	57
Table 3.3.8-4.	Results of Additional Interviews	58
Table 3.3.8-5.	Pilot Project Design Details	59
Table 3.3.8-6.	Satellite Imagery Procurement Plan and Specifications	61
Table 3.3.8-7.	Overview of Online Training Sessions in the Agriculture and Livestock Sector	61
Table 4.1.1-1.	Results of Output 1	65
Table 4.1.2-1.	Results of Output 2	66
Table 4.1.3-1.	Results of Output 3	67
Table 4.2.1-1.	Challenges and Solutions in implementing activities for Output 1	68
Table 4.2.2-1.	Challenges and Solutions in implementing activities for Output 2	70
Table 4.2.3-1.	Challenges and Solutions in implementing activities for Output 3	71
Table 4.3-1.	Outputs, Results and Inputs	73
Table 4.4-1.	Evaluation Results for Indicators of Output 1	75
Table 4.4-2.	Evaluation Results for Indicators of Output 2	75
Table 4.4-3.	Evaluation Results for Indicators of Output 3	76
Table 5.1-1.	Evaluations of Indicators for Overall Goal	77
Table 5.2-1.	Evaluations of Indicators for Project Purpose	78

List of Annex

Annex 1-1	Results of the Project
Annex 1-2	Plan of Operation
Annex 2	List of Products
Annex 3-1	PDM (ver. 1.0)
Annex 3-2	PDM (ver. 1.5)
Annex 3-3	PDM (ver. 2.0)
Annex 3-4	PDM (ver. 2.1)
Annex 4	Manual Metodológico de Manejo de Desastres
Annex 5	Manual Metodológico de Monitoreo Agrícola
Annex 6	Baseline Survey
Annex 7	EVALUATION REPORT (Endline Survey)
Annex 8	Photos

List of Contents

List of Abbreviations	i
List of Figures.....	ii
List of Tables	iii
List of Annex	iv
List of Contents	1
Chapter 1. Overview of the Project.....	3
1.1. Background of the Project	3
1.2. Name of the Project	4
1.3. Overall Goal and Project Purpose of the Project	4
1.4. Expected Outputs.....	4
1.5. Sites of the Project.....	4
1.6. Implementing Agency of the Project	6
1.7. Working Groups of the Project.....	6
1.8. Period of the Project	7
1.9. Implementation Structure of the Project.....	9
1.10. Implementation Methods of the Project	9
Chapter 2. Current Status of Space Policy in Paraguay	10
2.1. Current Status of AEP.....	10
2.2. Space Policy in Paraguay	14
Chapter 3. Activities and Outputs of the Project	16
3.1. Inputs from Japanese and Paraguayan Sides	16
3.1.1. <i>Results of Inputs from Japanese Side.....</i>	<i>16</i>
3.1.2. <i>Results of Inputs from Paraguayan Side.....</i>	<i>27</i>
3.2. Revision History of PDM.....	27
3.3. Outputs of Activities.....	30
3.3.1. <i>Creations and Discussions of Inception Report and Work Plan</i>	<i>30</i>
3.3.2. <i>Progress Reports and Project Completion Report</i>	<i>30</i>
3.3.3. <i>Reports of Baseline Survey and Endline Survey.....</i>	<i>31</i>
3.3.4. <i>Meetings of Joint Coordinate Committee.....</i>	<i>31</i>
3.3.5. <i>Monitoring and Monitoring Sheets.....</i>	<i>32</i>
3.3.6. <i>Activities related to Output 1</i>	<i>32</i>
3.3.7. <i>Activities related to Output 2</i>	<i>44</i>
3.3.8. <i>Activities Related to Output 3.....</i>	<i>54</i>
Chapter 4. Results of the Project.....	63
4.1. Results of Outputs.....	63
4.1.1. <i>Results of Output 1</i>	<i>63</i>
4.1.2. <i>Results of Output 2</i>	<i>64</i>
4.1.3. <i>Results of Output 3</i>	<i>65</i>
4.2. Issues and Ingenuities	65
4.2.1. <i>Issues and Solutions in Output 1</i>	<i>66</i>
4.2.2. <i>Issues and Solutions in Output 2</i>	<i>66</i>
4.2.3. <i>Issues and Solutions in Output 3</i>	<i>67</i>
4.3. Evaluation Results based on 6 Evaluation Criteria of DAC	68
4.4. Resultss for Indicators of Each Output.....	71
Chapter 5. Suggestions for Achievements of Overall Goal	73
5.1. Prospects of Achievements of Overall Goal.....	73
5.2. Results of Outputs and Activities for Achievements of Project Purpose.....	73
5.3. Suggestions to Paraguayan Side	74

5.4.	Recommendations for Output 1	エラー! ブックマークが定義されていません。
5.5.	Recommendations for Output 2.....	76
5.6.	Recommendations for Output 3.....	77
Chapter 6.	Action Plan	78
6.1.	Enhancement of Organizational Structure.....	78
6.2.	Enhancement of Capacities on Small Satellite Developments/Operations and Satellite Data Utilizations.....	78
6.3.	Drafts of Quantitative Indicators for Action Plan	78

Chapter 1. Overview of the Project

1.1. Background of the Project

The Republic of Paraguay set agriculture as one of its main industries, and its soybean products and export is one of the high productivities in the world. Paraguayan economics is weak because it's depended on agricultural productions and international price competitions, the development of Paraguayan economic is behind even in Latin American and Caribbean regions. The Government of Paraguay (hereinafter referred as GOP) declared Plan Nacional de Desarrollo Paraguay (hereinafter referred as PND) in January 2014 which included 3 following pillars:

1. Reduction of Poverty;
2. Developments of Socioeconomics; and
3. Expansion into the Global Market.

Competitiveness and Innovations were raised as the 12th Item of the Plan, the development of a space sector is also enhanced as the part of the Paraguayan economic acceleration.

At the space sector, Paraguayan Space Agency (Agencia Espacial del Paraguay: hereinafter referred as AEP) which contributes research and development on aerospace, technological innovation and space policy conductions was established in 2014 based on Plan Estratégico Institucional 2018 – 2023 (hereinafter referred as PEI) in December 2017. AEP engaged the developments of space activities by PEI. AEP declared 4 middle-long-term strategies, and 17 detailed activity plans and schedules were shown in each item:

1. Contributing to the public-private developments through space developments;
2. Capacity developments for solving faced issues;
3. Developments and preparations for space infrastructures; and
4. Developments of sustainable systems.

In the 1st strategy, developments of essential cutting-edge technologies for space developments, enhancements to apply and implement space technologies into various fields, such as agriculture-livestock, mapping, national resource exploration, climate, geology, and environment, through cooperation with international institutions and companies were written. For the 2nd strategy, capacity developments for researchers and technicians through the cooperation with academia, agencies and domestic and international institutions were mentioned.

With the Japanese cooperation, the first Paraguayan small satellite “GuaraniSat-1” was released from Japan Experiment Module (hereinafter referred as JEM), International Space Station (hereinafter referred as ISS) by the cooperation among AEP, Japan Aerospace Exploration Agency (hereinafter referred as JAXA) and Kyushu Institute of Technology (hereinafter referred as Kyutech), and it was the Paraguayan giant first leap into the space in 2021. Japan International Cooperation Agency (hereinafter referred as JICA) keeps sending and supporting long-term trainees to Kyutech for enhancing small satellite developments and operations.

AEP is a young agency, capacities of human resources and budgets on developments of space technologies are limited. Applications and frameworks for decision makers on agriculture-livestock, disaster management and environmental management are unsatisfied. Under those conditions, the Request on space enhancement of the abilities on space system developments and satellite data utilizations for contributing to socioeconomics was submitted to the Government of Japan (hereinafter referred as GOJ) from GOP.

1.2. Name of the Project

Project for Management of Space Program Applied to the Socioeconomic Development in the Republic of Paraguay

1.3. Overall Goal and Project Purpose of the Project

Table 1.3-1. shows Overall Goal and Project Purpose of the Project.

Table 1.3-1. Overall Goal and Project Purpose

Overall Goal	Contribute to the development of national skills in the space sector and strengthen the country's social, economic, scientific and technological development.
Project Purpose	The ability to utilize space-related technologies in Paraguay is strengthened and geospatially informed decision-making is promoted.

1.4. Expected Outputs

Table 1.4-1. shows the Outputs of the Project.

Table 1.4-1. Outputs of the Project

Output	
Output 1	Human resources and infrastructure for AEP upstream and downstream will be strengthened.
Output 2	AEP and related agencies implement pilot projects to improve capacity for analyzing disaster risk and preventing and responding to natural disasters.
Output 3	AEP and related agencies implement pilot projects to improve capacity for management of agriculture and livestock information related to productivity and quality of products.

1.5. Sites of the Project

Table 1.5-1. shows the sites of the Project. also, Fig. 1.5-1. And Fig. 1.5-2. Show site maps.

Table 1.5-1. Sites of the Project

Name	Site
AEP Headquarters & GEOLab	Asunción
SPACELab	Universidad Nacional de Asunción, San Lorenzo City
Pilot Project Site (Disaster)	Bañado District, Asunción
Pilot Project Site (Agriculture-livestock)	Caaguazú District

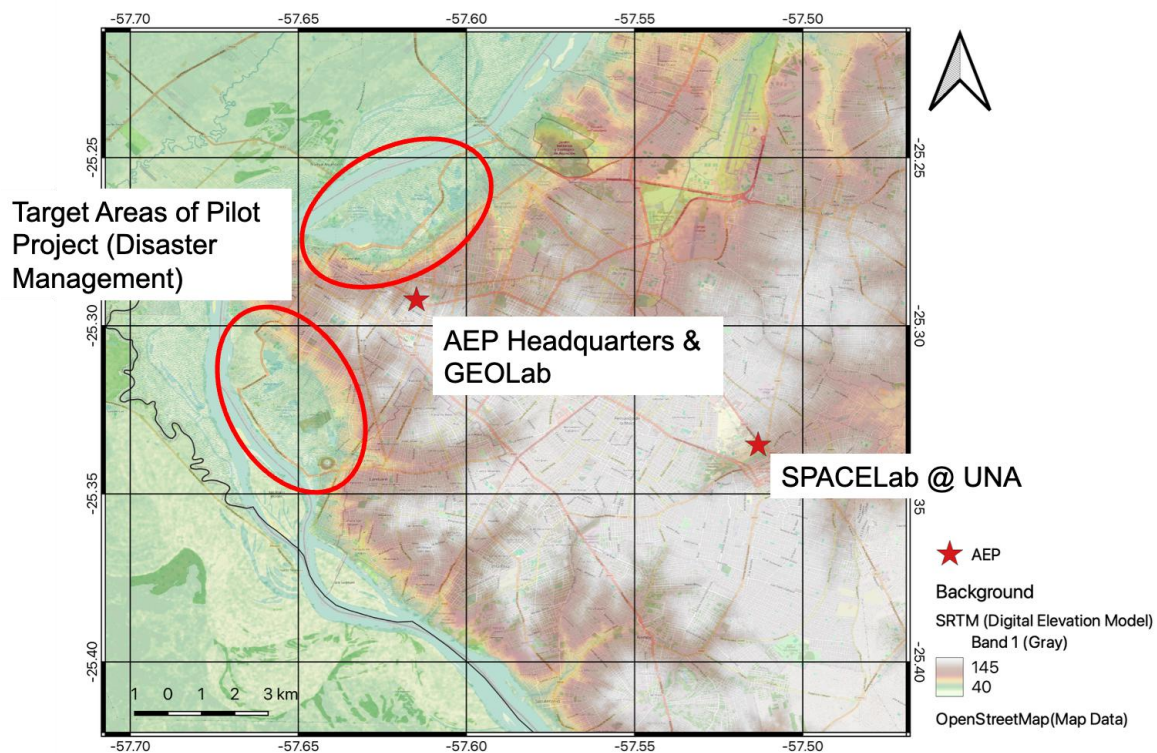


Fig. 1.5-1. Sites of AEP Headquarters/GEOLab, SPACELab and Pilot Project Site (Disaster)

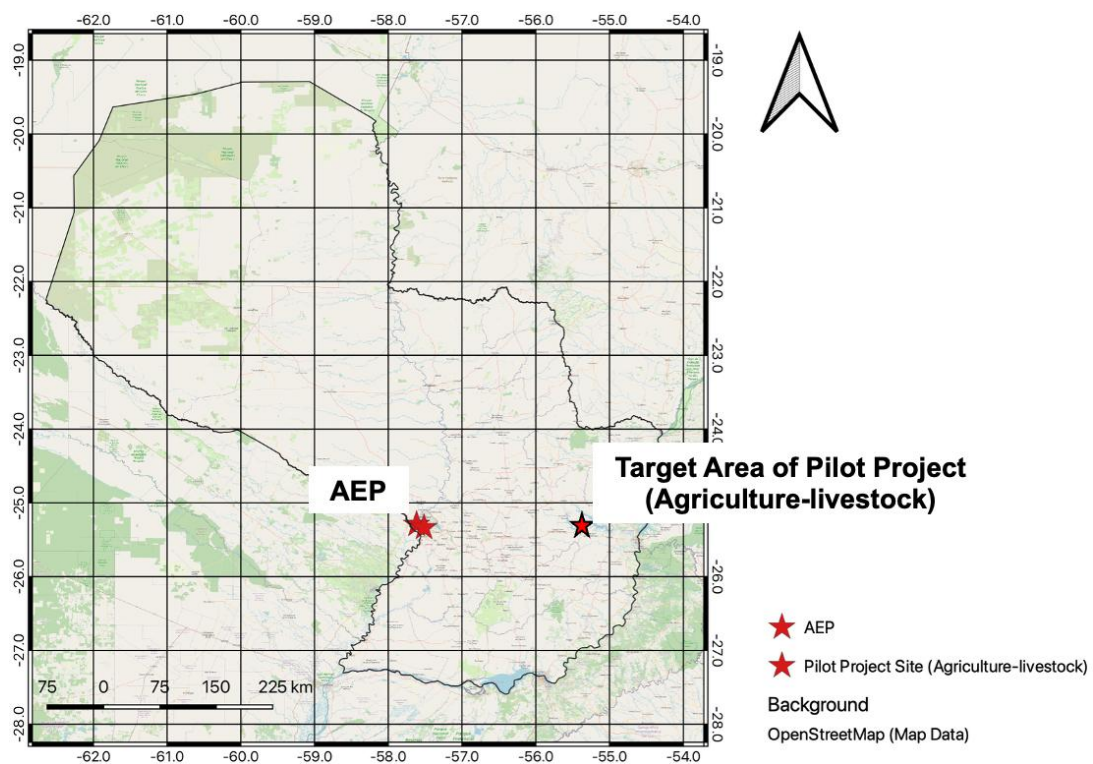


Fig. 1.5-2. Sites of AEP Headquarters and Pilot Project (Agriculture-livestock)

1.6. Implementing Agency of the Project

Paraguayan Space Agency (AEP: Agencia Espacial del Paraguay)

1.7. Working Groups of the Project

For Outputs 2 and 3, the Project Team invited relevant ministries and agencies to establish Working Groups for Disaster Management and Agriculture-livestock for making and setting purposes clear, sharing advices and interpretations on satellite data analysis techniques and application developments, having supports for field survey activities, discussions on the analysis results and letting AEP Team and Working Group (hereinafter referred as WG) members cooperate to develop and utilize satellite data applications sustainably even after the Project terminated. The Project Team received enough understood and cooperation from WG members because of AEP's proactive activities through the Project, and the Project Team conducted technical transfers and active discussions of satellite data analysis methods and interpretations. Moreover, derived projects were also released and conducted through the activities by AEP Team and relevant ministries and agencies. WG for Output was not established because Output 1 was designed for improvements of capacities for space system developments and operations without cooperation with relevant ministries and agencies. Table 1.7-1. and Table 1.7-2. show members of WGs.

Table 1.7-1. Working Group for Disaster Management

Member	Role
AEP	Coordination, satellite data analysis and field survey
SEN: National Emergency Secretary	Sharing interpretation about disaster responses, considering utilizations of hazard maps
MOPC: Ministry of Public Works and Communication	Sharing interpretation about urban infrastructure, considering utilizations of hazard maps
INE: National Institute of Statistics	Sharing civil and statistical information such as population
MADES: Ministry of Environment and Sustainable Development	Sharing interpretation and information about climate change and natural disasters
DMH: Director of Meteorology and Hydrology	Sharing weather data
UNA: National University of Asunción	Sharing academic points of view (natural science)
UCA: Catholic University	Sharing academic points of view (infrastructure)
PTI-ITAIPU	Sharing knowledge about spatial information analysis

Table 1.7-2. Working Group for Agriculture-livestock

Member	Role
AEP	Coordination, satellite data analysis and field survey
MAG: Ministry of Agriculture and Livestock	Sharing interpretation about agricultural policies and considering satellite data utilizations
SENAVE: National Plant, Seed Quality and Health Service	Providing the target site, supporting field survey, considering satellite data analysis and applications
INDERT: National Institute for Rural and Land Development	Sharing information about agricultural development at rural sites
INE: National Institute of Statistics	Sharing civil and statistical information such as population and agricultural products
MADES: Ministry of Environment and Sustainable Development	Sharing information about developments and protections of environment
DMH: Director of Meteorology and Hydrology	Sharing weather data
UNA: National University of Asunción	Sharing academic points of view (agriculture)
UCA: Catholic University	Sharing academic points of view (agriculture)
PTI-ITAIPU	Sharing knowledge about spatial information analysis
IPTA: Paraguayan Institute of Agricultural Technology	Sharing knowledge on the agricultural sector

Table 1.7-3. Derived Projects

Project	Content	Project Member
Tomato Planting Monitoring	To estimate areas of tomato fields by creating land coverage maps with satellite data	AEP and SENAVE
Planning for Development of Data Infrastructure	To plan to develop an integration data platform for statistical and geographic information system (GIS) data	AEP, INE and others

1.8. Period of the Project

The Project was conducted between October 2023 and October 2025. Fig. 1.8-1. shows the implementation plan.

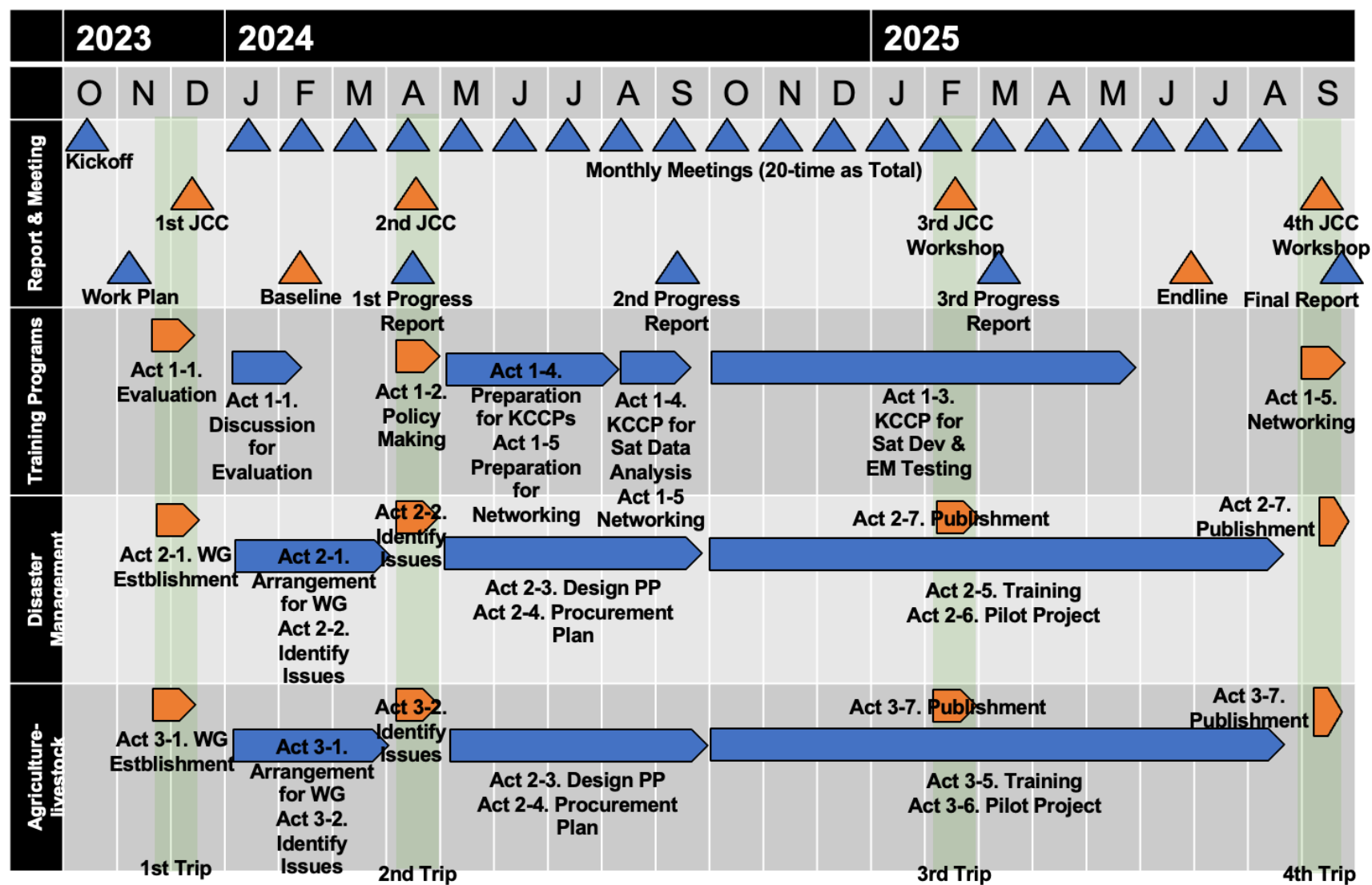


Fig. 1.8-1. Period and Implementation Plan of the Project

1.9. Implementation Structure of the Project

The President of AEP was set as the Chair of Joint Coordination Committee (hereinafter referred as JCC). Director of GEOLab, AEP from Paraguayan Side was set as the Project Manager of JCC. Colleagues of SPACELab and GEOLab were set as technical members of JCC. JICA Paraguay Office and JICA Consultant Team were set as members from Japan.

The President of AEP was set as the Project Manager of the Project Team. Director of GEOLab was set as the Project Manager of the Project Team. Colleagues of SPACELab and GEOLab and JICA Consultant Team were set as members of the Project Team.

JCC members invited relevant ministries and agencies who contribute to socioeconomic issues especially on disaster management and agriculture-livestock directly as observers for JCC, and they reflect expectations and requests by relevant ministries and agencies to the operation of the Project. Those relevant ministries and agencies, moreover, joined as members of Working Groups. The Project Team deepened discussions about specific utilization methods in Working Group (Disaster Management), and the Project Team established soybean monitoring methods and revised and improved their methods through the observations and field survey for 2-season. Fig. 1.9-1. shows the Implementation Structure of the Project.

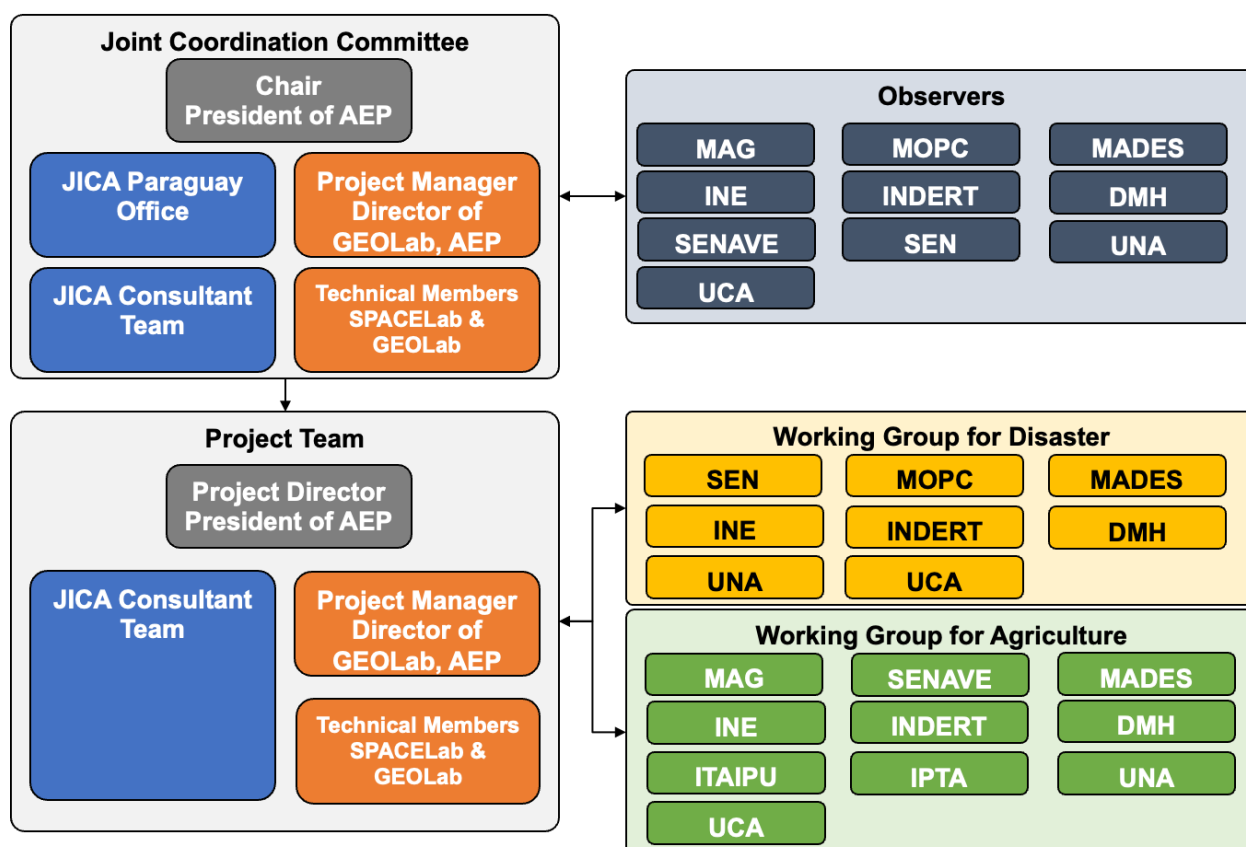


Fig. 1.9-1. Implementation Structure

1.10. Implementation Methods of the Project

“Satellite Developments”, “Satellite Data Utilizations”, “Disaster Managements”, “Agriculture-livestock” and “Capacity Developments” were keywords of the Project. “Satellite Developments” was an expected item to be accelerated by PEI and the Project. Also, the Project focused on “Satellite Data Utilizations” especially applications for “Natural Disasters” such as heatwaves, floods, droughts and forest

fires, and for “Agriculture-livestock”, the main industry in Paraguay. Those topics are affected by climate change these days. In the Project, both AEP Colleagues and JICA Consultant Team worked to enhance Paraguayan satellite data analysis techniques, and the Project Team contributed to applying those techniques into agriculture-livestock and disaster management sectors for mitigating and reducing impacts of climate change. Table 1.4-1. shows Outputs of the Project. The Project Team, moreover, achieved Goal 2 (Zero Hunger), Goal 11 (Sustainable Cities and Communities) and Goal 13 (Climate Action) of Sustainable Development Goals (hereinafter referred as SDGs) through all activities of the Project (Fig. 1.10-1.). Satellite data utilizations for disaster management sectors are expected to contribute to sustainable urban plannings and sustainable cities and communications. Satellite data utilizations for agriculture-livestock sectors are expected to contribute to stable and sustainable productivities. Disaster management and agriculture-livestock sectors are expected receive huge impacts from climate change. Developing capacities who contribute to small satellite developments and satellite data utilizations leads the enhancement s of socioeconomics in Paraguay.

Preparatory Study for Planning of Satellite Technology-related Facilities in Paraguay (hereinafter referred as “Preparatory Survey”) was begun since December 2024. Preparatory Survey was designed to scrutinize validities of installations of satellite technology-related facilities, and it was to make the outline plan and calculate the approximate project cost of the Grant Aid. The Project was also designed to develop the Space Program which contributes to enhancing socioeconomic in Paraguay through the activities of discussions among relevant ministries and agencies and technical transfers, such as Pilot Projects for Disaster Management and Agriculture-livestock and Knowledge Co-Creation Programs (hereinafter referred as KCCP(s)) for satellite data utilizations and satellite system development including GuaraniSat-2 Engineering Model Test in Japan. JICA Consultant Team accelerated the space cooperation between Japan and Paraguay by sharing information and collaborating survey activities with the Team of Preparatory Survey through providing the technical association methods.



Fig. 1.10-1. Goals of SDGs Which the Project Aimed

Chapter 2. Current Status of Space Policy in Paraguay

2.1. Current Status of AEP

AEP was declared and established by “Ley 5151” (Law No. 5151), and AEP supervised by the Presidency Office of Paraguay.

AEP has joined BIRDS Project (Joint Global Multi Nation Birds), which Kyutech promotes academic satellite developments project for enhancing non-advanced-space-technology countries. As one of the results, GuaraniSat-1, the first small satellite of Paraguay, was released into the space environment from Japan Experiment Module (hereinafter referred as JEM), the International Space Station (hereinafter referred as ISS) on March 14, 2021. The missions of GuaraniSat-1 were demonstrations of remote sensing technologies and Perovskite Solar Power System.

AEP, also, conducts to a joint development of a 6-U-sized-small-satellite with an IoT mission with

Japanese company, ArkEdge Space. AEP joins a small satellite mission, named KITSUNE conducted by Kyutech.

AEP has a plan to hire 1 or 2 new technical colleagues for SPACELab and GEOLab annually, and they are ambitious to strengthen as 22 colleagues at SPACELab and 24 colleagues at GEOLab until 2031.

According to the current organizational structure of AEP, 2 technical departments of AEP exist: General Directorate of Planning and Management and General Directorate of Aerospace Execution and Development. However, SPACELab on the campus of UNA for small satellite developments and operations and GEOLab in the building of Ministry of National Defense in Asunción actually exist, and they conduct their own responsibilities.

As a future organizational structure, AEP has a strategy to organize SPACELab for space system developments and operations, and GEOLab for satellite data utilizations as the actual status of AEP.

SPACELab would conduct 5 departments: Department of Education and Outreach; Department of Space System Research; Department of Technological Development; Department of Industrial Development and Department of Space Operation.

GEOLab would conduct 4 departments: Department of Earth Science Research; Department of Earth Science Solution Development; Department of Geospatial Monitoring and Alerts and Department of Earth Observation, GNSS and GIS.

Roles of SPACELab and GEOLab would be classified clearly, advancement and utilizations of science and technologies which contribute to socioeconomic developments in Paraguay are expected through operating both space system developments and utilizations as like two-wheel. Fig. 2.1-1. and Fig. 2.1-2. show the current (as of 2025) and the future (expected in 2028) structures of AEP.

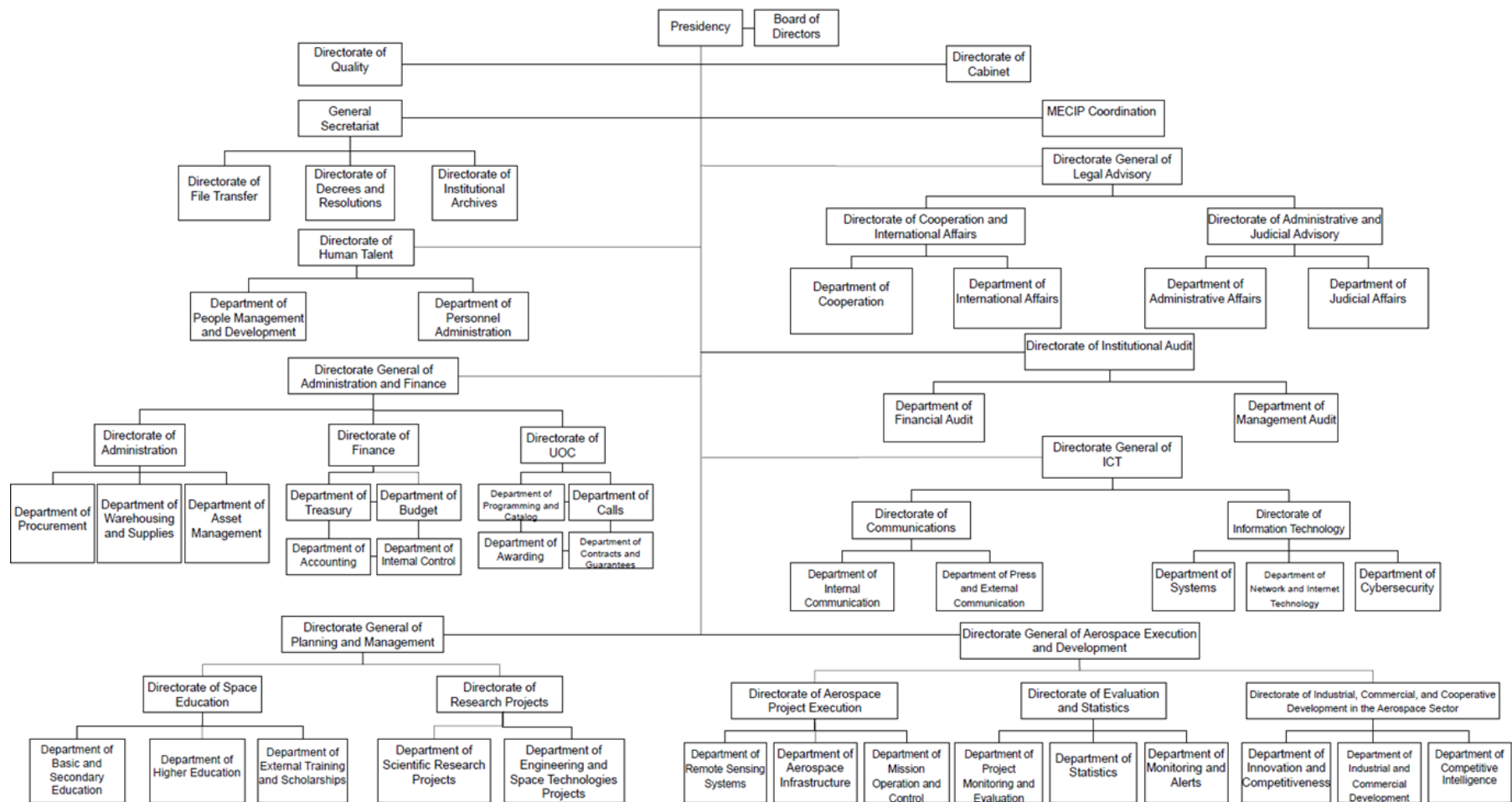


Fig. 2.1-1. Structure of AEP (as of July 2025)

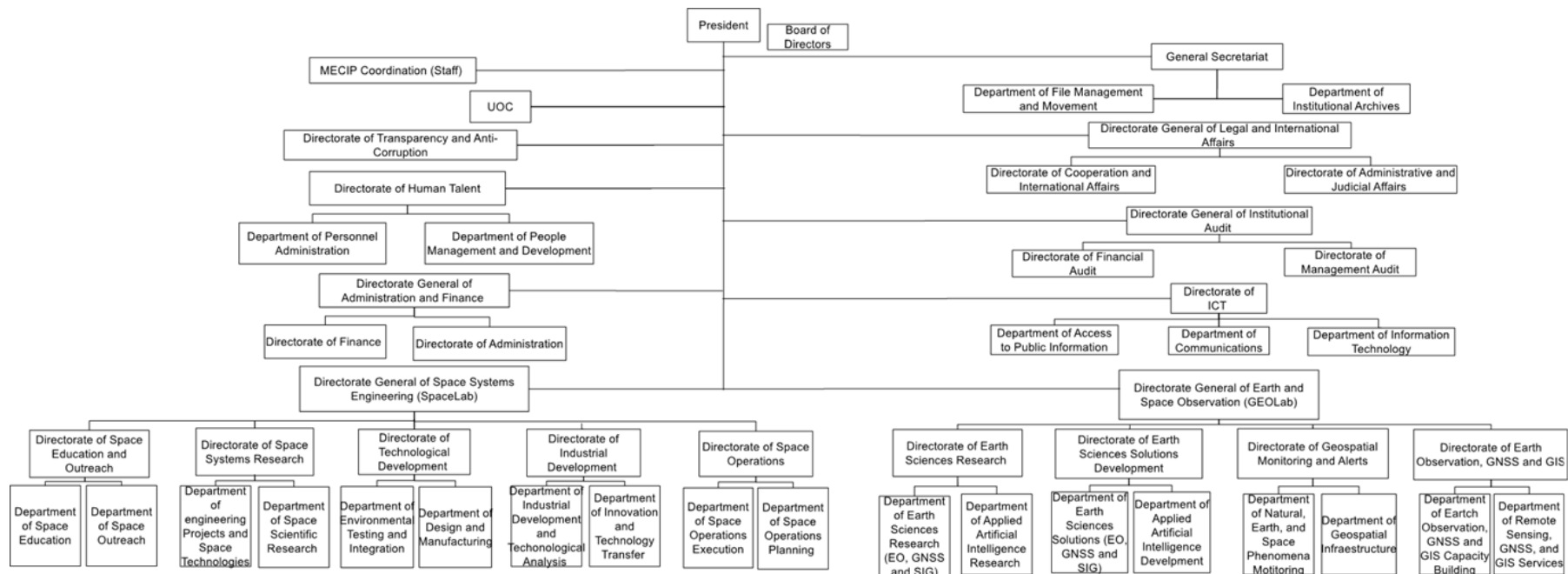


Fig. 2.1-2. Structure of AEP (Expected in 2028)

2.2. Space Policy in Paraguay

Interests in advancing science and technology in global and applications and solutions for agriculture-livestock and disaster managements by space technologies were raised higher although the space technology as primitive and following footsteps. GOP established AEP as the specialized agency for advancing space technologies in authentic in 2014. AEP was allocated the national budget, and AEP began to its activities.

1. GOP declared Plan Nacional de Desarrollo Paraguay 2030 in December 2014, space technology developments were also conducted as a part of the strategies through the following activities:
2. Reduction of poverty and developments of society;
3. Inclusive economic growth;
4. Expansion to the world; and
5. Competitiveness and innovation.

GOP also declared PEI. AEP promotes to advance the national level of space activities by following PEI. AEP shows activity items and the schedule by following strategic pillars shown Plan Nacional de Desarrollo Paraguay 2030:

1. Contributions to developing public and private sectors through aerospace system developments;
2. Capacity developments for people who can contribute to urgent issues;
3. Developments of space infrastructure; and
4. Developments of sustainable systems.

Developments of cutting-edge technologies required for space system developments, applications with space technologies for public and private sectors which contribute to various fields, such as agriculture-livestock, mapping, mineral explorations, climate, geology and environment, promotions to social implementations, and strengths of cooperation with international agencies, private companies were referred and included by the 1st pillar, above. Capacity developments by cooperation with academia, governmental agencies and domestic/international institutions for enhancing researchers and engineers on space technology developments were also shown by the 2nd pillar, above.

GOP, moreover, declared Draft of Strategic Plan 2024-2033 in 2024. Table 2.2-1. shows the purposes on the document.

Table 2.2-1. Purposes of the Strategic Plan 2024-2033

	Purpose	Summary
1	Enhancement of Independency and Establishment of National Space Technology	Reducing technical dependence by improving own abilities of space technology development Developing sustainable technical capacities by developments and operations of Earth observation satellites
2	Applications for agriculture, environment and disaster management	Satellite data utilizations for agricultural enhancement and optimizations Satellite data utilizations for preparations for climate change, floods and droughts
3	Education and Capacity Developments	STEM educations for young generation and capacity developments for space technologies in Paraguay Strengthening cooperation with universities and research institutions in Paraguay
4	Promotions of International Cooperation and Space Diplomacies	International engagements through attendances to Committee on the Peaceful of Outer Space (hereinafter referred as COPUOS) Joint developments of small satellites and human resource exchanges with friendly nations such as Japan, Taiwan and United States

Japanese technical assistance beside the Project, Paraguay had a giant leap to the space activities through releasing their first small satellite, GuaraniSat-1 from JEM, ISS in 2021 by cooperation among AEP, JAXA and Kyutech. Capacity development programs on small satellite developments at Kyutech have still been continued until nowadays.

Moreover, Preparatory Survey was begun by JICA in 2024. Preparatory Survey is conducted with the aim of creating an environment for developments, testing and operations of small satellites in order to

Paraguay to develop space technologies independently and sustainably, and space technologies contribute to promoting the developments socioeconomics in Paraguay. The Project and Preparatory Survey are as two-wheel to enhance Paraguayan space technologies from both sides of techniques and facilities, and both projects promote AEP as a hub between space technologies and cooperation with relevant ministries and agencies applying and contributing to socioeconomic especially disaster management and agriculture-livestock issues by utilizing space technologies as keywords.

Agriculture-livestock occupies 10% of GDP and 60% of export volumes in Paraguay¹, it is easy to receive impacts by droughts and floods which would be caused by climate change, and the industrial vulnerabilities are pointed. Developments of mitigations of climate change are urgent matters for agriculture-livestock in Paraguay. AEP contributes to improving productivities and quality improvements of the agricultural products through providing appropriate mitigation methods for climate change by satellite data utilizations. In addition, AEP is expected to contribute to safe civilian lives through applying satellite data utilizations on early warning systems and damage reductions as disaster preventions and mitigations. AEP, moreover, promotes space technical innovations through international space cooperation and with governments, privates and academia in Japan and Latin American and Caribbean countries. Those activities follow National Strategic Plan 2023, PEI and AEP Low (Ley 5151 (Low No. 5151)), and Paraguay also expect the results through them.

Fig. 2.2-1. Shows the technical enhancement by the Project and AEP’ role as Space Tech Hub among domestic and international cooperation

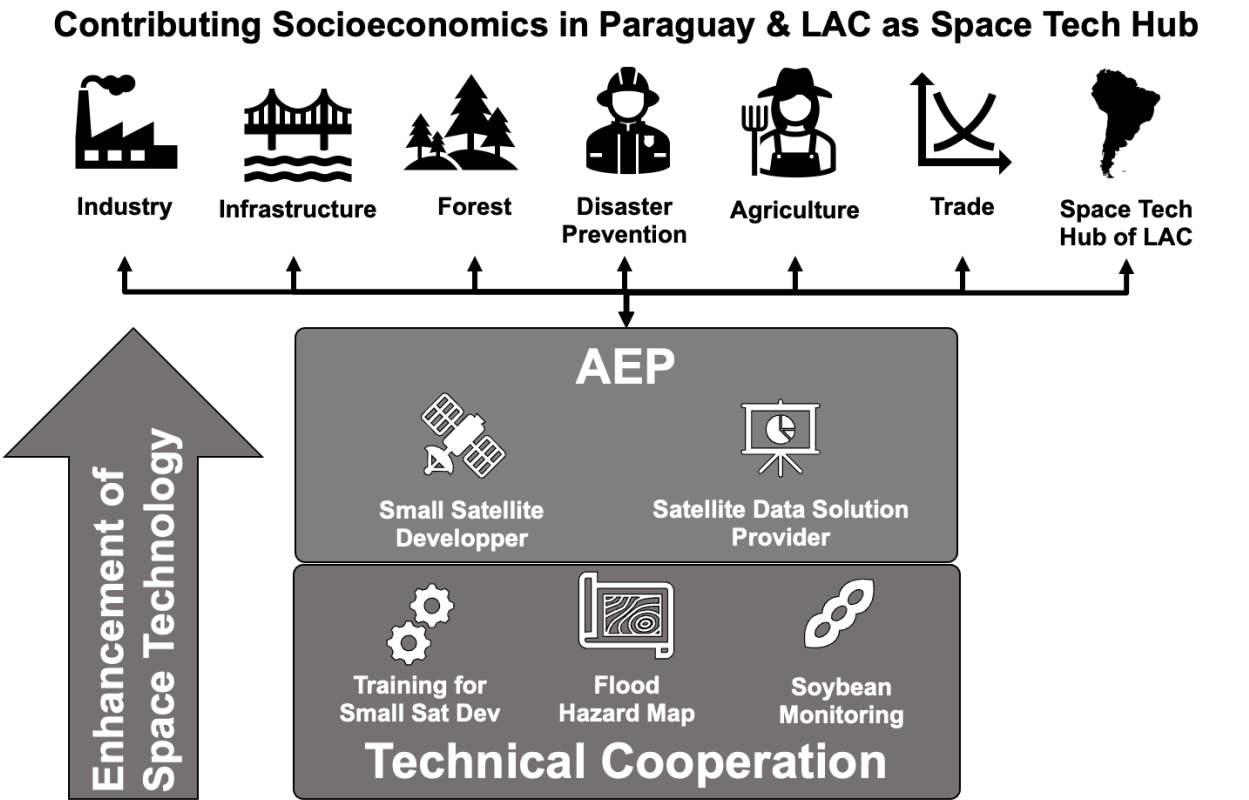


Fig. 2.2-1. AEP’ Role as Space Tech Hub by Public-Private-Academia Space Cooperation with Japan

¹ <https://tradingeconomics.com/paraguay/agriculture-value-added-percent-of-gdp-wb-data.html>

Chapter 3. Activities and Outputs of the Project

3.1. Inputs from Japanese and Paraguayan Sides

By appropriate inputs from Japanese and Paraguayan sides, the Project was operated smoothly. 3.3.1. and 3.3.2 show the results of inputs from both Japanese and Paraguayan sides.

3.1.1. Results of Inputs from Japanese Side

For the operation of the Project, Japanese side inputted items shown below:

1. Experts;
2. Technical Transfers to AEP Team;
3. Procurements of Equipment; and
4. Procurements of Satellite Data.

Experts developed a consortium among 3 organizations and company and engaged the Project. Table 3.1.1-1. shows Experts.

Table 3.1.1-1. Experts

1	Name/Affiliation	Shinsaku Nakamura/Japan Space Systems
	In Charge	Chief Expert/Survey and Analysis
	Main Activities	- Conduct meetings - Evaluate satellite data analysis methods and tools at AEP - Make policies for the enhancements based on the evaluation results about AEP facilities - Provide training programs for satellite data analysis and applications - Conduct Baseline and Endline Survey - Compile Reports
	Trips	1 st Trip: November 19 – December 9, 2023 2 nd Trip: April 14 – April 29, 2024 3 rd Trip: February 19 – March 2, 2025 4 th Tri: August 30 – September 15, 2025
2	Name/Affiliation	Kei Sato/PASCO CORPORATION
	In Charge	Vice-chief/Satellite Data Utilizations for Disaster Management
	Main Activities	- Conduct meetings - Conduct activities for Output 2 - Compile Reports
	Trips	1 st Trip: November 19 – December 9, 2023 2 nd Trip: April 5 – April 29, 2024 3 rd Trip: January 31 – February 24, 2025 4 th Trip: August 30 – September 16, 2025
3	Name/Affiliation	Yoshinori Kobayashi/Japan Space Forum
	In Charge	Planning Satellite Data Utilizations
	Main Activities	- Provide training programs on small satellite developments and operations - Provide a training program on satellite data utilizations - Provide networking opportunities among AEP and Japanese ministries/agencies, academia and private companies
	Trips	1 st Trip: November 24 – December 9, 2023 2 nd Trip: April 12 – April 29, 2024 3 rd Trip: - 4 th Trip: September 2 – September 16, 2025
4	Name/Affiliation	Atsushi Kimura/PASCO CORPORATION
	In Charge	Satellite Data Utilizations for Agriculture-livestock A
	Main Activities	- Conduct activities for Output 3 - Conduct and manage schedule for Pilot Project for Agriculture-livestock
	Trips	1 st Trip: November 19 – December 9, 2023 2 nd Trip: - 3 rd Trip: - 4 th Trip: September 6 – September 17, 2025

5	Name/Affiliation	Akie Koga /PASCO CORPORATION
	In Charge	Satellite Data Utilizations for Agriculture-livestock B
	Main Activities	- Conduct activities for Output 3 - Support smooth operation of Pilot Project for Agriculture-livestock
	Trips	1 st Trip: - 2 nd Trip: April 5 – April 19, 2024 3 rd Trip: February 5 – February 24, 2025 4 th Trip: September 4 – September 17, 2025

Table 3.1.1-2. shows equipment procured in the Project. All equipment was handover on August 19, 2024, the first day of KCCP for Downstream.

Table 3.1.1-2. Equipment Procured in the Project

#	Equipment	Detailed	Purpose	Qty
1	GNSS Receiver	GARMIN ETREX 32X	GPS logger for field survey	1
2	GNSS Receiver	GlobalSat BU-353N5	GPS logger for data analysis	1
3	HDD	ADATA HV300 (2TB)	HDD as a satellite data archive system	1

Table 3.1.1-3. and Table 3.1.1-4. show satellite data procured in the Project. All satellite datasets were handover through the Project appropriately.

Table 3.1.1-3. Satellite Data for Agriculture-livestock: PlanetScope

No.	Scene ID	Observation Time (UTC)	Thumbnail
1	20220924_134437_75_2407	2022-09-24 13:44:37	 Includes material © (2023) Planet. All rights reserved.
2	20221002_125613_83_2432	2022-10-02 12:56:13	 Includes material © (2023) Planet. All rights reserved.
3	20221008_133906_06_227b	2022-10-08 13:39:06	 Includes material © (2023) Planet. All rights reserved.
4	20221023_125228_19_2453	2022-10-23 12:52:28	 Includes material © (2023) Planet. All rights reserved.
5	20221026_125132_06_2460	2022-10-26 12:51:32	 Includes material © (2023) Planet. All rights reserved.

6	20221103_125430_21_2431	2022-11-03 12:54:30	
7	20221106_125007_34_241b	2022-11-06 12:50:07	
8	20221116_132619_92_2484	2022-11-16 13:26:19	
9	20221119_133554_31_2416	2022-11-19 13:35:54	
10	20221127_132711_03_2490	2022-11-27 13:27:11	 Includes material © (2020) Planet. All rights reserved.
11	20221214_134644_99_2413	2022-12-14 13:46:44	
12	20221220_125200_13_2430	2022-12-20 12:52:00	
13	20221227_125319_27_2453	2022-12-27 12:53:19	 Includes material © (2020) Planet. All rights reserved.

14	20230104_124939_36_2423	2023-01-04 12:49:39	 Includes material © (2023) Planet. All rights reserved.
15	20230117_132847_92_249d	2023-01-17 13:28:47	 Includes material © (2023) Planet. All rights reserved.
16	20230124_132900_38_248c	2023-01-24 13:29:00	 Includes material © (2023) Planet. All rights reserved.
17	20230204_125233_06_241f	2023-02-04 12:52:33	 Includes material © (2023) Planet. All rights reserved.
18	20230209_132737_43_249b	2023-02-09 13:27:37	 Includes material © (2023) Planet. All rights reserved.
19	20230218_125529_09_2439	2023-02-18 12:55:29	 Includes material © (2023) Planet. All rights reserved.
20	20240228_130410_26_24ba	2024-02-28 13:04:10	 Includes material © (2023) Planet. All rights reserved.
21	20240312_135833_70_24f6	2024-03-12 13:58:33	 Includes material © (2023) Planet. All rights reserved.

22	20240320_140042_61_24d3	2024-03-20 14:00:42	
23	20240328_134643_23_2424	2024-03-28 13:46:43	
24	20240403_135812_82_2498	2024-04-03 13:58:12	
25	20240418_130837_67_24c7	2024-04-18 13:08:37	
26	20240429_135814_33_24eb	2024-04-29 13:58:14	 Includes material © (2023) Planet
27	20240507_140136_63_2483	2024-05-07 14:01:36	
28	20240522_140212_14_2484	2024-05-22 14:02:12	 Includes material © (2023) Planet. All rights reserved.
29	20240531_130804_86_24c4	2024-05-31 13:08:04	 Includes material © (2023) Planet. All rights reserved.

30	20240602_140204_09_24d3	2024-06-02 14:02:04	
31	20240906_142005_17_2470	2024-09-06 14:20:05	
32	20240930_141057_04_24d6	2024-09-30 14:10:57	
33	20240930_141058_94_24d6	2024-09-30 14:10:58	
34	20241013_135951_86_24bd	2024-10-13 13:59:51	
35	20241022_140645_72_2516	2024-10-22 14:06:45	
36	20241027_140523_15_24de	2024-10-27 14:05:23	 Includes material © (2025) Planet. All rights reserved.
37	20241029_140405_73_24d7	2024-10-29 14:04:05	

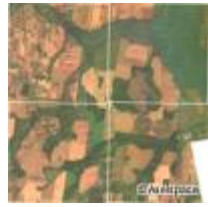
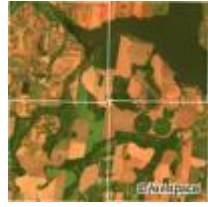
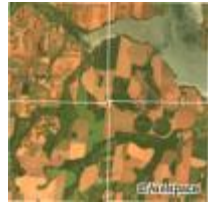
38	20241109_140822_80_251c	2024-11-09 14:08:22	
39	20241113_131859_45_24d0	2024-11-13 13:18:59	
40	20241116_131929_11_24a1	2024-11-16 13:19:29	
41	20241126_140257_07_24df	2024-11-26 14:02:57	 Includes material © (2025) Planet. All rights reserved.
42	20241211_132059_86_2417	2024-12-11 13:20:59	 Includes material © (2025) Planet. All rights reserved.
43	20241217_132527_58_24ce	2024-12-17 13:25:27	
44	20241223_140825_06_24b7	2024-12-23 14:08:25	
45	20241227_140601_28_24fa	2024-12-27 14:06:01	 Includes material © (2025) Planet. All rights reserved.

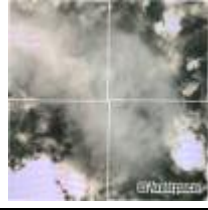
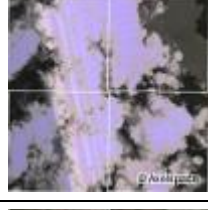
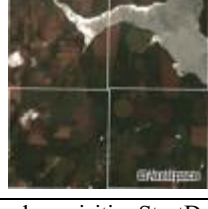
46	20250101_140635_83_24e0	2025-01-01 14:06:35	
47	20250104_140508_83_2521	2025-01-04 14:05:08	
48	20250108_140835_63_24c6	2025-01-08 14:08:35	 Includes material © (2025) Planet. All rights reserved.
49	20250111_140626_66_24e6	2025-01-11 14:06:26	
50	20250116_140739_39_2523	2025-01-16 14:07:39	
51	20250121_140605_80_24dd	2025-01-21 14:06:05	
52	20250202_132959_19_24c3	2025-02-02 13:29:59	
53	20250225_140755_45_24df	2025-02-25 14:07:55	

54	20250318_140839_29_24ed	2025-03-18 14:08:39	
55	20250330_140608_20_2515	2025-03-30 14:06:08	
56	20250411_141941_42_2504	2025-04-11 14:19:41	
57	20250420_140915_07_24db	2025-04-20 14:09:15	
58	20250501_142045_29_2541	2025-05-01 14:20:45	
59	20250511_134516_92_24b4	2025-05-11 13:45:16	
60	20250519_141424_73_24d7	2025-05-19 14:14:24	

Scene IDs were collected from metadata.json files, and observation times were referred acquired values on metadata.json files.

Table 3.1.1-4. Satellite Data Procured for Agriculture-livestock: GRUS

No.	Scene ID	Observation Time (UTC)	Thumbnail
1	2261301354880	2024-10-02 14:19:42	
2	2264522332560	2024-10-05 14:14:34	
3	2276333252528	2024-10-16 14:11:06	
4	2279554230816	2024-10-19 13:36:33	
5	2288144998640	2024-10-27 14:10:42	
6	2290292477984	2024-10-29 14:17:19	
7	2295660948800	2024-11-03 14:17:53	

8	2307471886992	2024-11-14 14:10:19	
9	2320357353664	2024-11-26 14:10:17	
10	2325725820384	2024-12-01 14:09:32	
11	2343978708560	2024-12-18 13:33:24	
12	2354716953568	2024-12-28 14:07:49	
13	2382633696688	2025-01-23 14:17:02	
14	2383707438496	2025-01-24 14:19:34	

Scene IDs were referred captureId values from metadata.json files, and observation times were referred acquisitionStartDateTime values on metadata.json files.

3.1.2. Results of Inputs from Paraguayan Side

For the operation of the Project, Paraguayan side inputted items shown below:

1. Staffing;
2. Arrangements with relevant ministries and agencies;
3. Arrangements with other cooperation agencies;
4. Sharing required data;
5. Arrangements of an office for Experts; and
6. Necessary expenses for other items which the Project did not cover.

Counterparts of the Project were SPACELab for small satellite developments and GEOLab for satellite data utilizations.

3.2. Revision History of PDM

Table 3.2-1. shows the first version of PDM. Table 3.2.2. also shows the revision history of PDM.

Table 3.2-1. PDM (First Version)

Narrative Summary	Objectively Verification Indicators	Means of Verification	Important Assumption
Overall Goal			
Contribute to the development of national skills in the space sector and strengthen the country's social, economic, scientific and technological development	1. # of projects utilizing space related technology in public and private sector 2. # of public data based on geospatial information 3. # of users of data provided	- Government Statistics - Report from AEP and/or other institutions	Mechanism of data provision for governmental statistics or decision-making process is well established.
Project Purpose			
The ability to utilize space-related technologies in Paraguay is strengthened and geospatially informed decision-making is promoted.	1. # of interagency projects in which AEP was involved 2. # of value-added products based on satellite data by AEP	Government Statistics, Project Report	
Outputs			
Output1: Human resources and infrastructure for AEP upstream and downstream will be strengthened.	1-1. # of trained persons considering gender balance 1-2. # of seminars and workshops 1-3. satisfaction of seminars and workshops	Project Report	- Counterpart personnel is continuously secured properly - Other institutions, such as government and universities accept involvement of pilot projects.
Output2: AEP and related agencies implement pilot projects to improve capacity for analyzing disaster risk, and preventing and responding to natural disasters.	Same as 1-1, 1-2, 1-3 # of PoC, # of practical plans from activity, # of papers and reports related to activity	Project Report	- Counterpart personnel is continuously secured properly - Other institutions, such as government and universities accept involvement of pilot projects.
Output3: AEP and related agencies implement pilot projects to improve capacity for management of agriculture and livestock information related to productivity and quality of products.	Same as 1-1, 1-2, 1-3 # of PoC, # of practical plans from activity, # of papers and reports related to activity	Project Report	- Counterpart personnel is continuously secured properly - Other institutions, such as government and universities accept involvement of pilot projects.

Activities	Inputs		Important Assumption
	Japanese Side	Paraguayan Side	
1-1: Conduct an evaluation of AEP's existing technical methods and tools and make recommendations for future planning	- Short-term experts (Data utilization planning, Satellite development/testing, Data utilization in disaster risk reduction/agriculture and livestock sector) - Training for Counterpart Personnel in Japan - Local cost for the activities	- Allocation of counterpart personnel - Coordination among ministries and organizations - Arrangements between projects with other development partners, etc. - Arrangements for providing necessary data - Office space for Japanese professionals - Local costs (maintenance costs for existing equipment not covered by JICA support, meeting preparation costs, operating costs required for the project, etc.)	
1-2: Develop enhancement plan based on a diagnosis of the infrastructure available in the AEP.			Pre-conditions
1-3: Provide training in satellite development and operations.			
1-4: Provide training in satellite data and other processing and applications.			
1-5: Liaison between AEP and Japanese governmental institutions, universities, and private companies.			
2-1: Set up working groups consisting of AEP and related organizations to identify issues and implement pilot projects.			
2-2: Identify issues where space-related technologies can be effectively applied in the field of disaster risk reduction			
2-3: Determine scope for applying space-related technologies to the issues and Design pilot projects			
2-4: Develop plan and procure equipments (hardware and software) for satellite imagery and data processing			
2-5: Train personnel in the use of tools, methods, and techniques for disaster risk reduction.			
2-6: Implement pilot projects with existing agreements with academia and other governmental and non-governmental organizations			
2-7: Publish results of pilot projects locally and internationally.			
3-1: Set up working groups consisting of AEP and related organizations to identify issues and implement pilot projects.			
3-2: Identify issues where space-related technologies can be effectively applied in the agriculture and livestock sector.			
3-3: Determine scope for applying space-related			

technologies to the issues and Design pilot projects			
3-4. Develop plan and procure equipments (hardware and software) for satellite imagery and data processing			
3-5. Train personnel in the use of tools, methods, and techniques to improve productivity and quality in agriculture and livestock sector.			
3-6. Implement pilot projects with existing agreements with academia and other governmental and non-governmental organizations			
3-7. Publish results of pilot projects locally and internationally.			

Table 3.2-2. Revisions of PDM

Ver.	Date	Revision		Reason
		Item	Content	
1.0	June 19, 2023	-		First Version
1.5	December 5, 2023	Period of Project	Revised as “October 2023 and September 2025” from “September 2023 and August 2025”.	Due to following the beginning date of the Project
		Indicators	Revised as “Number of value-added products based on satellite data by AEP” from “Number of value-added satellite data products in and beside pilot projects by GEOLab, AEP”.	To contribute to enhancing satellite data analysis techniques at GEOLab.
			Added “Number of Paraguayan staff have training programs in Japan and Paraguay”.	To confirm the results of training programs.
		Activity 1-2	Revised as “Develop enhancement plan based on a diagnosis of GEOLab, AEP” from “Develop enhancement plan based on a diagnosis of the infrastructure available in the AEP”.	To make the enhancement of satellite data analysis techniques as the main pillar.
		Activity 1-3	Revised as “Provide hands-on training in satellite development, especially testing EM of Guaranisat-2 (Plan A: enhancing facility and having tests at SPACELab, or Plan B: sending 2-staff and having tests at Kyutech)” from “Provide training in satellite development and operations”.	Both Japanese and Paraguayan sides began to consider Guaranisat-2 EM Testing. Options were raised, and both Japanese and Paraguayan sides would have discuss how realize the testing.
		Activity 2-4	Revised as “Develop plan and procure equipment (hardware and software) for satellite imagery and data collecting/processing” from “Develop plan and procure equipment (hardware and software) for satellite imagery and data processing”.	To add satellite data collecting/processing.
		Activity 2-6	Revised as “Implement pilot projects with Working Group and existing agreements with academia and other governmental and non-governmental organizations” from “Implement pilot projects with existing agreements with academia and other governmental and non-governmental organizations”.	To add WG and confirm WG to operate Pilot Project.
		Activity 3-4	Revised as “Develop plan and procure equipment (hardware and software) for satellite imagery and	To add satellite data collecting/processing.

			data collecting/processing” from “Develop plan and procure equipment (hardware and software) for satellite imagery and data processing”.	
		Activity 3-6	Revised as “Implement pilot projects with Working Group and existing agreements with academia and other governmental and non-governmental organizations” from “Implement pilot projects with existing agreements with academia and other governmental and non-governmental organizations”.	To add WG and confirm WG to operate Pilot Project.
2.0	April 25, 2024	Activity 1-3	Revised as “Provide 6-month hands-on training in satellite development, including testing EM of Guaranisat-2 at Kyutech between October 2024 and March 2025” from “Provide hands-on training in satellite development, especially testing EM of Guaranisat-2 (Plan A: enhancing facility and having tests at SPACELab, or Plan B: sending 2-staff and having tests at Kyutech)”.	To confirm the activity through discussions after the First Meeting of JCC.
2.1	February 19, 2025	Activity 1-3	Revised as “Provide 6-month hands-on training in satellite development, including testing EM of Guaranisat-2 at Kyutech between October 2024 and May 2025” from “Provide 6-month hands-on training in satellite development, including testing EM of Guaranisat-2 at Kyutech between October 2024 and March 2025”.	To reflect the updated schedule due to the delay of GuaraniSat-2 EM Development.

3.3. Outputs of Activities

3.3.1. Creations and Discussions of Inception Report and Work Plan

Inception Report and Work Plan were submitted on November 21, 2023. Work Plan was confirmed at the First Meeting of JCC on December 5, 2023.

3.3.2. Progress Reports and Project Completion Report

Table 3.3.2-1. shows overviews of Progress Reports and Project Completion Report.

Table 3.3.2-1. List of Reports

Report	Submission Date	Overview
Progress Report (Vol. 1)	February 20, 2023	To report all activities until February 2024 since the beginning of the Project. Main activities: • First Meeting of JCC • Revised PDM (ver. 1.5) • Activities in the 1st Trip • Preparations for establishments of WGs
Progress Report (Vol. 2)	September 9, 2024	To report activities between March 2024 and August 2024. Main activities: • Second Meeting of JCC • Revised PDM (ver. 2.0) • Activities in the 2nd Trip • Establishments of WGs • Field Survey • Baseline Survey • KCCP for Downstream
Progress Report (Vol. 3)	March 31, 2025	To report September 2024 and March 2025. Main activities: • Third Meeting of JCC • Workshop • KCCP for Downstream

		• KCCP for Upstream • Pilot Project (Disaster Management) • Pilot Project (Agriculture-livestock)
Draft Project Completion Report	First Submission on June 27, 2025	To report all activities about the Project. Both JICA Consultant Team and AEP Team updated their activities.
Project Completion Report	Final Submission on September 26, 2025	To report all activities about the Project.

3.3.3. Baseline Survey and Endline Survey

To evaluate the results of the Project for setting the targets of future space strategic plans in Paraguay, JICA Consultant Team and AEP Team conducted Baseline Survey and Endline Survey. Baseline Survey and Endline Survey were conducted as parts of Activity 1-1, AEP's whole activities including developments and operations of small satellites and satellite data utilizations were set as targets of those survey.

JICA Consultant Team and AEP Team made questionnaire sheets after the First Meeting of JCC. They reported as the results of Baseline Survey at the end of March 2024. Table 3.3.3-1. shows the schedule of Baseline Survey.

Table 3.3.3-1. Schedule of Baseline Survey

#	Activity	Period	Notice
1	Making Questionnaire	January 10 – February 23, 2024	Translated in Spanish
2	Online Survey	February 26 – March 8, 2024	
3	Evaluate Answers	March 11 – March 22, 2024	
4	Report	March 29, 2024	

For the baseline survey, the questionnaire was developed through consultations between the JICA consultant team and AEP, and the survey was conducted by AEP. JICA Consultant Team and AEP Team worked together to collect answers, evaluate, analyze and make the report.

JICA Consultant Team and AEP Team conducted Endline Survey after the Third Meeting of JCC. For ensuring objectivity and fairness in the evaluation, the survey was outsourced to and conducted by UNA as an independent third party. The questionnaire was made based on the one which JICA Consultant Team and AEP Team used for Baseline Survey, and UNA added more for evaluating the status at the end of the Project. the survey was conducted in April and May, and the report was submitted on June 20, 2025. Table 3.3.3-2. shows the schedule of Endline Survey.

Table 3.3.3-2. Schedule of Endline Survey

#	Activity	Period	Notice
1	Making Questionnaire	April 22 – May 2, 2025	
2	Online Survey	May 5 – May 21, 2025	
3	Evaluate Answers	May 21 – June. 13, 2025	
4	Report	June 20, 2025	

Annex 6 and Annex 7 show the results of Baseline Survey and Endline Survey respectively. The results of this survey are described under each output in the following sections.

3.3.4. Meetings of Joint Coordinate Committee

JICA Consultant Team and AEP Team conducted the meetings of JCC 4-time. Table 3.3.4-1. shows the overview of the meetings of JCC.

Table 3.3.4-1. Overviews of Meetings of JCC

Time	Date	Location	Content
First	December 5, 2023	Hilton Asunción	Confirmation of Work Plan Revision of PDM (ver. 1.5)
Second	April 24, 2024	Consejo Nacional de Ciencia y Tecnología	Confirmation of Activities Revision of PDM (ver. 2.0)
Third	February 19, 2025	Ministerio de Industria y Comercio	Confirmation of Activities Held with Workshop for sharing results of Pilot Projects and Preparatory Survey
Final	September 12, 2025	La Misión Hotel	Confirmation of all outputs Confirmation of Action Plan Confirmation of Project Completion Report

3.3.5. Monitoring and Monitoring Sheets

JICA Consultant Team and AEP Team made Monitoring Sheets and reported to JICA Paraguay Office. Table 3.3.5-1. shows the overviews of Monitoring Sheets.

Table 3.3.5-1. List of Monitoring Sheet

#	Date	Content
1	March 3, 2024	To monitor activities until March 2024 since the beginning of the Project. Main activities: • Activities in the 1st Trip • The First Meeting of JCC • Baseline Survey • Preparations for establishments of WGs
2	September 18, 2024	To monitor activities between April and September 2024. Main activities: • Activities in the 2nd Trip • The Second Meeting of JCC • KCCPs for both Upstream and Downstream • Results of presurvey for operations of Pilot Projects for both disaster management and agriculture-livestock
3	March 31, 2025	To monitor activities between October and February 2025. Main activities: • Activities in the 3rd Trip • The Third Meeting of JCC • KCCPs for both Upstream and Downstream • Progress of Pilot Projects for both disaster management and agriculture-livestock

3.3.6. Activities related to Output 1

Activity 1-1. Conduct an evaluation of AEP's existing satellite data analysis methods and tools.

For developing the effective Space Program in Paraguay by AEP based on the space activity status at AEP, JICA Consultant Team and AEP Team required to understand utilization status of space systems and satellite data in the begging of the Project. JICA Consultant Team and AEP Team had interview server and Baseline Survey to AEP and relevant ministries and agencies. They also took Endline Survey for evaluate effectiveness of the Project at the end of the Project.

JICA Consultant Team and AEP Team received information which were useful for considerations about issues on disaster management and agriculture-livestock sectors and satellite data utilizations through the interview survey.

All ministries, agencies and universities including AEP had limitations of huma resources, facilities, techniques and budgets, and issues on enhancements of capacities developments for satellite data

utilizations and application developments were unveiled through Endline Survey. On the other hand, AEP was expected by relevant ministries, agencies and universities to become as a hub for sharing space information and space techniques which were matched with AEP's purpose for expanding and improving space technologies for contributing socioeconomic developments.

Those results were applied into designing and operating KCCPs as Output 1, establishing WGs and designing and conducting Pilot Projects as Outputs 2 and 3.

Endline Survey pointed effects by Pilot Projects of both disaster management and agriculture-livestock made relevant ministries, agencies and universities understand about importances of satellite data utilizations deeply. Also, Endline Survey showed difficulties to access to satellite data became small, and the Project played a role to expand satellite data utilizations for contributing socioeconomic issues in Paraguay. On the other hand, Endline Survey collected expectations to AEP to continue to provide technical transfers to relevant ministries, agencies and universities due to special knowledge and interpretations were still required for satellite data utilizations and application developments.

Those results were applied to develop Actions Plans by AEP Team through discussions with JICA Consultant Team. Refer Chapter 6.

Results of interview survey and Endline Survey were shown below.

During the first trip, which took place from November 19 to December 9, 2023, we visited relevant institutions with the cooperation of AEP and conducted interviews to evaluate satellite data analysis methods and tools. AEP is the agency to provide space systems and satellite data. Thus, the purpose of the interview survey was to clarify the role and status about existing satellite data analysis systems and tools of AEP in Paraguay by understanding expectations on the space systems and satellite data utilizations of relevant ministries, agencies and universities, which directly face socioeconomic issues and to consider the utilization of space systems and satellite data in Paraguay. Table 3.3.6-1. shows an overview of results from the government ministries, universities, and institutions' interviews.

Table 3.3.6-1. Overview of results from the government ministries, universities, and institutions' interviews

#	Visiting Ministries, Universities and Institutions	Overview
1	National Emergency Secretary (SEN)	• They usually prepare to set up evacuation shelters, and when a disaster occurs, they respond by carrying out rescue operations and setting up evacuation shelters in the affected areas. • The northwest is sparsely populated and understaffed. • It is the Authorized User for International Disaster Charter, and in the event of a disaster, it dispatches staff to AEP and applies for the procurement of satellite data with AEP's cooperation. • All they did was monitoring the weather conditions by using Windy.
2	Ministry of Public Works and Communication (MOPC)	• They conduct environmental assessments (including safety) of public works projects and develop plans for environmentally friendly public works. • Agricultural and livestock civil engineering work (irrigation and embankments) is outside their jurisdiction. • They are interested in early alert systems, climate change, and environmental impact assessment.
3	Ministry of Agriculture and Livestock (MAG)	• They are developing an application for managing the risks of damage to crops due to climate change. • They manage 48 hectares of farmland where technical verification can be carried out, and there is a possibility of implementing a pilot project on the farmland. • There is a possibility of exchanging opinions in a working group based on industry-academia-government collaboration.
4	National Plant, Seed Quality and Health Service (SENAVE)	• SENAVE aims to ensure quality and stable supply of seeds. • They are exploring the use of satellite data for soil quality control, etc. • They also crack down on illegal agricultural crops (drug plants).
5	Ministry of Environment and Sustainable Development (MADES)	• The organization is engaged in forest management, forest fire monitoring, wetland management, etc. • The United Nations and various international cooperation agencies (JICA, USAID, nature conservation organizations, etc.) are involved in forest conservation. There is some overlap in objectives and target areas, which poses a challenge that requires organization. • The first thing to do is to standardize data and analysis methods.
6	National Forestry Institute (INFONA)	• They manage primary forests, plant trees, and manage dairy farms. • They monitor forests using equipment and analytical methods that are comparable to those used in forest monitoring in Japan, including analysis of both commercial and free satellite data by using ArcGIS, and publish the data.
7	Ministry of Economy and Planning (MEF)	• They believe that utilizing satellite data for territory management and policy planning/analysis is effective. • They have experience in land use classification using Sentinel-2.
8	National Institute of Statistics (INE)	• Statistical data is being collected from various ministries and agencies, and efforts are being made to standardize the statistical data, but publication standards have not yet been established. • There is expectation for future pilot projects that combine satellite data with statistical information held by INE (for example, if statistical information on agricultural yields and household surveys can be obtained from MAG).
9	National University of Asuncion (UNA)	• With support from Japan, the Faculty of Forestry has been conducting forest fire monitoring and surveys of forest carbon stocks.
10	Catholic University (UCA)	• They focus on environmental management and disasters (especially floods and droughts) by using Remote Sensing. They also focus on urban engineering, IoT, neuro-engineering, etc.

Results of Baseline Survey which JICA Consultant Team and AEP Team analyzed was reported in March 2024. Refer Annex 6 for the results of Baseline Survey.

Enhancement of interpretations for reading analyzed satellite data based on knowledge about object fields beside on satellite data analysis on desks was raised as the primary issue through the survey. Also, space system cooperations among relevant ministries nor lack opportunities for AEP sharing technical transfers were raised other issues although relevant ministries and agencies were interested in achieving utilizations of space systems.

Draft of installation plan equipment for small satellite developments, satellite data analysis and capacity development programs after the visitation of the Former Prime Minister Kishida in May 2024. The draft was shared among JICA Consultant Team and AEP Team at the monthly meeting in May 2024. Also, the Preparatory Survey was begun in December 2024, and JICA Consultant Team cooperated and share information for accelerating space program managements.

Endline Survey was operated between April and June 2025. Table 3.3.6-2. and Table 3.3.6-3. show the results and suggestions through Endline Survey.

Table 3.3.6-2. Evaluation for Space System Utilizations by Endline Survey

Item	Evaluation
Expansion of Space Tech Utilizations	The project has been evaluated as having overcome the fundamental barriers to entry for various stakeholders in expanding the use of space technology. A joint project with SENAIVE for managing tomato cultivation areas was begun as one of results of overcoming these barriers. Moreover, a data infrastructure development project, including the utilization of satellite data, was initiated in collaboration with INE and other ministries.
Securing Human Resources	The project has been evaluated as having led to the emergence of demand for personnel with advanced satellite data analysis skills and high expectations for technical transfer by AEP. The relevant ministries were able to clarify the scale of human resources required.
Data Access & Usability	The project has been evaluated as having helped overcome barriers to accessing satellite data, such as the shared recognition that free data can be utilized. The establishment of systems for timely and continuous satellite data distribution is expected as a future requirement.
Proactive Development of Apps	The project has been evaluated as having revealed the need for interpreting analysis results from satellite data in key areas such as agricultural management (57.1% have never used satellite data to update data) and disaster management (early warning and prevention). To further mature satellite data utilization, expectations were expressed for the acquisition of advanced analytical skills beyond basic satellite data analysis.

Refer Annex 7 for the detailed results by Endline Survey.

Activity 1-2. Develop enhancement plan based on a diagnosis of GEOLab, AEP

The first issue on GEOLab, AEP was to achieve knowledge and interpretations for reading satellite data analysis results with results by field survey through correlations between the desk analysis and on-site perspectives. Based on the results, policies for Activities 1-3, 1-4 and 1-5 were set through the discussions between JICA Consultant Team and AEP Team. The policies were shown below:

Policy for Activity 1-3

The policy was set for: 1) enhancing and deepening knowledge about small satellite developments, testing and operations; and 2) conducting GuaraniSat-2 Engineering Model Test. KCCP for Upstream (small satellited developments and operations) was designed to improve capacities of AEP to deepen understanding small satellite designs, developments, testing and operations, as well as to achieve the frameworks of space international cooperations through lectures with Japanese and international students at Kyutech. Moreover, the testing of Engineering Model of GuaraniSat-2, which was developed by AEP independently, was designed and conducted as a part of KCCP, and letting AEP to achieve testing data and interpretations to improve components for developing Flight Model of GuaraniSat-2 as their next step was

designed and conducted.

Policy of Activity 1-4

KCCP was designed and implemented to enable attendees to achieve advanced, effective, and practical satellite data utilization technologies and knowledge for the two themes of disaster managements and agriculture-livestock and to deepen their knowledge for sustainable satellite data utilizations and practical applications in collaboration with related organizations in Paraguay.

Policy of Activity 1-5

The events were designed to provide opportunities for networking and collaborations between space-related parties in Japanese industry and academia, with the aims of strengthening cooperation between the two countries for utilizing future space technologies.

Activity 1-3. Conduct a six-month hands-on training, including testing of the GuaraniSat-2 Engineering Model (EM), at Kyushu Institute of Technology (Kyutech) from October 2024 to May 2025

① Name of Training

Satellite Development Training "Project for Management of Space Programs Applied to the Socioeconomic Development in Paraguay (Upstream Training)"

② Training Period

[First batch]

Training Period: October 4, 2024 – March 28, 2025

[Second batch]

Training Period: April 3, 2025 – May 30, 2025

③ Number of Certification

A total of three staff completed the training: one from AEP in the first batch and two from AEP in the second batch.

④ Training Overview

To improve Paraguay's overall space capabilities and enhance its social, economic, scientific, and technological capabilities, it is necessary to strengthen its space technology utilization capabilities and promote geospatial information-based decision-making. This training program aimed to deepen the skills and knowledge of satellite development and testing, and to promote Paraguay's own satellite data collection. The AEP engineers participating in the training received six months of hands-on training at Kyutech (hereinafter referred to as the "1st Batch") to acquire fundamental planning and knowledge on nanosatellite mission definition, engineering model development, and testing. Furthermore, two months of hands-on training at Kyutech (hereinafter referred to as the "2nd Batch") included a series of engineering model tests of AEP's 3U nanosatellite, GuaraniSat-2, to acquire test data for flight model development and component improvements.

Table 3.3.6-3. KCCP (Upstream Training Schedule) (1st Batch)

Date		Training content
1	2024/10/7 - 2024/10/11	- Orientation, facility tour, kickoff (10/7) - Participation in the International Low Carbon Urban Development Forum (10/8, 9)
2	2024/10/14 - 2024/10/18	- Introduction to the BIRDS-RP satellite project - Mission idea discussion - Lecture on satellite power subsystem I

3	2024/10/21 - 2024/10/25	- Subsystem assignment - Mission objectives and concept discussion
4	2024/10/28 - 2024/11/1	-Mission requirements and success criteria discussion -Special lecture on machine learning techniques for measuring magnetic fields on CubeSat - Introduction to space system lecture
5	2024/11/4 - 2024/11/8	-Mission requirements discussion -Mission concept and model review -Discussion on satellite main bus budget calculation
6	2024/11/11 - 2024/11/15	-Discussion on satellite internal configuration - Introduction to space system lecture (11/14, 11/15) -Satellite power subsystem lecture (11/15)
7	2024/11/18 - 2024/11/22	-Discussion on requirements and verification documents -Preparation of mission component list -Lecture on satellite power subsystem (11/22)
8	2024/11/25 - 2024/11/29	- Introduction to space system lecture (11/28, 11/29) -Satellite power subsystem lecture (11/29) -Bread Board Model (BBM) component procurement
9	2024/12/1 - 2024/12/6	-Mission power consumption discussion (12/4) -Mission operation model and interface discussion (12/4)
10	2024/12/9 - 2024/12/13	- Mission data budget and configuration update discussion (12/11) - Introduction to satellite engineering lecture (12/12) - Satellite power subsystem lecture (12/13)
11	2024/12/16 - 2024/12/20	- Introduction to satellite engineering lecture (12/19) - BBM development plan discussion (12/20) - Satellite power subsystem lecture (12/20)
12	2024/12/23 - 2024/12/27	-Mission Definition Review discussion (12/25) -Introduction to satellite engineering lecture (12/26)
13	2025/1/6 - 2025/1/10	- Introduction to satellite engineering lecture (1/9) - BBM Development (1/6 - 1/10) - Mission definition improvement comments and improvement (1/9 - 1/10)
14	2025/1/13 - 2025/1/17	- BBM test plan and objectives discussion (1/13 - 1/17) - Introduction to space system lecture (1/16) - Satellite power subsystem lecture (1/17)

15	2025/1/20	-	2025/1/24	- BBM development (1/20 - 1/24) - Introduction to satellite engineering lecture (1/23) - Satellite power subsystem lecture (1/24)
16	2025/1/27	-	2025/1/31	- BBM functional test (1/27 - 1/31) - Introduction to space system lecture (1/26, 1/30) - Introduction to satellite engineering lecture (1/30)
17	2025/2/3	-	2025/2/7	- BBM functional test (2/3 - 2/7) - Introduction to satellite engineering lecture (2/6) - Satellite power subsystem lecture (2/7)
18	2025/2/10	-	2025/2/14	-Command and integration test discussion (2/10 - 2/14) - Introduction to satellite engineering lecture (2/13) - Introduction to space system lecture (2/13)
19	2025/2/17	-	2025/2/21	- BBM functional test (2/17 - 2/21) - BBM software development (2/17 - 2/21) - BBM integration test preparation (2/17 - 2/21)
20	2025/2/24	-	2025/2/28	- BBM integration test with satellite main bus (2/24 ~2/28) - Engineering Model (EM) board circuit diagram preparation (2/24 - 2/28)
21	2025/3/3	-	2025/3/7	- BBM integration test with satellite main bus (3/3 - 3/7) - EM board layout design (3/3 - 3/7) - EM board parts list preparation (3/5 - 3/7)
22	2025/3/10	-	2025/3/14	- BBM power consumption test (3/10 - 3/14) - EM board and component procurement (3/12)
23	2025/3/17	-	2025/3/21	- BBM integration test with satellite main bus (3/17 – 3/21) - BBM integration test with ethernet out-of-band channel (eOBC) (3/18 – 3/21) - Preparation of PDR documents (3/17 – 3/20)
24	2025/3/24	-	2025/3/28	- BBM integration test (3/24 - 3/25) - Communication subsystem Electro-Magnetic Compatibility (EMC) test (3/25 - 3/27) - PDR (3/27) - JICA training report (3/28)

Table 3.3.6-4. KCCP (Upstream Training Schedule) (2nd Batch)

Date		Training content		
1	2025/4/2	-	2025/4/4	Orientation, facility tour - Satellite delivery to clean room - Checking the work area - Discussion of equipment and test requirements list - Antenna repair/PCB soldering repair - Measurement of GuaraniSat-2 EM
2	2025/4/7	-	2025/4/11	Attaching the antenna to the +Y panel - Disassembling each subsystem - Backplane board testing

		- Functionality check of the satellite power supply common line - Confirmation of communication between the control system (ADCS) and onboard computer (OBC) - Communication system testing and ground station setup - Confirmation of communication between the communication system and ground station - Preparation of Kyutech test facilities for testing - Improvement of the antenna deployment mechanism
3	2025/4/14 - 2025/4/18	Setup of acoustic test chamber - Installing the antenna on the +Y panel - Antenna radio wave measurement and frequency adjustment - Antenna pattern measurement - Preparation of Kyutech test facilities for the test - Dipole antenna adjustment for the communication system (436 MHz) and LoRa communication (436.9 MHz) - Antenna pattern measurement for the communication system (436 MHz) and LoRa communication (436.9 MHz) - Installing the GPS and Astradyne second payload on the -Y panel
4	2025/4/21 - 2025/4/25	Antenna deployment mechanism testing in a clean room - Post-assembly subsystem and payload testing - Battery pack installation - Satellite assembly and vibration test preparation for functional verification testing
5	2025/4/28 - 2025/5/2	Satellite assembly for vibration testing - CW beacon check, OBC, EPS, and communication system function confirmation - Vibration testing conducted on Z, X, and Y axes - Solar panel deployment during Z-axis random vibration testing (troubleshooting for string malfunction during deployment and resolving with Astradyne) - Solar panel deployment during X axis quasi-static vibration testing (dealing with a malfunction in the string securing the solar panel releasing) - Dealing with a malfunction in which the satellite would not power on during vibration testing - Conducting shock testing on 3 axes - Removing the antenna from the satellite for low-temperature testing in a chamber
6	2025/5/5 - 2025/5/9	Satellite functional test - Software update and program - PVC -Y panel repair - Communication test - Satellite disassembly for thermal vacuum test
7	2025/5/12 - 2025/5/16	Additional satellite functional tests - Installation of thermocouples to satellite subsystems and payloads for thermal vacuum tests - Mechanical structure verification and installation of jigs for thermal vacuum tests - Satellite installation inside the thermal vacuum test chamber - Test facility pump, power supply and software verification - Verification of test equipment electrical connections, power supply, heat source, and sensors - Verification of 22 thermocouples, 6 heat sources, and power supply - Vacuuming the chamber and testing satellite functionality
8	2025/5/19 - 2025/5/23	Depressurize the chamber - Pre-test function confirmation test - Start thermal cycle change from low temperature - Complete 4 cycles of thermal cycle test - Conduct function confirmation test at highest and lowest temperatures - Remove the satellite from the thermal vacuum chamber - Remove the thermocouple from the satellite

9	2025/5/26 - 2025/5/30	FIUNA mission test - Satellite assembly and final functional test - Packing of satellite and tools - Clean room cleaning
---	-----------------------	---

⑤ Achievements from Training

Through the implementation of the first and second batches of this training program, the following results were achieved through testing of the developed "BIRDS-RP" and "GuaraniSat-2" engineering models.

- (1) Gaining knowledge to generate satellite mission ideas based on social issues to be solved
- (2) Promoting understanding of small satellite subsystems
- (3) Gaining knowledge to define mission objectives and concepts
- (4) Acquire design technology for mission requirements and bus budgets and configurations based on those requirements.
- (5) Knowledge about BBM component procurement
- (6) BBM design and development, software development technology
- (7) Gain knowledge of a series of testing techniques such as BBM functionality testing, integration testing, and power consumption testing
- (8) Improving knowledge of Preliminary Design Review (PDR)
- (9) Knowledge about a series of testing techniques for satellite Engineering Models (EM), including antenna testing, communication testing, vibration testing, shock testing, functionality testing, and thermal vacuum testing.
- (10) The results of (1) to (9) above provide knowledge for the development of Flight Models (FM) for future domestically developed satellites such as GuaraniSat-2.

Activity 1-4. Conduct training on processing and application of satellite data and other information

① Name of Training

Data Utilization Training "Project for Management of Space Programs Applied to the Socioeconomic Development in Paraguay (Downstream Training)"

② Training Period

Training Period: August 19 – September 18, 2024

③ Number of Certification

A total of 7 people completed the training: six from AEP and one from SENAVE

④ Training Overview

This training program was designed to strengthen Paraguay's overall space capabilities and promote social, economic, scientific, and technological developments by strengthening its space technology utilization capabilities and promoting geospatial information-based decision-making. AEP and related organization staff who participated in this training learned advanced and effective satellite data utilization techniques and knowledge for two themes: disaster prevention and agriculture and livestock. The goal is to collaborate with related organizations in Paraguay to utilize satellite data sustainably and apply it to practical operations. Furthermore, by providing an opportunity for networking and collaboration with Japanese space industry and academia, the program aims to strengthen future collaboration between the two countries in utilizing space technology.

Table 3.3.6-5. KCCP (Downstream Training Schedule)

Date	time	Destinations
August 18		Arrival in Japan

August 19	10:00-12:00	Briefing at JICA TIC
	13:30-15:30	Training objectives and curriculum explanation
August 20	10:00-11:30	Ministry of Land, Infrastructure, Transport and Tourism *
	15:30-16:30	Japan Weather Association *
August 21	10:00-12:00	ArkEdge Space 1
	13:30-16:30	ArkEdge Space 2
August 22	9:45-11:30	JAXA (Agricultural use of space technology)
	13:15-16:15	Networking with space-related companies *
August 23	10:00-11:30	Ministry of Agriculture, Forestry and Fisheries
	14:00-15:30	Yanmar Agri
	15:30-17:00	United Nations Office for Outer Space Affairs (UNOOSA) *
August 26	10:00-12:00	JAXA Tsukuba Space Center *
	14:00-16:15	National Agriculture and Food Research Organization (NARO).
August 27	10:00-12:00	Public Works Research Institute / International Centre for Water Hazard and Risk Management under the auspices of UNESCO (ICHARM) *
	14:00-16:00	National Research Institute for Earth Science and Disaster Resilience (NIED) *
August 28	10:00-11:30	Axelspace 1 *
	13:00-16:30	Axelspace 2
August 29	10:00-12:00	Synspective 1 *
	13:30-16:30	Synspective 2
August 30	10:00-12:00	Foundation of River & Basin Integrated Communications (FRICS)
	14:00-15:30	Sagri
September 2	10:30-12:00	Achievement report preparation
	14:00-16:15	Sony
September 3	10:30-11:30	Super embankment
	15:00-17:00	Metropolitan Area Outer Underground Discharge Channel
September 4	13:30-16:30	Shizuoka Prefecture
September 5	10:15-12:00	Gifu University 1
	13:30-16:30	Gifu University 2
September 6	10:00-12:00	Agricultural Field Survey in Gifu Prefecture
September 9	10:00-12:00	Hokkaido University 1
	13:30-16:30	Hokkaido University 2
September 10	13:00-15:00	Farm in Kuromatsunai
September 11	10:00-12:00	Smartlink Hokkaido 1
	14:00-16:30	Smartlink Hokkaido 2
September 12	10:00-12:00	Hokkaido Agricultural Field Training 1

	14:00-16:30	Hokkaido Agricultural Field Training 2
September 13	10:00-12:00	Smartlink Hokkaido 3
September 17	10:00-12:00	Pilot project preparation 1
	13:30-16:30	Pilot project preparation 2
September 18	9:00-11:00	Achievement report
	11:00-12:00	Certificate of Completion
September 19		Leaving Japan

*These were held as a joint session with another JICA program, Rwanda Training Program.

⑤ Achievements from Training

A curriculum was designed that combined lectures, practical training, and field trips. The unit goals which Table 3.3.6-6. shows were achieved.

Table 3.3.6-6. KCCP (unit objectives)

Unit goals	Curriculum Structure
Unit Goal 1: Acquire knowledge on disaster prevention and solving social issues in agriculture and livestock using optical and SAR satellite data	All Curriculum
Unit Goal 2: Acquire knowledge of utilization examples in Japan using optical and SAR satellite data	All Curriculum
Unit Goal 3: Acquire knowledge about the administrative use of satellite data by Japanese government ministries and agencies	• Ministry of Land, Infrastructure, Transport and Tourism • Ministry of Agriculture, Forestry and Fisheries • Shizuoka Prefecture
Unit Goal 4: Acquire knowledge about research and development of space technology for social implementation by Japanese research institutes and universities	• JAXA • National Agriculture and Food Research Organization (NARO) • Public Works Research Institute, National Research and Development Agency • National Research Institute for Earth Science and Disaster Resilience (NIED) • Gifu University • Hokkaido University
Unit Goal 5: Acquire knowledge about private companies' efforts to utilize satellite data for business, public services, and solving social issues	• Japan Weather Association • ArkEdge Space • Yanmar Agri • Axelspace • Synspective • FRICS • Sony • Smartlink Hokkaido
Unit Goal 6: Creating future collaboration through networking with various space-related players in Japan's industry and academia	• Networking with space-related companies • All other curriculum
Unit Goal 7: Promoting agency cooperation between JAXA and AEP	JAXA (Agricultural Use of JAXA, Tsukuba Space Center)
Unit Goal 8: Acquire analytical and verification techniques for practical use of satellite data through field surveys, practical training, and hands-on activities	• Super embankment • Metropolitan Area Outer Underground Discharge Channel • Agricultural Field Survey in Gifu Prefecture • Kuromatsunai Farm • Hokkaido Agricultural Field Training
Unit Goal 9: Apply the results of Unit Goals 1 to 8 above to future work and future space utilization cooperation.	• Pilot project preparation • All other curriculum

Activity 1-5. Collaborate with AEP and Japanese government agencies, universities, and private companies.

As part of KCCP (Downstream Training), a networking event to introduce each other's activities in collaboration with JAXA, universities, private companies (Axelspace, Synspective, etc.), and CONSEO companies was held in Tokyo on August 22, 2024. Table 3.3.6-7. shows the companies that collaborated with KCCP and the satellite data, platforms, equipment, etc. that were considered or procured.

On September 12, 2025, JAXA and Japanese space companies were invited for a workshop in Paraguay. Through discussions between JAXA and SPACELab staff, a strategy for strengthening future operations was discussed. In the workshop after the final JCC meeting, JAXA gave a keynote speech and business networking took place among Japanese companies, AEP, relevant ministries, and local companies, aiming to strengthen space business collaboration between Japan and Paraguay.

AEP began developing a satellite data platform in collaboration with Japanese companies in 2024. In addition, many Japanese companies have already expressed their desire to collaborate with AEP (small satellite constellation development and operation, ground station network construction, data platform development, data application development, etc.).

Table 3.3.6-8. Companies, academia and government organizations collaborated in KCCP

#	Industry, academia, and government	Content	Status	Remarks
Private company				
1	ArkEdge Space	Small satellite constellation development and data utilization Site Visit of the satellite control ground station	Currently collaborating on the development of ArkEdge Insight	During the pilot project, ArkEdge Insight will be introduced, and practical use of satellite data will be considered.
2	Axelspace	Optical small satellite constellations and their data utilization	Completion	AxelGlobe data is procured and used in a pilot project (agriculture and livestock).
3	CTI Engineering International	Hands-on seminar on flood simulation (iRIC) (Online training)	Completion	In pilot project (disaster prevention) activities, seminars on flood simulation were conducted.
4	Sagri	Private sector initiatives for agriculture using satellite data	Completion	Collaboration at KCCP
5	Synspective	SAR small satellite constellation and data utilization platform	Completion	Collaboration at KCCP
6	Smartlink Hokkaido	Introducing smart agriculture initiatives by Hokkaido farmers	Completion	Collaboration at KCCP
7	Sony Group	Introduction to low-power, low-cost communication technology	Completion	Collaboration at KCCP They are exploring cooperation in global satellite communications.
8	Yanmar Agri	Smart agriculture initiative integrating IoT and space technology	Completion	Collaboration at KCCP
9	Consortium for Satellite Earth Observation (CONCEO)	Company introduction and exchange	Completion	Collaboration at KCCP
University				
10	Gifu University	Introduction to flood forecast simulation research using satellite data/hands-on	Completion	Collaboration at KCCP Hands-on simulation lessons were continued even in the Pilot Project (Disaster Prevention).
11	Hokkaido University	Agricultural research using space technology Satellite data utilization training in livestock farming	Completion	Collaboration at KCCP Practical application of satellite data for grass species management and livestock production is under consideration.

Ministries and agencies, local governments, etc.				
12	Ministry of Land, Infrastructure, Transport and Tourism	Japan's flood control measures, river administration, and satellite data utilization	Completion	Collaboration at KCCP
13	Ministry of Agriculture, Forestry and Fisheries	Activities to utilize satellite data for agricultural statistics	Completion	Collaboration at KCCP
14	JAXA	Examples of satellite data utilization in agriculture and site visit of Tsukuba Space Center and introduction of disaster response efforts using satellite data	Completion	Collaboration at KCCP
15	National Agriculture and Food Research Organization	Space technology case study and research in agriculture	Completion	Collaboration at KCCP
16	Public Works Research Institute	Introducing efforts to manage flood disasters and risks using satellite data	Completion	Collaboration at KCCP
17	National Research Institute for Earth Science and Disaster Resilience	Understanding earthquake damage using satellite data and introducing satellite operations during disasters	Completion	Collaboration at KCCP
18	FRICS	River disaster prevention information River monitoring	Completion	Collaboration at KCCP
19	Japan Weather Association	Weather forecasts and disaster information transmission in Japan	Completion	Collaboration at KCCP
20	United Nations Office for Outer Space Affairs	Introducing UN disaster response efforts using satellite data	Completion	Collaboration at KCCP
21	Metropolitan Area Outer Underground Discharge Channel	Case studies of disaster response in the Tokyo metropolitan area	Completion	Collaboration at KCCP
22	Shizuoka Prefecture	Use of satellite image analysis for land subsidence monitoring	Completion	Collaboration at KCCP

3.3.7. Activities related to Output 2

Activity 2-1. Set up working groups consisting of AEP and related organizations to identify issues and implement pilot projects

JICA Consultant Team visited relevant organizations expected to be involved in disaster prevention, accompanied by AEP, and conducted interviews. Then it was selected candidate organizations for the Disaster Prevention Working Group (WG). The candidate organizations are listed in Table 3.3.7-1. A request letter from AEP was sent to these candidate organizations. The organizations that responded to the call and regularly joined as core members of WG are those highlighted in light blue in Table 3.3.7-1.

Table 3.3.7-1. Disaster Prevention Field: Candidate Organizations for the Working Group

Organization Name

Paraguayan Space Agency (AEP)	National Emergency Secretary (SEN)
Vice-Ministry of Economy and Planning (MEF)	Ministry of Public Works and Communication (MOPC)
National Institute of Statistics (INE)	Ministry of Environment and Sustainable Development (MADES)
National Forestry Institute (INFONA)	Director of Meteorology and Hydrology (DMH)
National University of Asuncion (UNA)	Catholic University (UCA)
National Institute for Rural and Land Development (INDERT)	

* The Technological Park (PTI) of Itaipu Hydroelectric Power Plant (ITAIPU) joined since July 2024.

Prior to implementing the WG activities, guidelines for the WG were created and a preliminary explanation regarding their utilization was provided. During the WG meetings, explanations and discussions primarily focused on the pilot project. The WG meetings conducted are as shown in Table 3.3.7-2. below.

Table 3.3.7-2. WG Meeting for Disaster Prevention Field

Meeting	Date (Paraguay)	Place	Summary of contents	Achievement
WG Premeeting	March 6th, 2024	Online	• Approval of WG guidelines • Formation of the WG	• Formation of the WG
1st WG Meeting	April 24th, 2024	CONACYT	• Purpose of WG meetings • Introduction of satellite data utilization case • Schedule for the Pilot Project • Review of Interview Findings and Discussion on Satellite Data Usage • Sharing and Approval of Pilot Project Scope Proposal	• Scope of pilot project approval
2nd WG Meeting	July 4th, 2024	Online	• Data required for flood simulation • Flood hazard map creation workflow • Utilization of flood hazard maps	• Design of pilot project approval
3rd WG Meeting	November 25th, 2024	Online	• Sharing of pilot project progress • Workshop schedule and presentation content • Conversion of inundation maps to Flood hazard maps • Utilization of flood hazard maps	• Progress sharing

Activity 2-2. Identify issues where space-related technologies can be effectively applied in the field of disaster risk reduction

To identify challenges where space-related technologies could be effectively applied, JICA Consultant Team visited relevant organizations in the disaster prevention field during our first trip from November to December 2023 and conducted interviews. The interviews focused on understanding the organizations, operational activities, their knowledge of and experience utilizing earth observation satellite data, and the potential for utilizing such data based on their work. The information gathered from each organization was arranged, and the results regarding the anticipated content, role, and challenges for applying space-related technologies are shown in Table 3.3.7-3.

Table 3.3.7-3. Results of the Interview Survey on the Application of Space-Related Technologies in the Disaster Prevention Field

Institution	Expected for Satellite Data Utilization	Roles	Challenges
SEN	- Damage Information Collection - Flood Early Warning - Forest Fire Monitoring	- Request data collection and distribution to International Charter by sending staff to AEP at the disaster strikes - Announce the damaged status - Flood Alert	- Cooperation with AEP is important. - Cooperation with AEP is required for Extracting damaged information. - Documents for satellite data utilization when the disaster has occurred that is unprepared - Windy and NASA' hotspot are available for flood early warning system and forest fire monitoring.
MEF	- Flood Hazard/Risk mapping * Applying to land territory managements also.	- Land territory management for disaster mitigation - Distributions of flood hazard/risk maps as the preliminary phase	- Knowledge and interpretation are required for making flood hazard/risk maps - Cooperation with AEP is required.
MOPC	- Flood Hazard/Risk mapping * Applying to planning and safety assessment before/after public constructions. - Integration of Flood Early Warning Systems into Public Works	- Safety assessment for infrastructure - Public constructions with consideration of disaster mitigation	- Knowledge and interpretation are required for making flood hazard/risk maps - Cooperation with AEP is required.
INE	Updating Statistical Information Using Satellite Data	- Sharing statistical information with SEN when disaster has occurred by SEN's request - Providing statistical information for developing flood hazard/risk maps	<u>No issues from the point of sharing statistical information.</u>
MADES	- Forest Fire Monitoring - Creation of Forest Fire Risk Map	- Monitoring forest fire and providing information to SEN and other institutions - Early warning system by suing forest fire risk maps	- Only NASA's hotspot information is available for forest fire monitoring - No cooperation with INFONA for monitoring forest fire - Standard for forest fire assessment, 5 institutions have own - Human resources especially for patrolling are lack at the national parks
INFONA	- Forest Fire Monitoring - Creation of Forest Fire Risk Map	- Monitoring forest fire and providing information to SEN and other institutions - Early warning system by suing forest fire risk maps.	<u>They have enough abilities to utilize satellite data for monitoring, and there are no issues about their technical aspect.</u> Standard for forest fire assessment, 5 institutions have own
DMH	Flood Early Warning	Providing meteorological information to SEN for flood early warning system.	Standard is unprepared for countermeasure at the flood occurred
UNA	- Forest Fire Monitoring - Creation of Forest Fire Risk Map	- Providing knowledge and interpretation about algorithm for forest fire analysis - Providing knowledge and interpretation from experts.	<u>No issues from the point of providing knowledge and interpretation.</u>

Institution	Expected for Satellite Data Utilization	Roles	Challenges
UCA	Flood Early Warning	- Providing and developing low-price sensors for water levels and flows - Providing information by sensors - Providing knowledge and interpretation from experts.	<u>No issues from the point of providing knowledge and interpretation.</u>

Based on information gathered during the hearing survey, the relevant agencies for flood disasters in the disaster prevention sector were identified as SEN, MEF, MOPC, INE, DMH, and UCA. For forest fires, the relevant agencies were SEN, MADES, INFONA, and UNA.

At the first Disaster Prevention Working Group meeting held in April 2024, based on the results of the hearings, the WG discussed issues where the application of space-related technologies would be effective. It was confirmed that the application of space-related technologies would be effective for the following types of disasters and disaster management phases:

- Disaster type: Floods
- Disaster management phases: Emergency response phase, Preparedness phase
- Issues: 1) the standard operation procedure for satellite data utilizations on flood events was not established; and 2) regional flood hazard maps were not released.
- Challenge: 1) Standard Procedure Manual for Satellite Data Utilization (Emergency Response Phase); 2) Flood Hazard Map Creation (Preparedness Phase)

SEN and UCA identified the creation of hazard maps, usable in the preparedness phase for flood disasters, as a task where the application of space-related technologies would be effective. INE identified the development of a standard manual for utilizing satellite data during the emergency response phase as a task.

Activity 2-3. Determine scope for applying space-related technologies to the issues and design pilot projects

Based on the types of disasters and disaster management phases raised at the first Disaster Prevention Working Group meeting held in April 2024, discussions were held, and the pilot project was defined as creating flood hazard maps to be utilized in the preparedness phase for flood disasters. The target area was designated as the Bañado area in Asuncion.

A field survey was conducted for creation of flood hazard maps as the pilot project. The area highlighted in blue color near the river in Fig. 3.3.7-1. is the Bañado District, and both the Norte Area and Sur Area, outlined in red, were surveyed. Fig. 3.3.7-2. shows the field survey in progress.

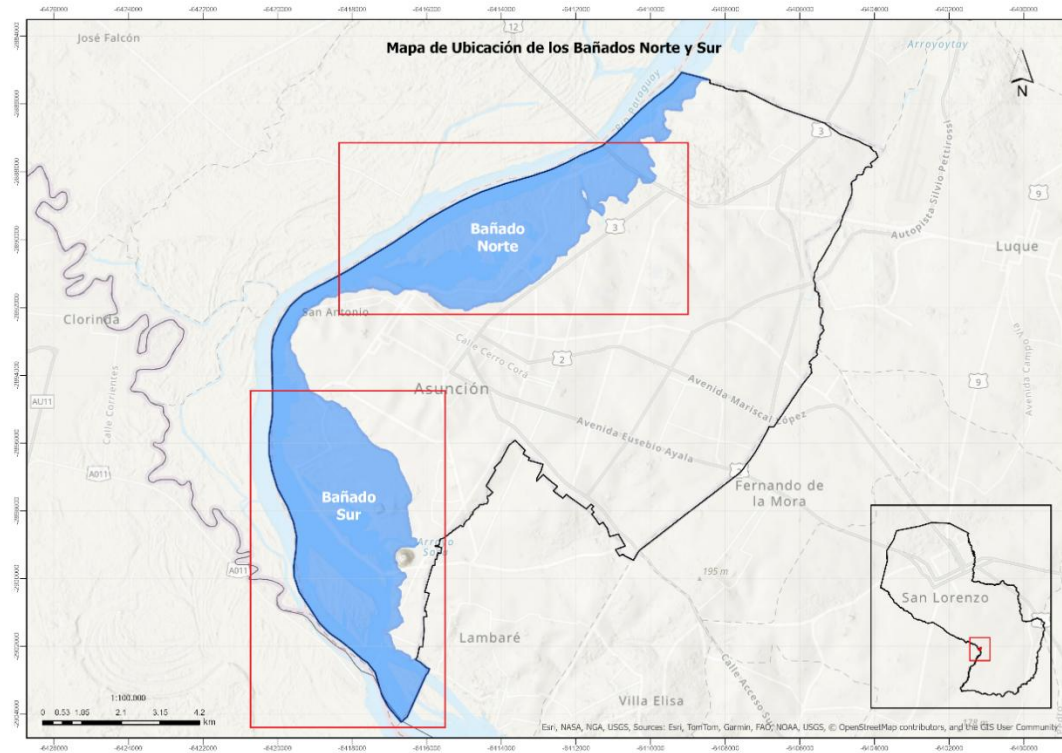


Fig. 3.3.7-1. Field Survey Location

The Bañado area in the target area is a region illegally filled with debris by residents on land that was originally a wetland. It features a flat terrain with low elevation near a river. It adjoins wetlands, and a highway crossing nearby acts as a barrier, blocking the escape route for accumulated water. Consequently, this area experiences not only seasonal flooding during the rainy season but also frequent flash floods triggered by sudden downpours. Many homes in this area are single-story structures. Residents report that floods exceeding 2 meters have submerged homes up to the roof. Furthermore, the entire area is flat and low-lying, making evacuation difficult during flooding.



Fig. 3.3.7-2. Photo of Filed Survey (Left: Building of residence, Right: Wetland)

To create a flood hazard map, it is necessary to calculate inundation areas through flood inundation analysis. For calculating inundation areas, simulations must be performed according to various flood scenarios. Based on the resulting inundation areas, the map must be finalized by inputting various information to create a flood hazard map suitable for use in that region. Selecting the appropriate software for flood inundation analysis and preparing the necessary data for the analysis are also crucial. Regardless of the specific software used, learning the fundamentals of hydrology and flood inundation analysis is

essential.

Therefore, the pilot project was structured into five components: “Data Preparation,” “Training on Flood Inundation Analysis Software,” “Flood Inundation Simulation and Creation of Flooded Area Maps,” “Creation of Flood Hazard Maps,” and “Consultation on Utilization of Flood Hazard Maps.” Fig. 3.3.7-3. shows the pilot project schedule, and Fig. 3.3.7-4. shows the implementation flow.

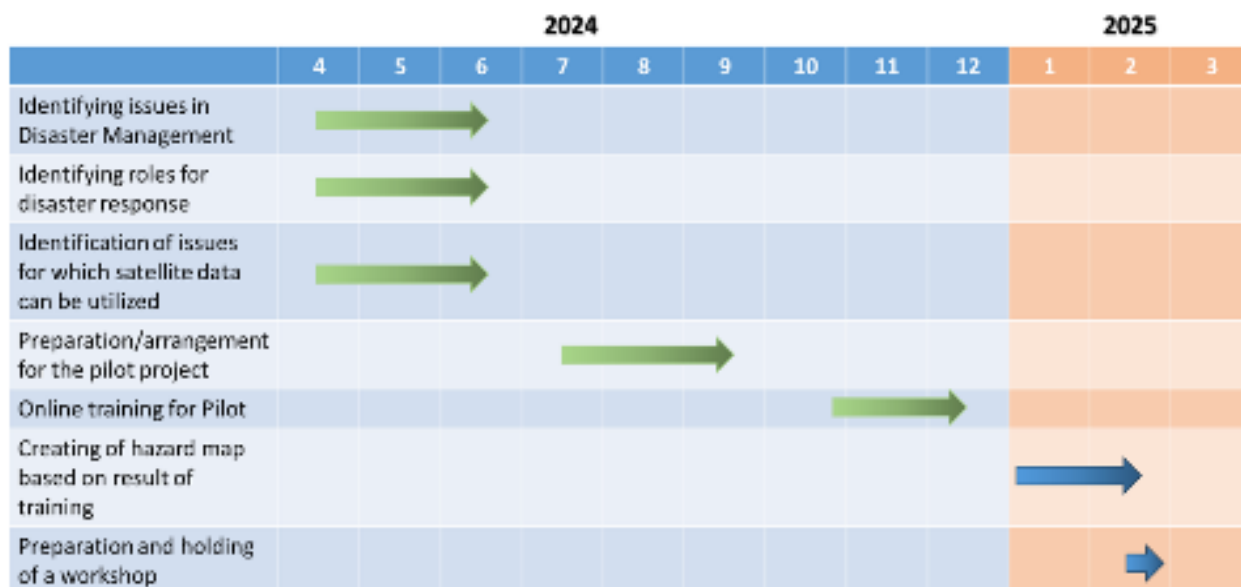


Fig. 3.3.7-3. Pilot Project Schedule for Disaster Prevention Field

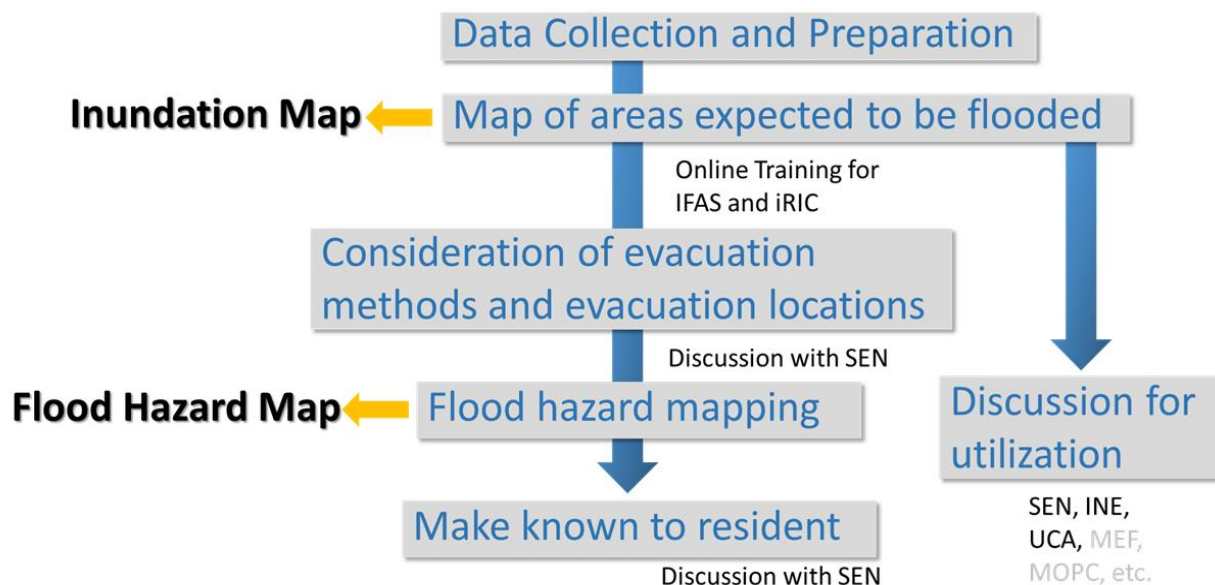


Fig. 3.3.7-4. Pilot Project Flowchart for Disaster Prevention Field

Activity 2-4. Develop plan and procure equipment (hardware and software) for satellite imagery and data collecting/processing

As a pilot project, this project formulated the necessary data for creating flood hazard maps and considered purchasing satellite data. In the disaster prevention field, since satellite data observed during

floods is accumulated at AEP through the International Charter, it was decided not to purchase data. The data required for creating flood hazard maps is shown in Table 3.3.7-4.

Table 3.3.7-4. Data Requirement for Flood Inundation Analysis

Data	Contents	Remark
Rainfall Data	• Observation station location • Observation interval (daily, hourly) • Observation period	• It is desirable to have all data available from the start of observations
Hydrological Data	• Paraguay River water level and flow volume • Observation interval (daily, hourly) • Observation period	• It is desirable to have all data available from the start of observations
Water Level of Ypacarai Lake	• Observation interval (daily, hourly) • Observation period	• It is desirable to have all data available from the start of observations
Historical Flood Records	• Period and rainfall at that time • Photos during flooding, etc. • Newspaper articles, YouTube videos, etc.	• It is also beneficial to have photographs and videos, not just time periods
DEM Data	• DEM (Digital Elevation Model)	• A Digital Terrain Model (DTM) is desirable • Elevation accuracy is particularly important in flat terrain
Land Use Data	• Land cover/land use data derived from satellite data, etc.	-
Bridge Drawings	• Design drawings for the two bridges spanning the Paraguay River, etc.	• Drawings are useful for estimating water levels during river floods
Hydrological Data for the Argentine Side	• Paraguay River water level and flow volume • Observation interval (daily, hourly) • Observation period	• As an international river, it is necessary to verify water levels and flow volume in the lower reaches and conduct verification across the entire Paraguay River basin

In the Bañado area, the pilot project area, two types of flooding occur: river overflow flooding caused by seasonal river inflows and internal flooding caused by flash floods such as sudden downpours. Therefore, iRIC, which can simulate both river overflow and internal flooding, was selected as the software for the pilot project. iRIC is a numerical simulation platform for hydraulic engineering, available for free use. It is software capable of analyzing river flow and riverbed changes, with ongoing functional enhancements including various numerical simulation models such as flood, runoff, tsunami, and debris flow models.

Activity 2-5. Train personnel in the use of tools, methods, and techniques for disaster risk reduction

The types of data required for iRIC to be utilized in flood inundation simulations were shared with AEP. AEP took the lead in collecting this data with the cooperation of organizations participating in the Disaster Prevention Working Group, thereby strengthening collaboration between AEP staff and related agencies. Furthermore, insights were gained regarding the data necessary for flood inundation simulations, particularly the importance of DEM data.

During the training in Japan, participants gained insights into Japanese flood control measures, river administration, river management and information systems, Japanese weather forecasting and disaster information dissemination, and Japan's approach to disaster response using satellite data. At the International Centre for Water Hazard and Risk Management (ICHARM), an introduction to iRIC and the RRI model (Rainfall-Runoff-Inundation model) developed by Japan, both to be used in the pilot project, served as an entry point for the pilot project. Field visits to Japanese river management sites included the Sumida River Super Levee and the Metropolitan Area Outer Floodway, providing hands-on experience with Japanese flood control. At Gifu University, participants experienced flood inundation analysis using test data from iRIC, which will be employed in the pilot project.

As part of the pilot project, the “Flood Inundation Analysis Software Training” conducted a total of 12 online training sessions from November 6 to December 13 (Japan time), focusing on the use of iRIC. The online training covered available satellite data, DEMs, satellite rainfall data, general flood management, and flow models. It also included hands-on training using iRIC to simulate flood inundation based on collected data from Paraguay. The schedule and content of the online training sessions are shown in Table 3.3.7-5.

Table 3.3.7-5. 1st Online Training

NO.	Date	Contents
1	November 6th, 2024	General Flood Management and Hydraulic Analysis, Required Information
2	November 7th, 2024	Utilizing Satellite Data and Introduction to Satellite Products for Hydraulic Analysis
3	November 8th, 2024	Introduction of GSMap, DEM (Merit, FbDEM, etc.), and review for the training session
4	November 12th, 2024	Introduction of iRIC and Hands-On Training (Input Data and Parameter Verification)
5	November 13th, 2024	Hands-On Training (Calculation Execution and Result Visualization)
6	November 14th, 2024	Introduction of other iRIC functions, and review for the training sessions
7	November 19th, 2024	Hands-On Training 1 (Using Actual Data from Paraguay)
8	November 20th, 2024	Hands-On Training 2 (Using Actual Data from Paraguay)
9	November 21st, 2024	Introduction to Hydrographs and Hands-On Training (Creating Hydrographs)
10	November 26th, 2024	Hands-On Training (Creating Flood Forecast Maps)
11	December 4th, 2024	Presentation of Calculation Results by Trainees, Discussion, and Overall Training Review
12	December 13th, 2024	Online Q&A Session

To widely share insights with relevant organizations in the disaster prevention field, participants were recruited by notifying not only AEP but also WG members. As a result, 38 individuals registered to participate from AEP, DMH, INE, MOPC, UCA, and UNA. Of these, 15 attended all sessions, while 13 participated later by watching the videos. All online training sessions were recorded on video to allow prospective participants who missed the live sessions to learn later. It is noted that viewing the online training videos, combined with the distributed lecture materials and the manual described later, enables not only repeated review for self-study but also serves as training for new staff joining AEP and other WG member agencies. Indeed, after the online training concluded, 13 additional individuals participated by watching the videos.

Certificates of training completion (see Fig. 3.3.7-5.) were issued to the 15 individuals who completed all lectures.



Fig. 3.3.7-5. Certificate for Training

Additional online training sessions on the RRI model, requested during the online training for flood hazard map creation, were held from June 24 to August 25 (Japan time), totaling nine sessions. The RRI model, developed by the ICHARM, which was also visited during the domestic training, is a model that predicts, on a basin-wide scale, the phenomenon where rain falling within a watershed collects in rivers, leading to flooding and overflow. Understanding the RRI model in addition to iRIC enables flood simulations to be conducted even in river areas where river flow is not measured. The schedule and content of the online training sessions are shown in Table 3.3.7-6. Ten participants attended the second online training session. All participants completed all sessions, and certificates of completion were issued, as in the first session.

Table 3.3.7-6. 2nd Online Training

NO.	Date	Contents
1	June 24th, 2025	Overview of Runoff and Flood Analysis, Introduction to Satellite Products Used in Runoff and Flood Analysis
2	June 26th, 2025	Analysis Methods Using Satellite Products and Ground Rainfall Data, How to install the RRI Model
3	July 1st, 2025	Hands-On Training 1, 2: Preparation Methods for Terrain Data and Rainfall Data, RRI Model Execution Method
4	July 3rd, 2025	Hands-on Training for the RRI Model 3: Visualization of Calculation Results, Explanation of Challenges
5	July 22nd, 2025	Introduction to the RRI Model GUI and Practical Application in the Ypane River Basin
6	July 24th, 2025	Flood Analysis Near Alberdi Using the RRI Model GUI
7	July 29th, 2025	Explanation of Various Data Formats and Hydrological Parameters for the RRI Model
8	July 31st, 2025	Presentation of Challenges by Trainees and Exchange of Opinions
9	July 25th, 2025	Identification of Issues with the RRI Model GUI and Usage of GSMap

Following the first online training session, the participants learned about the information required for flood hazard maps and their utilization by creating flood hazard maps based on flood inundation simulation results and visiting WG members to discuss their practical application.

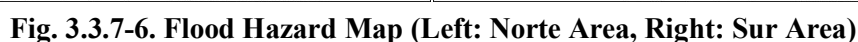
Activity 2-6. Implement pilot projects with Working Group and existing agreements with academia and other governmental and non-governmental organizations

Data was collected through Working Group members to conduct flood inundation simulations for creating flood hazard maps. The data collected with the cooperation of Working Group members is shown in Table 3.3.7-7.

Table 3.3.7-7. List of Acquired Data

Data	File Name	Remark
Rainfall Data	• ENG_AsuncionPort_EXP214832_nivel218 (Excel)	• Same location as water level and flow volume meters • Refer to the Precipitation tab; unit is [mm]
Hydrological Data	• ENG_AsuncionPort_EXP214832_nivel218 (Excel) • EXP 214832_nivel219 (Excel) • EXP 214832_nivel222 (Excel)	• Water level [m]; flow volume [m ³] • 219 and 222 contain water level data only • 222 also lacks installation location information
Land Use Data	• LandCover_FCA_UNA_2011	• Shape file
River Network Data	• RiverNetwork_PY_INE2012	• Shape file
Basin Boundary Data	• Lim_Cuencas2013	• Shape file
DEM Data	• DEM_PY_ALOSPARSAR_12.5M	• GeoTIFF file • Created by JAXA using ALOS PALSAR
Bridge Drawings	• Adenda_N3.ATLAS_DE_PLAN_CAD	• CAD file (DWG format)
Hydrological Data for the Argentine Side		• Not available
Historical Flood Records	• Priority 1: 30 and 31 December 2015, 1 January 2016 • Priority 2: 28 and 29 May 2019 • Priority 3: 19 November 2018	• Period when severe flooding occurred in the pilot target area

Regarding flood hazard maps, this project introduced flood hazard maps developed by Japanese municipalities, demonstrated what information is necessary for hazard maps beyond just flood inundation areas, drafted a flood hazard map, consulted with SEN, the actual user, and created a flood hazard map incorporating the information needed in Paraguay. The resulting flood hazard map is shown in Fig. 3.3.7-6.



For the pilot project, the training conducted and the process of creating flood hazard maps by adding information to inundation areas were compiled and organized into a manual. This enables AEP staff and WG members who did not participate this time to learn about creating flood hazard maps, thereby enhancing staff capabilities. For details of the manual, refer to Annex 4.

Following the implementation of this pilot project, UNA students who newly learned flood inundation analysis through the online training lecture materials and videos were able to create flood hazard maps for other regions using this manual, thereby expanding the pilot project.



Activity 2-7. Publish results of pilot projects locally and internationally

On February 19, 2025, during the third trip, a workshop was held in Paraguay to present the results of the pilot project. The workshop included explanations of project activities, the formation of working groups, discussions on identifying issues and utilizing satellite data, and the pilot project design. The project presented what they learned through online training and introduced the flood hazard maps they created.

Coinciding with the workshop, the first edition of the pilot project manual was released, and attendees were asked to provide feedback for review and improvement. This first edition manual reproduces the content learned in the online training and is organized to enable flood inundation simulations using iRIC. The official final edition was released at the final JCC meeting. Additionally, AEP plans to continue reviewing and improving it as necessary. Furthermore, AEP published the results of this pilot project in the Atlas released annually by GEOLab.

For the flood hazard maps created in the pilot project, AEP developed a web-based dashboard (Fig. 3.3.7-7.) that can be accessed and viewed freely on computers and smartphones. This dashboard was made publicly accessible via a QR code during the final JCC meeting.



Fig. 3.3.7-8. Photo of Disaster Prevention in the Workshop

3.3.8. Activities Related to Output 3

Activity 3-1. Establish a working group (WG) within AEP and related institutions to identify issues and implement pilot projects.

In this project, a WG was officially established with nine core institutions, as indicated in blue in Table 3.3.8-1. During the implementation period, the WG was further expanded with the participation of the PTI of ITAIPU Hydroelectric Power Plant and the Paraguayan Institute of Agricultural Technology (IPTA), reflecting growing interest and collaboration.

Table 3.3.8-1. Candidate Institutions for the Agriculture and Livestock WG

Institutions	
Paraguayan Space Agency (AEP)	Ministry of Agriculture and Livestock (MAG)
Vice-Ministry of Economy and Planning (MEF)	National Plant, Seed Quality and Health Service (SENAVE)
National Institute of Rural and Land Development (INDERT)	National Institute of Statistics (INE)
Ministry of Environment and Sustainable Development (MADES)	National Forestry Institute (INFONA)
Director of Meteorology and Hydrology (DMH)	National University of Asuncion (UNA)
Catholic University (UCA)	

Note: The PTI of ITAIPU Hydroelectric Power Plant and the Paraguayan Institute of Agricultural Technology (IPTA) joined during the project period

The WG convened regularly throughout the project, holding a total of four meetings, including a preliminary session. Each meeting served as a platform for sharing information, discussing key issues, and making decisions related to the pilot project. The agendas and outcomes of these meetings are summarized in Table 3.3.8-2.

Table 3.3.8-2. Summary of WG Meetings

Meeting	Date (Local Time)	Venue	Summary	Outcome
Pre-WG Meeting	March 6, 2024	Online	• Approval of WG guidelines • Formation of the WG	• WG officially formed
1st WG Meeting	April 24, 2024	Hybrid (On-site & Online)	• Sharing of identified issues • Presentation and approval of pilot project scope	• Scope approved
2nd WG Meeting	July 4, 2024	Online	• Explanation of methodology and data acquisition • Request for cooperation	• Methodology approved
3rd WG Meeting	November 25, 2024	Online	• Sharing of monitoring results	• Feedback on results

Prior to the official formation of the Working Group (WG), a series of interviews were conducted jointly with AEP during the initial visit to Paraguay. These interviews targeted the institutions listed as WG candidates in Table 3.3.8-1. and served as the foundation for a preparatory meeting held in March 2024. During this meeting, the project team provided an overview of the WG guidelines to the candidate institutions, which led to the formal establishment of the WG. Furthermore, as a result of AEP's proactive outreach and coordination efforts, the PTI of ITAIPU Hydroelectric Power Plant and the Paraguayan Institute of Agricultural Technology (IPTA) also joined the WG, further strengthening its institutional base.

Activity 3-2. Identification of Issues Where Space-Related Technologies Are Effective in the Agriculture and Livestock Sector:

In the agriculture and livestock sector, several issues were identified where the application of space-related technologies is considered effective. These include the lack of established methods for wide area monitoring of crop growth, difficulties in taking early action against climate change, the significant labor required to assess growth conditions, and the limited information of domestic statistics and forecasts related to crop types and yields.

To clarify these issues, the project team conducted interviews with relevant institutions during the initial visit to Paraguay. Based on the information gathered, key themes such as satellite data utilization, institutional roles, and existing challenges were systematically organized (see Table 3.3.8-3). These discussions revealed strong expectations for the use of satellite image analysis. In addition, although AEP possesses experience in basic vegetation analysis, a major challenge identified was the lack of sufficient validation of analytical results through field-based surveys. This highlights the need for integrating remote sensing with ground-truthing to ensure the reliability and applicability of satellite-derived insights.

Table 3.3.8-3. Summary of Interview Results from Ministries, Universities, and Institutions Related to the Agriculture and Livestock Sector

Institution	Expectations for Satellite Data Use in Agriculture and Livestock	Potential Satellite Data Applications	Challenges
MAG	Use satellite data to accurately assess agricultural damage for insurance compensation during disasters. Promote smart agriculture by integrating UAV and satellite data. Utilize data for climate-resilient agriculture to enhance food security.	• Real-time monitoring of soil moisture • Creation of variable fertilization maps for targeted pesticide application	• Collaboration with AEP is essential • Lack of personnel capable of integrating satellite and UAV data • Need for knowledge

Institution	Expectations for Satellite Data Use in Agriculture and Livestock	Potential Satellite Data Applications	Challenges
MEF	Use satellite data for strategic regional planning	Sharing information on suitable cultivation areas based on climate change	Need for knowledge sharing wit
SENAVE	Ensure the quality and safety of agricultural products in Paraguay	- Guarantee traceability of domestic agricultural products - Soil and water quality surveys	- Limited development of field polygon data - Need for nationwide soil and water surveys using satellite data
INDERT	Organize spectral characteristics of crops cultivated in Paraguay in collaboration with SENAVE	Crop information surveys	- Need to establish a satellite analysis department and train personnel - Need for knowledge sharing within WG
INE	Build a national geospatial information infrastructure	Updating statistical data using satellite data	No major issues in providing statistical information
MADES	Detect illegal logging and illicit crop cultivation in protected areas	- Early detection of deforestation - Detection of illegal crop cultivation	Need for collaboration with GEOLab
INFONA	Monitor land use changes and interested in earlier detection	Early detection and reporting of land use changes	Need for collaboration with MADES and other agriculture-related institutions
DMH	—	Provide meteorological information to warn of crop failure and disaster damage due to abnormal weather	Need for knowledge sharing within WG
UNA	Conduct research on smart agriculture integrating UAV data	Application of satellite data to smart agriculture	Need for knowledge sharing within WG
UCA	Conduct research on meteorology, land use changes, and development of numerical analysis models	- Early detection of land use changes - Development and sharing of numerical analysis algorithms using satellite data	Need for knowledge sharing within WG

Building on the strong expectations for satellite image analysis identified through interviews with ministries, universities, and institutions in the agriculture and livestock sector, additional interviews were conducted during the second visit, focusing on the most relevant stakeholders (see Table 3.3.8-4.). These follow-up discussions confirmed that wide-range monitoring is a critical theme, contributing to both labor reduction and improved risk management. Furthermore, it was recognized that with the development of standardized manuals and procedures, the broader deployment of such technologies is not only feasible but also scalable.

Table 3.3.8-4. Results of Additional Interviews

Institution	Issues and Expectations
MAG	The main targets are small- and medium-scale farmers. Monitoring crop health, soil moisture, and yield prediction throughout the growing season is considered important. While satellite images such as Landsat and MODIS are already in use, there is interest in utilizing higher-resolution imagery.
SENAVE	With field offices nationwide, staff conduct on-site inspections about once a month to monitor pests and diseases. Farmers report yields, and the data is managed via a portal, but currently there is no data sharing with other ministries. They expressed interest in future collaboration.
INDERT	Conducts field surveys to understand farming conditions for land registry management and is interested in reducing labor through satellite data utilization.

The results of the additional interviews indicate that space technologies are effective tools for addressing practical challenges in the agriculture and livestock sector and suggest concrete directions for future

technological implementation.

Activity 3-3. Defining the Scope for Applying Space-Related Technologies and Designing Experimental Initiative

Drawing on the issues identified in Activity 3-2 —namely, the lack of established methods for wide-area monitoring of crop growth, challenges in early response to climate change, the labor-intensive nature of growth assessment, and limitations in the accuracy of domestic statistics and forecasts— a pilot project was designed with a focus on developing a method for wide-area monitoring of soybean growth. This scope was selected for its practical relevance to reducing labor costs and enhancing risk management in agricultural operations.

Among the identified challenges, the need for large-scale crop monitoring emerged as a particularly critical theme. Given the significance of soybean production in Paraguay, soybeans were selected as the target crop. The proposed scope directly addresses operational needs and was regarded as highly practical by participating institutions. In addition, this initiative contributes to the collection of fundamental data necessary for analyzing planted area, which support the improvement of domestic agricultural statistics. The scope was presented and formally approved during the first WG meeting held in person in April 2024.

In response to previously noted technical challenges—particularly the need for field validation—the project design also incorporated elements aimed at strengthening the capacity to interpret analytical results. Details of the pilot project design are provided in Table 3.3.8-5.

Table 3.3.8-5. Pilot Project Design Details

Item		Description	Remarks
Objective		Verification of a wide-area monitoring method for soybean growth using satellite imagery	—
Data Used		• Satellite imagery (Sentinel-2, PlanetScope, GRUS) • Meteorological data	Satellite data procurement is described in Activity 3-4. Meteorological data provided by DMH.
Target Area		Collaborative fields in Caaguazú region managed by SENAVE (see Fig. 3.3.8-1.)	Fields were selected based on interviews with MAG and SENAVE, considering criteria such as: minimum size of 30m × 30m, feasibility of measuring plant height, and accessibility for day trips from Asunción.
Period		① September 2024 – February 2025 ② February 2024 – July 2024	① Pilot project implementation period ② Post-operational phase
Methodology	Growth Analysis:	NDVI and time-series analysis will be used to monitor crop growth and generate growth maps. Monthly field surveys will be conducted to link satellite data with ground observations.	—
	Field Surveys:	Monthly surveys during the pilot period to measure soybean growth stage, plant height, and pod count.	—
	Monitoring Method Validation & Data Accumulation:	NDVI time-series analysis of soybean fields over the past two cropping seasons and the post-operational phase to assess differences in growth patterns between rainy and dry seasons.	In addition to data validation, multi-temporal image analysis will be used to accumulate insights, as growth speed is expected to vary between seasons.
	Crop Classification.	Using phenological data collected through growth analysis, methods for crop classification will be explored and prototype classification maps will be developed.	—

Implementation Structure	Led by AEP, with data sharing and joint implementation by WG members	Field survey support by SENAVE; meteorological data provided by DMH
Outputs	Growth maps, analysis manuals	—

In promoting the use of space-related technologies in the agriculture and livestock sector, it is essential not only to establish analytical methods for specific issues but also to pursue broader utilization through continuous data accumulation. From this perspective, the project included an attempt during the post-operational phase to develop procedures for creating crop classification maps based on the information gathered through growth monitoring.

This initiative was decided in consultation with AEP, based on feedback received from MAG during the third visit, where they expressed interest in using satellite data to support national agricultural statistics through improved understanding of cropping conditions.

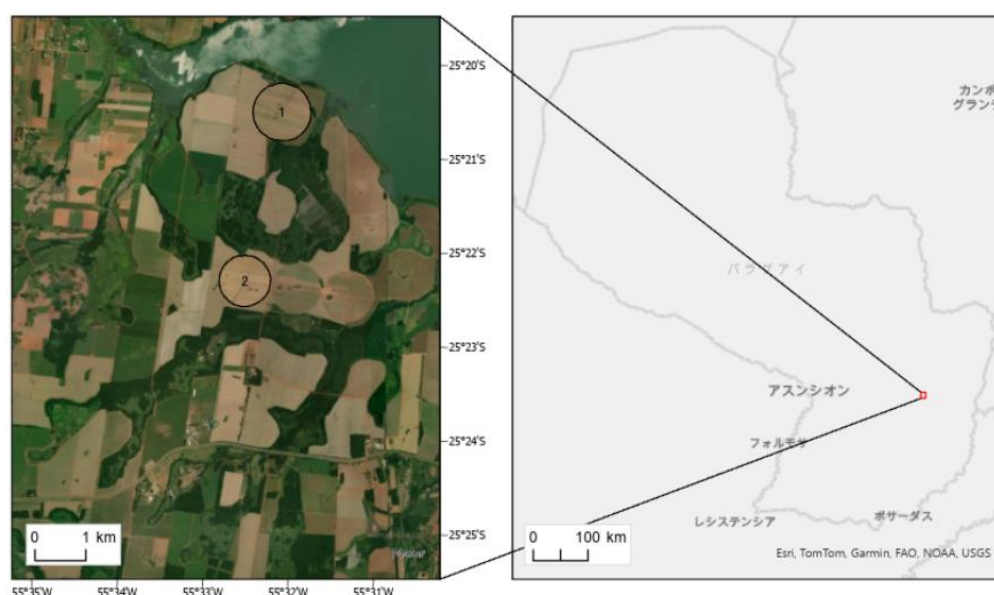


Fig. 3.3.8-1. Location Map and Overview of the Target Area

Activity 3-4. Development of a Procurement Plan for Satellite Data and Data Processing/Collection Equipment (Hardware and Software)

To support continued utilization, a satellite data procurement plan was developed. Based on discussions with AEP, it was determined that procurement of related equipment (hardware and software) was not necessary for this activity, and therefore no procurements were planned.

To ensure sustainable operations, the project adopted a policy of leveraging freely available satellite data wherever possible. However, through discussions with AEP, it was mutually recognized that acquiring high temporal resolution imagery is essential for effective monitoring. Based on this shared understanding, an agreement was reached to procure satellite imagery that would contribute to long-term knowledge accumulation.

Accordingly, a procurement plan was formulated in alignment with both the analytical timeline and the crop growth calendar. The specifications and procurement details of the selected imagery are summarized in Table 3.3.8-6.

Table 3.3.8-6. Satellite Imagery Procurement Plan and Specifications

Item	Specification	
	PlanetScope	GRUS
Operating Agency	Planet Labs (USA)	Axelspace (Japan)
Resolution (GSD)	Approx. 3.7 m	Panchromatic: 2.5 m Multispectral: 5.0 m
Imaging Frequency	Daily	Approx. once every two days (mid-latitude regions)
Procurement Period	Pilot project period, two previous cropping seasons for analysis, and post-operational phase	Pilot project period
Procurement Policy	Scenes will be flexibly added or modified as needed, based on the crop calendar and analysis timeline	

Activity 3-5. Capacity Building on Satellite Data Analysis and Utilization for Enhancing Agricultural Productivity and Quality

Capacity building in satellite data analysis and utilization for the agriculture and livestock sector was carried out in a phased approach, progressing from conceptual understanding to the development of practical skills.

In the initial phase, participants visited relevant institutions in Japan as part of a training program designed to build foundational knowledge of satellite data applications. The institutions visited are listed in Activity 1.

Subsequent field-based training sessions were held in both Japan and Paraguay to promote hands-on experience in data collection and analysis. These sessions aimed to strengthen participants' ability to interpret satellite data in relation to actual field conditions. Specifically, prior to field surveys, NDVI maps were used to predict vegetation status in the target areas, and participants were guided through a process of comparing satellite-derived data with on-site observations. This approach helped participants understand how satellite data contributes to situational awareness and supports improved analytical accuracy.

For growth monitoring analysis, instructional materials were provided, including procedures for generating automated growth maps using ArcGIS. Beyond tool usage, the training emphasized understanding the underlying concepts and workflows, enabling participants to apply these skills in their professional activities.

During the post-operational phase, online training sessions were conducted to support the continued use of satellite data in the field. These sessions focused on applying insights gained from previous training and fieldwork. Topics included:

- Basic techniques for creating crop classification maps using data accumulated through the pilot project, and
- Fundamentals of satellite-based soil moisture analysis, in response to MAG's expressed interest in this area.

The training was delivered in four sessions using Google Earth Engine (GEE), with screen sharing and interactive Q&A to enhance participant engagement and understanding. Details of the training content and outcomes are presented in Table 3.3.8-7. A total of 24 participants took part in the training: 11 from AEP, 9 from MAG, and 4 from SENAVE.

Table 3.3.8-7. Overview of Online Training Sessions in the Agriculture and Livestock Sector

No.	Date (Local Time)	Training Content	Outcomes
1	July 15, 2025	• Overview of satellite imagery • Introduction to Google Earth Engine (GEE) • Interpretation of growth monitoring results from the pilot project • Importance of phenology in crop mapping • Basic techniques for crop mapping • Hands-on Preparation ①: NDVI time-series extraction (GEE) • Hands-on Preparation ②: Extraction of cultivated areas (GEE)	• NDVI time-series data • Map of cultivated areas (unclassified)

2	July 18, 2025	- Review of supervised learning methods for crop classification - Hands-on ①: Feature extraction for crops (GEE) - Hands-on ②: Creation of training data (GEE) - Hands-on ③: Random forest model construction and accuracy assessment (GEE) - Hands-on ④: Prediction of crop classification map (GEE)	- Random forest classification model and accuracy evaluation - Crop classification map
3	July 29, 2025	- Case studies of agriculture-related projects led by NASA and JAXA - Technical fundamentals of soil moisture measurement (SMAP satellite) - Hands-on: Acquisition of soil moisture data (GEE)	Soil moisture map
4	July 30, 2025	- Exercise: Analysis of soil moisture data and crop classification maps - Group discussion among participants	Overlay map combining crop classification results and soil moisture data

Activity 3-6. Implementation of the Pilot Project Utilizing Existing Agreements with the WG, Academia, and Governmental/Non-Governmental Organizations

By leveraging existing agreements, the pilot project and subsequent post-operational activities were successfully implemented, yielding multiple outcomes through satellite-based monitoring and field surveys.

To support the pilot project, essential data for analysis and validation were first organized. Agricultural management information—including cropping conditions and agricultural management records—was collected with the cooperation of SENAWE, which maintains an agreement with AEP. Satellite imagery was procured flexibly in accordance with the established procurement plan, tailored to the required timing and geographic coverage.

Field polygon data were generated by AEP using the acquired imagery and served as foundational spatial datasets for identifying target plots for analysis. Meteorological data were obtained through collaboration with DMH, a participating WG institution, and were used to analyze factors influencing crop growth and to cross-reference with satellite observations.

This comprehensive data preparation process helped establish a robust framework that enhanced analytical accuracy and ensured the reliability of validation efforts.

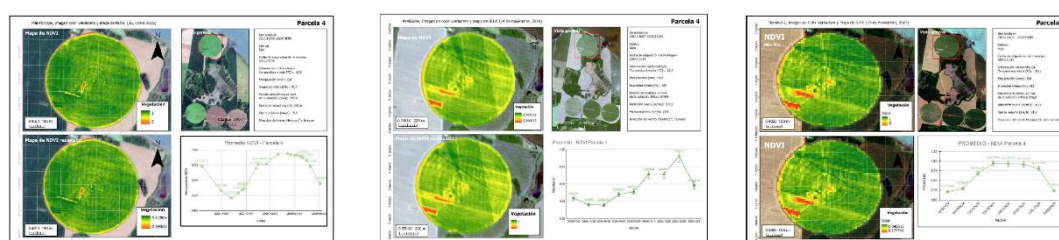


Fig. 3.3.8-2. Example of Growth Maps Created by AEP
(Left: PlanetScope; Center: GRUS; and Right: Sentinel-2)

Satellite-based NDVI analysis was conducted to visualize the growth status of soybeans, resulting in the creation of growth maps. A selection of these maps is shown in Fig. 3.3.8-2.

In parallel with the time-series analysis of satellite imagery, AEP—excluding training activities—conducted five field surveys in collaboration with SENAWE on the following dates: October 7, November 4, and December 9, 2024; January 17 and February 13, 2025. These surveys focused on areas identified as underperforming in the satellite analysis, where factors such as poor drainage were confirmed. In addition, field-level data on crop growth stages were collected and compiled as baseline information. Scenes from the field surveys are shown in Fig. 3.3.8-3.



Fig. 3.3.8-3. Scenes from Field Surveys

An analysis using historical satellite data was conducted to assess the impact of seasonal and temperature variations on crop growth, contributing to the accumulation of technical insights. During the post-operational phase, the same fields were used to validate the monitoring methodology, confirming both the reproducibility and practical applicability of the analytical approach.

In the online training sessions during the post-operational phase, participants carried out a trial to generate crop classification maps for surrounding areas using phenological data on soybeans—such as peak NDVI dates—accumulated during the project. A prototype of the resulting crop classification map is presented in Fig. 3.3.8-4.

Although limited ground-truth data prevented full validation, the training successfully introduced core analytical techniques and workflows for satellite image interpretation. This initiative laid a technical foundation for future applications and provided participants with a valuable opportunity to deepen their understanding of satellite data utilization. The effort also aimed to enhance future implementation potential, contingent on the development of a more robust local data collection system.



Fig. 3.3.8-4. Prototype Crop Classification Map Predicted Using Google Earth Engine (GEE)

The methods and procedures developed through these activities were compiled into a manual. An overview of the manual is shown in Fig. 3.3.8-5., with full details provided in Annex 5.



Fig. 3.3.8-5. Overview of the Satellite Data Utilization Manual for the Agriculture and Livestock Sector

Activity 3-7. Dissemination of Pilot Project Results at Local and International Levels

The results of the pilot project were shared with relevant institutions through a local workshop and the publication of a technical manual.

On February 19, 2025, a results-sharing workshop was held locally for stakeholders and technical experts. The workshop presented key activities and outcomes of the pilot project, including the formation of WG, satellite data analysis methodologies, and deliverables such as growth maps and the satellite data utilization manual. Future directions for the application of satellite technologies in agriculture were also discussed (see Fig. 3.3.8-6.).

The workshop generated strong interest in the use of high-resolution satellite imagery, with participants noting that such technologies are “highly useful for local agricultural management.



Fig. 3.3.8-6. Scenes from the Workshop

Chapter 4. Results of the Project

4.1. Results of Outputs

4.1.1. Results of Output 1

The results of Output 1 are summarized by activities in Table 4.1.1-1.

Table 4.1.1-1. Results of Output 1

Activity	Activity details	Results
Activity 1-1	Evaluate AEP's existing satellite data analysis methods and tools	<u>Achieved</u> After understanding of Paraguayan capabilities in small satellite developments and satellite data utilizations, JICA Consultant Team and AEP Team evaluated the status and abilities of small satellite developments and satellite data utilizations in AEP.
Activity 1-2	Develop strategy for their enhancement based on an evaluation of satellite development facilities available at AEP's SPACELab	<u>Achieved</u> Through the interview survey, JICA Consultant Team and AEP Team explained the importance of field surveys to deepen knowledge and consideration of the satellite data analysis results, and they conducted field survey before Pilot Projects and demonstrated importance. A policy (strengthening plan) for enhancing space business cooperation between Japan and Paraguay was formulated. Through discussions with AEP, a policy for strengthening future operations was compiled.
Activity 1-3	Conduct six-month hands-on training, including testing of the GuaraniSat-2 Engineering Model (EM), at Kyutech from October 2024 to May 2025	<u>Achieved</u> By participating in BIRDS-RPM (a small satellite development program run by Kyutech in collaboration with Rwanda, Paraguay, and the Maldives), the attendee was able to deepen their knowledge of the basic technologies involved in small satellite development and operation, as well as the importance of international collaboration in space development. Furthermore, by the test of GuaraniSat-2 EM, AEP Team was able to not only acquire the skills required for operating a test environment but also progress one stage in the development of GuaraniSat-2, which AEP develops independently. AEP began to develop GuaraniSat-2 FM, aiming for the launch in October 2026.
Activity 1-4	Conduct training on processing and application of satellite data and other data	<u>Achieved</u> By learning about specific examples of satellite data utilizations in disaster managements and agriculture by Japanese ministries and local governments, AEP Team was able to deepen their knowledge of space systems and satellite data utilizations as the national institution. Through lectures at Gifu University and Hokkaido University, AEP Team was able to improve their satellite data analysis skills. In particular, the flood simulation analysis technologies implemented at Gifu University were applied into creating flood hazard maps and used as basic data for cross-ministerial studies of countermeasures in Paraguay.
Activity 1-5	Collaborate with AEP and Japanese government organizations, universities, and private companies	<u>Achieved</u> Discussions and workshops (business networking) were held with Japanese government agencies, universities, and private companies. It was expected

		space cooperation between Japan and Paraguay through industry, academia, and government promoted, leading to the creation of new space businesses. In particular, the business networking held in September 2025 led to the start of planning and discussions for the development of GuaraniSat-3 among 3 parties: a Japanese company, a Paraguayan company and AEP.
--	--	--

4.1.2. Results of Output 2

The results of Output 2 are summarized by activities in in Table 4.1.2-1.

Table 4.1.2-1. Results of Output 2

Activity	Activity details	Results
Activity 2-1	Establish working groups within AEP and related agencies to identify challenges and implement pilot projects.	<u>Achieved</u> The Working Group was formed in April 2024, and a total of 4 times WG meetings (including preliminary discussions) were held, the working group's setting can be considered achieved.
Activity 2-2	Identify challenges in disaster prevention where space-related technologies can be effectively applied.	<u>Achieved</u> The current status of disaster prevention agencies, the application and role of space-related technologies, and associated issues were systematically reviewed. As a result, deficiencies in the satellite data utilization standard operation procedure during the emergency response phase of disaster management for flood disasters and inadequacies in flood hazard maps during the preparatory phase were identified as key issues. This achievement can be considered accomplished.
Activity 2-3	Determine the scope for applying space-related technologies to these challenges and design experimental initiatives.	<u>Achieved</u> As the scope for applying space technology, it was decided to create flood hazard maps for use in the preparatory phase of flood disaster response. The implementation flow and schedule for creating the flood hazard maps were successfully established, thereby achieving this objective.
Activity 2-4	Develop plans for purchasing satellite data and data processing/collection equipment (hardware and software).	<u>Achieved</u> The activities can be considered successful, as the data required for creating flood hazard maps was identified and collected from WG members.
Activity 2-5	Conduct capacity building on satellite data analysis and usage methods that contribute to disaster risk prevention and mitigation.	<u>Achieved</u> Through Japan-based training and online training, the participants acquired the fundamental knowledge necessary for creating flood hazard maps and learned how to utilize flood inundation analysis software. Furthermore, the online training sessions were recorded on video, and together with the lecture materials, were made publicly available; manuals were also developed, making the outputs usable for future human resource development.
Activity 2-6	Implement pilot projects utilizing existing agreements with WGs, academia, and other governmental and non-governmental organizations.	<u>Achieved</u> Using flood inundation analysis software, the flood inundation simulation was conducted to calculate the inundation areas. Furthermore, based on the calculated inundation areas, a draft flood hazard map was created. Through discussions with SEN, the necessary information for Paraguay was inputted, and the creation of Paraguay's flood hazard map can be considered an achievement.

Activity 2-7	Publish the results of pilot projects locally and internationally.	<u>Achieved</u> This was achieved by holding workshops and publicly releasing flood hazard maps and manuals locally.
--------------	--	--

4.1.3. Results of Output 3

The results of Output 3 are summarized by activities in Table 4.1.3-1.

Table 4.1.3-1. Results of Output 3

Activity	Activity details	Results
Activity 3-1	Establish a WG at AEP and related institutions to identify issues and implement the pilot project	<u>Achieved</u> The WG was formed in April 2024, and through a total of four WG meetings (including preliminary consultations), a coordination framework was established among relevant institutions.
Activity 3-2	Identify issues in the agriculture and livestock sector where space-related technologies can be effectively applied	<u>Achieved</u> The current situation and challenges of relevant institutions were reviewed, and potential applications of space technologies, and key issues were successfully identified.
Activity 3-3	Define the scope of applying space-related technologies to the identified issues and design experimental approaches	<u>Achieved</u> Based on the issues identified in Activity 3-2—such as the lack of wide-area monitoring methods, difficulty in early response to climate change, labor-intensive growth assessment, and limitations in statistical accuracy—the pilot project was designed with a focus on establishing a method for as wide-area monitoring of soybean growth.
Activity 3-4	Develop a procurement plan for satellite data and equipment (hardware and software) for data processing and collection	<u>Achieved</u> Through information sharing with WG members, the timing for satellite image procurement was determined, and a procurement plan was developed accordingly.
Activity 3-5	Conduct capacity building on satellite data analysis and utilization methods to improve productivity and quality in agriculture and livestock	<u>Achieved</u> Through training on satellite data analysis, participants acquired foundational skills in field surveys, automated analysis, and crop classification. As a result, AEP became capable of independently creating and applying growth maps.
Activity 3-6	Implement the pilot project by leveraging existing agreements with the WG, academia, and other governmental and non-governmental organizations	<u>Achieved</u> In collaboration with WG members, a soybean growth map linked to field survey results was created, and a prototype crop classification map was developed using the collected data.
Activity 3-7	Disseminate the results of the pilot project locally and internationally	<u>Achieved</u> A workshop was held locally to present the growth map and manual. The methods used in the project were shared both within and outside the WG in a format applicable to other regions.

4.2. Issues and Ingenuities

Geographical constraints, time differences in 12-hour, and long-trip-intervals, about 10-month between the 2nd and the 3rd Trips were huge issues for operating the Project between Japan and Paraguay. 4.2.1 to 4.2.3 show issues, ingenuities and precepts which JICA Consultant Team and AEP Team faced for the operations of the Project.

4.2.1. Issues and Solutions in Output 1

Table 4.2.1-1. shows the challenges faced in implementing the activities for Output 1, as well as the solutions.

Table 4.2.1-1. Challenges and Solutions in implementing activities for Output 1

Activity	Challenges and Solutions
Activity 1-1	In order to confirm the status of AEP's existing facilities and satellite data analysis methods and tools, interview survey was conducted to not only with AEP but also with user ministries and agencies. multifaceted assessments of the status of space systems and satellite data utilization in Paraguay was conducted.
Activity 1-2	By conducting specific interviews about AEP's organizational structure and outlook, which are important in formulating medium- to long-term plans, the awareness of formulating plans with an eye to the future were shared among the Project Team.
Activity 1-3	- Enhancement of capacities for launching the Paraguayan flight models and continuing small satellite developments by AEP independently were required, KCCP for Upstream was considered and prepared for 6-month program as the 1st Batch and 2-month as the 2nd including the engineering model test which was developed by AEP for raising the level of satellite developments and operation capacities. 2nd Batch of KCCP was a highly challenging program, because its purpose was to complete the development of the GaraniSat-2 Engineering Model and conduct testing at Kyutech. Multiple online preparation meetings were held to ensure smooth implementation of the training.
Activity 1-4	AEP requested that as many engineers as possible participate; however, due to the initially assumed upper limit of the project budget, it was necessary to adjust the number of participants within this limit. For the agriculture and livestock field study in particular, the amount of on-site verification work that could be performed was limited depending on the time of visit to Japan, so we reached an agreement with AEP in advance on the content of the field study. Regarding the number of participants in the training, we reduced the initial two visits to Japan to one, allowing as many analysis engineers as possible to come to Japan within budget.
Activity 1-5	Rather than a one-sided introduction from our Japanese organization, the Paraguayan side also presented general information, current efforts in agriculture and livestock farming and disaster prevention, as well as the challenges facing both themes and expectations for satellite use, leading to effective discussions aimed at continuing cooperation between the two sides.

4.2.2. Issues and Solutions in Output 2

Table 4.2.2-1. shows the challenges faced in implementing the activities for Output 2, as well as the solutions.

Table 4.2.2-1. Challenges and Solutions in implementing activities for Output 2

Activity	Challenges and Solutions
Activity 2-1	- In the disaster prevention field, floods and forest fires are identified as disasters. Consequently, depending on the disaster type, some organizations may not qualify as WG member institutions. Therefore, guidelines for establishing the WG were created to ensure alignment on the content to be discussed within the WG, as well as on activity plans and outcomes. Furthermore, regarding the types of disasters to be covered, broad input was sought during WG meetings to ensure the focus would be on disasters of high interest. - After the WG was formed, there was a prolonged period without travel for on-site pilot project support or workshop organization, making it difficult to hold face-to-face WG meetings. This challenge was addressed by conducting WG meetings online during periods when the JICA consultant team was absent.
Activity 2-2	None

Activity 2-3	When defining the scope of the pilot project, it was necessary to encourage active involvement from the WG members in the disaster prevention field. Therefore, discussions during WG meetings were handled by AEP, allowing members to debate in their native languages and fostering the generation of ideas from WG members.
Activity 2-4	The data required for creating flood hazard maps encompasses not only satellite data but also various types of data. Furthermore, to ensure the flood hazard maps accurately reflect local conditions in Paraguay, locally measured data is essential. Since AEP's independent data collection efforts have limitations, explanations of the data to be used were provided during WG meetings, and efforts were made to collect data through WG members. Additionally, collecting data from WG members strengthened collaboration between AEP and related organizations.
Activity 2-5	- Due to the 12-hour time difference between Japan and Paraguay, training sessions were conducted during the morning hours in Japan and the evening hours in Paraguay, lasting approximately 1 to 2 hours per day. - As data processing by iRIC requires a considerable amount of time and might not be completed within the training session, data simplification was performed. Additionally, computational processing for each workflow step was conducted in advance, so that the processing results could be presented during the training sessions. - To allow for reviewing training or learning missed sessions later, online lectures were recorded as videos and made available on a shared platform along with the lecture materials. This also enabled training for new members.
Activity 2-6	To incorporate flood inundation simulation results into flood hazard maps, it was necessary to input information required for on-site application in Paraguay. Therefore, while referring to examples from Japan, the information needed for Paraguay was formulated through discussions with SEN, thereby deepening mutual understanding. Additionally, to facilitate these discussions, a draft flood hazard map was prepared for discussion purposes.
Activity 2-7	At the workshop, the implementation details of the pilot project were shared, and by widely publishing and sharing the flood hazard map creation manual, efforts were made to enable the collection of broad feedback for improvement.

4.2.3. Issues and Solutions in Output 3

Table 4.2.3-1. shows the challenges faced in implementing the activities for Output 3, as well as the solutions.

Table 4.2.3-1. Challenges and Solutions in implementing activities for Output 3

Activity	Challenges and Solutions
Activity 3-1	Some WG contact points were often in senior management positions, which made scheduling meetings time-consuming. In particular, although MAG showed strong interest in the project, their representative frequently traveled for work, making it difficult to arrange in-depth discussions. To address this, technical-level participation was encouraged to facilitate more practical communication.
Activity 3-2	Among WG members, MAG and SENAVE were one of the primary user ministries in the agriculture and livestock sector. In line with AEP's intention to maintain balanced engagement, efforts were made to strengthen relationships with both institutions through close consultations and needs assessments. These identified needs were then used to enhance the content of the training in Activity 3-5.
Activity 3-3	Some tasks, such as acquiring meteorological data, were on the project's critical path and posed potential risks to progress. Since WG cooperation was essential for data acquisition, members were asked to actively share information to prevent delays.
Activity 3-4	In agriculture, crop monitoring is highly sensitive to weather and farming activities, making the timing of satellite image acquisition critical. Therefore, the image procurement plan was kept flexible and adjusted based on local conditions. To strengthen field coordination, SENAVE was engaged to support communication with farmers.

Activity 3-5	• This was the first WG focused on satellite utilization in agriculture. Despite the presence of satellite-related departments and personnel in each ministry, there was limited shared understanding of roles and collaboration. To address this, online training introduced international examples such as JASMAI (by JAXA and MAFF) and NASA Harvest, highlighting the potential for sustainable frameworks in satellite data use. • There were challenges in coordinating with departments outside the one to which MAG's contact person belonged. To promote the continued operation of the WG, AEP actively reached out and encouraged participation from technical staff in other departments during online training, fostering broader organizational understanding and dissemination of satellite technologies.
Activity 3-6	• Due to the lack of travel during the pilot project and time zone differences, it was difficult to monitor analysis progress in real time. Monthly meetings and email communication were used to maintain regular updates and prevent delays. Given the large volume of satellite imagery, a tool for automated crop classification map generation was proposed, and its workflow was shared with AEP to improve efficiency. • The limited availability of ground data posed challenges to the accuracy of crop classification maps. This issue was addressed by explaining the need for continued discussion and collaboration within the WG to improve data quality.
Activity 3-7	• Project results were presented at a workshop, where dialogue with participants helped demonstrate the usefulness and applicability of the technology. The manual developed as part of the project was made publicly accessible online.

4.3. Evaluation Results based on 6 Evaluation Criteria of DAC

The results of this project were evaluated by JICA Consultant Team and AEP members based on the Organization for Economic Co-operation and Development/Development Assistance Committee (OECD-DAC)'s six criteria for evaluating ODA, as follows:

■ Relevance

The Project demonstrated the effectiveness of satellite data utilization in disaster management and agriculture, high-priority sectors for solving social issues, and also building up technologies for developing socioeconomics through small satellite developments in preparation for the future utilizations of data acquired by Paraguay's own satellites. Those activities were appropriate as in line with Paraguay's National Development Plan 2030, which aims to improve capacity in the space sector as a whole, as well as social, economic, scientific, and technological capabilities, by strengthening the ability to utilize space-related technologies and promoting decision-making based on geospatial information.

■ Coherence

The Project was carried out as part of Japan's Country Assistance Policy for Paraguay (June 2021), Priority Area 1: Sustainable Economic Development, and Development Objective 1-1: "Environmental Development for Major Agriculture-livestock Products." In response to the significant impact of climate change on agriculture-livestock industry in Paraguay, the pillar of the country's socioeconomics due to natural disasters such as heatwaves, floods, droughts, and forest fires, this project expands the use of satellite technology to promote efforts to mitigate and mitigate the impacts of climate change in agriculture-livestock productions and disaster managements. The Project was expected to contribute to SDGs Goal 2 (Zero Hunger), Goal 11 (Sustainable Cities and Communities), and Goal 13 (Climate Action). Furthermore, during former Prime Minister Kishida's visit to Paraguay in May 2024, the leaders of both countries announced the Japan-Paraguay Space Cooperation Program, a Japanese industry-academia-government collaboration aimed at utilizing Japan's space technology and industry to address agricultural production challenges through the use of satellite data.

■ Effectiveness

The Project Purpose was set as "The ability to utilize space-related technologies in Paraguay is strengthened and geospatially informed decision-making is promoted". Effectiveness of the Results were shown by following Indicators of the Project Purpose.

Indicator 1: Number of interagency projects in which AEP was involved

Four Projects including Pilot Projects conducted through the Project were operated. Two more Projects with SENAVE for monitoring tomato fields and with INE and other institutions for developing Data Infrastructure were begun derived from the Project.

Indicator 2: Number of value-added satellite data products in and beside pilot projects by GEOLab, AEP

Three value-added satellite data products were released in Pilot Project. Flood Hazard Maps and Hazard Map Creation Method were released and utilized as a basic data for discussions about disaster managements. Crop Monitoring Method by satellite data analysis and field survey was established, and wide area monitoring for agricultural productions became possible. One value-added satellite data product as an application for monitoring tomato field was released beside the Pilot Project.

Indicator 3: Number of Paraguayan staff have training programs in Japan and Paraguay

Total 10 trainees had training programs on upstream and downstream of space technologies in Japan between August 2024 and May 2025. By participating in BIRDS-RPM (a small satellite development program run by Kyutech in collaboration with Rwanda, Paraguay, and the Maldives), the attendee was able to deepen their knowledge of the basic technologies involved in small satellite development and operation, as well as the importance of international collaboration in space development. Furthermore, by the test of GuaraniSat-2 EM, AEP Team was able to not only acquire the skills required for operating a test environment but also progress one stage in the development of GuaraniSat-2, which AEP develops independently. AEP began to develop GuaraniSat-2 FM, aiming for the launch in October 2026. By learning about specific examples of satellite data utilizations in disaster managements and agriculture by Japanese ministries and local governments, AEP Team was able to deepen their knowledge of space systems and satellite data utilizations as the national institution. Through lectures at Gifu University and Hokkaido University, AEP Team was able to improve their satellite data analysis skills. In particular, the flood simulation analysis technologies implemented at Gifu University were applied into creating flood hazard maps and used as basic data for cross-ministerial studies of countermeasures in Paraguay.

■ Impact

As impacts on social systems: the overall goal of the project is to "improve Paraguay's overall space capabilities and strengthen its social, economic, scientific, and technological capabilities." By strengthening its own small satellite development capabilities, Paraguay has become a hub for small satellite development in Latin America. As a result, Paraguay is expected to be able to lead the way in space technology development in the region. Furthermore, INE and related organizations have begun exploring the integration of social infrastructure data, including satellite data, at the national level. The Project has no impact on human rights, gender, or the environment.

As impacts on people's happiness: while regional flood hazard maps based on flood simulations were not available, the flood hazard maps developed through the pilot project and the results of the Working Group's activities would contribute to future flood prevention measures and local resident evacuation. The Working Group of agriculture-livestock through Pilot Project launched a new project with MAG, SENAVE, and related organizations, strengthening the use of satellite data in the agriculture-livestock sector.

■ Efficiency

Huge time difference about 12-hour, long distance between Japan and Paraguay, JICA Consultant Team and AEP Team were difficult to have activities in Asunción often. Both JICA Consultant Team and AEP Team had communications frequently, and they input all items on schedule. Both JICA Consultant Team and AEP Team, moreover, utilized online systems for holding monthly meetings, other discussions and online training programs effectively even though considerations of the time lags between Japan and Paraguay. Table 4.3-1. shows the Outputs, their results and inputs from both Japanese and Paraguayan sides.

Table 4.3-1. Outputs, Results and Inputs

Output	Result	Inputs from Japan	Inputs from Paraguay
Output 1: Human resources and infrastructure for AEP upstream and downstream will be strengthened.	All KCCPs were conducted, and Space Strategic Plan was designed.	• Experts • Preparations for KCCPs • Conductions of KCCPs • Preparations for Workshop • Conductions of Workshops	• Staffing • Preparations for KCCPs • Attending KCCPs in Japan • Preparations for Workshop • Conductions of Workshops
Output 2: AEP and related agencies implement pilot projects to improve capacity for analyzing disaster risk, and preventing and responding to natural disasters.	WG discussed about issues and made floods hazard maps, created, revised and released Manual	• Experts • Finding issues • Preparations for establishments of WG • Proposing satellite data analysis methods • Technical transfers • Publishments of Results	• Staffing • Arrangements of relevant ministries/agencies • Preparations for establishments of WG • Establishments of WG • Operations of WG • Publishments of Results • Considerations and operations of derived projects
Output 3: AEP and related agencies implement pilot projects to improve capacity for management of agriculture and livestock information related to productivity and quality of products.	WG discussed about issues and conducted field survey for monitoring soybean growth, created, revised and released Manual	• Experts • Finding issues • Preparations for establishments of WG • Proposing satellite data analysis methods • Technical transfers • Publishments of Results	• Staffing • Arrangements of relevant ministries/agencies • Preparations for establishments of WG • Establishments of WG • Operations of WG • Publishments of Results • Considerations and operations of derived projects

■ Sustainability

Policy and Institutional Aspects

Through the Project, JICA Consultant Team and AEP Team established WGs for satellite data utilizations on disaster management and agriculture-livestock sectors. Project for tomato field monitoring with SENAVE and MAG was derived from Pilot Project. Also, the consideration about data infrastructure for integrating national level data was begun to be discussed among AEP, INE and other relevant agencies. AEP has established a framework that enables it to contribute to future socioeconomic developments through cooperation with relevant ministries and agencies.

Organization and Structure

Regarding the organizational structure, AEP would establish two technical departments: SPACELab which would have responsibilities to upstream activities (small satellite developments and operations); and GEOLab which would have responsibilities to downstream activities (satellite data utilizations). The ability to analyze satellite data obtained through the operation of developed small satellites and to provide solutions based on those analyses could serve as the foundation for sustainable space utilization, and remains both a future objective and an ongoing challenge.

Technical

Through the Project, the AEP team acquired the capacity to develop small satellites, appropriately analyze satellite data, and compile information—based on satellite data analysis and field survey results—that contributes to addressing socioeconomic challenges, particularly in the agriculture-livestock and disaster management sectors. As a result, the AEP team has become able to contribute to future economic development through cooperation with relevant ministries and agencies.

Financial

Approaching to MEF for raising the annual budget would be important due to AEP budgets was limited for conducting their space activities. cooperation with relevant stakeholders, especially academia/research institutions and private sectors could be also important. Arrangement of sustainable financial structure would lead to broaden the ranges of sustainable small satellite developments and operations and satellite data utilizations, and it would contribute to improvements of space technologies for the enhancements of

socioeconomics in Paraguay.

Environmental and Social Aspects

Techniques of small satellite developments and satellite data utilizations are available to be applied into ecosystem managements in Paraguay where has received impacts of droughts and flood caused by climate change. Space techniques would contribute to the sustainable developments from both socioeconomic development and environmental management aspects.

Responding to Risks

Satellite data analysis techniques with the main pillar to utilize open-free GIS software and satellite data were installed through the Project, the idea was designed to arrange the sustainable technical foundations with low operation fees.

Operation and Maintenance

AEP Team establishes and works new projects under the cooperation with WG members. AEP is the middle way to arrange the structure which enables to provide new satellite data applications contributing to socioeconomic issues by operations of sustainable WGs.

4.4. Resultss for Indicators of Each Output

Table 4.4-1., Table 4.4-2., and Table 4.4-3. shows the results for indicators of Output 1, 2, and 3, respectively.

Table 4.4-1. Results for Indicators of Output 1

#	Indicator	Results
1-1	Number of trained persons considering gender balance	Total 10 Trainees (7 males and 3 females) 7 trainees (4 males and 3 females) attended KCCP on Satellite Data Utilization between August and September 2024; 1 trainee (1 male) attended KCCP on Small Satellite Development including as a developer at BIRDS-RPM Project (Satellite Development among Rwanda, Paraguay and Moldova) between October 2024 and March 2025; and 2 trainees (2 males) attended KCCP on Small Satellite Development (GuaraniSat-2 Engineering Model Testing) between April and May 2025.
1-2	Number of seminars and workshops	3 Times 2 workshops were held for introductions of results of Pilot Projects and Space Business Networking on February 19, 2025, and September 12 respectively. Also, a workshop among Japanese space business sector, Rwanda Space Agency and AEP as a part of KCCP on Satellite Data Utilization at Tokyo on August 22, 2024.
1-3	Satisfaction of seminars and workshops	Satisfied AEP Team achieved and shared the abilities to develop and operate space technologies of upstream and downstream through workshops and seminars. They also developed new collaborations for enhancing space business with Japanese space companies. Attendees commented: new business creations were expected through accelerations of space system developments through the business level cooperation.

Table 4.4-2. Results for Indicators of Output 2

#	Indicator	Results
2-1	Number of trained persons considering gender balance	7 Trainees (4 males and 3 females) 7 trainees (4 males and 3 females) attended KCCP on Satellite Data Utilization between August and September 2024; and total 38 trainees attended online training programs for monitoring hydrological analysis with open-free software, iRIC and RRI Model for analyzing satellite data between October 2024 and August2025.
2-2	Number of seminars and workshops	3 Times 2 workshops were held for introductions of results of Pilot Projects and Space Business Networking on February 19, 2025, and September 12 respectively. Also, a workshop among Japanese space business sector, Rwanda Space Agency and AEP as a part of KCCP on Satellite Data Utilization at Tokyo on August 22, 2024.
2-3	Satisfaction of seminars and	Satisfied

	workshops	AEP Team achieved and shared their results of Pilot Projects on workshops. They also developed new projects and cooperation with relevant ministries and agencies by utilizing space technologies for contributing to solutions of socioeconomic issues in Paraguay.
2-4	Number of PoC, Number of practical plans from activity, number of papers and reports related to activity	PoC: 2 • 1 of PoC: AEP Team applied their achieved methods to release flood hazard maps by satellite data analysis and discussions with SEN as PoC. • 1 of practical plan from the activity: AEP Team began projects with INE and other agencies for developing Data Infrastructure; and • 3 papers/reports related to activity were released: Results of Pilot Project were compiled as hazard maps and the manual. The first and revised versions were released in February 2025 and September 2025 respectively. Also, the results of Pilot Project were introduced at Small Satellite Conference at Salt Lake City, United States in August 2025.

Table 4.4-3. Results for Indicators of Output 3

#	Indicator	Results
3-1	Number of trained persons considering gender balance	7 Trainees (4 males and 3 females) 7 trainees (4 males and 3 females) attended KCCP on Satellite Data Utilization between August and September 2024; and 24 trainees attended online training for monitoring soybean growth by satellite data analysis.
3-2	Number of seminars and workshops	3 Times 2 workshops were held for introductions of results of Pilot Projects and Space Business Networking on February 19, 2025, and September 12 respectively. Also, a workshop among Japanese space business sector, Rwanda Space Agency and AEP as a part of KCCP on Satellite Data Utilization at Tokyo on August 22, 2024.
3-3	Satisfaction of seminars and workshops	Satisfied AEP Team achieved and shared their results of Pilot Projects on workshops. The result was described by participants as “highly beneficial for local agricultural management.” They also developed new projects and cooperation with relevant ministries and agencies by utilizing space technologies for contributing socioeconomic issues in Paraguay.
3-4	Number of PoC, Number of practical plans from activity, number of papers and reports related to activity	<u>Satisfied</u> PoC: 3 • 1 of PoC: AEP Team applied an analyzed satellite data distribution application provided by a Japanese company for monitoring crop growths as PoC. • 3 of practical plans from the activity: AEP Team began projects with SENAIVE for monitoring tomato fields, with INE and other agencies for developing Data Infrastructure and with a private company for developing satellite data application as practical plans which were derived from the activity; and • 2 of papers/reports related to activity were released: Results of Pilot Project were compiled as the manual, and the first and revised versions were released in February 2025 and September 2025 respectively. Also, the results of Pilot Project were introduced at Small Satellite Conference at Salt Lake City, United States in August 2025.

Chapter 5. Suggestions for Achievements of Overall Goal

5.1. Prospects of Achievements of Overall Goal

Overall Goal of the Project was set as to “Contribute to the development of national skills in the space sector and strengthen the country's social, economic, scientific and technological development”. JICA Consultant Team and AEP Team evaluate its indicators for prospecting their achievements of Overall Goal. Table 5.1-1. shows the results of the evaluations.

Table 5.1-1. Evaluations of Indicators for Overall Goal

#	Indicator	Evaluation
1	Number of projects utilizing space related technology in public and private sector	Current Status (as of August 2025): 4 Projects Future (3-year after the end of the Project): 6 Projects Derived projects for utilizing space technologies by public and private sectors from the Project have been operated. 1. International cooperation for the developments GuaraniSat-2: testing at Kyutech, the mission component provision by NASA/JPL, the component provision from AEM (Mexican Space Agency) and the solar power system provision from Italian company. 2. Tomato field monitoring project with SENAVE 3. Development of data infrastructure with INE and relevant agencies 4. Development of application with Japanese company WGs were established for aiming to utilize space technologies for contributing to disaster management and agriculture-livestock. AEP Team set Action Plan to develop applications and space technologies with WGs. 1. Agricultural Projects: 2 2. Disaster Management. Project: 1 3. Development Data Infrastructure Project: 1 4. Public-Private Project: 1
2	Number of public data based on geospatial information	Current Status (as of August 2025): 48 Datasets Future (3-year after the end of the Project): 100 Datasets AEP Team provides information of forest fires through monitoring with satellite data. AEP Team distributes data over the internet and sends as letters to relevant ministries and agencies. By utilizing free Sentinel-2 data operated by ESA, target areas can be observed approximately once every five days. When monitoring three crops per year, assuming that approximately 40% of the data are affected by high cloud coverage, around 100 datasets per year can be analyzed and distributed to relevant ministries and agencies, as data with high cloud coverage are difficult to analyze
3	Number of users of data provided	Current Status (as of August 2025): 50 Users Future (3-year after the end of the Project): 300 Users

Accordingly, provided that continued efforts are made, there is a reasonable prospect for achieving the Overall Goal.

5.2. Results of Outputs and Activities for Achievements of Project Purpose

The Project Purpose of the Project was set as “The ability to utilize space-related technologies in Paraguay is strengthened and geospatially informed decision-making is promoted”. JICA Consultant Team and AEP Team evaluate its indicators for prospecting their achievements of Project Purpose. Table 5.2-1. shows the results of the evaluations.

Table 5.2-1. Results of Outputs and Activities for Project Purpose

#	Indicator	Results
1	Number of interagency projects in which AEP was involved	Current Status (as of August 2025): 4 Projects Derived projects for utilizing space technologies by public and private sectors from the Project have been operated. 1. International cooperation for the developments GuaraniSat-2: testing at Kyutech, the mission component provision by NASA/JPL, the component provision from AEM (Mexican Space Agency) and the solar power system provision from Italian company. 2. Tomato field monitoring project with SENAVE 3. Development of data infrastructure with INE and relevant agencies 4. Development of application with Japanese company
2	Number of value-added satellite data products in and beside pilot projects by GEOLab, AEP	Value-added Satellite Data Products: 3 Products Other value-added Satellite Data Products: 2 Products 3 Products were released through the Pilot Projects: 1. Flood Hazard Maps 2. Manuals for Flood Simulations and Hazard Map Creation 3. Soybean Growth Monitoring 2 Products were released beside Pilot Projects: 1. Tomato Field Monitoring Project with SENAVE 2. Satellite data application development with Japanese company
3	Number of Paraguayan staff have training programs in Japan and Paraguay	4 Training Programs were provided through the Project. A staff from another agency also attended KCCP for Downstream. 1. KCCP for Downstream 2. KCCP for Upstream, First Badge & Second Badge 3. Online Training Programs for Flood Simulations and Hazard Maps 4. Online Training Programs for Soybean Growth Monitoring

Project Purpose was achieved: all indicators were filled with enough results through the Project.

5.3. Suggestions to Paraguayan Side

Suggestions to Paraguayan side for small satellite developments and operations and satellite data utilizations were compiled through the Project.

Small Satellite Developments and Operations

- To address the shortage of engineers with advanced expertise, it is necessary to increase the frequency of the development and testing cycle for small satellites. Therefore, rather than rushing to increase the size of satellites, it is necessary to stagger and overlap development projects for 1-12U small satellites. This allows engineers in charge of each component to work on one small satellite every 6 months - 1 year, rather than every two years. This will improve technology, transfer skills to other engineers, and ultimately secure capable human resources. Furthermore, given the limitations of funding an entire project with a national budget, it is important for Paraguay to actively participate in small satellite projects in other countries and take on some of the components and testing to achieve a high-frequency development cycle.
- Regarding the lack of testing and operation facilities for small satellites in Paraguay, the Japanese government is currently considering developing such facilities within the framework of grant aid. This will not only reduce the additional costs of overseas testing, but also encourage neighboring countries, particularly in Latin America, to conduct small satellite testing in Paraguay, which could encourage other countries to participate in international satellite development through barter and potentially obtain funding for testing from other countries. However, even if the testing and operation facilities are developed, it is necessary to consider the need to improve the ability to operate the facilities and to conduct ongoing satellite testing to maintain operational capabilities.
- Unable to identify the optimal onboard sensors and satellite data for satellite data utilization in Paraguay, the country is currently unable to develop satellites for its own use. It is expected that activities to promote satellite data utilization in Paraguay, such as this JICA project, will identify priority applications, which will in turn promote the development of small satellites equipped with

sensors that will contribute to those applications. In doing so, it is important to consider the budget constraints of the AEP and explore the possibility of joint international missions equipped with payloads and subsystems from other countries. It is also expected that in the future, sharing of small satellite constellations with other countries (participating in virtual constellations of identical satellites by multiple countries) will also be considered.

- Satellite development cannot be completed in six months. It takes at least two years in typical Kyutech program. This time, AEP carried out everything from mission design, design, procurement, and development of BBM, but subsequent processes include improving the bus and components/developing and testing the Flight Model (FM). Therefore, in order to acquire practical skills in satellite development, it would be even better if the training included experiencing all of the processes.
- When actual satellites are developed in collaboration with other countries, there are issues such as the risk of delays in satellite components/payloads development in other countries and the issue of paying import duties when transporting satellites across borders. When conducting this kind of trainings, it is necessary to anticipate these issues in advance and set schedule margins in the planning stage as well as cost margins in order to ensure smooth implementation.

Satellite Data Utilizations

- Because activities will continue with a limited AEP budget, collaboration with relevant stakeholders, particularly academia/research institutions and the private sector, is necessary to lobby financial authorities and secure an increase in the budget. It is important for AEP to take the lead in strengthening collaboration with the domestic and international private sector, and for Paraguayan academia/research institutions to participate in collaborative activities with the private sector, thereby creating a virtuous cycle in which domestic private companies spin out and start-up companies are created.
- As it is difficult to promote adaptation in all utilization themes due to resource constraints, it is important to continue activities to promote the use of satellite data in agriculture and livestock and disaster response, which were the focus of this training. Demonstrating good practices through actual implementation will lead to increased budgets from financial authorities and the expansion of adaptation themes. It is also necessary to link this to budgetary measures for the training of engineers and human resource development for deployment.
- In continuing to promote the use of satellite data, obtaining various types of satellite data will be a challenge. While open and free data will continue to be obtained and utilized, other commercial data will also be required to achieve the goal. Therefore, it is important to acquire as much satellite data as possible at the lowest possible cost while expanding international cooperation between space agencies. Furthermore, for the time being, commercial data required for high-priority applications will be purchased within the budget. At the same time, it will be necessary to advance research and development of domestic small satellites and consider obtaining own data from domestic satellites to use it for the high-priority applications.
- The training's goal was achieved, and participants expressed various expectations for future implementation activities toward the practical application of space technology to Paraguay's socioeconomic needs. It is also important for Paraguay, to establish a path for industry-government-academia collaboration and roles in utilizing space technology, and to promote practical applications that contribute to solving socioeconomic and societal challenges. Furthermore, rather than relying solely on one side of the world, given Paraguay's geographic location and its proximity to South America, where many countries are keen to develop and utilize small satellite data. That cooperation will build a win-win relationship that benefits Japan as well, through near-real-time data acquisition by each receiving station and the establishment of a regional base in South America (where Japanese private companies can use Paraguay as a base to promote business ecosystems in South America).

Enhancements of Budget Allocations and Organizational Structure

- Approaching to MEF for raising the annual budget would be important due to AEP budgets was limited for conducting their space activities. cooperation with relevant stakeholders, especially

academia/research institutions and private sectors could be also important. Arrangement of sustainable financial structure would lead to broaden the ranges of sustainable small satellite developments and operations and satellite data utilizations, and it would contribute to improvements of space technologies for the enhancements of socioeconomics in Paraguay.

- Enhancements of technical capacities are required for expanding and continuing activities at AEP. Developments and implementations of capacity development plans including career plan based on the knowledge gained from training in Japan and Pilot Projects would lead to expanding the base of space talents in Paraguay for future.

Interactions with Japanese space-related ministries, universities, and private companies

- Through two KCCP (upstream and downstream) and activities for Output 1, this project held workshops in Tokyo and Asuncion. It also provided the opportunity for participants to learn about Japanese space technology, space policy, and space business through university lectures. These activities enabled AEP to advance application development with Japanese companies. This is a major step and achievement in space development and utilization. JICA Consultant Team hopes to see the development of space policy and space business involving Paraguayan private companies in the future.

5.4. Recommendations for Satellite Data Utilizations on Disaster Managements

Through the activities of Output 2, the project promoted collaboration with relevant ministries and agencies regarding the utilization of satellite data in disaster prevention and fostered human resource development. Based on these efforts, recommendations were compiled for Paraguay concerning the strengthening of collaboration with relevant ministries and agencies and the creation of flood hazard maps implemented in the pilot project.

Strengthening Collaboration with Relevant Ministries and Agencies

This project established a Working Group (WG) involving ministries and agencies relevant to disaster prevention. A pilot project was implemented to determine the most appropriate and most desired applications of satellite data for these agencies. Through this pilot project, data necessary for flood inundation simulations was collected with the cooperation of WG members, strengthening collaboration with other ministries and agencies. Continuing WG activities is expected to further strengthen these relationships and lead to the development of procedures documenting collaboration and utilization of satellite data, not limited to flood hazard maps. Particularly, as cooperation regarding international charters for satellite data collection during disasters is being implemented between SEN and AEP, there is a need for procedures covering satellite data utilization during the disaster management phase, including coordination and initial response systems when disasters occur.

Flood Hazard Map

In the flood hazard map creation conducted during the pilot project, the inundation areas obtained after flood inundation simulations were used as a basis. Through discussions with SEN, necessary information for the flood hazard map, such as evacuation shelter information and evacuation route information, was incorporated into the creation process. Further discussions with SEN are also needed regarding the scenarios used in the flood inundation simulations. Since different flood scenarios must be considered for each region requiring a flood hazard map, it is hoped that, implementing on the workflow established in the pilot project, collaboration with SEN will deepen, enabling the sequential development of flood hazard maps for other regions. Furthermore, it is hoped that within the same region, flood hazard maps will be developed for different scenarios, contributing to resident evacuation drills and disaster countermeasure planning.

It is expected that personnel training will continue broadly, utilizing the lecture materials and videos from the online training conducted in the pilot project, thereby establishing a system that does not rely on specific staff members.

5.5. Recommendations for Satellite Data Utilizations on Agriculture-livestock

Through the activities of Output 3, the project promoted collaboration with relevant ministries and agencies regarding the utilization of satellite data in agriculture and livestock sector and fostered human resource development. Based on these efforts, recommendations were compiled for Paraguay concerning satellite utilization in agriculture sector.

Satellite Data Utilization in Agriculture Sector

The utilization of satellite data in the agriculture and livestock sector is significantly influenced by local weather conditions and regional characteristics, making it challenging to produce clear and immediate results. In particular, information related to crop growth and livestock management is subject to considerable seasonal and annual variability. As such, observations conducted over a single year are often insufficient to identify reliable trends. Therefore, satellite data applications should be approached from a medium- to long-term perspective, grounded in continuous data collection and field-based analysis.

Given these characteristics, it is essential to clearly communicate to relevant ministries and counterpart organizations in the target country that satellite data utilization is not intended to yield instant outcomes. Rather, it is a process of gradually building reliable insights over time. When forming consensus with local policymakers, it is effective to manage expectations by presenting case studies that demonstrate the long-term benefits of satellite data, along with practical models for sustained application.

It was also observed that some institutions—such as MAG and other related agencies—collect data independently. In such cases, there is a risk of data fragmentation, duplication, and inefficient use. Strengthening collaboration among relevant institutions is therefore critical. The WG established under this project provides a valuable framework for promoting inter-ministerial cooperation. Moving forward, the WG should serve as a central platform for advancing open and collaborative data sharing and utilization. It is important for stakeholders to recognize that satellite data utilization is not merely a technical task, but a strategic tool for cross-sectoral information integration.

Efficient Project Execution

Furthermore, in the local context, formal documentation is often emphasized. When organizing WG meetings or making requests to relevant institutions, it is necessary to prepare official documents such as invitation letters and Terms of Reference (ToR). These documents are not mere formalities; they play a key role in clarifying roles, responsibilities, and expectations among stakeholders. It is therefore advisable to prepare templates in advance and establish a system for providing appropriate explanations when making such requests.

Finally, regarding the procurement of satellite imagery, when data obtained by the Japanese side is to be shared with overseas counterparts, it may be necessary to confirm usage permissions and distribution restrictions. These confirmation processes can be time-consuming. Therefore, it is important to initiate procedures related to satellite image procurement and distribution early in the project and coordinate closely with relevant institutions.

Chapter 6. Action Plan

As response to the recommendations for achieving the Overall Goal referred in Chapter 5, AEP declared Action Plan through discussions with JICA Consultant Team.

6.1. Enhancement of Organizational Structure

To improve Cooperation with Relevant Ministries and Agencies through Developing and Utilizing Space Technologies by improving the frameworks, scopes and activities of Working Groups which were established through the Project.

To become as a hub of space technologies and information about small satellite developments/ operations and satellite data utilizations in Latin American and Caribbean countries.

To promote collaboration with a private sector of Paraguay and the other countries. To enhance space technology's capabilities of domestic companies as well as institutions/academia through the collaboration with overseas companies.

6.2. Enhancement of Capacities on Small Satellite Developments/Operations and Satellite Data Utilizations

To send Colleagues as international students for achieving master's and doctor's degrees of space system developments and operations and satellite data utilizations to Japan and European countries.

To plan practical developments of GuaraniSat Series and operations including obtaining budgets and domestic/international space development frameworks. Also, to achieve frequent cycle of satellite development opportunities through the implementation of not only GuaraniSat Series Program but also participation in other countries' nano/micro satellite programs.

To work on domestic/international joint research projects by utilizing satellite data and providing analyzed data and applications especially contributing disaster managements, agriculture-livestock and others.

6.3. Drafts of Quantitative Indicators for Action Plan

Table 6.3-1. shows the quantitative indicators for Action Plan.

Table 6.3-1. Drafts of Quantitative Indicators for Action Plan

Field	Activity	Value and Current Status	Target Value	Evaluation Date and Acquisition Method
Enhancement of Organizational Structure	Cooperation with Relevant Ministries and Agencies in Paraguay	Number of Joint Research projects: 3 Agriculture: 1 Data Infrastructure: 1 Gov-Private Collaboration: 1	Number of Joint Research projects: 6 Agriculture: 2 Disaster Management: 1 Data Infrastructure: 1 Gov-Private Collaboration: 2	3-year-later since the End of the Project Reports, Applications, System Logs, etc.
	International Space Tech Hub in LAC	Number of Consultations for Small Satellite Developments: 0	Number of Consultations for Small Satellite Developments: 2 Space Agencies: 1 Academia: 1	3-year-later since the End of the Project Reports,
		Number of Data and Technique Sharing of Satellite Data Utilizations: 0	Number of Data and Technique Sharing of Satellite Data Utilizations: 2 Disaster Management: 2	3-year-later since the End of the Project Reports, MOU Documents, etc.

	Collaboration with a private sector	Number of MOU or joint project with private companies MOU: 2; Domestic 1; International 1	Number of MOU or joint project with private companies MOU: 4, Domestic 2; International 2	3-year-later since the End of the Project Reports, MOU Documents, etc.
Enhancement of Small Satellite Developments and Operations and Satellite Data Utilizations	Degrees at International Universities	Number of Doctor's and Master's Degrees for Small Satellite Developments and Operations: 5 Doctor: 1 Masters: 4	Number of Doctor's and Master's Degrees for Small Satellite Developments and Operations: 7 Doctor: 1 Masters: 6	3-year-later since the End of the Project Careers
		Number of Doctor's and Master's Degrees for Satellite Data Utilizations: 1 Doctor: 0 Masters: 1	Number of Doctor's and Master's Degrees for Satellite Data Utilizations: 4 Doctor: 1 Masters: 3	3-year-later since the End of the Project Careers
	Master Plan of GuaraniSat Series Development and Operation	Number of Developed and/or Developing Satellites: 2	Number of Developed and/or Developing Satellites: 3	3-year-later since the End of the Project Results of Developments and Operations, Master Plan, etc.
		Number of Operated Satellites: 1	Number of Operated Satellites: 2	
		Achieved Number of Joint Satellite Development Program with Other Countries Joint Program: 0	Achieved Number of Joint Satellite Development Program with Other Countries Joint Program: 3	
		Number of Scheduled Satellite Including Obtaining Budget: 0	Number of Scheduled Satellite Including Obtaining Budget: 1	

別添 1-1 (Annex 1-1): Results of the Project

List of Dispatch of the Experts

1	Name/Affiliation	Shinsaku Nakamura/Japan Space Systems
	In Charge	Chief Expert/Survey and Analysis
	Main Activities	- Conduct meetings - Evaluate satellite data analysis methods and tools at AEP - Make policies for the enhancements based on the evaluation results about AEP facilities - Provide training programs for satellite data analysis and applications - Conduct Baseline and Endline Survey - Compile Reports
	Trips	1 st Trip: November 19 – December 9, 2023 2 nd Trip: April 14 – April 29, 2024 3 rd Trip: February 19 – March 2, 2025 4 th Trip: August 30 – September 15, 2025
2	Name/Affiliation	Kei Sato/SASCO CORPORATION
	In Charge	Vice-chief/Satellite Data Utilizations for Disaster Management
	Main Activities	- Conduct meetings - Conduct activities for Output 2 - Compile Reports
	Trips	1 st Trip: November 19 – December 9, 2023 2 nd Trip: April 5 – April 29, 2024 3 rd Trip: January 31 – February 24, 2025 4 th Trip: August 30 – September 16, 2025
3	Name/Affiliation	Yoshinori Kobayashi/Japan Space Forum
	In Charge	Planning Satellite Data Utilizations
	Main Activities	- Provide training programs on small satellite developments and operations - Provide a training program on satellite data utilizations - Provide networking opportunities among AEP and Japanese ministries/agencies, academia and private companies
	Trips	1 st Trip: November 24 – December 9, 2023 2 nd Trip: April 12 – April 29, 2024 3 rd Trip: - 4 th Trip: September 2 – September 16, 2025
4	Name/Affiliation	Atsushi Kimura/PASCO CORPORATION
	In Charge	Satellite Data Utilizations for Agriculture-livestock A
	Main Activities	- Conduct activities for Output 3 - Conduct and manage schedule for Pilot Project for Agriculture-livestock
	Trips	1 st Trip: November 19 – December 9, 2023 2 nd Trip: - 3 rd Trip: - 4 th Trip: September 6 – September 17, 2025
5	Name/Affiliation	Akie Koga /PASCO CORPORATION
	In Charge	Satellite Data Utilizations for Agriculture-livestock B
	Main Activities	- Conduct activities for Output 3 - Support smooth operation of Pilot Project for Agriculture-livestock
	Trips	1 st Trip: - 2 nd Trip: April 5 – April 19, 2024 3 rd Trip: February 5 – February 24, 2025 4 th Trip: September 4 – September 17, 2025

List of Counterpart

1	Name/Affiliation	Osvaldo Almirón/President of AEP
	In Charge	Project Director
2	Name/Affiliation	Alejandro Roman/Director of GEOLab, AEP
	In Charge	Project Manager
3	Name/Affiliation	Adolfo Jara/Director of SPACELab, AEP
	In Charge	Capacity Building for Small Satellite Developments
4	Name/Affiliation	Anibal Mendoza/ SPACEPab, AEP
	In Charge	Technical Member for Small Satellite Developments and Operations
5	Name/Affiliation	Esteban Fretes/ SPACEPab, AEP
	In Charge	Technical Member for Small Satellite Developments and Operations
6	Name/Affiliation	Luis Miranda/ SPACEPab, AEP

	In Charge	Technical Member for Small Satellite Developments and Operations
7	Name/Affiliation	Javier / SPACEPab, AEP
	In Charge	Technical Member for Small Satellite Developments and Operations
8	Name/Affiliation	Thanya Idoyaga/Member of GEOLab, AEP
	In Charge	Technical Member for Satellite Data Utilizations
9	Name/Affiliation	Rodrigo / Member of GEOLab, AEP
	In Charge	Technical Member for Satellite Data Utilizations
10	Name/Affiliation	Rebeca / Member of GEOLab, AEP
	In Charge	Technical Member for Satellite Data Utilizations
11	Name/Affiliation	Veronica / Member of GEOLab, AEP
	In Charge	Technical Member for Satellite Data Utilizations
12	Name/Affiliation	Junior Sosa/ Member of GEOLab, AEP
	In Charge	Technical Member for Satellite Data Utilizations

List of Training Programs

#	Name	Period	# of Trainees	Location
1	KCCP (Downstream)	August 19 – September 18, 2024	7 (6 from AEP and 1 from SENAve)	Tokyo, Shizuoka, Gifu, Makinohara & Hokkaido
2	KCCP (Upstream) (1 st Batch)	October 4, 2024 – March 28, 2025	1 from AEP	Kyutech
3	KCCP (Upstream) (2 nd Batch)	April 3 – May 30, 2025	2 from AEP	Kyutech
4	Online Training (Flood Simulation) (1 st Batch)	November 6 – December 13, 2024	38 from AEP, DMH, INE, MOPC, UNA, & UCA	Online
5	Online Training (Flood Simulation) (1 st Batch)	June 24 – August 25, 2025	10	Online
5	Online Training (Crop Monitoring)	July 15 – July 30, 2025	24 from AEP, MAG & SENAve	Online

別添1-2 (Annex 1-2): Plan of Operation

Plan of Operation (PO)

2.1

Date: September 12, 2025

Project Title: Project for Management of Space Programs applied to the Socioeconomic Development

Monitoring

Inputs		Year	FY 2023				FY 2024				FY 2025				Remarks	Issue	Solution
			I	II	III	IV	I	II	III	IV	I	II	III	IV			
Expert																	
1. Short-term experts (Satellite development / testing)		Plan															
		Actual															
2. Short-term experts (Data utilization planning)		Plan															
		Actual															
3. Short-term experts (Data utilization in disaster risk reduction)		Plan															
		Actual															
4. Short-term experts (Data utilization in agriculture and livestock sector)		Plan															
		Actual															
Equipment																	
Computing resource		Plan															
		Actual															
Satellite data		Plan															
		Actual															
Training in Japan																	
Upstream		Plan															
		Actual															
Downstream		Plan															
		Actual															
In-country/Third country Training																	
N/A		Plan															
		Actual															

Activities					Year	1st Year				2nd Year				3rd Year				Responsible Organization		Achievements	Issue & Countermeasures
						I	II	III	IV	I	II	III	IV	I	II	III	IV	Japan	GOP		
Sub-Activities																					
Output1: Human resources and infrastructure for AEP upstream and downstream will be strengthened.																					
1-1: Conduct an evaluation of AEP's existing technical methods and tools and make recommendations for future planning.					Plan													JICA	AEP	Baseline Survey and Endline Survey were operated and the reports were submitted.	
					Actual																
1-2: Develop enhancement plan based on a diagnosis of GEOLab, AEP.					Plan													JICA	AEP	KCCP was designed and conducted in between Aug and Sept 2024.	
					Actual																
1-3: Provide 6-month hands-on training in satellite development, including testing EM of GuaraniSat-2 at Kyutech between October 2024 and May 2025.					Plan													JICA	AEP	KCCP including GuaraniSat-2 EM Test was designed and conducted between September 2024 and May 2025.	
					Actual																
1-4. Provide training in satellite data and other processing and applications.					Plan													JICA	AEP	KCCP was designed and conducted in between Aug and Sept 2024. Also, online training programs for satellite data analysis were provided.	
					Actual																
1-5. Liaison between AEP and Japanese governmental institutions, universities, and private companies.					Plan													JICA	AEP	Workshop was held for developing space business network between Japan and Paraguay in September 2025.	
					Actual																

Output2: AEP and related agencies implement pilot projects to improve capacity for analyzing disaster risk, and preventing and responding to natural disasters.

[illegible]

Output3: AEP and related agencies implement pilot projects to improve capacity for management of agriculture and livestock information related to productivity and quality of products.

[illegible]

[illegible]

別添 2 (Annex 2): List of Products

List of Products

#	Product	Submission Date	Notice
1	Inception Report (業務計画書)	November 22, 2023	In Japanese
2	Work Plan	April 4, 2024	In English Confirmation delayed due to fixing activities of KCCP for Upstream
3	Progress Report (ver. 1)	February 20, 2024	In English
4	Progress Report (ver. 2)	September 30, 2024	In English
5	Progress Report (ver. 3)	March 13, 2025	In English
6	Project Completion Report	September 26, 2025	In English
7	MANUAL METEDOLÓGICO DE MANEJO DE DESASTRES (Methodological Manual of Disaster Management)	September 12, 2025	In Spanish
8	MANUAL METEDOLÓGICO DE MONITOREO AGRICOLA (Methodological Manual of Agricultural Monitoring)	September 12, 2025	In Spanish
9	Report of Baseline Survey	March 29, 2024	In English
10	EVALUATION REPORT (Report of Endline Survey)	June 30, 2025	In English

Project Design Matrix (Draft)

Project Title: Project for Management of Space Programs applied to the Socioeconomic Development

Implementing Agency: Paraguayan Space Agency

Target Group: Personnel of AEP and related institutions(AEP)

Period of Project: September 2023 - August 2025 (2 years)

Project Site: Asuncion

Ver. 1.0

Dated May 26, 2023

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	Achievement	Remarks
Overall Goal (realises 3 years after project) Contribute to the development of national skills in the space sector and strengthen the country's social, economic, scientific and technological development	1. # of projects utilizing space related technology in public and private sector 2. # of public data based on geospatial information 3. # of users of data provided	- Government Statistics - Report from AEP and/or other institutions	Mechanism of data provision for governmental statistics or decision-making process is well established.		
Project Purpose (realises at the end of the project) The ability to utilize space-related technologies in Paraguay is strengthened and geospatially informed decision-making is promoted.	1. # of interagency projects in which AEP was involved 2. # of value-added products based on satellite data by AEP	Government Statistics, Project Report			
Outputs (Key components of the project) Output1: Human resources and infrastructure for AEP upstream and downstream will be strengthened. Output2: AEP and related agencies implement pilot projects to improve capacity for analyzing disaster risk, and preventing and responding Output3: AEP and related agencies implement pilot projects to improve capacity for management of agriculture and livestock	1-1. # of trained persons considering gender balance 1-2. # of seminars and workshops 1-3. satisfaction of seminars and workshops Same as 1-1, 1-2, 1-3 # of PoC, # of practical plans from activity, # of papers and reports related to activity Same as 1-1, 1-2, 1-3 # of PoC, # of practical plans from activity, # of papers and reports related to activity	Project Report Project Report Project Report Project Report Project Report Project Report	- Counterpart personnel is continuously secured properly - Other institutions, such as government and universities accept involvement of pilot projects.		

Activities	Inputs		Important Assumption
	The Japanese Side	The Paraguay Side	
1-1: Conduct an evaluation of AEP's existing technical methods and tools and make recommendations for future planning	- Short-term experts (Data utilization planning, Satellite development/testing, Data utilization in disaster risk reduction/agriculture and livestock sector) - Training for Counterpart Personnel in Japan - Local cost for the activities	- Allocation of counterpart personnel - Coordination among ministries and organizations - Arrangements between projects with other development partners, etc. - Arrangements for providing necessary data - Office space for Japanese professionals - Local costs (maintenance costs for existing equipment not covered by JICA support, meeting preparation costs, operating costs required for the project, etc.)	
1-2: Develop enhancement plan based on a diagnosis of the infrastructure available in the AEP.			Pre-Conditions
1-3: Provide training in satellite development and operations.			
1-4: Provide training in satellite data and other processing and applications.			
1-5: Liaison between AEP and Japanese governmental institutions, universities, and private companies.			
2-1: Set up working groups consisting of AEP and related organizations to identify issues and implement pilot projects.			
2-2: Identify issues where space-related technologies can be effectively applied in the field of disaster risk reduction			
2-3: Determine scope for applying space-related technologies to the issues and Design pilot projects			
2-4: Develop plan and procure equipments (hardware and software) for satellite imagery and data processing			
2-5: Train personnel in the use of tools, methods, and techniques for disaster risk reduction.			
2-6: Implement pilot projects with existing agreements with academia and other governmental and non-governmental organizations			
2-7: Publish results of pilot projects locally and internationally.			
3-1: Set up working groups consisting of AEP and related organizations to identify issues and implement pilot projects.			
3-2: Identify issues where space-related technologies can be effectively applied in the agriculture and livestock sector.			
3-3: Determine scope for applying space-related technologies to the issues and Design pilot projects			
3-4: Develop plan and procure equipments (hardware and software) for satellite imagery and data processing			
3-5: Train personnel in the use of tools, methods, and techniques to improve productivity and quality in agriculture and livestock sector.			
3-6: Implement pilot projects with existing agreements with academia and other governmental and non-governmental organizations			
3-7: Publish results of pilot projects locally and internationally.			

Project Design Matrix (PDM)

Project Title: Project for Management of Space Programs applied to the Socioeconomic Development

Implementing Agency: Paraguayan Space Agency

Target Group: Personnel of AEP and related institutions(AEP)

Period of Project: October 2023 - September 2025 (2 years)

Project Site: Asuncion

1.5

Dated: December 5, 2023

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	Achievement	Remarks
Overall Goal (realises 3 years after project) Contribute to the development of national skills in the space sector and strengthen the country's social, economic, scientific and technological development	1. # of projects utilizing space related technology in public and private sector 2. # of public data based on geospatial information 3. # of users of data provided	- Government Statistics - Report from AEP and/or other institutions	Mechanism of data provision for governmental statistics or decision-making process is well established.		
Project Purpose (realises at the end of the project) The ability to utilize space-related technologies in Paraguay is strengthened and geospatially informed decision-making is promoted.	1. # of interagency projects in which AEP was involved 2. # of value-added satellite data products in and beside pilot projects by GEOLab, AEP 3. # of Paraguayan staff have training programs in Japan and Paraguay	Government Statistics, Project Report			
Outputs (Key components of the project) Output1: Human resources and infrastructure for AEP upstream and downstream will be strengthened. Output2: AEP and related agencies implement pilot projects to improve capacity for analyzing disaster risk and preventing and responding to natural disasters. Output3: AEP and related agencies implement pilot projects to improve capacity for management of agriculture and livestock information related to productivity and quality.	1-1. # of trained persons considering gender balance 1-2. # of seminars and workshops 1-3. satisfaction of seminars and workshops Same as 1-1, 1-2, 1-3 # of PoC, # of practical plans from activity, # of papers and reports related to activity Same as 1-1, 1-2, 1-3 # of PoC, # of practical plans from activity, # of papers and reports related to activity	Project Report Project Report Project Report Project Report Project Report Project Report	- Counterpart personnel is continuously secured properly - Other institutions, such as government and universities accept involvement of pilot projects.		

Activities	Inputs		Important Assumption
	The Japanese Side	The Paraguay Side	
1-1: Conduct an evaluation of AEP's existing technical methods and tools and make recommendations for future planning.	- Short-term experts (Data utilization planning, Satellite development/testing, Data utilization in disaster risk reduction/agriculture and livestock sector) - Training for Counterpart Personnel in Japan - Local cost for the activities	- Allocation of counterpart personnel - Coordination among ministries and organizations - Arrangements between projects with other development partners, etc. - Arrangements for providing necessary data - Office space for Japanese professionals - Local costs (maintenance costs for existing equipment not covered by JICA support, meeting preparation costs, operating costs required for the project, etc.)	
1-2: Develop enhancement plan based on a diagnosis of GEOLab, AEP.			Pre-Conditions
1-3: Provide hands-on training in satellite development, especially testing EM of Guaranisat2 (Plan A: enhancing facility and having tests at SPACELab, or Plan B: sending 2-staff and having tests at Kyutech).			
1-4: Provide training in satellite data and other processing and applications.			
1-5: Liaison between AEP and Japanese governmental institutions, universities, and private companies.			
2-1: Set up working groups consisting of AEP and related organizations to identify issues and implement pilot projects.			
2-2: Identify issues where space-related technologies can be effectively applied in the field of disaster risk reduction.			
2-3: Determine scope for applying space-related technologies to the issues and design pilot projects.			
2-4: Develop plan and procure equipment (hardware and software) for satellite imagery and data collecting/processing.			
2-5: Train personnel in the use of tools, methods, and techniques for disaster risk reduction.			
2-6: Implement pilot projects with Working Group and existing agreements with academia and other governmental and non-governmental organizations.			
2-7: Publish results of pilot projects locally and internationally.			
3-1: Set up working groups consisting of AEP and related organizations to identify issues and implement pilot projects.			
3-2: Identify issues where space-related technologies can be effectively applied in the agriculture and livestock sector.			
3-3: Determine scope for applying space-related technologies to the issues and Design pilot projects.			
3-4: Develop plan and procure equipment (hardware and software) for satellite imagery and data collecting/processing.			
3-5: Train personnel in the use of tools, methods, and techniques to improve productivity and quality in agriculture and livestock sector.			
3-6: Implement pilot projects with Working Group and existing agreements with academia and other governmental and non-governmental organizations.			
3-7: Publish results of pilot projects locally and internationally.			

Project Design Matrix (PDM)

Project Title: Project for Management of Space Programs applied to the Socioeconomic Development

Implementing Agency: Paraguayan Space Agency

Target Group: Personnel of AEP and related institutions(AEP)

Period of Project: October 2023 - September 2025 (2 years)

Project Site: Asuncion

2.0

Dated: April 25, 2024

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	Achievement	Remarks
Overall Goal (realises 3 years after project) Contribute to the development of national skills in the space sector and strengthen the country's social, economic, scientific and technological development	1. # of projects utilizing space related technology in public and private sector 2. # of public data based on geospatial information 3. # of users of data provided	- Government Statistics - Report from AEP and/or other institutions	Mechanism of data provision for governmental statistics or decision-making process is well established.		
Project Purpose (realises at the end of the project) The ability to utilize space-related technologies in Paraguay is strengthened and geospatially informed decision-making is promoted.	1. # of interagency projects in which AEP was involved 2. # of value-added satellite data products in and beside pilot projects by GEOLab, AEP 3. # of Paraguayan staff have training programs in Japan and Paraguay	Government Statistics, Project Report			
Outputs (Key components of the project) Output1: Human resources and infrastructure for AEP upstream and downstream will be strengthened. Output2: AEP and related agencies implement pilot projects to improve capacity for analyzing disaster risk and preventing and responding to natural disasters. Output3: AEP and related agencies implement pilot projects to improve capacity for management of agriculture and livestock information related to productivity and quality.	1-1. # of trained persons considering gender balance 1-2. # of seminars and workshops 1-3. satisfaction of seminars and workshops Same as 1-1, 1-2, 1-3 # of PoC, # of practical plans from activity, # of papers and reports related to activity Same as 1-1, 1-2, 1-3 # of PoC, # of practical plans from activity, # of papers and reports related to activity	Project Report Project Report Project Report Project Report Project Report Project Report	- Counterpart personnel is continuously secured properly - Other institutions, such as government and universities accept involvement of pilot projects.		

Activities	Inputs		Important Assumption
	The Japanese Side	The Paraguay Side	
1-1: Conduct an evaluation of AEP's existing technical methods and tools and make recommendations for future planning.	- Short-term experts (Data utilization planning, Satellite development/testing, Data utilization in disaster risk reduction/agriculture and livestock sector) - Training for Counterpart Personnel in Japan - Local cost for the activities	- Allocation of counterpart personnel - Coordination among ministries and organizations - Arrangements between projects with other development partners, etc. - Arrangements for providing necessary data - Office space for Japanese professionals - Local costs (maintenance costs for existing equipment not covered by JICA support, meeting preparation costs, operating costs required for the project, etc.)	
1-2: Develop enhancement plan based on a diagnosis of GEOLab, AEP. 1-3: Provide 6-month hands-on training in satellite development, including testing EM of GuaraniSat-2 at Kyutech between October 2024 and March 2025. 1-4. Provide training in satellite data and other processing and applications. 1-5. Liaison between AEP and Japanese governmental institutions, universities, and private companies.			Pre-Conditions
2-1: Set up working groups consisting of AEP and related organizations to identify issues and implement pilot projects.			
2-2: Identify issues where space-related technologies can be effectively applied in the field of disaster risk reduction. 2-3. Determine scope for applying space-related technologies to the issues and design pilot projects. 2-4. Develop plan and procure equipment (hardware and software) for satellite imagery and data collecting/processing. 2-5. Train personnel in the use of tools, methods, and techniques for disaster risk reduction. 2-6. Implement pilot projects with Working Group and existing agreements with academia and other governmental and non-governmental organizations. 2-7. Publish results of pilot projects locally and internationally.			
3-1: Set up working groups consisting of AEP and related organizations to identify issues and implement pilot projects. 3-2: Identify issues where space-related technologies can be effectively applied in the agriculture and livestock sector.			
3-3. Determine scope for applying space-related technologies to the issues and Design pilot projects. 3-4. Develop plan and procure equipment (hardware and software) for satellite imagery and data collecting/processing. 3-5. Train personnel in the use of tools, methods, and techniques to improve productivity and quality in agriculture and livestock sector.			
3-6. Implement pilot projects with Working Group and existing agreements with academia and other governmental and non-governmental organizations. 3-7. Publish results of pilot projects locally and internationally.			

別添3-4 (Annex 3-4): PDM ver. 2.1

Project Design Matrix (PDM)

Project Title: Project for Management of Space Programs applied to the Socioeconomic Development
Implementing Agency: Paraguayan Space Agency
Target Group: Personnel of AEP and related institutions(AEP)
Period of Project: October 2023 - September 2025 (2 years)

2.1
Dated: September 12, 2025

Project Site: Asuncion					
Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	Achievement	Remarks
Overall Goal (realises 3 years after project) Contribute to the development of national skills in the space sector and strengthen the country's social, economic, scientific and technological development	1. # of projects utilizing space related technology in public and private sector 2. # of public data based on geospatial information 3. # of users of data provided	- Government Statistics - Report from AEP and/or other institutions	Mechanism of data provision for governmental statistics or decision-making process is well established.	Action Plan was established based on the results of the Project.	Action Plan was established at the Final JCC Meeting.
Project Purpose (realises at the end of the project) The ability to utilize space-related technologies in Paraguay is strengthened and geospatially informed decision-making is promoted.	1. # of interagency projects in which AEP was involved 2. # of value-added satellite data products in and beside pilot projects by GEOLab, AEP 3. # of Paraguayan staff have training programs in Japan and Paraguay	Government Statistics, Project Report		AEP Colleagues and JICA Consultant achieved the Project Purpose through all Outputs and Activities.	None
Outputs (Key components of the project) Output1: Human resources and infrastructure for AEP upstream and downstream will be strengthened. Output2: AEP and related agencies implement pilot projects to improve capacity for analyzing disaster risk and preventing and responding to natural disasters. Output3: AEP and related agencies implement pilot projects to improve capacity for management of agriculture and livestock information related to productivity and quality of products.	1-1. # of trained persons considering gender balance 1-2. # of seminars and workshops 1-3. satisfaction of seminars and workshops Same as 1-1, 1-2, 1-3 # of PoC, # of practical plans from activity, # of papers and reports related to activity Same as 1-1, 1-2, 1-3 # of PoC, # of practical plans from activity, # of papers and reports related to activity	Project Report Project Report Project Report Project Report Project Report Project Report	- Counterpart personnel is continuously secured properly - Other institutions, such as government and universities accept involvement of pilot projects.	Output 1: All KCCPs were conducted, and Space Strategic Plan was designed. Output 2: Created Flood Hazard Map and released Manual Output 3: Soybean growth monitoring were conducted with creation of maps, and released Manual	None

Activities	Inputs		Important Assumption
	The Japanese Side	The Paraguay Side	
1-1: Conduct an evaluation of AEP's existing technical methods and tools and make recommendations for future planning. 1-2: Develop enhancement plan based on a diagnosis of GEOLab, AEP. 1-3: Provide 6-month hands-on training in satellite development, including testing EM of GuaraniSat-2 at Kyutech between October 2024 and May 2025. 1-4. Provide training in satellite data and other processing and applications. 1-5. Liaison between AEP and Japanese governmental institutions, universities, and private companies. 2-1: Set up working groups consisting of AEP and related organizations to identify issues and implement pilot projects. 2-2: Identify issues where space-related technologies can be effectively applied in the field of disaster risk reduction. 2-3. Determine scope for applying space-related technologies to the issues and design pilot projects. 2-4. Develop plan and procure equipment (hardware and software) for satellite imagery and data collecting/processing. 2-5. Train personnel in the use of tools, methods, and techniques for disaster risk reduction. 2-6. Implement pilot projects with Working Group and existing agreements with academia and other governmental and non-governmental organizations. 2-7. Publish results of pilot projects locally and internationally. 3-1: Set up working groups consisting of AEP and related organizations to identify issues and implement pilot projects. 3-2: Identify issues where space-related technologies can be effectively applied in the agriculture and livestock sector. 3-3. Determine scope for applying space-related technologies to the issues and Design pilot projects. 3-4. Develop plan and procure equipment (hardware and software) for satellite imagery and data collecting/processing. 3-5. Train personnel in the use of tools, methods, and techniques to improve productivity and quality in agriculture and livestock sector. 3-6. Implement pilot projects with Working Group and existing agreements with academia and other governmental and non-governmental organizations. 3-7. Publish results of pilot projects locally and internationally.	- Short-term experts (Data utilization planning, Satellite development/testing, Data utilization in disaster risk reduction/agriculture and livestock sector) - Training for Counterpart Personnel in Japan - Local cost for the activities	- Allocation of counterpart personnel - Coordination among ministries and organizations - Arrangements between projects with other development partners, etc. - Arrangements for providing necessary data - Office space for Japanese professionals - Local costs (maintenance costs for existing equipment not covered by JICA support, meeting preparation costs, operating costs required for the project, etc.)	Pre-Conditions 

MANUAL METODOLÓGICO DE **MANEJO DE DESASTRES**

Proyecto de Gestión de Programa Espacial
Aplicado al Desarrollo Socioeconómico

2025

AUTORIDAD DE LA AGENCIA ESPACIAL DEL PARAGUAY

Osvaldo Almirón Riveros, Ministro - Presidente de la Agencia Espacial del Paraguay

EQUIPO TÉCNICO DEL GEOLAB

Alejandro Román, Director General de Ejecución y Desarrollo Aeroespacial

Thanya Idoyaga, Jefa del Departamento de Monitoreo y Alerta

Rodrigo Fleytas, Jefe del Departamento de Teledetección

Rebeca Cristaldo, Analista de Sistemas de Información Geográfica

Juniors Sosa, Analista de Sistemas de Información Geográfica - DISERGEMIL

Verónica Cano, Analista de Sistemas de Información Geográfica

Analia Del Pozo, Analista de Sistemas de Información Geográfica

Lourdes Cristaldo, Analista de Sistemas de Información Geográfica

EQUIPO DE COOPERACIÓN TÉCNICA

Nakamura Shinsaku, Japan Space Systems

Sato Kei, PASCO Corporation

Kobayashi Yoshinori, Japan Space Forum

Kimura Atsushi, PASCO Corporation

Koga Akie, PASCO Corporation

CON EL APOYO DE EXPERTOS EN HIDROLOGÍA

Nakamura Kazuhiro, CTI Engineering International

Fujita Daisuke, CTI Engineering International

ELABORACIÓN Y DISEÑO DEL MANUAL

Thanya Idoyaga, Jefa del Departamento de Monitoreo y Alerta

Verónica Cano, Analista de Sistemas de Información Geográfica

COLABORADORES

Joaquina Mauger, Analista de Sistemas de Información Geográfica

REVISIÓN

Lourdes Cristaldo, Analista de Sistemas de Información Geográfica

Ana Paula Insfran, Analista de Sistemas de Información Geográfica

ÍNDICE DE CONTENIDO

Lista de Figuras	4
Lista de Tablas	5
Introducción	6
Antecedentes	8
Objetivos	10
Conceptos	11
Materiales y Métodos	14
↳ Diagnóstico inicial	14
↳ Creación de capacidades	21
↳ Software y modelo hidráulico utilizado	23
↳ Datos utilizados	26
↳ Preparación de datos hidrológicos	28
↳ Ejecución de simulaciones	36
Resultados	39
Conclusión	47
Anexos	48
↳ Procedimiento de desarrollo del Modelo por iRIC Nays2D_Flood.	48
↳ Análisis Geoespacial del Modelo Hidráulico en ArcGIS Pro	99
Referencias	109

LISTA DE FIGURAS

• Figura 1. Conformación de la mesa de trabajo interinstitucional.	9
• Figura 2. Mapa de Ubicación de los Bañados Norte y Sur.	16
• Figura 3. Mosaico del Modelo Digital de Elevación (DEM) de Paraguay, generado por el GEOLab a partir de ALOS PALSAR (resolución espacial: 12,5 m).	19
• Figura 4. Participantes de la capacitación virtual sobre modelación hidráulica con iRIC/Nays2DFlood	21
• Figura 5. Participantes por institución en la capacitación virtual (2024).	21
• Figura 6. Procedimiento para el desarrollo del modelo Nays2D_Flood en iRIC.	25
• Figura 7. Nivel máximo histórico del Río Paraguay.	27
• Figura 8. Caudal del Río en Asunción según la Estación ANNP.	27
• Figura 9. Precipitación y nivel del agua sobre 5.5 m en el Puerto de Asunción ANNP.	27
• Figura 10. Conversión de datos de precipitación a caudal.	29
• Figura 11. Río Paraguay en la Cuenca del Río de la Plata.	30
• Figura 12. Ejemplo de precipitación.	30
• Figura 13. Nivel del agua en Asunción ANNP (1982-1983).	31
• Figura 14. Nivel del agua en Asunción (15/05-14/06 de 1983).	31
• Figura 15. Modelo hietográfico de Asunción ANNP (22/12/1997).	32
• Figura 16. Escala visual de peligro de inundación según la altura del agua.	40
• Figura 17: Mapa de peligro de inundación fluvial – Bañado Sur.	45
• Figura 18: Mapa de peligro de inundación fluvial – Bañado Norte.	45
• Figura 19: Mapa de peligro de inundación pluvial – Bañado Sur.	46
• Figura 20: Mapa de peligro de inundación pluvial – Bañado Norte.	46

LISTA DE TABLAS

• Tabla 1. Fuentes de datos iniciales utilizados en el diagnóstico	18
• Tabla 2. Modalidad y número de participantes	21
• Tabla 3. Cronograma y contenidos de la capacitación virtual (2024).	22
• Tabla 4. Comparación de modelos hidráulicos.	24
• Tabla 5. Coeficientes de rugosidad (Manning's n) propuestos por el USACE-HEC-RAS para cálculos 2D.	35
• Tabla 6. Parámetros de la simulación fluvial.	36
• Tabla 7. Parámetros de la simulación pluvial.	37
• Tabla 8. Comparación entre simulación fluvial y pluvial	38
• Tabla 9. Interpretación de la paleta de colores por nivel de peligro de inundación.	40

1. INTRODUCCIÓN

El “Proyecto de Gestión del Programa Espacial Aplicado al Desarrollo Socioeconómico” fue una iniciativa conjunta entre la Agencia Espacial del Paraguay (AEP) y la Agencia de Cooperación Internacional de Japón (JICA). Su propósito consistió en potenciar el uso de tecnologías espaciales para fortalecer un desarrollo socioeconómico sostenible en Paraguay. El proyecto se orientó a la aplicación de estas capacidades en sectores estratégicos como la agricultura y la gestión de desastres, con la intención de generar aportes técnicos y metodológicos de valor para el país.

En este marco se ejecutó el “Proyecto Piloto de Manejo de Desastres para el Bañado Norte y Bañado Sur” en Asunción, concebido como una experiencia práctica que permitió demostrar la utilidad de la información espacial y del modelado hidráulico en la gestión del riesgo. Este piloto buscó generar insumos técnicos que sirvieran de apoyo a la planificación territorial y a la toma de decisiones frente a escenarios de inundación.

La implementación estuvo a cargo del Laboratorio de Observación de la Tierra y SIG – GEOLab de la Agencia Espacial del Paraguay, que lideró un proceso de cooperación interinstitucional con organismos públicos, técnicos y académicos. Este esquema de trabajo facilitó la articulación de capacidades y el desarrollo de metodologías aplicadas al análisis del riesgo, integrando información topográfica, hidrológica y registros históricos de caudales y precipitaciones.



Foto: Paraguaype



Uno de los ejes centrales fue la capacitación de profesionales paraguayos, impartida por expertos japoneses con amplia experiencia en modelado hidráulico y gestión de datos espaciales. Estas instancias de formación fortalecieron las competencias técnicas locales y favorecieron la transferencia de conocimiento, asegurando que las metodologías y procedimientos aplicados quedaran instalados en el país.

Entre los principales resultados se destacan la conformación de una mesa de trabajo interinstitucional como espacio de coordinación, la elaboración de mapas de peligro para las zonas estudiadas y la preparación de un manual metodológico que documenta de manera sistemática los procedimientos utilizados. Este último constituye un instrumento clave, concebido para preservar y difundir el conocimiento generado, de modo que pueda ser replicado en otros territorios y aprovechado por diferentes actores nacionales.

El proyecto piloto dejó instalado un conjunto de herramientas técnicas, capacidades profesionales y documentación metodológica que hoy conforman un recurso estratégico para la gestión del riesgo en Paraguay. Si bien no representa una solución inmediata a los problemas de inundación, sí establece una base sólida sobre la cual se pueden desarrollar nuevos análisis y acciones, asegurando que la experiencia y el conocimiento adquiridos permanezcan disponibles para su uso futuro.

2. ANTECEDENTES

El presente proyecto se desarrolla en el marco del Programa de Gestión Espacial Aplicado al Desarrollo Socioeconómico (JICA-AEP), una iniciativa conjunta entre la Agencia Espacial del Paraguay (AEP) y la Agencia de Cooperación Internacional del Japón (JICA). Este programa tiene como propósito aplicar tecnologías espaciales y geoespaciales en beneficio del desarrollo sostenible del país, promoviendo la innovación tecnológica y la creación de capacidades locales.

La alianza entre la AEP y JICA constituye un hito histórico, pues dio origen al primer programa de cooperación internacional en el sector espacial de América Latina, y al segundo a nivel mundial liderado por JICA. Este hecho refleja la confianza depositada en Paraguay para posicionarse como referente en la región, impulsando proyectos que integran el uso de datos satelitales con la gestión territorial y el desarrollo socioeconómico.



AGENCIA
ESPACIAL
DEL PARAGUAY



La cooperación se basa en tres ejes estratégicos:

- Convertir a Paraguay en un HUB regional en el desarrollo de nanosatélites y pruebas ambientales.
- Ampliar el uso de datos satelitales en sectores como la agricultura y la gestión de desastres.
- Fortalecer capacidades nacionales, garantizando la transferencia de conocimientos técnicos hacia instituciones locales.

Para llevar adelante estos ejes estratégicos, la AEP creó dos laboratorios que constituyen las líneas de desarrollo institucional:



Paraguay al espacio

Enfocado en la ingeniería de sistemas espaciales, con actividades orientadas al diseño, desarrollo y pruebas de nanosatélites. Su objetivo es posicionar a Paraguay en el mapa regional de la tecnología satelital.



Paraguay desde el espacio

Orientado a la observación de la Tierra y a la aplicación de datos satelitales para el monitoreo territorial. Constituye la base técnica para proyectos de aplicación de tecnología espacial.

Dentro del Programa de Gestión Espacial Aplicado al Desarrollo Socioeconómico JICA-AEP se definieron dos proyectos pilotos:

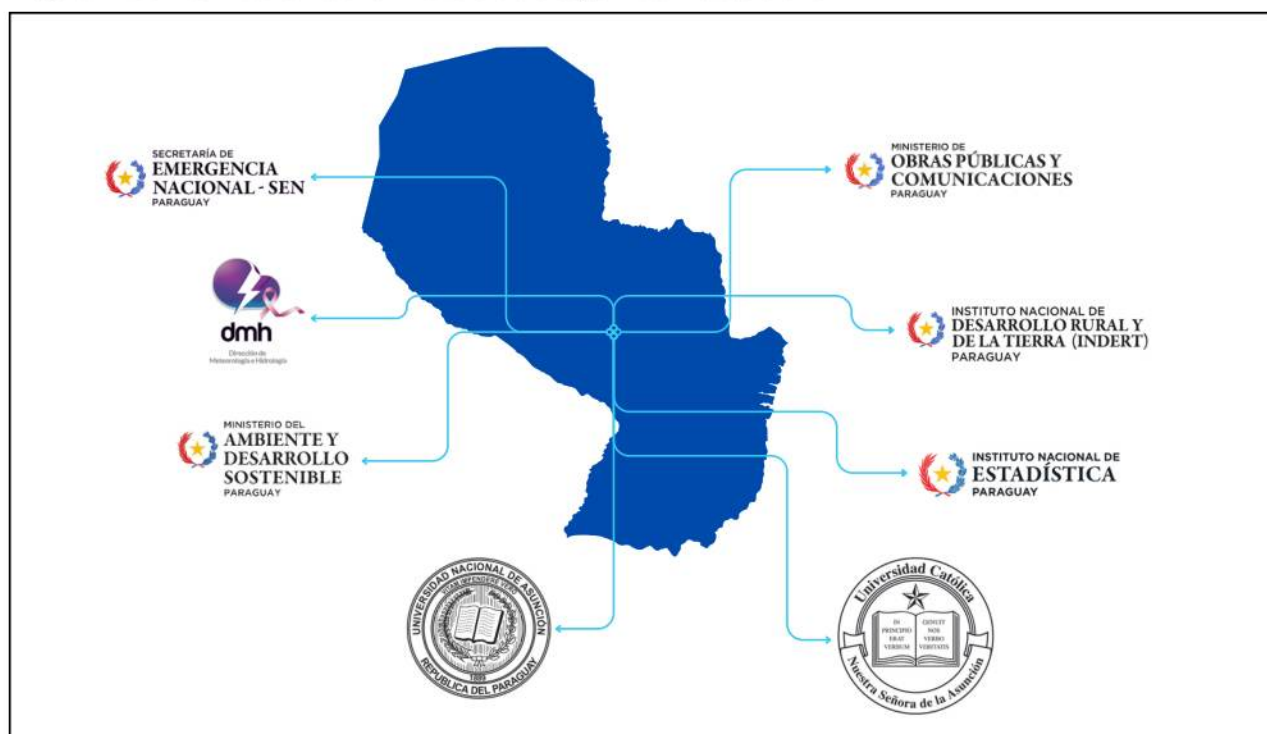
1. Proyecto piloto para la Agricultura: Aplicación de tecnologías satelitales para el monitoreo del desarrollo fenológico de cultivos estratégicos, como la soja en Caaguazú, mediante el análisis de índices NDVI históricos y actuales.
2. Proyecto piloto para el Manejo de Desastres: Implementación de simulaciones hidráulicas y generación de mapas de peligro de inundación en los Bañados Norte y Sur de Asunción, integrando metodologías de modelado fluvial y pluvial, así como procesos de capacitación interinstitucional.

Ambos proyectos no solo produjeron resultados aplicables en sus áreas específicas, sino que también dejaron como legado manuales metodológicos replicables, consolidando así la capacidad nacional para dar continuidad a estas iniciativas.

Como parte del proyecto piloto para el manejo de desastres se elaboró el presente manual, concebido como un documento metodológico de referencia. Asimismo, en este mismo marco se conformó la mesa de trabajo interinstitucional, espacio para la coordinación de datos, la capacitación técnica y la articulación entre instituciones nacionales.

La mesa de trabajo interinstitucional se conformó con la participación de entidades públicas, académicas y técnicas como se observa en la Figura 1, que aportaron información para la construcción de los modelos y el diseño de estrategias de gestión del riesgo. Este espacio permitió coordinar esfuerzos, compartir conocimientos y establecer una red de colaboración que trasciende el marco de este proyecto.

Figura 1. Conformación de la mesa de trabajo interinstitucional.



Fuente: elaboración propia (2025).

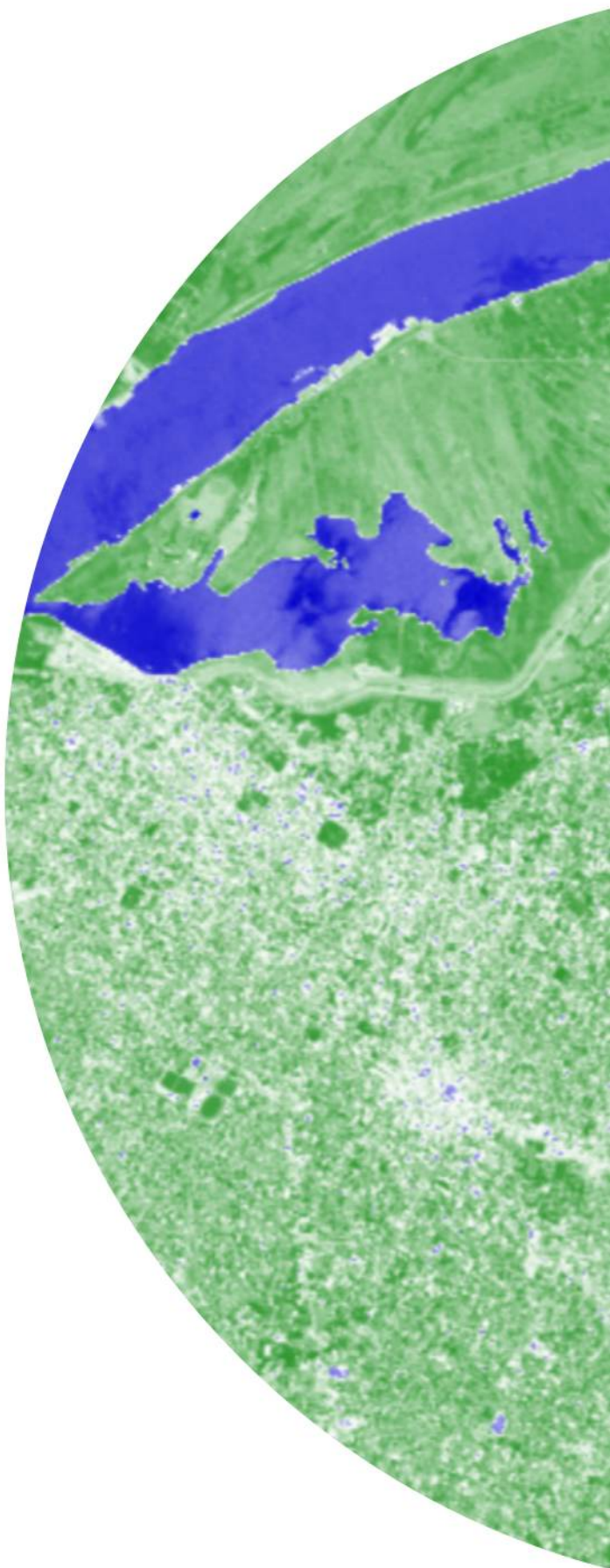
3. OBJETIVOS

GENERAL

Contribuir al desarrollo de habilidades nacionales en el sector espacial y fortalecer el desarrollo social, económico, científico y tecnológico del país.

ESPECÍFICOS

- 1 Establecer un Grupo de Trabajo compuesto por la Agencia Espacial del Paraguay e instituciones y organizaciones relacionadas para identificar problemas e implementar el proyecto piloto de manejo de desastres para las zonas de Bañado Norte y Bañado Sur en Asunción.
- 2 Capacitar a los colaboradores de la Agencia Espacial del Paraguay e instituciones y organizaciones relacionadas en el uso de datos interinstitucionales, herramientas, metodologías y técnicas para la reducción del riesgo de desastres.
- 3 Simular escenarios de inundación utilizando el software iRIC Nays2dFlood para las zonas de Bañado Norte y Bañado Sur en Asunción
- 4 Publicar los resultados de los proyectos piloto a nivel local e internacional..



4. CONCEPTOS

Riesgo: la combinación de la probabilidad de que se produzca un evento y sus consecuencias sean negativas (United Nations International Strategy for Disaster Reduction, 2009).

Amenaza: se define como la probabilidad de ocurrencia de un evento detonador o desencadenante. Estos eventos detonadores son tanto de origen natural, por ejemplo, lluvias, tormentas, erupciones volcánicas o sismos, como de origen antrópico (Herzer et al., 2002)

Peligro: Factor inherente al proceso que puede generar interrupciones o provocar daños a personas o bienes (Raffino, 2021).

Vulnerabilidad: Es el factor interno de una comunidad o sistema. Comprende las características de la sociedad de sufrir un daño o pérdida grave en caso que se concrete una amenaza (Renda et al., 2017).

Desastres: entendidos en un sentido amplio como procesos o eventos con resultados o efectos de connotación negativa que, sobre cierto umbral económico-social y/o de percepción, afectan parte o la totalidad del medio ambiente natural o del construido y su funcionalidad (Ferrando, 2003).

Gestión de riesgo: es el enfoque y la práctica sistemática de gestionar la incertidumbre para minimizar los daños y las pérdidas potenciales. Abarca la evaluación y el análisis del riesgo, al igual que la ejecución de estrategias y de acciones específicas para controlar, reducir y transferir el riesgo (United Nations International Strategy for Disaster Reduction, 2009).

Reducción de Riesgos de Desastres: es la práctica de reducir el riesgo de desastres mediante esfuerzos sistemáticos dirigidos al análisis y a la gestión de los factores causales de los desastres, lo que incluye la reducción del grado de exposición a las amenazas, la disminución de la vulnerabilidad de la población y la propiedad, una gestión sensata de los suelos y del medio ambiente, y el mejoramiento de la preparación ante los eventos adversos (United Nations International Strategy for Disaster Reduction, 2009).

Zonificación de Riesgo: es el un conjunto de herramientas que permiten identificar y categorizar el riesgo latente de una unidad de análisis, en base a criterios que permitan determinar y priorizar acciones para la reducción del riesgo (Arana, 2014).

Hietograma: es una representación gráfica, en la cual se plasma la variación o intensidad de la precipitación con respecto al tiempo y se representa por medio de diagramas de barras (Avila, 2022).

Hidrograma: un gráfico de la descarga de precipitación en un cuerpo de agua trazado cronológicamente contra el tiempo. Consiste en el flujo de las tres fases del escurrimiento: escurrimiento superficial, flujo intermedio y flujo base (Subramanya, 2013).

Inundaciones Fluviales: inundación fluvial es un fenómeno causado cuando el nivel del agua de un río aumenta, superando la cota de coronación de las bandas fluviales y desbordándose en las tierras circundantes, conocidas como llanuras aluviales, normalmente a causa de un exceso de lluvia o de deshielo (Leandro et al. 2010 citado por United Nations, s.f.).

Inundaciones Pluviales: es un fenómeno causado por precipitaciones intensas que supera la capacidad de drenaje y puede ocasionar potenciales impactos sobre las viviendas e infraestructuras urbanas, así como daños indirectos, como retenciones en carreteras, interrupción de los servicios básicos (agua, luz y gas) o pérdidas económicas debido a alteraciones en el comercio e industria (Ihobe, 2022).

Teledetección: Chuvieco (2008), define la teledetección como aquella técnica que permite adquirir imágenes de la superficie terrestre desde sensores aéreos o espaciales.

El término teledetección es una traducción del inglés “remote sensing”, y se refiere no sólo a la captación de datos desde el aire o desde el espacio sino también a su posterior tratamiento (Ormeño, 2006; Chuvieco, 1995).

Sistema de Información Geográfica (SIG): un conjunto de métodos, herramientas y datos que están diseñados para actuar coordinada y lógicamente para capturar, almacenar, analizar, transformar y presentar toda la información geográfica y de sus atributos con el fin de satisfacer múltiples propósitos (Van Humboldt, 2006).

Imágenes satelitales: son datos recogidos por sensores en plataformas de satélites, normalmente de la Tierra. Las imágenes de satélite suelen constar de varias longitudes ondas representadas de bandas. (Environmental Systems Research Institute, 2025).

Mapa de Peligros: representan los peligros de los fenómenos de un lugar específico. Incorporan información tanto de la distribución espacial del riesgo como de la probabilidad de que ocurra ese riesgo en un periodo de tiempo (Aliaga, 2016).

ArcGIS PRO: ArcGIS Pro es una aplicación de escritorio basada en 'cintas' que permite almacenar múltiples elementos, como mapas, layouts, tablas, gráficos y escenas, en un solo proyecto y trabajar con ellos según sea necesario (Environmental Systems Research Institute, 2022).

Análisis Geoespacial: se refiere a aquellas ramas de análisis de datos en los que la referencia geográfica de los objetos contiene información importante. Requiere establecer supuestos o sacar conclusiones sobre los datos que describen las relaciones espaciales o las interacciones espaciales entre casos (Goodchild y Haining, 2005).

iRIC: el software de International River Interface Cooperative es una plataforma gratuita de simulación numérica que soporta una amplia variedad de solucionadores computacionales para problemas en ciencias e ingeniería del agua (iRIC, s.f.).

Nays2DFlood: es un solucionador de flujos de inundación que permite al usuario establecer fácilmente las condiciones de entrada de un número arbitrario de ríos de entrada que ingresan desde el extremo superior o los lados de un complejo río/llanura de inundación (iRIC, s.f.).

5. MATERIALES Y MÉTODOS

5.1. Diagnóstico Inicial

El diagnóstico inicial constituyó el punto de partida del proyecto, orientado a evaluar las condiciones institucionales, técnicas y sociales vinculadas a la gestión del riesgo de inundaciones en Asunción. Esta etapa permitió identificar brechas de información, capacidades técnicas disponibles y prioridades estratégicas, garantizando que las siguientes fases del proyecto se basaran en un entendimiento compartido de la problemática.

5.1.1. Identificación de necesidades institucionales

Se efectuó un relevamiento institucional con el objetivo de conocer el grado de preparación de las entidades responsables de la gestión de riesgos y desastres. Entre los principales hallazgos se destacan:

a) Disponibilidad de recursos técnicos y humanos

- La Agencia Espacial del Paraguay (AEP), la Secretaría de Emergencia Nacional (SEN) y otras instituciones de la mesa de trabajo cuentan con equipos técnicos, aunque en número limitado.
- Se evidenció la necesidad de ampliar los recursos humanos disponibles para monitoreo y modelación de inundaciones, así como de mejorar la dotación de equipamiento informático para ejecutar simulaciones complejas.

b) Requerimiento de herramientas de análisis

- Las instituciones manifestaron limitaciones en el acceso y uso de modelos hidráulicos y de sistemas de información geográfica (SIG).
- Se señaló la importancia de disponer de plataformas que integren datos hidrológicos, topográficos y de infraestructura, de modo a apoyar tanto la simulación de escenarios como la toma de decisiones en tiempo real durante emergencias.

c) Capacitación y fortalecimiento institucional:

- Los actores coincidieron en la necesidad de formación continua en el uso de software de modelación (como iRIC/Nays2DFlood) y de análisis espacial.
- Se resaltó la importancia de desarrollar competencias en la interpretación de resultados, con el fin de que la información técnica pueda transformarse en insumos prácticos para planes de gestión, políticas públicas y estrategias comunitarias de respuesta.

d) Ausencia de una institución líder en cartografía de peligros de inundación:

- Uno de los hallazgos más relevantes del diagnóstico fue constatar que actualmente ninguna institución pública en Paraguay se encuentra específicamente encargada de producir mapas oficiales de peligro de inundación.
- Esta carencia representa una limitación significativa para la gestión integral del riesgo, ya que dificulta la disponibilidad de información homogénea, validada y accesible para la planificación urbana, la mitigación de desastres y la protección de comunidades vulnerables.
- Ante esta situación, el proyecto cobra aún mayor relevancia al aportar metodologías estandarizadas y resultados que pueden servir de referencia institucional.

5.1.2. Selección del área de estudio

La selección del área de estudio se realizó de manera participativa, en coordinación con las instituciones integrantes de la mesa de trabajo. A través de encuestas, reuniones y consultas técnicas se definieron las zonas prioritarias donde implementar el proyecto piloto.

a) Criterios de selección:

- Alta exposición a inundaciones recurrentes, tanto fluviales (por crecidas del río Paraguay) como pluviales (por lluvias intensas).
- Presencia de población vulnerable asentada en zonas de riesgo, muchas veces en condiciones de precariedad habitacional.
- Existencia de infraestructura crítica (caminos, servicios públicos, centros de salud y educativos) que puede verse seriamente afectada durante un evento de inundación.

b) Áreas seleccionadas:

- Se definieron como áreas de intervención los sectores de Bañado Norte y Bañado Sur de Asunción, que cumplen con todos los criterios mencionados.
- Estas zonas fueron identificadas como altamente prioritarias, debido a la magnitud de los impactos sociales y económicos que generan las inundaciones recurrentes y a la necesidad de contar con información actualizada para apoyar procesos de reubicación, mitigación y planificación urbana.

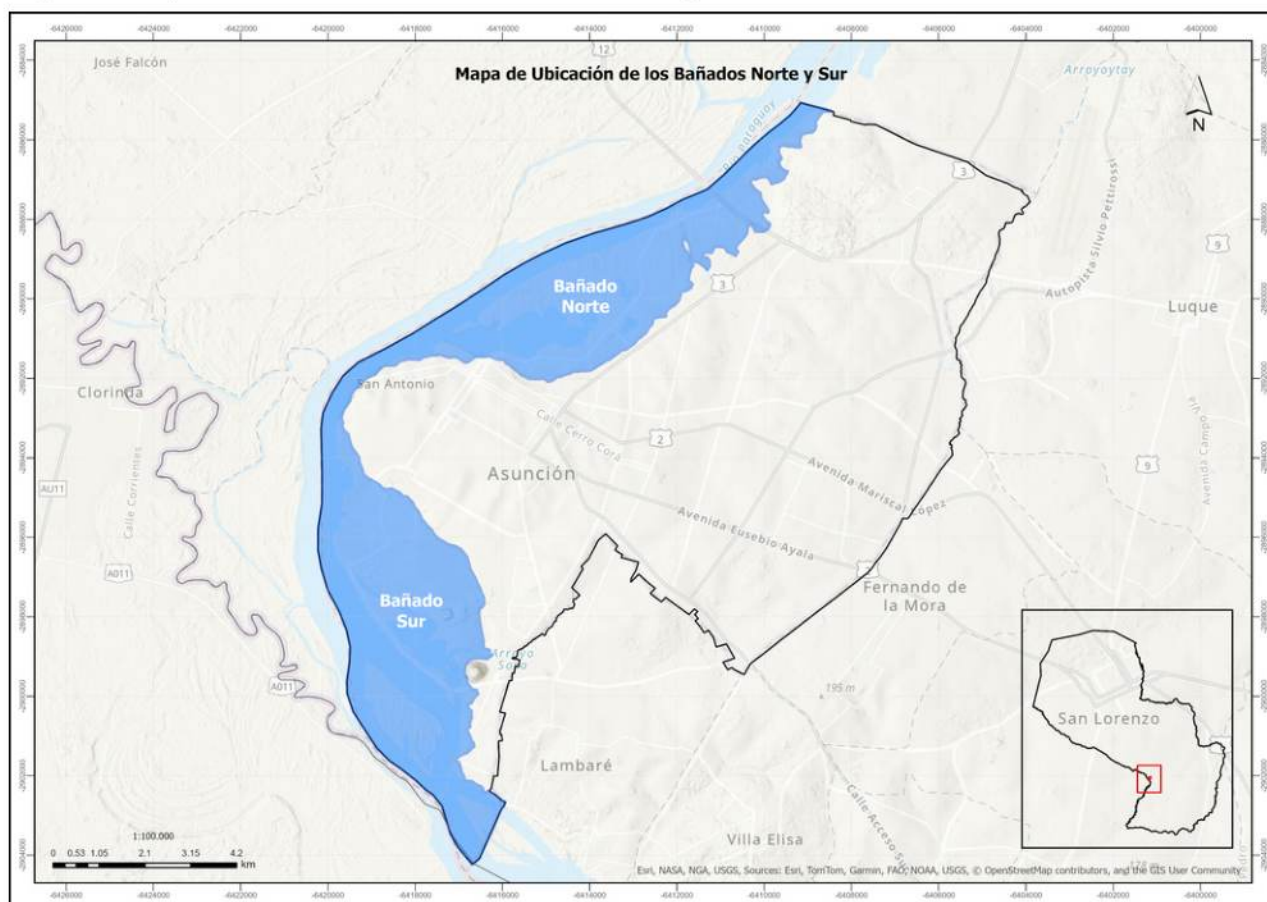
De esta forma, la selección del área de estudio respondió no solo a criterios técnicos, sino también a demandas expresas de las instituciones locales y de las comunidades directamente afectadas.

5.1.3. Ubicación del área de estudio

Los sectores de Bañado Norte y Bañado Sur se encuentran en la margen izquierda del río Paraguay, en el distrito capital de Asunción. Estas áreas forman parte de una extensa planicie aluvial caracterizada por baja altitud y elevada susceptibilidad a inundaciones. Históricamente, han funcionado como zonas naturales de expansión del río durante crecidas, acumulando agua en épocas de lluvias intensas.

La localización de los Bañados dentro de la trama urbana les otorga una particular relevancia: mientras que son áreas de alto valor ecológico y regulador en el sistema hídrico de Asunción, también concentran una elevada densidad poblacional asentada en condiciones de precariedad. Su posición geográfica, junto con la interacción de cursos de agua menores como arroyos urbanos, agrava la exposición tanto a inundaciones fluviales como pluviales. La Figura 2 ilustra la ubicación de los Bañados Norte y Sur, delimitando el área de estudio dentro del municipio de Asunción.

Figura 2. Mapa de Ubicación de los Bañados Norte y Sur.



Fuente: elaboración propia (2024).

5.1.4. Condiciones sociales y vulnerabilidad

Los Bañados constituyen uno de los espacios urbanos con mayores niveles de vulnerabilidad social del país. Gran parte de la población reside en viviendas de materiales precarios, muchas veces en asentamientos informales, con limitado acceso a servicios básicos como agua potable, alcantarillado sanitario, energía eléctrica y gestión adecuada de residuos.

Las inundaciones recurrentes afectan de manera sistemática a las familias, ocasionando la pérdida de enseres, daños en las viviendas y la necesidad de evacuaciones periódicas. A nivel económico, interrumpen medios de vida vinculados a la venta ambulante, la pesca artesanal y otras actividades informales. En términos sociales, generan procesos de desplazamiento temporario, fragmentación comunitaria y presión adicional sobre albergues y servicios públicos.

Otro factor clave es la presencia de infraestructura crítica, entre ellas: caminos de acceso, instituciones educativas, centros de salud y redes de servicios públicos. Estos elementos, al quedar anegados durante cada evento de crecida, aumentan la magnitud de los impactos y limitan las capacidades de respuesta.

5.1.5. Relevancia para el proyecto piloto

La elección de los Bañados Norte y Sur como área de estudio no solo responde a criterios técnicos de exposición al riesgo, sino también a su alto valor simbólico y representativo en la problemática de inundaciones en Paraguay. Son sectores donde convergen factores físicos, sociales y económicos que reflejan de manera clara los desafíos de la gestión del riesgo en entornos urbanos ribereños.

En este contexto, la implementación del proyecto piloto permitió:

- Aplicar modelos hidráulicos utilizando datos locales para simular escenarios de inundación fluvial y pluvial.
- Elaboración de mapas de peligro de inundación, con distintos niveles de profundidad y categorías de peligro.
- Producción de insumos cartográficos y metodológicos que puedan ser replicados en otras áreas del país.

Cabe señalar que el alcance del piloto no incluyó la validación en campo de los resultados obtenidos, debido a limitaciones de tiempo y recursos. Sin embargo, la metodología aplicada constituye un punto de partida sólido para futuros estudios más detallados y para la construcción de capacidades institucionales en Paraguay.

5.1.3. Recopilación de datos iniciales

Para caracterizar las condiciones físicas, hidrológicas y sociales del área de estudio, se desarrolló un proceso de recopilación y sistematización de información proveniente de diversas fuentes. Este trabajo fue esencial para garantizar la calidad de los insumos utilizados en la modelación hidráulica y en el análisis geoespacial posterior.

La recopilación incluyó datos topográficos, hidrológicos, de infraestructura y percepción comunitaria. Dichos insumos, presentados en la Tabla 1, constituyen la base técnica sobre la cual se configuraron los escenarios de inundación fluvial y pluvial.

Tabla 1. Fuentes de datos iniciales utilizados en el diagnóstico.

Fuente de información	Descripción	Periodo / Año	Institución que facilitó los datos
Modelo Digital de Elevación (DEM)	Imágenes satelitales ALOS PALSAR con resolución espacial de 12,5 m, procesadas por el GEOLab.	2011	GEOLab
Registros hidrológicos	Series históricas de nivel del río, caudal y precipitación diaria de la estación Asunción ANNP.	1960 - 2024	Dirección de Meteorología e Hidrología (DMH)
Infraestructura y servicios básicos	Cartografía digital de caminos, viviendas, servicios públicos e infraestructura crítica en zonas de riesgo.	2022	Instituto Nacional de Estadística (INE) / Humanitarian OSM
Percepción comunitaria	Talleres participativos y entrevistas con líderes locales para identificar experiencias y necesidades frente a inundaciones.	2024	Secretaría de Emergencia Nacional (SEN)

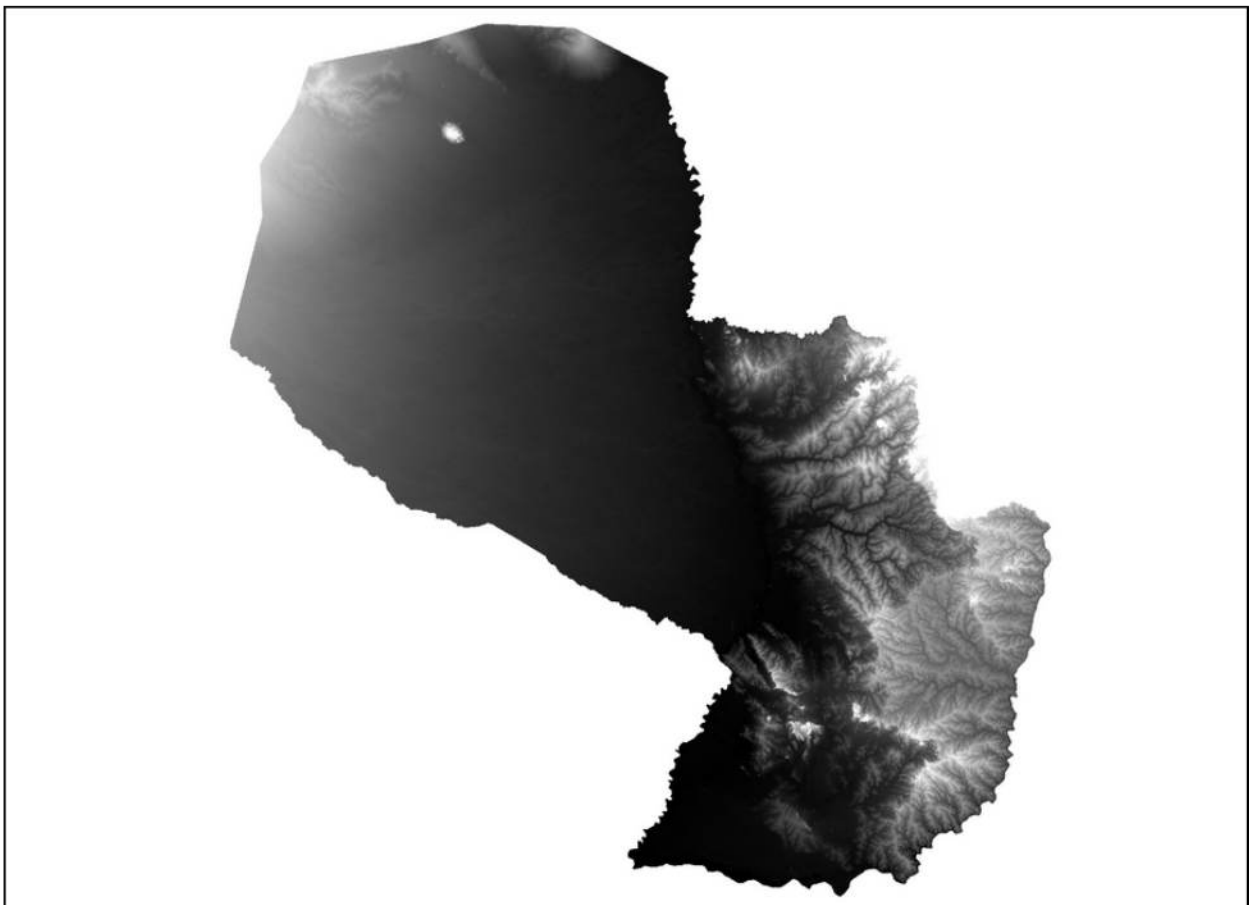
Fuente: elaboracion propia (2024).

La información presentada en la Tabla 1 se constituye en la base técnica para el desarrollo de las simulaciones y el análisis geoespacial. Cada conjunto de datos cumplió un rol específico en la construcción del modelo hidráulico que se detalla a continuación:

a) Modelo Digital de Elevación (DEM):

- El insumo fue generado a partir de imágenes ALOS PALSAR (sensor SAR de JAXA/METI), distribuidas por ASF DAAC (Alaska Satellite Facility) y procesadas por el GEOLab. Como resultado, se obtuvo un mosaico nacional con resolución espacial de 12,5 metros, que cubre todo el territorio paraguayo como se observa en la Figura 3.
- Este mosaico permite contar con una base homogénea y de alta resolución, que puede ser utilizada en futuros estudios de riesgo y facilita la replicación de la metodología en otras áreas del país.
- Para el caso particular del proyecto piloto, se utilizó únicamente una porción del mosaico correspondiente al área de estudio, con el fin de reducir el tiempo de cómputo del modelo y concentrar los análisis en la zona prioritaria. Esto garantizó que las simulaciones de inundación fluvial y pluvial reflejaran de manera adecuada las condiciones topográficas locales.
- El DEM permitió representar la morfología del terreno, identificar depresiones, planicies de inundación y pendientes, así como definir patrones de flujo y zonas de acumulación potencial de agua. Estos resultados constituyeron la base para la modelación hidráulica y el análisis geoespacial posterior.

Figura 3. Mosaico del Modelo Digital de Elevación (DEM) de Paraguay, generado por el GEOLab a partir de ALOS PALSAR (resolución espacial: 12,5 m).



Fuente: elaboracion propia (2024).

b) Registros hidrológicos:

- Se utilizaron series históricas de nivel del río, caudal y precipitación diaria correspondientes a la estación meteorológica Asunción ANNP, abarcando el período 1960–2024.
- Esta base de datos permitió analizar el comportamiento histórico de las inundaciones, incluyendo la identificación de máximos históricos (ejemplo: creciente de 1983).
- Los valores fueron empleados como condiciones de entrada en las simulaciones, posibilitando la construcción de escenarios fluviales y pluviales representativos de situaciones críticas.

c) Infraestructura y servicios básicos:

- A partir de cartografía digital del Instituto Nacional de Estadística (INE) y de la plataforma Humanitarian OSM (2022), se incorporó información sobre caminos, viviendas, centros de salud, escuelas y otras infraestructuras críticas.
- Estos datos permitieron identificar qué elementos de la infraestructura urbana y social se encuentran más expuestos a los diferentes niveles de inundación.
- La superposición de las capas de peligro con estas infraestructuras facilitó la generación de mapas de impacto directo sobre la población y los servicios básicos.

d) Percepción comunitaria:

- Se realizaron talleres y entrevistas con líderes locales en el año 2024, con el acompañamiento de la Secretaría de Emergencia Nacional (SEN).
- Esta información aportó una perspectiva cualitativa, permitiendo validar la experiencia de las comunidades frente a eventos pasados de inundación.
- La inclusión de este componente garantizó que el modelo no solo refleje datos físicos e hidrológicos, sino también las necesidades, prioridades y vulnerabilidades expresadas por la población afectada.

5.2. Creación de capacidades

Con el propósito de fortalecer las capacidades nacionales en la gestión del riesgo de inundaciones, se desarrolló una capacitación técnica dirigida al equipo del GEOLab y a representantes de diversas instituciones que integran la mesa de trabajo interinstitucional.

La actividad fue coordinada por PASCO Japón con el apoyo de CTI Engineering Co. Ltd., empresa japonesa de amplia experiencia en modelación hidráulica. Se realizó en modalidad virtual entre el 28 de octubre y el 19 de noviembre de 2024, en horario de 20:00 (Paraguay) y 08:00 (Japón), con un total de 38 participantes.

Figura 4. Participantes de la capacitación virtual sobre modelación hidráulica con iRIC/Nays2DFlood



a) Participación interinstitucional

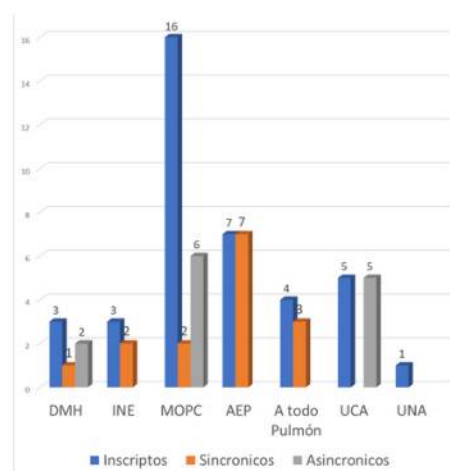
La capacitación se caracterizó por su enfoque interinstitucional, incorporando a entidades gubernamentales, académicas y de la sociedad civil. De los 38 participantes, 15 asistieron en modalidad sincrónica y 13 en modalidad asincrónica, mientras que el resto accedió mediante materiales complementarios que quedaron almacenados en la nube.

Tabla 2. Modalidad y número de participantes

Modalidad	Número de participantes	Porcentaje aproximado
Sincrónica	15	39%
Asincrónica	13	34%
Otros	10	27%
Total	38	100%

Fuente: elaboración propia (2024).

Figura 5. Participantes por institución en la capacitación virtual (2024).



Fuente: elaboración propia (2024).

b) Contenidos desarrollados

El programa de capacitación se diseñó con un enfoque progresivo, iniciando con conceptos básicos de análisis hidráulico e integrando gradualmente el uso del software iRIC/Nays2D Flood en condiciones reales de Paraguay, especialmente en los Bañados Norte y Sur. La siguiente tabla sintetiza la cronología de la capacitación:

Tabla 3. Cronograma y contenidos de la capacitación virtual (2024).

Día	Fecha Japón	Fecha Paraguay	Contenidos principales
1	29 de octubre	28 de octubre	Introducción a la gestión de inundaciones y fundamentos de análisis hidráulico
2	30 de octubre	29 de octubre	Uso de información satelital y DEM (SRTM, ALOS PALSAR)
3	31 de octubre	29 de octubre	Integración de datos climáticos (GSMP, ERA5) y cierre del primer módulo
4	6 de noviembre	5 de noviembre	Introducción al software iRIC y primeros ejercicios prácticos (con datos de Paraguay)
5	7 de noviembre	6 de noviembre	Ejecución de simulaciones básicas en iRIC (con datos de Paraguay)
6	8 de noviembre	7 de noviembre	Funciones complementarias de iRIC y validación preliminar de resultados
7	12 de noviembre	11 de noviembre	Análisis de escenarios de inundación fluvial con iRIC
8	13 de noviembre	12 de noviembre	Evaluación de medidas estructurales y efectos sobre el flujo
9	19 de noviembre	18 de noviembre	Presentación de resultados por los equipos participantes
10	20 de noviembre	19 de noviembre	Discusión de resultados, retroalimentación y cierre de la capacitación

Fuente: elaboración propia (2024).

c) Resultados de la capacitación

Más allá de la transferencia de conocimientos técnicos, el proceso constituyó un espacio común de aprendizaje que permitió articular a múltiples instituciones en torno al análisis de inundaciones. Este ejercicio reforzó la cooperación interinstitucional y sentó bases para el desarrollo de futuros proyectos de investigación y gestión del riesgo en el país.

5.3. Software y modelo hidráulico utilizado

El estudio de inundaciones puede abordarse desde dos perspectivas complementarias:

- Análisis hidrológico: busca estimar el escurrimiento generado por la precipitación en una cuenca, es decir, cuánta agua llega al cauce principal en función de la lluvia caída y de las características del terreno.
- Análisis hidráulico: se centra en cómo ese escurrimiento o caudal se propaga a través del río y las áreas aledañas, describiendo la profundidad, velocidad y extensión de la inundación sobre el terreno.

En este proyecto piloto se desarrolló únicamente el análisis hidráulico, debido a la disponibilidad de datos hidrométricos (niveles y caudales del río Paraguay registrados por la DMH) y a las limitaciones de tiempo para incorporar un modelo hidrológico completo. Sin embargo, se consideró importante explicar ambas perspectivas porque en futuros estudios podrían integrarse, logrando un enfoque más completo.

5.3.1. iRIC y el modelo Nays2DFlood

El software principal utilizado fue iRIC (International River Interface Cooperative), una plataforma gratuita que integra diferentes modelos hidráulicos y es ampliamente aplicada en estudios internacionales. Dentro de este entorno se seleccionó el modelo Nays2DFlood, diseñado para simular inundaciones en dos dimensiones (2D).

Este modelo resuelve las ecuaciones de flujo en superficie libre mediante volúmenes finitos, permitiendo analizar la propagación del agua a partir de condiciones de entrada como caudales y precipitaciones extremas. En el caso de los Bañados Norte y Sur, Nays2DFlood posibilitó:

- Representar la propagación del agua sobre planicies de inundación y áreas urbanas.
- Incorporar datos locales de caudales históricos, niveles de agua y topografía.
- Simular tanto la inundación fluvial (crecida del río Paraguay en 1983) como la pluvial (lluvia extrema de 1997).

La pertinencia de este modelo radica en su capacidad de trabajar con información disponible en Paraguay y en su gratuidad, lo que lo hace accesible para instituciones públicas y centros de investigación.



Nays2DFlood

5.3.2. ArcGIS Pro como apoyo al modelado

El modelado hidráulico fue complementado con el uso de ArcGIS Pro, un software de análisis geoespacial que permitió procesar e integrar los resultados en mapas de peligro de inundación.

Su aplicación facilitó:

- La conversión de datos numéricos en productos cartográficos comprensibles.
- La clasificación de niveles de peligro en función de la profundidad del agua.
- La identificación de infraestructura crítica y zonas residenciales expuestas.
- La comunicación visual de resultados a instituciones y comunidades.

De este modo, iRIC/Nays2DFlood permitió realizar la simulación hidráulica y ArcGIS Pro transformó esas salidas en productos útiles para la gestión del riesgo.



5.3.3. Comparación con otros modelos

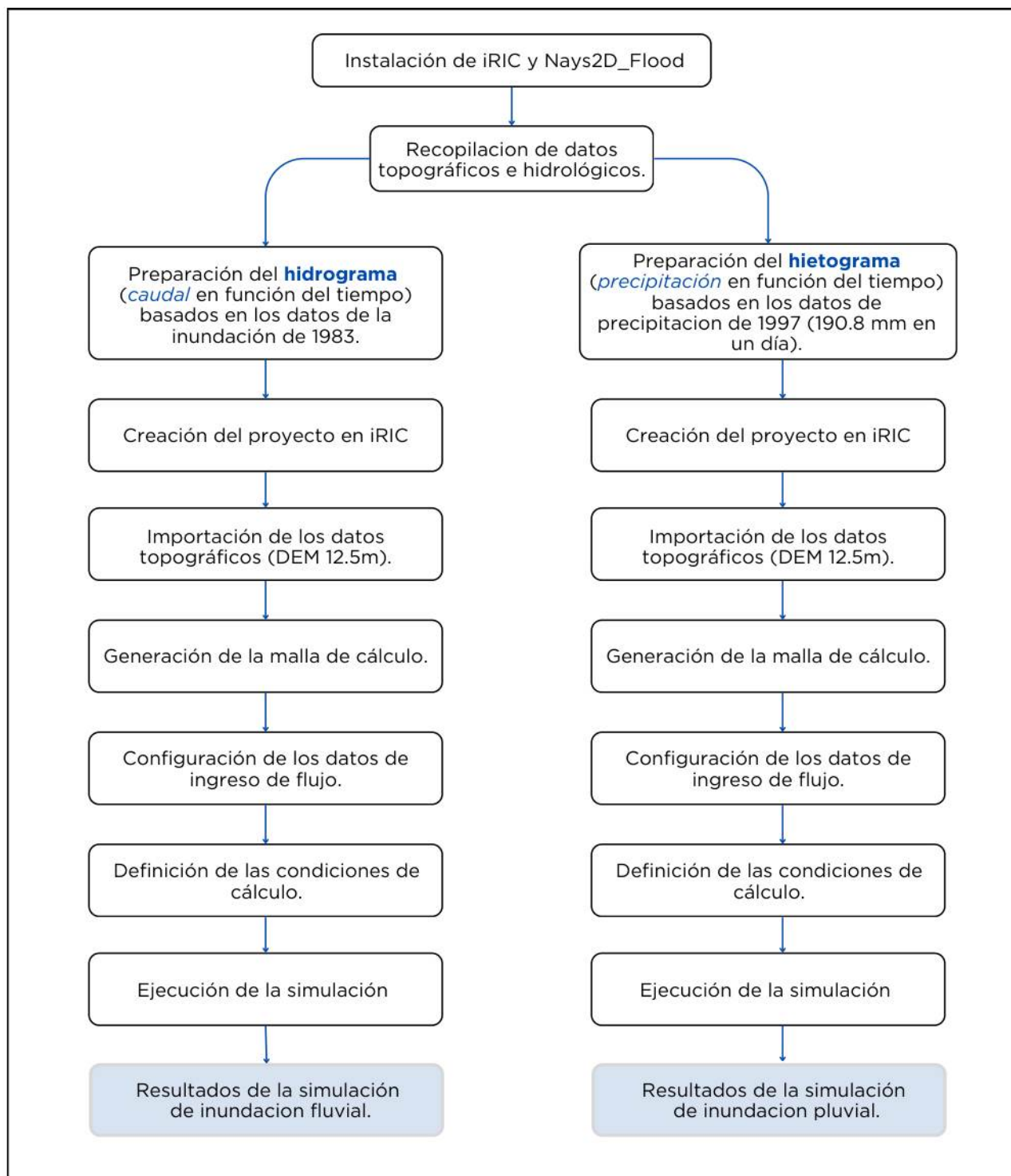
La selección de iRIC/Nays2DFlood se apoyó en un análisis comparativo con otros modelos de uso internacional (RRI, MIKE, HEC-RAS). La Tabla 4 muestra una síntesis de sus características.

Tabla 4. Comparación de modelos hidráulicos

Ítem	iRIC/Nays2DFlood	RRI	Serie MIKE	HEC-RAS
Método	Onda dinámica (shallow water equations)	Onda de difusión	Difusión / onda dinámica seleccionable	Onda dinámica
Ventajas	Módulos 1D-3D. Permite simular ríos y áreas urbanas. Interfaz amigable. Gratuito.	Integra escorrentía e inundación al mismo tiempo sin necesidad de caudales observados.	Amplia variedad de módulos (escorrentía, alcantarillado, inundación). Compatible con SIG.	Muy difundido. Modelos 1D (ríos) y 2D (inundación). Interfaz amigable. Gratuito.
Disponibilidad	Gratuito	Gratuito	Comercial	Gratuito

Fuente: elaboración propia (2025), adaptado de PASCO & CTI.

Figura 6. Procedimiento para el desarrollo del modelo Nays2D_Flood en iRIC.



Fuente: elaboración propia (2025).

5.4. Datos utilizados

La construcción del modelo hidráulico y el análisis geoespacial se basaron en la recopilación e integración de información topográfica e hidrológica. Estos datos fueron seleccionados porque permiten, respectivamente, representar el relieve de la zona de estudio y describir el comportamiento histórico del río Paraguay y de las precipitaciones que lo afectan. La correcta integración de ambos conjuntos de información constituye la base para realizar simulaciones confiables en el entorno del software iRIC, mediante el modelo Nays2D_Flood.

5.4.1. Datos topográficos

a) Modelo Digital de Elevación (DEM)

Se empleó un Modelo Digital de Elevación (DEM) con resolución espacial de 12.5 metros, generado a partir de imágenes del satélite ALOS PALSAR y procesado por el GEOLab.

b) Funciones del DEM en la simulación hidráulica

El DEM desempeña un papel central en la simulación porque:

- Representa la morfología del terreno, incluyendo elevaciones, pendientes y depresiones.
- Determina la dirección del escurrimiento superficial y permite identificar las áreas con tendencia a acumular agua.
- Sirve de base para la generación de la malla de cálculo en el modelo Nays2D_Flood, lo que posibilita aplicar las ecuaciones hidráulicas a nivel de celdas.

El DEM no es únicamente un mapa de alturas, sino el soporte geométrico que permite al modelo reproducir el movimiento del agua sobre la superficie terrestre.

5.4.2. Datos hidrológicos

a) Registros históricos

Los datos hidrológicos utilizados provienen de la Dirección de Hidrología y Meteorología (DMH), a través de la estación meteorológica Asunción ANNP, con un período de cobertura que abarca desde 1960 hasta 2024. Se incluyen tres variables fundamentales:

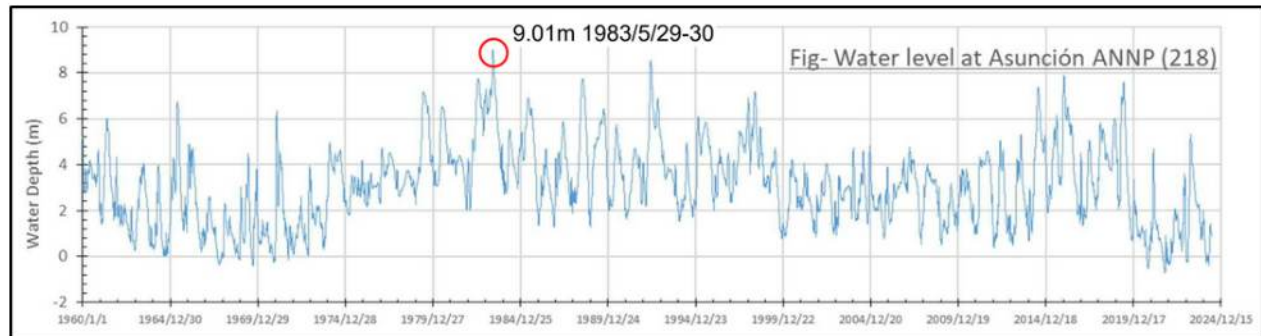
- Nivel diario del río Paraguay, expresado en metros (m).
- Caudal diario, en metros cúbicos por segundo (m^3/s).
- Precipitación diaria, en milímetros (mm).

b) Eventos extremos relevantes

Dentro de estas series históricas se identificaron valores críticos, que constituyen referencia para la calibración y validación del modelo:

- Nivel máximo histórico: 9.01 m (29 de mayo de 1983).

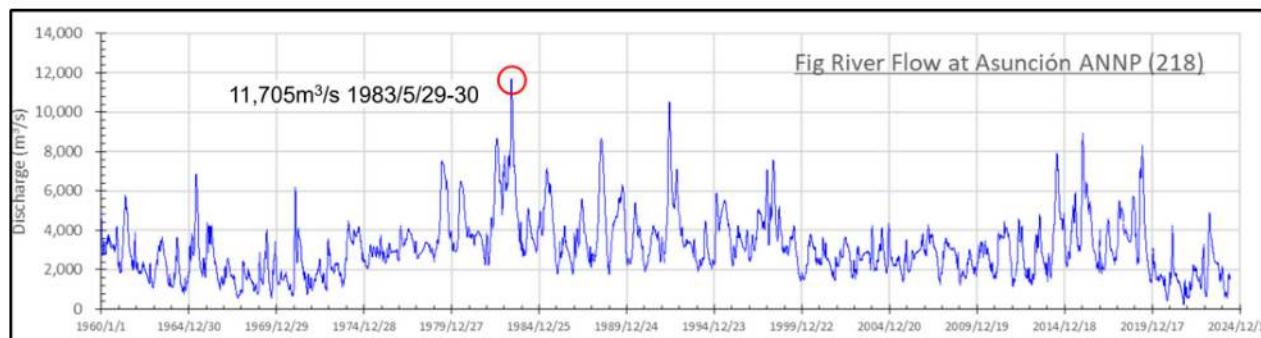
Figura 7. Nivel máximo histórico del Río Paraguay.



Fuente: CTI Engineering International (2024), a partir de registros de la Dirección de Meteorología e Hidrología (DMH).

- Caudal máximo registrado: 11,704 m³/s (29 de mayo de 1983).

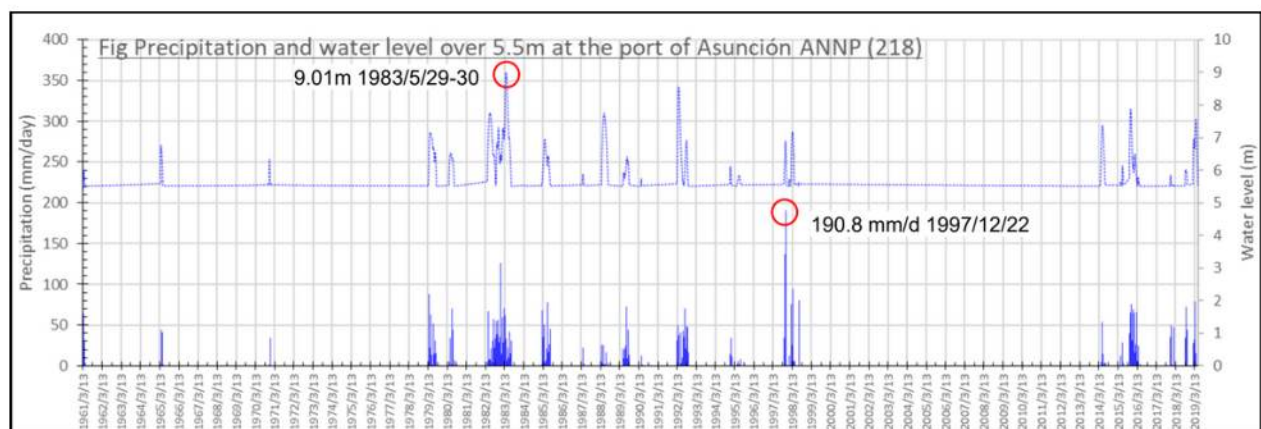
Figura 8. Caudal del Río en Asunción según la Estación ANNP.



Fuente: CTI Engineering International (2024), a partir de registros de la Dirección de Meteorología e Hidrología (DMH).

- Precipitación máxima diaria: 190.8 mm (22 de diciembre de 1997).

Figura 9. Precipitación y nivel del agua sobre 5.5 m en el Puerto de Asunción ANNP.



Fuente: CTI Engineering International (2024), a partir de registros de la Dirección de Meteorología e Hidrología (DMH).

- Nivel crítico para el Puerto de Asunción: 5.5 m, equivalente a un caudal de 5,092 m³/s.
 - Este umbral se superó en 22 ocasiones entre 1960 y 2019, evidenciando la recurrencia de eventos de riesgo en la zona urbana de Asunción.

Estos registros son fundamentales para establecer condiciones de frontera en las simulaciones, así como para analizar la severidad y frecuencia de las inundaciones históricas.

5.4.3. Integración de los datos en el modelo

Una vez recopilados y organizados, los datos topográficos e hidrológicos fueron incorporados en el software iRIC, donde se configuró el modelo hidráulico Nays2D_Flood.

Este modelo permite reproducir dos tipos de escenarios de inundación:

a) Inundación fluvial (riverine flood):

- Utiliza como insumo principal el caudal y nivel del río.
- Permite representar eventos de desbordamiento asociados a crecidas extraordinarias, como la registrada en 1983.

b) Inundación pluvial (inland flood):

- Se basa en eventos de precipitación extrema, como la lluvia de diciembre de 1997.
- Analiza la acumulación de agua sobre la superficie urbana en respuesta a lluvias intensas, independientemente del desborde del río.

La integración de ambos enfoques dentro de un mismo sistema de simulación posibilita un análisis más completo de los riesgos de inundación. Por un lado, se consideran los efectos de las crecidas del río Paraguay; por otro, se incorporan los impactos de lluvias intensas que afectan directamente a la ciudad. De esta manera, el modelo ofrece una herramienta robusta para evaluar tanto eventos históricos como escenarios hipotéticos de riesgo futuro.

5.5. Preparación de los datos hidrológicos

La preparación de los datos hidrológicos es un paso esencial para garantizar la confiabilidad de las simulaciones hidráulicas realizadas con el modelo Nays2D_Flood dentro del software iRIC. En este proceso se definen los insumos principales que permiten reproducir tanto los eventos de inundación fluvial, vinculados al caudal del río, como los eventos de inundación pluvial, asociados a precipitaciones extremas.

5.5.1. Preparación para la simulación de inundación fluvial (Riverine Flood Simulation)

a) Variable de entrada principal

El insumo clave para la simulación de inundaciones fluviales es el caudal del río Paraguay, expresado como una serie temporal de descarga en m^3/s . Este dato permite modelar la evolución de las crecidas y evaluar el desbordamiento del cauce en situaciones críticas.

b) Métodos para obtener el caudal

Existen dos formas principales de disponer de esta información:

- Análisis de escorrentía: estimación del caudal a partir de modelos hidrológicos que convierten la precipitación en flujo de agua en el río.
- Mediciones directas: registros observados de caudal en estaciones hidrométricas.

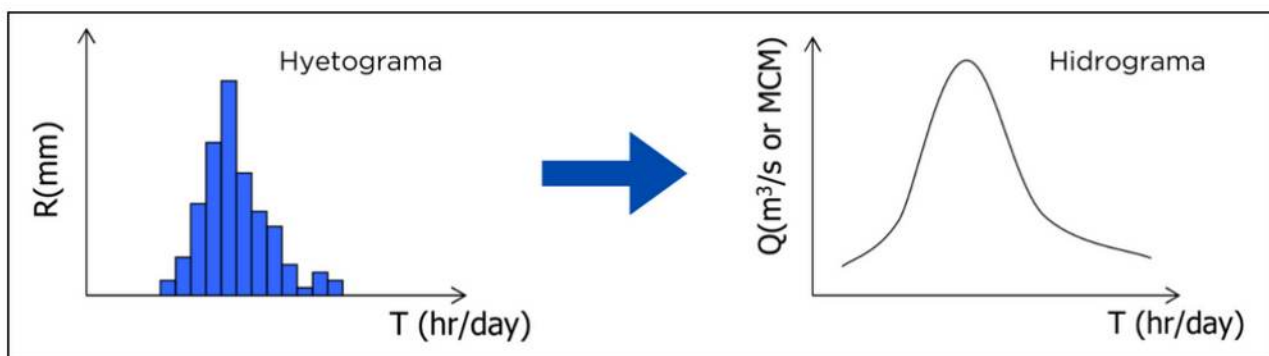
La elección del método depende de la disponibilidad y calidad de los datos de precipitación y caudal, así como de la escala de la cuenca hidrográfica.

c) Análisis de escorrentía

i. Definición

El análisis de escorrentía permite estimar el caudal en puntos específicos de la cuenca, utilizando como insumo un hietograma de precipitación (lluvia en función del tiempo). A partir de este insumo se genera un hidrograma (caudal en función del tiempo), que describe la forma en que el agua de lluvia escurre y alcanza el cauce principal.

Figura 10. Conversión de datos de precipitación a caudal.



Fuente: CTI Engineering International (2024).

ii. Caso del Río Paraguay

El Río Paraguay, con una longitud de 2,621 km y un área de captación de 365,592 km², constituye un sistema de gran escala. Por esta razón, para aplicar un análisis de escorrentía confiable es necesario:

- Incorporar información de precipitación de toda la cuenca.
- Considerar la presencia de estructuras hidráulicas (represas, azudes) que alteran el flujo natural del río.

Figura 11. Río Paraguay en la Cuenca del Río de la Plata.

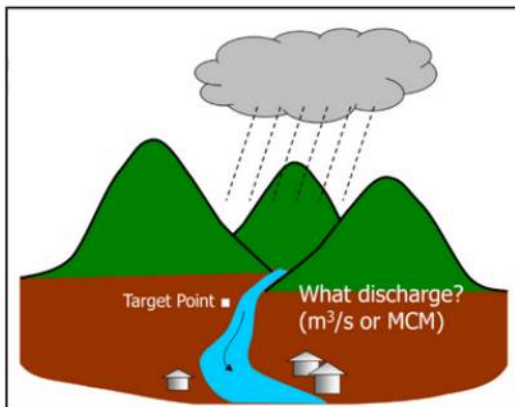


Fuente: CTI Engineering International (2024).

iii. Modelo RRI (Rainfall-Runoff-Inundation)

Para un análisis más profundo se puede emplear el modelo RRI, que tiene la capacidad de simular simultáneamente la escorrentía generada por lluvias intensas y la inundación por desbordamiento. Este modelo integra:

Figura 12. Ejemplo de precipitación.



Fuente: CTI Engineering International (2024).

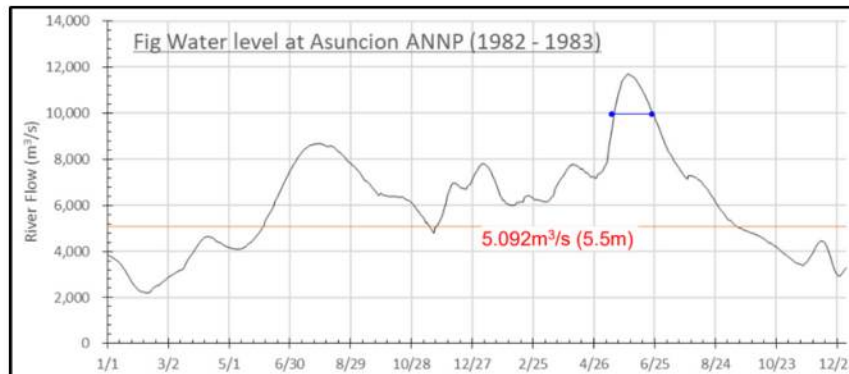
- Esorrentía superficial (2D): cada celda actúa como un tanque que acumula y libera agua.
- Flujo en cauce (1D): calcula el nivel del agua dentro del río.
- Inundación superficial (2D): reproduce la propagación lateral del agua sobre la superficie.

Dada la magnitud internacional del Río Paraguay, se requieren datos de precipitación no solo en territorio paraguayo, sino también en áreas adyacentes de Brasil. Esta necesidad representa un desafío logístico y técnico. Por ello, en este estudio se optó por utilizar directamente los datos observados en la estación ANNP, evitando la complejidad de un análisis de escorrentía a gran escala.

d) Hidrograma de referencia

Para el modelo se utilizó el hidrograma del evento de 1982-1983, que incluye un nivel crítico de 5.5 m (5,092 m³/s).

Figura 13. Nivel del agua en Asunción ANNP (1982-1983).



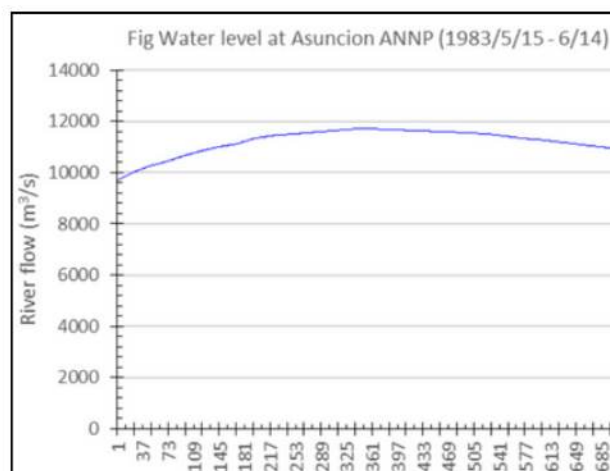
Fuente: CTI Engineering International (2024), a partir de registros de la Dirección de Meteorología e Hidrología (DMH).

e) Optimización y conversión temporal

Para mejorar la eficiencia del proceso de simulación se aplicaron dos ajustes:

1. Optimización temporal: en lugar de simular toda la serie histórica, se seleccionó un período representativo de un mes (15 de mayo - 14 de junio). Esto reduce el tiempo de cómputo sin comprometer la precisión.
2. Conversión de datos: los caudales diarios fueron transformados en caudales horarios mediante interpolación lineal, lo que permitió incrementar la resolución temporal y mejorar la precisión de las simulaciones.

Figura 14. Nivel del agua en Asunción (15/05-14/06 de 1983).



Fuente: CTI Engineering International (2024), a partir de registros de la Dirección de Meteorología e Hidrología (DMH).

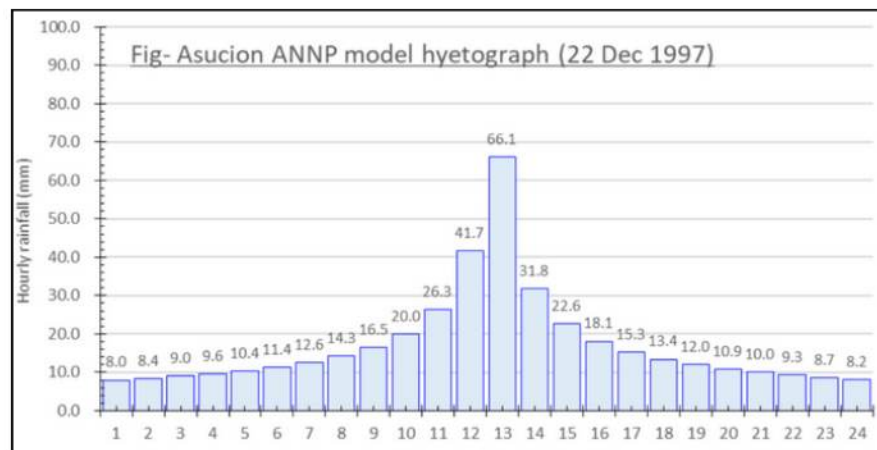
5.5.2. Preparación para la simulación de inundación pluvial (Inland Flood Simulation)

a) Evento de referencia

El insumo principal para la simulación pluvial es la precipitación extrema registrada el 22 de diciembre de 1997 en la estación Asunción ANNP, con un valor de 190.8 mm en un solo día.

Este evento se considera representativo para analizar la capacidad de la ciudad de responder a lluvias intensas y repentinas.

Figura 15. Modelo hietográfico de Asunción ANNP (22/12/1997).



Fuente: CTI Engineering International (2024).

b) Conversión de datos de precipitación

Para transformar la precipitación diaria en una distribución horaria —más adecuada para el modelo hidráulico— se empleó la fórmula de Mononobe, que permite estimar la intensidad de la lluvia en intervalos horarios.

$$r_t = R \cdot (5.3134 / t^{2/3})$$

Donde:

- r_t = intensidad de precipitación (mm/h).
- R = precipitación diaria total (mm).
- T = tiempo (h).

Este procedimiento genera un hietograma horario que sirve como condición de entrada en el modelo Nays2D_Flood para simular la inundación pluvial.

5.5.3. Cálculo de la pendiente energética

El cálculo de la pendiente energética es un paso necesario en la configuración del modelo hidráulico, ya que este parámetro define el gradiente de energía disponible en la frontera de entrada del río. En modelos bidimensionales como Nays2D_Flood, la pendiente controla la propagación del flujo y garantiza que el comportamiento del nivel del agua sea coherente con la dinámica real del cauce. Sin este valor, la simulación podría generar resultados poco realistas en términos de velocidad, niveles y extensión de la inundación.

a) Perfil longitudinal del tramo

Para determinar la pendiente, se trazó una polilínea a lo largo del eje del río Paraguay utilizando Google Earth, cubriendo el tramo que atraviesa los Bañados Norte y Sur en Asunción. El perfil topográfico obtenido permitió identificar la cota inicial y final del lecho, así como la longitud total del tramo considerado.

b) Cálculo de la pendiente

Del perfil longitudinal se obtuvo una diferencia de cotas de aproximadamente 3 metros en una longitud de 24,8 km. Con estos valores se calculó la pendiente media del cauce:

$$S = \frac{\Delta z}{L} = \frac{3}{24,800} \approx 0.00012 \quad (\approx 1/8.270)$$

Este resultado se asumió como representativo de la pendiente energética, considerando que en tramos sin influencia mareal relevante la pendiente del lecho se aproxima de forma adecuada al gradiente de energía.

c) Implementación en el modelo

El valor de $S=0.00012$ fue ingresado en el modelo Nays2D_Flood, dentro de la opción Boundary Condition > Inflow > Slope value at inflow. Esto permitió reproducir el gradiente longitudinal del río en el tramo de Asunción durante la simulación, aportando estabilidad numérica y consistencia hidrodinámica.

d) Consideraciones adicionales

El perfil longitudinal incluye variaciones locales producto de terraplenes, albardones y estructuras como el puente Héroes del Chaco. Para evitar que estas irregularidades distorsionaran el cálculo, se aplicó un suavizado mediante línea de tendencia.

5.5.4 Representación de obstáculos en el modelo

Para mejorar la precisión de la simulación hidráulica fue necesario incorporar obstáculos físicos que condicionan el flujo del agua en el área de estudio. Estos elementos fueron representados mediante polígonos vectoriales, integrados al modelo en iRIC/Nays2DFlood como superficies impermeables.

En este estudio se consideraron tres infraestructuras principales:

- Costanera Norte
- Costanera Sur
- Puente Héroes del Chaco

Estas obras actúan como barreras parciales o totales al desplazamiento del agua, modificando tanto la dirección como la velocidad del flujo durante un evento de inundación. Su inclusión en el modelo permitió obtener una representación más realista de las condiciones hidráulicas en los Bañados, especialmente en lo referente a la propagación de aguas hacia áreas urbanizadas y al comportamiento de los flujos en zonas de conexión vial.

5.5.5. Definición de rugosidad

La rugosidad del terreno es un parámetro fundamental en la modelación hidráulica, ya que determina la resistencia que la superficie opone al movimiento del agua. Este valor influye directamente en la velocidad de escurrimiento y en la acumulación en distintas zonas del modelo.

En este proyecto, se generó un polígono que abarca el área urbana de Asunción dentro del dominio de simulación. A dicho polígono se le asignó un coeficiente de rugosidad de 0,12, correspondiente a la categoría “developed medium intensity”.

La asignación de este valor se basó en los coeficientes de rugosidad de Manning propuestos por el U.S. Army Corps of Engineers (USACE) en el manual HEC-RAS para modelaciones 2D, que se presentan en la Tabla 5. Como puede observarse, la categoría developed medium intensity cubre valores entre 0,10 y 0,15, por lo que el valor seleccionado (0,12) resulta representativo de las condiciones de urbanización media que caracterizan a gran parte de Asunción.

La definición de rugosidad permitió diferenciar el comportamiento hidráulico del área urbana respecto a superficies naturales o de menor intervención, contribuyendo a una simulación más ajustada a las condiciones reales del territorio.

Tabla 5. Coeficientes de rugosidad (Manning's n) propuestos por el USACE-HEC-RAS para cálculos 2D

Categoría de superficie	Descripción	Coeficiente (n)
Water surface (open channel)	Superficie de agua sin obstrucciones	0.030 - 0.040
Developed, open space	Áreas urbanizadas con predominio de espacios abiertos (parques, lotes)	0.06 - 0.08
Developed, low intensity	Zonas residenciales de baja densidad	0.08 - 0.10
Developed, medium intensity	Áreas residenciales de media densidad, con calles y construcciones regulares	0.10 - 0.15
Developed, high intensity	Áreas urbanas de alta densidad (centros urbanos, comerciales)	0.12 - 0.18
Agricultural	Superficies agrícolas (cultivos, pastizales)	0.04 - 0.08
Forest	Zonas boscosas o arboladas	0.16 - 0.20
Wetlands / Marsh	Humedales con vegetación densa	0.20 - 0.30

Fuente: U.S. Army Corps of Engineers (USACE). (2016). HEC-RAS River Analysis System: 2D Modeling User's Manual (Version 5.0). Hydrologic Engineering Center, Davis, California.

5.6. Ejecución de simulaciones

Con los insumos hidrológicos y topográficos definidos, se desarrollaron simulaciones numéricas utilizando el software iRIC con el modelo Nays2D_Flood, orientadas a evaluar escenarios de inundación en Asunción bajo dos condiciones críticas: la inundación fluvial y la inundación pluvial.

La configuración de la malla de cálculo fue común a ambas simulaciones y se construyó a partir del Modelo Digital de Elevación (DEM) de 12,5 m. Los parámetros principales de la grilla fueron:

- $n_i = 300$ (número de celdas en dirección x)
- $n_j = 300$ (número de celdas en dirección y)
- $d_i = 66.284$ m (longitud total del dominio en dirección x)
- $d_j = 50$ m (resolución en dirección y)
- $W = 15.000$ m (ancho aproximado de la grilla)

Es importante destacar que $d_j = 50$ m corresponde a la resolución final del modelo simulado, lo que permitió representar adecuadamente la planicie de inundación dentro de las limitaciones de los datos disponibles. Estos parámetros se mantuvieron iguales tanto para la simulación fluvial como para la pluvial, asegurando la comparabilidad entre resultados.

a) Inundación fluvial

La inundación fluvial corresponde al desborde del río Paraguay durante eventos de crecida. Para este estudio se seleccionó el evento histórico de 1983, considerado uno de los más significativos en el registro hidrológico de Asunción.

- Condiciones de entrada: hidrograma del evento de 1983, interpolado de registros diarios a una serie horaria.
- Periodo simulado: del 15 de mayo al 14 de junio de 1983, abarcando la fase ascendente, el pico y el descenso de la crecida.
- Objetivo: reproducir el comportamiento del desborde lateral del río y delimitar las áreas de afectación, principalmente en los Bañados Norte y Sur.

Tabla 6 – Parámetros de la simulación fluvial.

Parámetro	Valor	Fuente
n_i, n_j	300 x 300	Elaboración propia
d_i	66.284 m	Elaboración propia
d_j (resolución)	50 m	Elaboración propia
W	15.000 m	Elaboración propia

Parámetro	Valor	Fuente
Evento histórico	Crecida de 1983	Registros hidrológicos ANNP de DMH
Periodo simulado	15/05 - 14/06/1983	Registros históricos ANNP de DMH
Tiempo de cómputo	10 horas	GEOLab - AEP

Fuente: Elaboración propia a partir de registros hidrológicos históricos de DMH y procesamiento en GEOLab - AEP.

b) Inundación pluvial

La inundación pluvial resulta de precipitaciones intensas que exceden la capacidad de drenaje urbano. Se simuló el evento del 22 de diciembre de 1997, cuando se registraron 190,8 mm de lluvia en 24 horas en la estación Asunción ANNP.

- Condiciones de entrada: serie horaria de precipitación generada a partir del valor diario mediante la fórmula de Mononobe.
- Periodo simulado: evento puntual de 24 horas correspondiente al 22/12/1997.
- Objetivo: identificar zonas urbanas críticas de acumulación y anegamiento en ausencia de desbordes fluviales.

Tabla 7 - Parámetros de la simulación pluvial.

Parámetro	Valor	Fuente
ni, nj	300 x 300	Elaboración propia
di	66.284 m	Elaboración propia
dj (resolución)	50 m	Elaboración propia
W	15.000 m	Elaboración propia
Evento histórico	Precipitación de 190,8 mm	Registros históricos ANNP de DMH
Fecha simulada	22/12/1997	Registros históricos ANNP de DMH
Tiempo de cómputo	2 horas	GEOLab - AEP

Fuente: Elaboración propia a partir de registros hidrológicos históricos de DMH y procesamiento en GEOLab - AEP.

c) Comparación entre simulaciones

Las simulaciones fluvial y pluvial compartieron la misma configuración de grilla y resolución, pero difirieron en insumos, duración y complejidad computacional.

Tabla 8 – Comparación entre simulación fluvial y pluvial

Aspecto	Fluvial	Pluvial
Evento histórico	Crecida de 1983	Lluvia de 190,8 mm en 1997
Duración simulada	30 días	24 horas
Resolución del modelo (dj)	50 m	50 m
Tiempo de cómputo	10 horas	2 horas
Áreas críticas	Bañados Norte y Sur	Sectores urbanos con insuficiencia de drenaje

Fuente: elaboración propia (2025).

c) Consideraciones finales

Las simulaciones realizadas permitieron representar de manera adecuada los procesos de inundación en la ciudad de Asunción, tanto por desborde fluvial como por precipitaciones extremas. Sin embargo, debe señalarse que la resolución espacial del modelo ($dj = 50\text{ m}$) estuvo condicionada por la disponibilidad de datos abiertos del DEM.

Si bien esta resolución permitió obtener resultados consistentes a escala general, puede ser insuficiente para capturar detalles microtopográficos relevantes en áreas urbanas. Por ello, se recomienda que en futuros estudios se gestionen insumos de mayor resolución espacial (por ejemplo, levantamientos LiDAR o fotogrametría aérea). Replicar la presente metodología con datos de mayor detalle permitirá reducir la incertidumbre en los resultados y fortalecer el soporte técnico para la planificación territorial y la gestión de riesgos en Asunción.

6. RESULTADOS

6.1. Resultados del análisis de inundación

A partir de las simulaciones realizadas en el software iRIC/Nays2D_Flood y del procesamiento geoespacial en ArcGIS Pro, se obtuvieron mapas de peligro de inundación que representan la distribución espacial de las profundidades de agua bajo escenarios fluviales y pluviales.

Estos mapas constituyen un insumo para la gestión del riesgo en Asunción, ya que permiten identificar las zonas más expuestas a diferentes niveles de inundación y visualiza el grado de peligro para la población y la infraestructura. Como destaca la CEPAL (2022), “los mapas de peligro constituyen la base fundamental para la planificación de la gestión del riesgo de inundaciones”.

Además, los productos generados cumplen una doble función:

- Técnica, al ofrecer información para los tomadores de decisiones en materia de planificación urbana y mitigación del riesgo.
- Comunicacional, al facilitar la comprensión del fenómeno de inundación en las comunidades afectadas, promoviendo una cultura de prevención.

Este enfoque metodológico ha sido aplicado en experiencias internacionales donde se reconoce que los mapas de peligro de inundación no solo describen la amenaza física, sino que también son herramientas prácticas para orientar políticas públicas y proyectos de infraestructura (Banco Mundial, 2021).

6.1.1. Interpretación de la paleta de colores por nivel de peligro

Los mapas de peligro generados en este estudio emplean una paleta de colores estandarizada que clasifica los rangos de profundidad del agua en cinco categorías de peligro, desde bajo hasta extremo. Esta simbología se diseñó con el objetivo de facilitar tanto la lectura técnica como la comprensión comunitaria de los resultados, asegurando que los productos puedan servir como insumo en distintos niveles de decisión.

La clasificación adoptada en este proyecto constituye una elaboración propia del equipo técnico, desarrollada a partir de la revisión de experiencias internacionales. Se tomó como referencia:

- Mapas de peligro de inundación desarrollado en Japón, que introduce categorías diferenciadas para la comunicación del riesgo en áreas urbanas facilitado por los consultores de PASCO.

A partir de estas fuentes, se construyó una clasificación ajustada a la realidad de Asunción, en la que se buscó equilibrar criterios técnicos de modelación hidráulica con la necesidad de transmitir los resultados de manera clara a instituciones y comunidades. En este proyecto piloto, se utilizó la siguiente clasificación de profundidades:

Tabla 9. Interpretación de la paleta de colores por nivel de peligro de inundación

Color	Profundidad del agua	Categoría de peligro	Descripción	Efectos típicos
Azul	< 0.5 m	Peligro bajo	Anegamientos superficiales	Dificulta la movilidad, afecta caminos y genera impactos moderados en infraestructura.
Verde	0.5 – 3 m	Peligro medio	Inundación moderada	Afecta viviendas de un piso, servicios básicos e instalaciones públicas.
Amarillo	3 – 5 m	Peligro alto	Inundación severa	Supera la altura de viviendas de un piso, ocasiona daños significativos en infraestructura y amenaza la seguridad de la población.
Rojo	5 – 10 m	Peligro muy alto	Inundación crítica	Cubre totalmente edificaciones bajas y medianas; hace inviable la permanencia de población.
Celeste	> 10 m	Peligro extremo	Inundación máxima	Asociada a cauces principales o depresiones marcadas; áreas no aptas para asentamientos humanos.

Fuente: elaboración propia (2025)

La combinación de esta simbología con referencias visuales, como se aprecia en la Figura 16, permite comprender gráficamente la relación entre el nivel del agua, la infraestructura (particularmente las viviendas) y la escala humana. Esta forma de presentación es fundamental para garantizar que la información sea comprensible no solo para especialistas, sino también para las comunidades expuestas, en línea con las recomendaciones de la CEPAL (2022).

Figura 16. Escala visual de peligro de inundación según la altura del agua.



Fuente: elaboración propia (2025)

6.1.2. Inundación fluvial – Escenario 1983

a) Bañado sur

- *Resultados de la simulación.*

El mapa de peligro de inundación fluvial para el Bañado Sur, correspondiente a la Figura 17, reproduce el comportamiento del evento histórico de 1983, mostrando un gradiente claro de profundidades:

- En la franja ribereña, inmediata al cauce principal del río Paraguay, las profundidades alcanzan entre 5 y 10 m, lo que corresponde a condiciones de inundación crítica. Estas áreas coinciden con depresiones naturales y zonas más bajas donde la energía del flujo se concentra. En sectores puntuales, asociados a depresiones marcadas, se observan áreas con valores cercanos o superiores a los 10 m, lo que las hace incompatibles con cualquier tipo de uso urbano.
- En las zonas intermedias, entre el borde ribereño y los barrios de mayor consolidación, se extiende una franja con profundidades de 3 a 5 m, categoría que se considera de inundación severa. La magnitud de estas áreas refleja la exposición de asentamientos precarios localizados en planicies de inundación.
- Hacia la transición con la periferia urbana consolidada, los valores predominantes se reducen a entre 0,5 y 3 m. Estas profundidades, aunque moderadas, son suficientes para comprometer viviendas de un piso, caminos de acceso y servicios básicos.
- Finalmente, en los sectores más elevados aparecen anegamientos superficiales (<0,5 m), que si bien no representan un riesgo estructural alto, dificultan la movilidad y la accesibilidad, lo cual en situaciones de emergencia retrasa la respuesta humanitaria.

- *Infraestructura potencialmente afectada.*

Al superponer los resultados de la simulación con datos de Humanitarian OSM (actualizado a agosto de 2024) y Cartografía Digital 2022, se identificó que 10.594 infraestructuras actualmente existentes quedarían bajo condiciones de inundación si un evento de magnitud similar al de 1983 volviera a repetirse. Esto incluye 10 escuelas y 9 instalaciones críticas (centros de salud, iglesias y servicios públicos). Es importante subrayar que estos datos no representan la situación de 1983, sino una estimación de los daños que se producirían en la actualidad ante un escenario comparable.

b) Bañado Norte

- *Resultados de la simulación.*

El mapa de peligro de inundación fluvial para el Bañado Norte, correspondiente a la Figura 18, reproduce el comportamiento de un evento de magnitud similar al de 1983, mostrando un gradiente de profundidades que abarca desde anegamientos superficiales hasta niveles críticos:

- En la planicie central del bañado, se concentran valores de 0,5 a 3 m, que corresponden a condiciones de inundación moderada. Estos niveles afectan directamente a viviendas, caminos principales y servicios básicos.
- En sectores puntuales, asociados a depresiones naturales y zonas de baja pendiente, se observan profundidades de 3 a 5 m, clasificadas como inundación severa localizada, con riesgo significativo para la población y la infraestructura allí asentada.
- En las áreas próximas al cauce y zonas bajas más profundas, se identifican superficies relevantes con profundidades de 5 a 10 m, lo que corresponde a condiciones de inundación crítica. En puntos muy específicos, los valores alcanzan más de 10 m, evidenciando la incompatibilidad de estas áreas con cualquier uso urbano bajo escenarios de crecida.
- Finalmente, en los bordes de mayor cota se registran anegamientos superficiales (<0,5 m), que si bien no implican daños estructurales de gran magnitud, dificultan la movilidad y el acceso a servicios esenciales durante emergencias.

- *Infraestructura potencialmente afectada.*

Si un evento con características similares al de 1983 volviera a ocurrir en la actualidad, la superposición de la simulación con los datos de Humanitarian OSM (actualizado a agosto de 2024) y la Cartografía Digital 2022 permite estimar que 702 infraestructuras existentes quedarían afectadas. Entre ellas se encuentran 1 escuela y 5 instalaciones críticas, que incluyen centros de salud, servicios básicos y equipamientos comunitarios.

La distribución por rangos de profundidad es la siguiente:

- 517 infraestructuras bajo <0,5 m, principalmente afectadas por anegamientos y problemas de accesibilidad.
- 180 infraestructuras en zonas de 0,5 a 3 m, con impactos más severos sobre viviendas y equipamientos.
- 5 infraestructuras en áreas de 3 a 5 m, con riesgo de daños estructurales.
- El resto se encuentra distribuido en las categorías de 5-10 m y >10 m, que aunque representan superficies menos extensas en comparación con otros sectores, concentran el mayor nivel de peligro.

6.1.3. Inundación pluvial – Escenario 1997

a) Bañado sur

- *Resultados de la simulación.*

El mapa de peligro de inundación pluvial para el Bañado Sur, correspondiente a la Figura 19, basado en la precipitación máxima del 22 de diciembre de 1997 (190,8 mm/día), muestra un gradiente claro de profundidades:

- La categoría más extensa corresponde a profundidades de 0,5 a 3 m, lo que representa un nivel de peligro medio. Estas condiciones son suficientes para comprometer viviendas de un piso, caminos y servicios básicos.
- En depresiones localizadas, los valores alcanzan entre 3 y 5 m, considerados de peligro alto, con afectación crítica para asentamientos precarios.
- De manera puntual se observan áreas con profundidades de 5 a 10 m, que corresponden a peligro muy alto. Estas acumulaciones se concentran en zonas bajas donde el drenaje natural es limitado, generando un escenario crítico para la población residente.
- Finalmente, en sectores periféricos y más elevados se registran anegamientos <0,5 m, que aunque de menor gravedad estructural, restringen la movilidad y la accesibilidad en contextos de emergencia.
- No se identifican superficies con profundidades superiores a 10 m, lo que marca una diferencia con los escenarios fluviales extremos como el de 1983.

- *Infraestructura potencialmente afectada.*

La superposición de los resultados de la simulación con los datos de Humanitarian OSM (agosto 2024) y Cartografía Digital 2022 indica que 4.463 infraestructuras actuales quedarían expuestas bajo un evento pluvial similar al de 1997. Entre ellas se incluyen 3 escuelas y diversas instalaciones comunitarias. Estos datos no corresponden a la situación de 1997, sino que representan los daños potenciales que se producirían hoy si un episodio de igual magnitud volviera a repetirse.

b) Bañado Norte

- *Resultados de la simulación.*

El mapa de peligro de inundación pluvial para el Bañado Norte, correspondiente a la Figura 20, refleja un patrón similar al del Sur, con un predominio del rango 0,5–3 m:

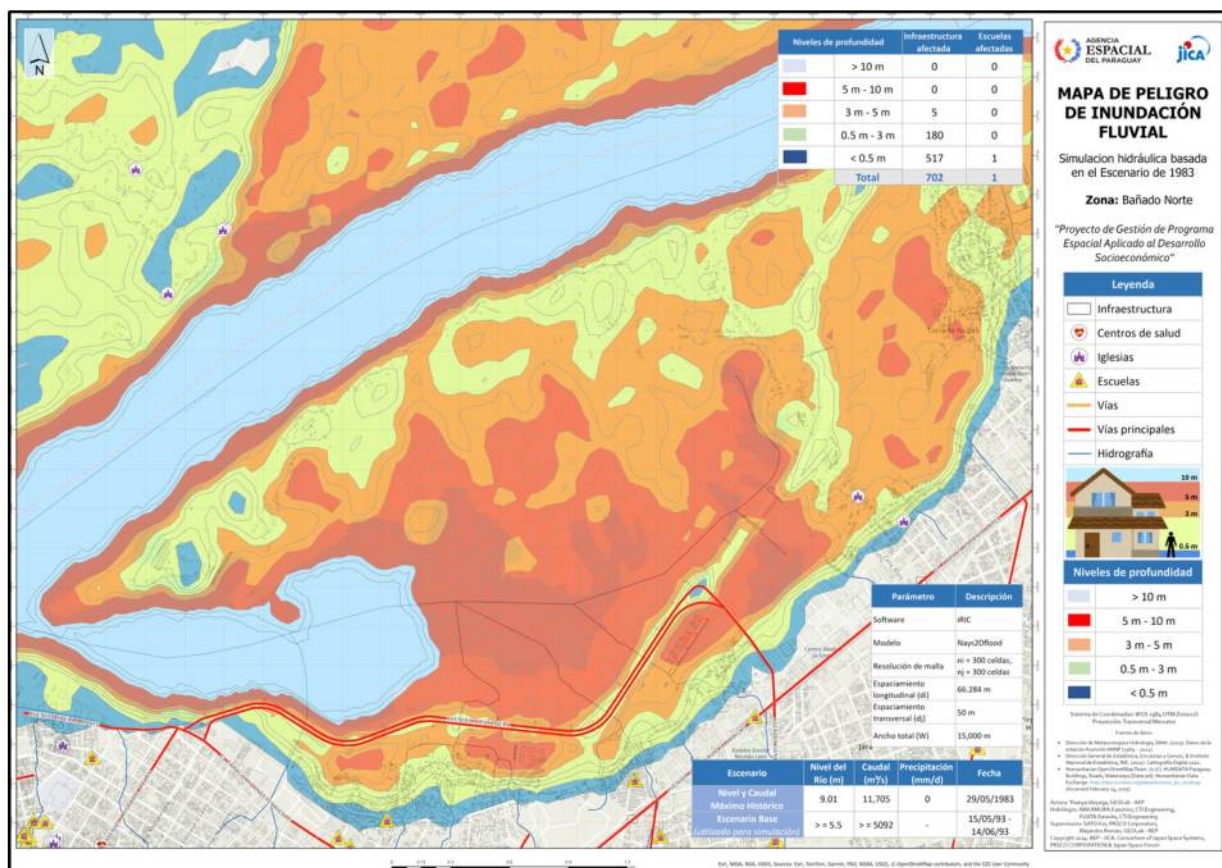
- La mayor superficie corresponde a profundidades de 0,5 a 3 m, nivel de peligro medio que afecta directamente a los asentamientos y a la infraestructura vial.
- En sectores de depresión natural se identifican zonas con valores de 3 a 5 m, clasificadas como peligro alto.

- De manera puntual se registran áreas con profundidades de 5 a 10 m, consideradas de peligro muy alto, aunque de extensión reducida.
- En los bordes de transición urbana predominan acumulaciones <0,5 m, que generan anegamientos menores pero persistentes.
- Al igual que en el Bañado Sur, no se observaron superficies en la categoría de >10 m.

- *Infraestructura potencialmente afectada.*

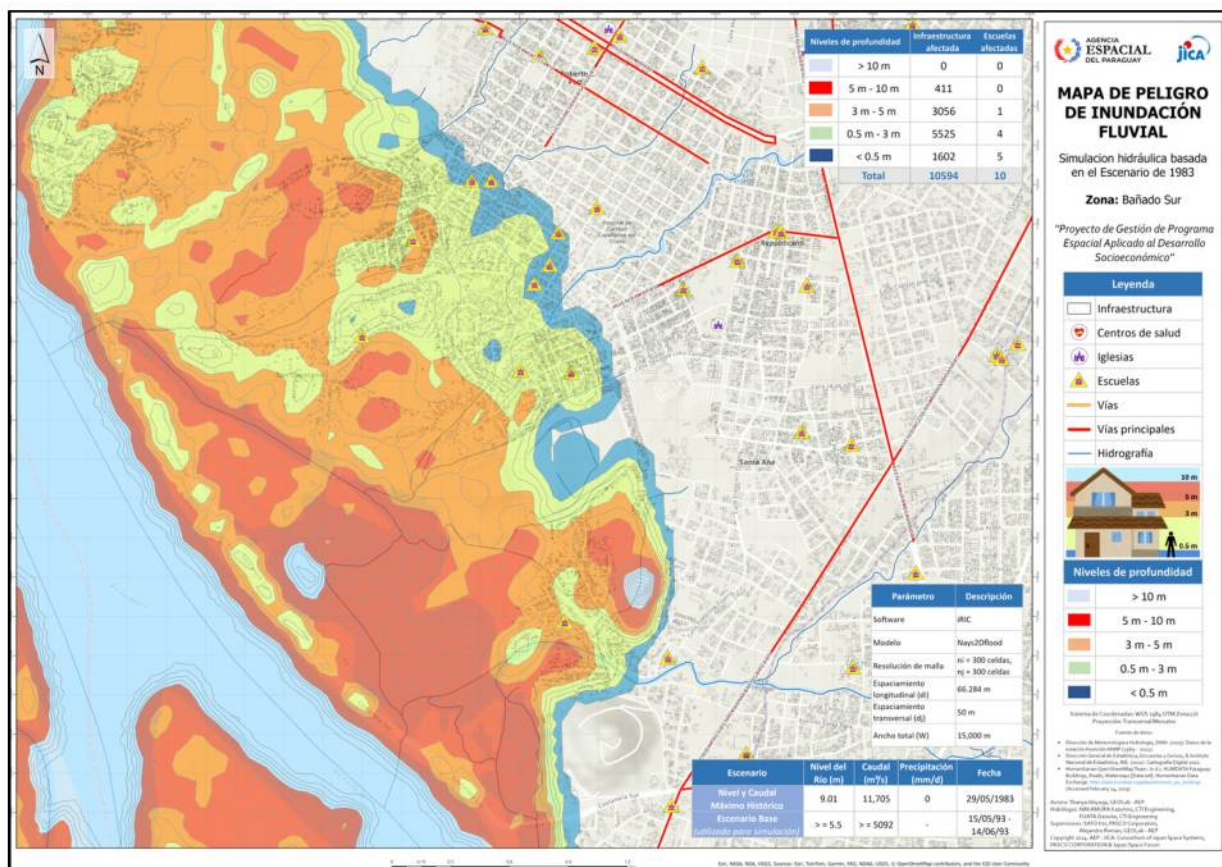
Al contrastar la simulación con los datos de Humanitarian OSM (2024) y Cartografía Digital 2022, se estimó que 701 infraestructuras quedarían bajo condiciones de inundación, incluidas 2 escuelas. Esta cifra debe interpretarse como un escenario hipotético de afectación actual y no como un registro histórico del evento de 1997.

Figura 16: Mapa de peligro de inundación fluvial – Bañado Sur.



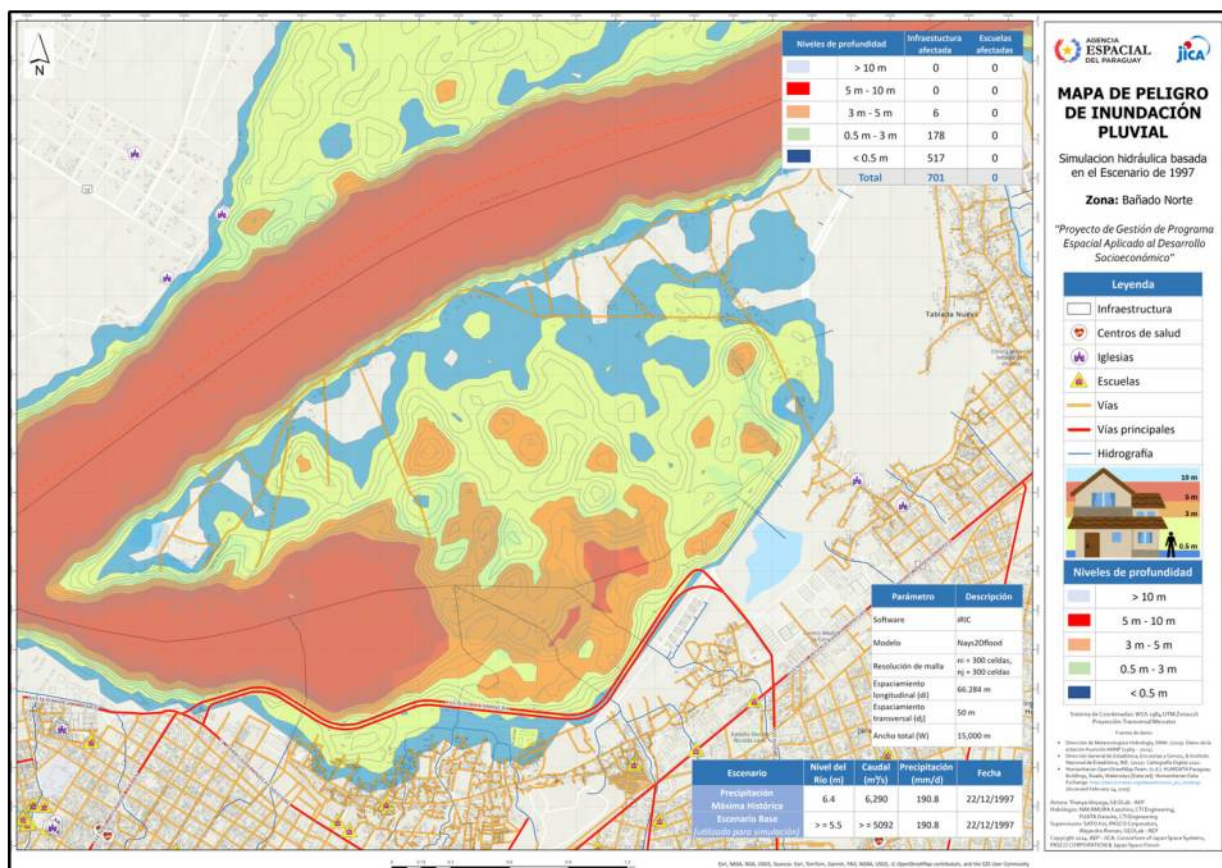
Fuente: elaboración propia (2025)

Figura 17: Mapa de peligro de inundación fluvial – Bañado Norte.



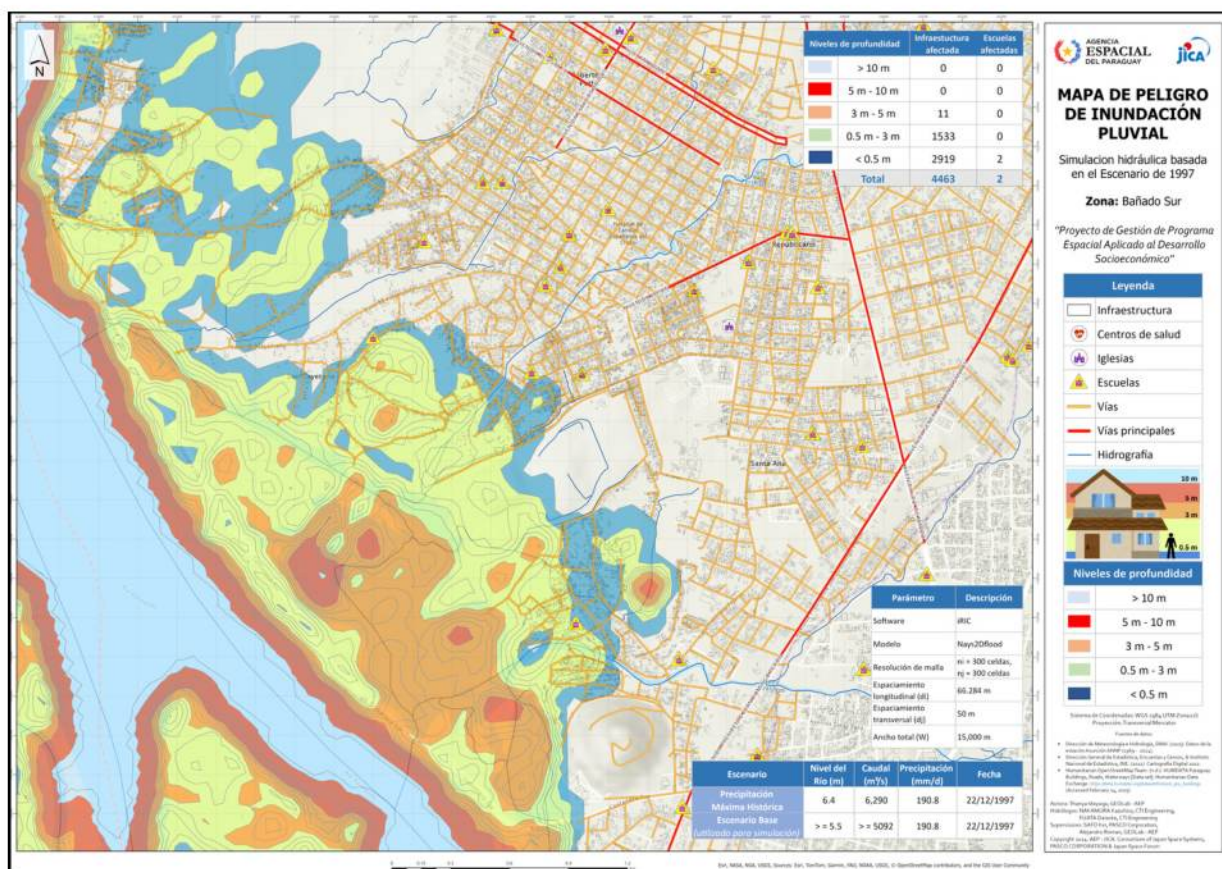
Fuente: elaboración propia (2025)

Figura 18: Mapa de peligro de inundación pluvial - Bañado Sur.



Fuente: elaboración propia (2025)

Figura 19: Mapa de peligro de inundación pluvial - Bañado Norte.



Fuente: elaboración propia (2025)

7. CONCLUSIÓN

El proyecto piloto de manejo de desastres demostró que la cooperación interinstitucional es la base para fortalecer la gestión del riesgo de inundaciones en Paraguay. A través de un esfuerzo colectivo se lograron productos concretos que hoy constituyen aportes valiosos para el país: los mapas de peligro de inundación en los Bañados Norte y Sur, la capacitación de la mesa de trabajo interinstitucional y la elaboración de un manual metodológico que asegura la replicabilidad de la experiencia en otras zonas del territorio nacional.

La capacitación impartida, acompañada por el apoyo técnico de expertos japoneses y la coordinación con JICA, no solo permitió transferir herramientas y metodologías, sino que también fomentó nuevas dinámicas de cooperación entre instituciones locales. Este proceso instaló capacidades y promovió una forma distinta de trabajar, en la que el conocimiento técnico y la experiencia internacional se combinaron con el saber local para dar respuestas más integrales.

El manual metodológico representa uno de los logros más relevantes, ya que trasciende el caso puntual de los Bañados y abre la posibilidad de aplicar la metodología en diferentes contextos del país. Este documento, junto con los productos cartográficos, constituye una referencia práctica para la planificación, la gestión territorial y la reducción del riesgo de desastres.

El proyecto también mostró el valor de utilizar datos alternativos provenientes de múltiples fuentes, como imágenes satelitales, registros hidrológicos, cartografía digital y datos abiertos. Esta integración permitió superar limitaciones de información y demostró que, incluso en contextos de restricciones, es posible generar resultados sólidos y de alto impacto para la gestión del riesgo.

No obstante, el piloto también señaló oportunidades de mejora que orientan el trabajo futuro. Es necesario avanzar hacia el uso de modelos digitales de elevación de mayor resolución, incorporar procesos de validación en campo y establecer mecanismos permanentes de actualización de datos hidrológicos y topográficos. Asimismo, fortalecer las plataformas de acceso público e interacción digital permitirá acercar esta información no solo a instituciones técnicas, sino también a comunidades y autoridades locales.

Gracias a este apoyo y al compromiso de las instituciones nacionales, el proyecto piloto no se limitó a un ejercicio académico, sino que sentó las bases de una práctica replicable y sostenible en el tiempo. En conjunto, el piloto mostró que la suma de cooperación internacional, trabajo interinstitucional y compromiso local puede transformar limitaciones en oportunidades y abrir el camino hacia una gestión más resiliente del riesgo de inundaciones en Paraguay.

8. ANEXOS

8.1. Procedimiento de desarrollo del modelo por iRIC Nays2D_Flood.

En esta sección se presenta un paso a paso de los procedimientos necesarios para la construcción y ejecución de un modelo de simulación de inundaciones, utilizando el software iRIC con el modelo Nays2D_Flood en conjunto con el software SIG ArcGIS Pro. Este procedimiento integra tanto la simulación hidráulica como el análisis espacial, garantizando la coherencia entre los insumos, el proceso de modelado y los productos finales.

- 1.Instalación del software iRIC y ArcGIS Pro en un equipo que cumpla con los requisitos mínimos de hardware y sistema operativo.
- 2.Procesamiento y análisis de datos espaciales en ArcGIS Pro, incluyendo la preparación de la cartografía base, la corrección y el recorte del Modelo Digital de Elevación (DEM), y la generación de capas temáticas necesarias para el modelo hidráulico.
- 3.Definición de la grilla de estudio en iRIC e importación de los datos topográficos.
- 4.Configuración de la grilla en Nays2D_Flood, incorporando el caudal de entrada y salida, junto con parámetros hidráulicos y del terreno.
- 5.Ejecución de la simulación en iRIC, generando los resultados hidráulicos que representan la distribución espacial de la inundación en el área de estudio.
- 6.Procesamiento de resultados en ArcGIS Pro, donde los datos obtenidos en iRIC se transforman en mapas de profundidad de la inundación, permitiendo su análisis espacial y la representación cartográfica de las zonas afectadas.
- 7.Validación del modelo, comparando los mapas generados con registros de campo o estudios previos, con el fin de evaluar la precisión y la fiabilidad de las simulaciones.

Es importante señalar que todas las figuras incluidas en esta sección fueron generadas en el flujo de trabajo combinado entre iRIC y ArcGIS Pro, lo que asegura la coherencia entre los procedimientos descritos y los resultados gráficos presentados.

8.1.1. Instalación del Software iRIC y Nays2D_Flood

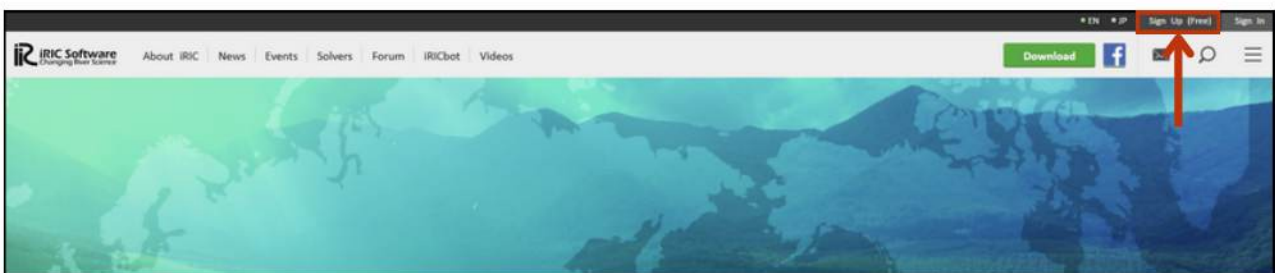
8.1.1.1. Requerimientos del sistema:

Para garantizar un rendimiento óptimo al utilizar el software iRIC, se recomiendan los siguientes requisitos del sistema:

- Sistema Operativo: Windows 10 o superior.
- Procesador: CPU de 64 bits con al menos 4 núcleos.
- Memoria RAM: 8 GB o más.
- Espacio en Disco Duro: Al menos 2 GB de espacio libre para la instalación, además de espacio adicional para almacenar proyectos y datos de simulación.
- Tarjeta Gráfica: Compatible con OpenGL 2.0 o superior.
- Resolución de Pantalla: Mínimo de 1280x1024 píxeles.
- Conexión a Internet: Requerida para la descarga del software y actualizaciones.

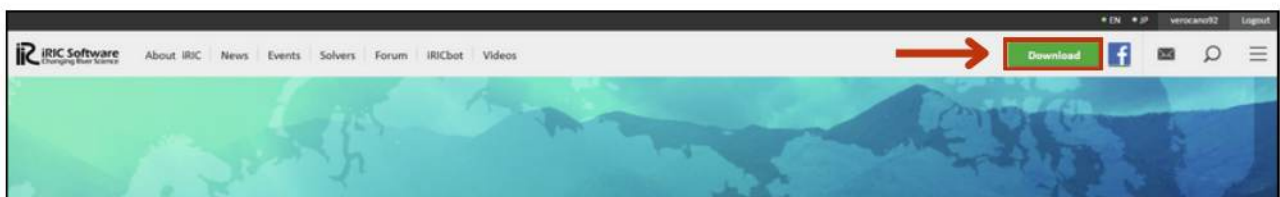
8.1.1.2. Descarga del programa:

- Para acceder a la página web de iRIC, visita el siguiente enlace:
<https://i-ric.org/en/about/>.
- En la esquina superior derecha, se hace clic en "Sign Up" para crear una nueva cuenta de usuario.



- Se completa el formulario con los datos, se aceptan los términos y condiciones, y una vez registrado, se procede con el siguiente paso.

- Una vez registrado, se inicia sesión con la cuenta creada para acceder a las opciones de descarga.



- Para descargar el software, se selecciona la última versión disponible de iRIC en la página oficial.



- Antes de continuar con la descarga, se debe leer y aceptar los términos de uso de iRIC. Una vez aceptados, se podrá proceder a seleccionar la última versión disponible para la descarga.

iRIC Terms of Use

By using materials and software provided by the International River Interface Cooperative (IRIC), including software and other material downloadable from this site (hereinafter referred to as IRIC contents), the user recognizes and agrees to the following points.

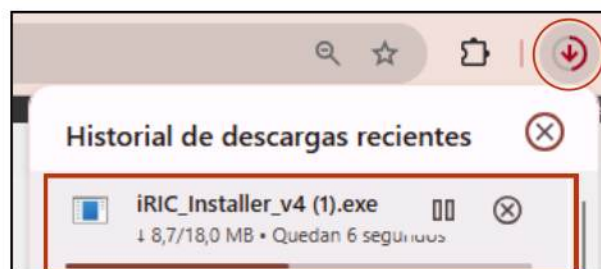
1. IRIC contents can be used free of charge for both commercial and non commercial purposes, but neither IRIC nor any other entity or person guarantees the accuracy or validity of the IRIC contents.
2. Therefore, any user of IRIC contents assumes all responsibility. Even if the user or other entity suffers damage resulting from IRIC contents, IRIC does not bear any burden or responsibility for that damage.
3. When using IRIC contents, the user must indicate such use using the IRIC logo. Please use either the logo mark displayed on the lower right of IRIC software windows or any of the following logos on any material displaying IRIC results.



4. IRIC develops software and provides information to contribute to the creation of a better society. Any use of the IRIC contents contrary to that purpose is forbidden.
5. Please contact us from the forum or inquiries on this site if you have information on software defects or potential functional improvements or if you find any mistake or problem in the IRIC contents.
6. We may use the information provided by users to improve the IRIC contents or otherwise improve our activities. However, any changes may not correspond to the information provided.
7. Personal information such as email addresses registered on this website will be used for the development and improvement of IRIC and for the administration and improvement of the website. We will not use this information for other purposes or provide it to any third party.
8. In the event that other matters arise not covered by this simple agreement or any doubts arise as to the meaning of any part of this agreement, IRIC will resolve the issue through consultation with the user.

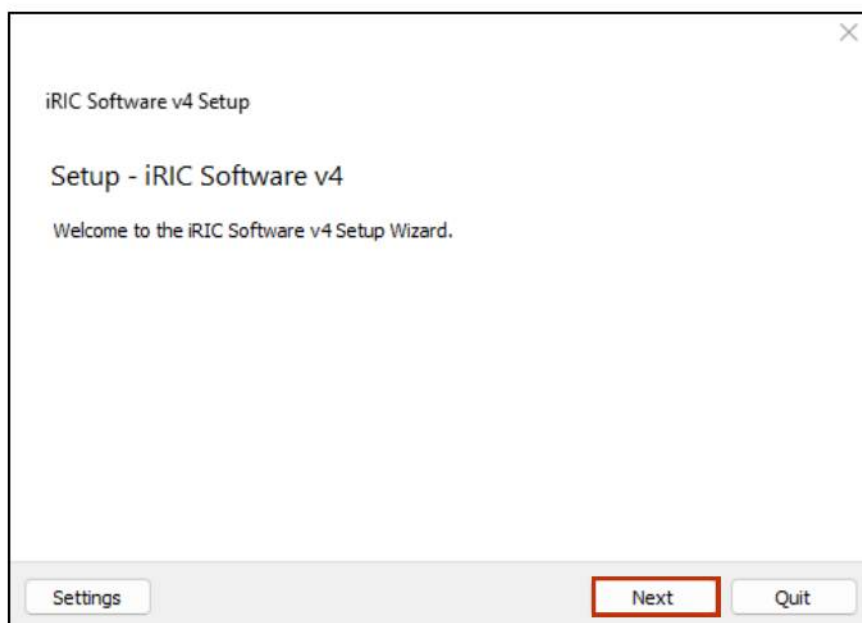
I agree and download

- Se espera unos momentos mientras se completa la descarga. Una vez finalizada, se accede a la sección de descargas en el Explorador de Archivos.

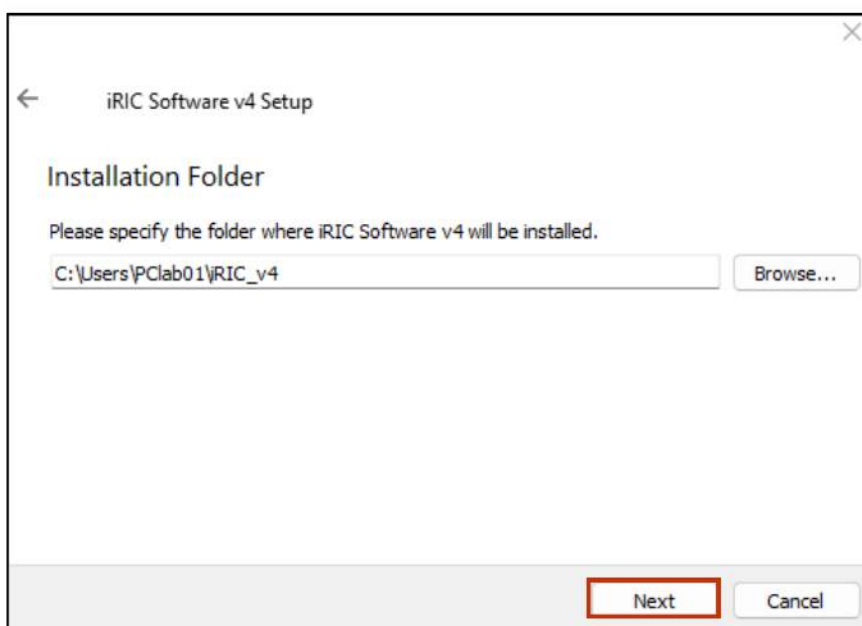


8.1.1.3. Instalación del software iRIC

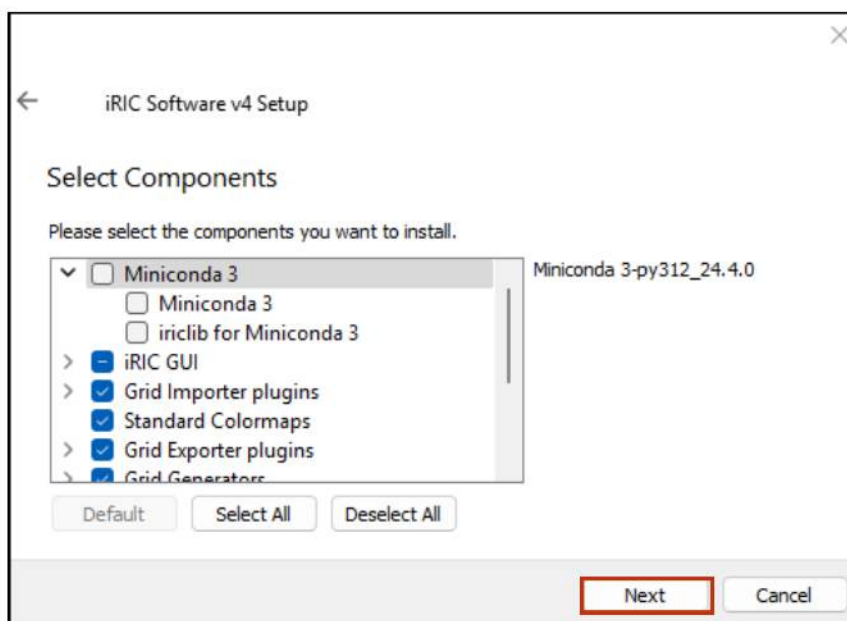
- Una vez ejecutado el archivo iRIC_Installer_v4, seleccionar "Next" para continuar con la instalación.



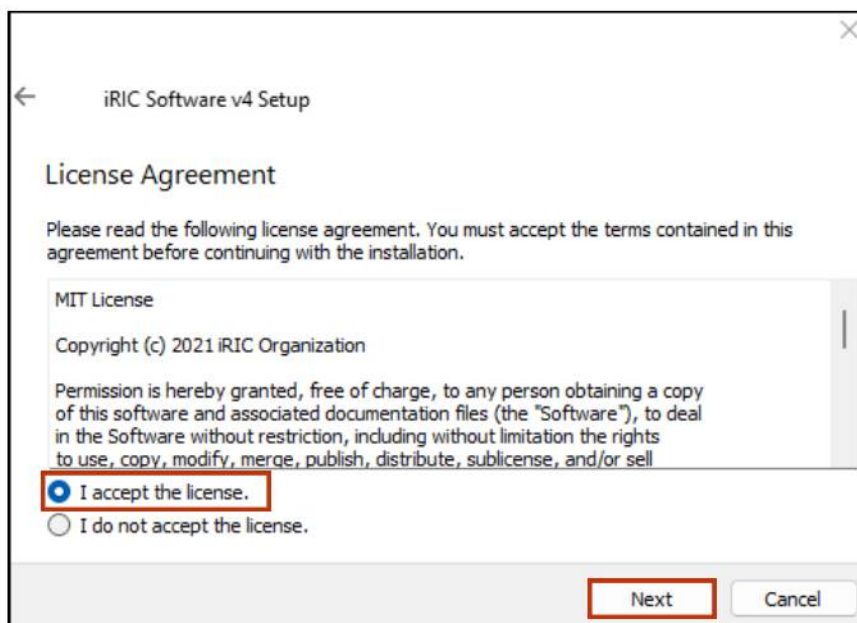
- Seleccionar la carpeta destino donde desee instalar el software. Si no se requiere cambios de la ubicación predeterminada, continuar haciendo clic en "Next".



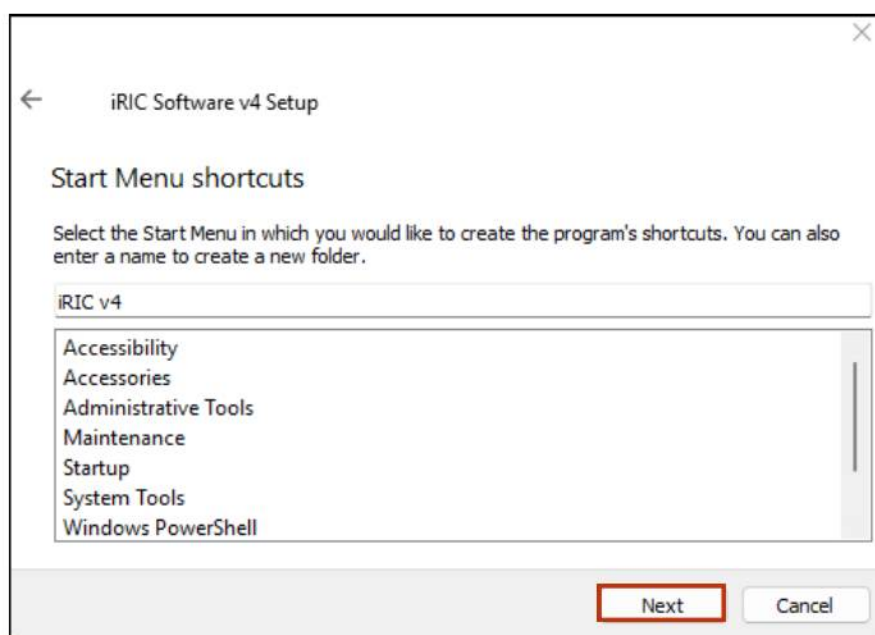
- Sin realizar ninguna modificación, clic en "Next" para continuar con el proceso de instalación.



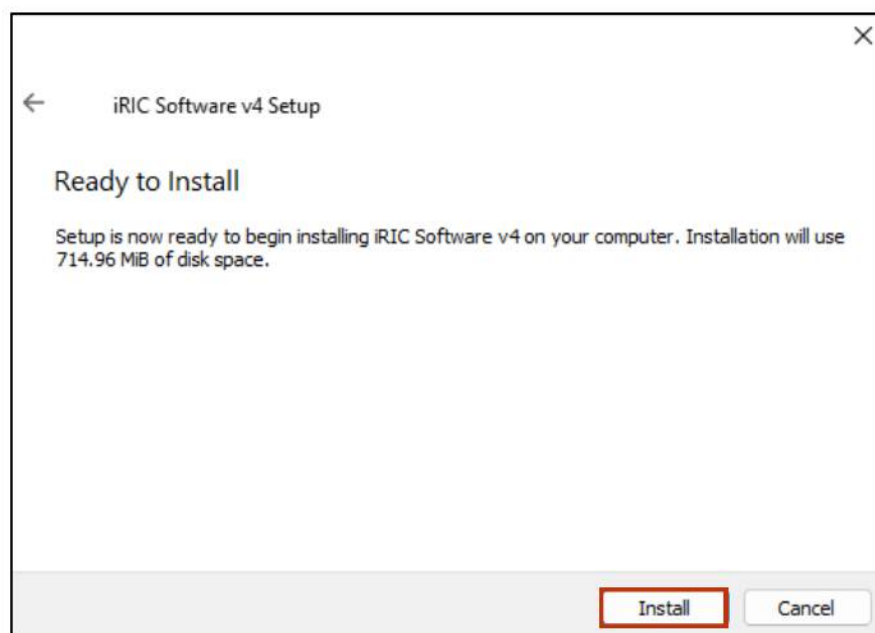
- Aceptar los términos de la licencia seleccionando la opción correspondiente y luego clic en "Next" para continuar.



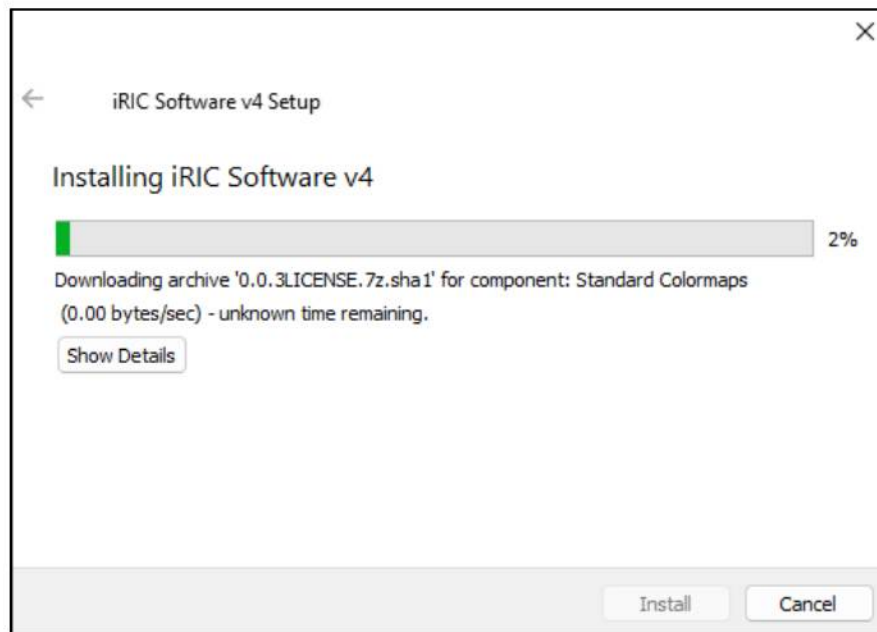
- Clic en “Next” para continuar con la instalación.



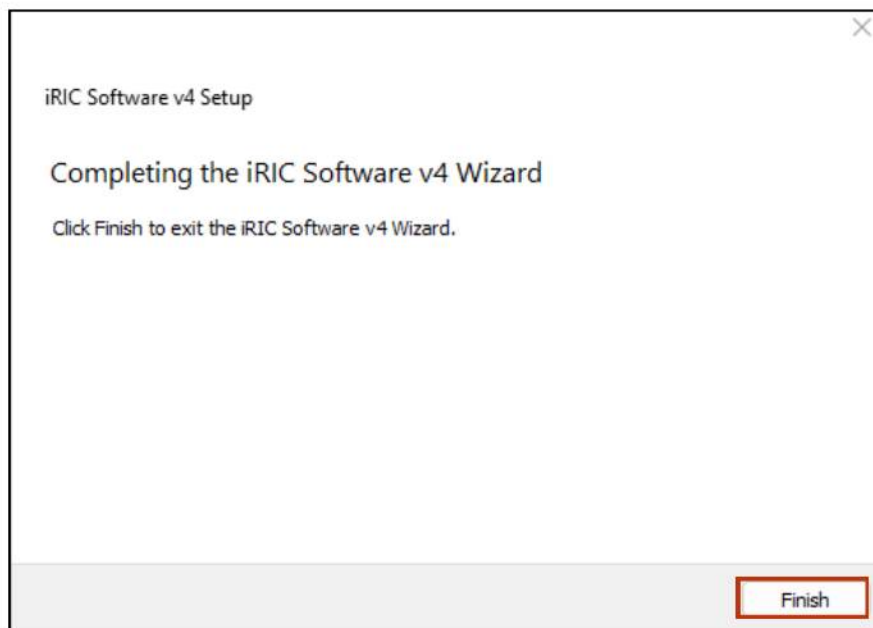
- Clic en “Install” para iniciar la instalación.



- Aguardamos que se complete la instalación.



- Clic en “Finish” para terminar el proceso.



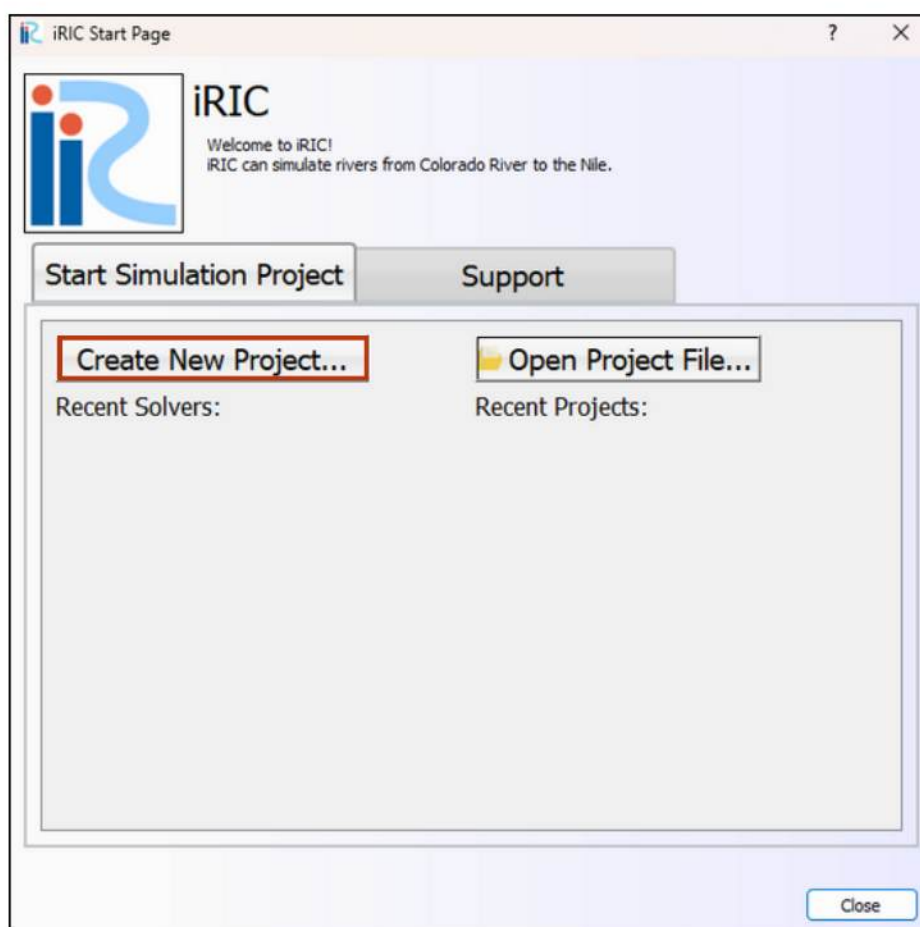
8.1.2. Creación del Proyecto en iRIC

8.1.2.1. Crear proyecto

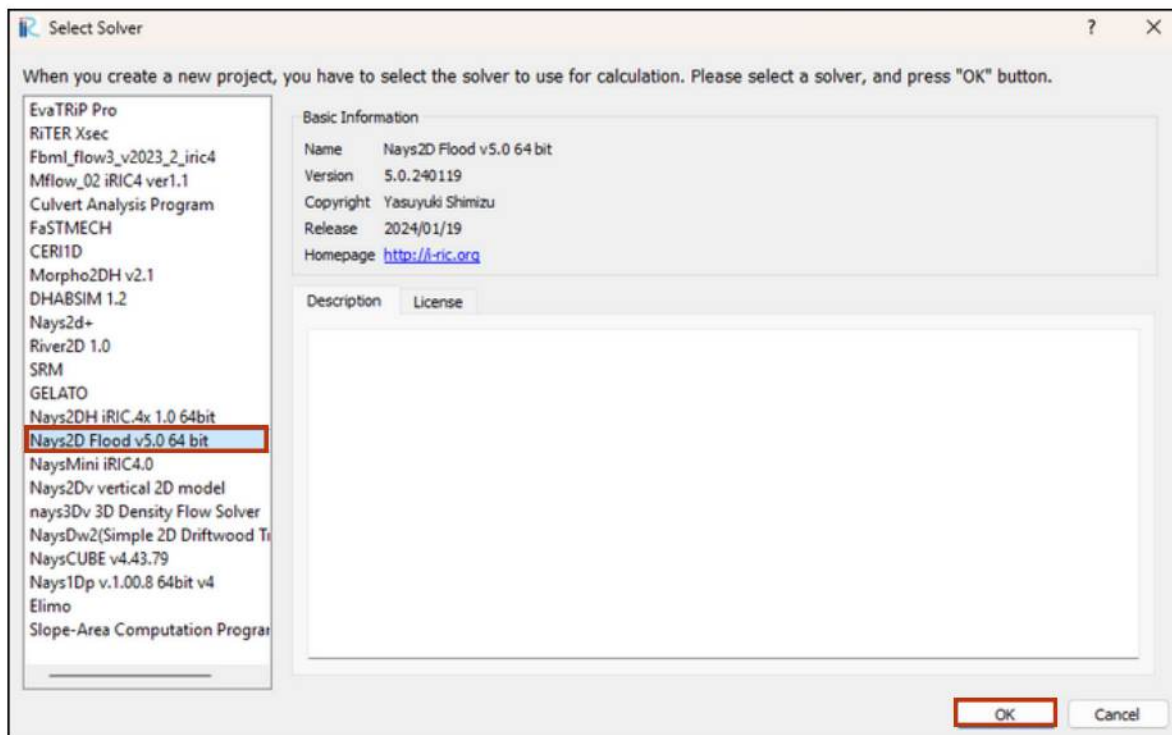
- Iniciar con iRIC.



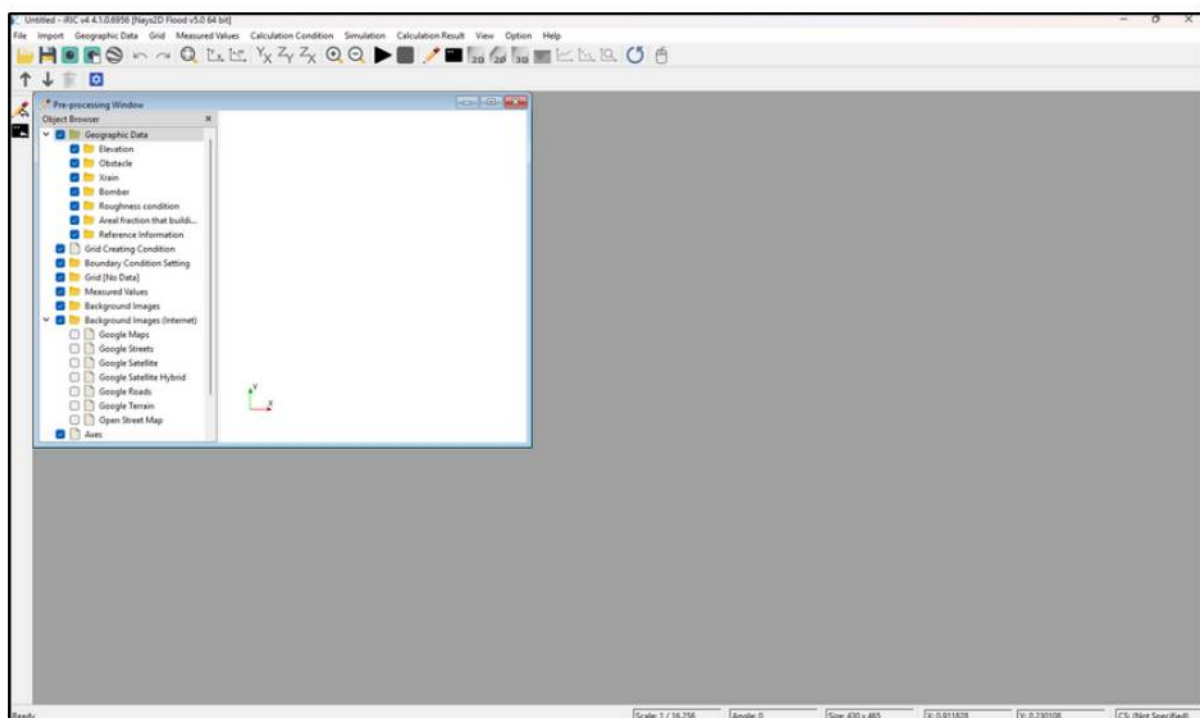
- Crear un nuevo proyecto: Al abrir el programa iRIC, aparecerá una ventana emergente que ofrece dos opciones: crear un nuevo proyecto seleccionando "Create New Project" o abrir un proyecto previamente trabajado eligiendo "Open Project File".



- Se abrirá una ventana emergente llamada "Select Solver", la cual permite seleccionar el método o algoritmo adecuado para resolver problemas específicos en el software, ya sea de análisis numérico, optimización o simulación.
- En el mismo seleccionamos la opción "Nays2D Flood v5.0 64 bit", ya que es una herramienta especializada para la simulación bidimensional (2D) de inundaciones. Este emplea principalmente para modelar la propagación del agua en áreas urbanas y rurales, teniendo en cuenta variables clave como la topografía, las precipitaciones, los caudales y las características del terreno.
- Su función principal es predecir cómo se comportan las aguas durante un evento de inundación, lo cual es crucial para la planificación urbana y la mitigación de desastres.



- La nueva área de trabajo en iRIC se muestra con una interfaz organizada en varias secciones clave:
 - Barra de herramientas superior: Contiene opciones de importación, configuración de datos geográficos, generación de mallas y simulaciones.
 - Ventana de preprocesamiento (Pre-processing Window): Permite administrar los datos geográficos, las condiciones de grilla, la malla y las imágenes de fondo.
 - Área principal de trabajo: Espacio donde se visualizarán las simulaciones y análisis.
 - Panel de estado inferior: Muestra información de escala, ángulo y coordenadas.
- A partir de este entorno, se pueden cargar y configurar los datos necesarios para la simulación de inundaciones.



- Herramientas principales del menú a ser utilizadas:



- 1- Guardar.
- 2- Ejecutar Simulación.
- 3- Ventana de Preprocesador Focus.
- 4- Abrir nueva ventana de Post-Procesamiento 2D.
- 5- Play para visualizar simulación.
- 6- Temporizador de simulación.

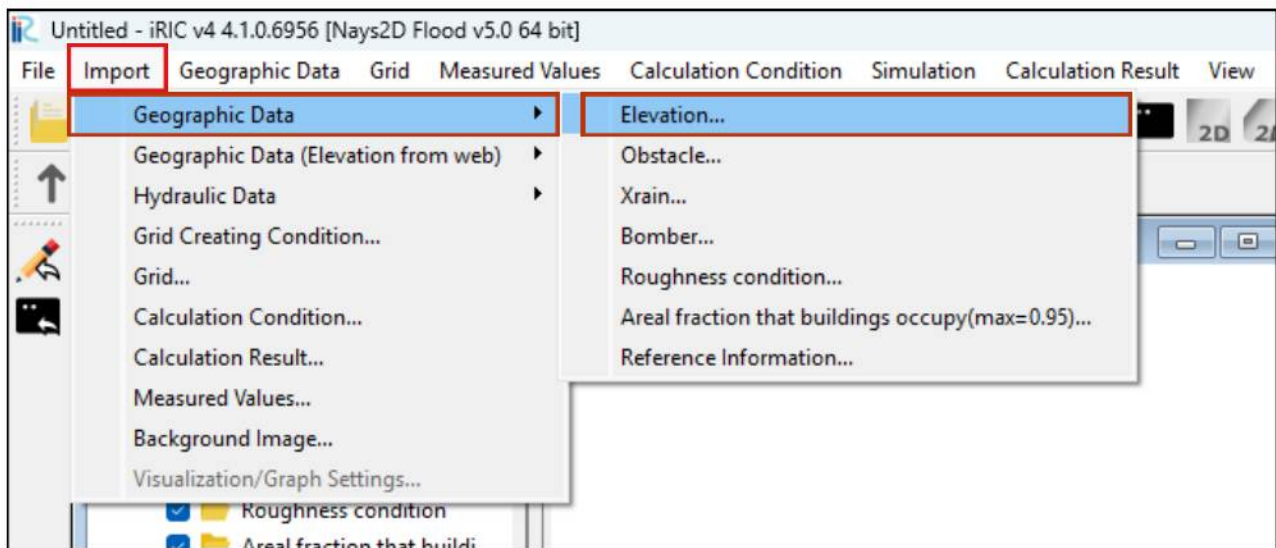
8.1.3. Importación de los datos topográficos

8.1.3.1. Descarga de datos para simulación de inundación:

- Para la obtención de los datos que se utilizarán, es descargado del siguiente enlace: <https://drive.google.com/drive/folders/15wO8vHjFoM-VzUOI8FNyp1ETP5o6tvt?usp=sharing>.
- Se descargan todos los archivos de la carpeta, y se importan los datos del **“DEM_PY_Training01”**, al que se le debe especificar el sistema de coordenadas de **“EPSG:32721: WGS 84 zone 21S”**. Dependiendo de la capacidad de la computadora y del tamaño del DEM, puede tardar algunos momentos en importar los datos.

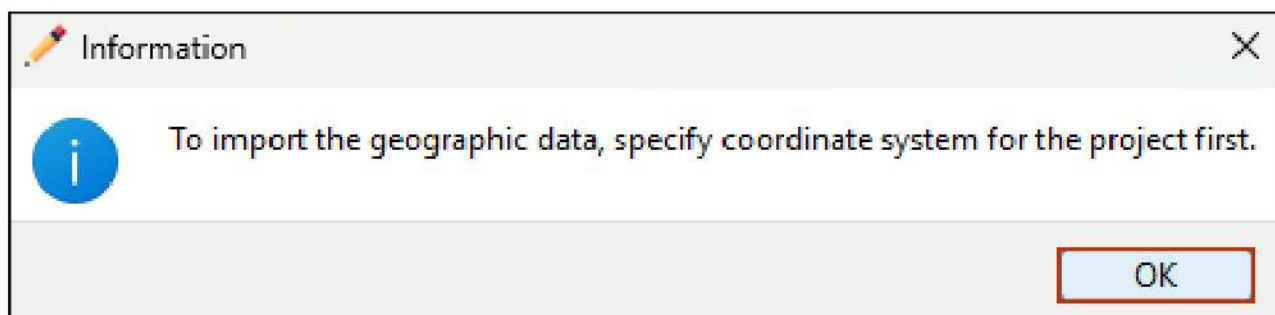
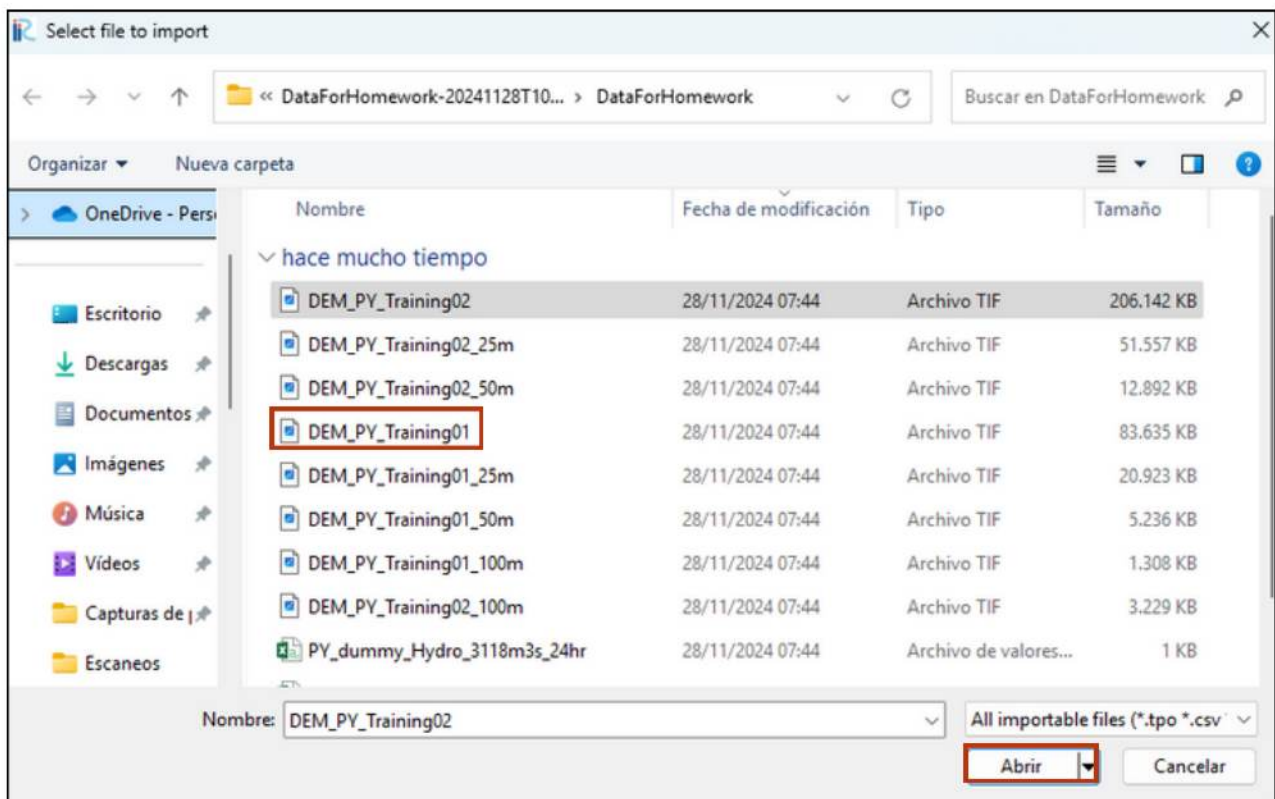
8.1.3.2. Importar datos:

- Desde el panel de control, se selecciona el elemento “Import”, entre las opciones se elige **“Geographic data”** y luego **“Elevation”**.

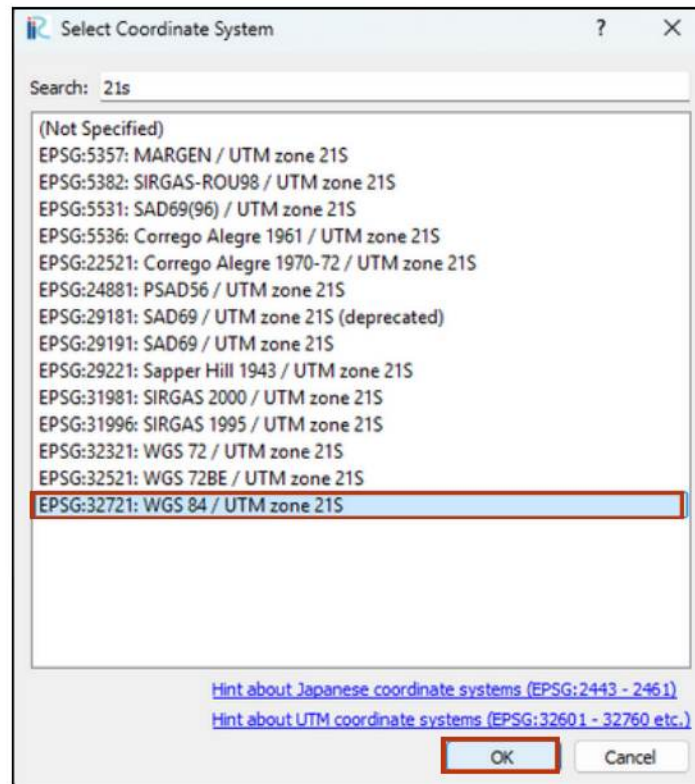


Este proceso permite cargar el Modelo Digital de Elevación (DEM), que servirá como referencia para representar con precisión la topografía del terreno. Esto es fundamental para definir las condiciones iniciales y de contorno en las simulaciones, asegurando resultados más realistas y precisos.

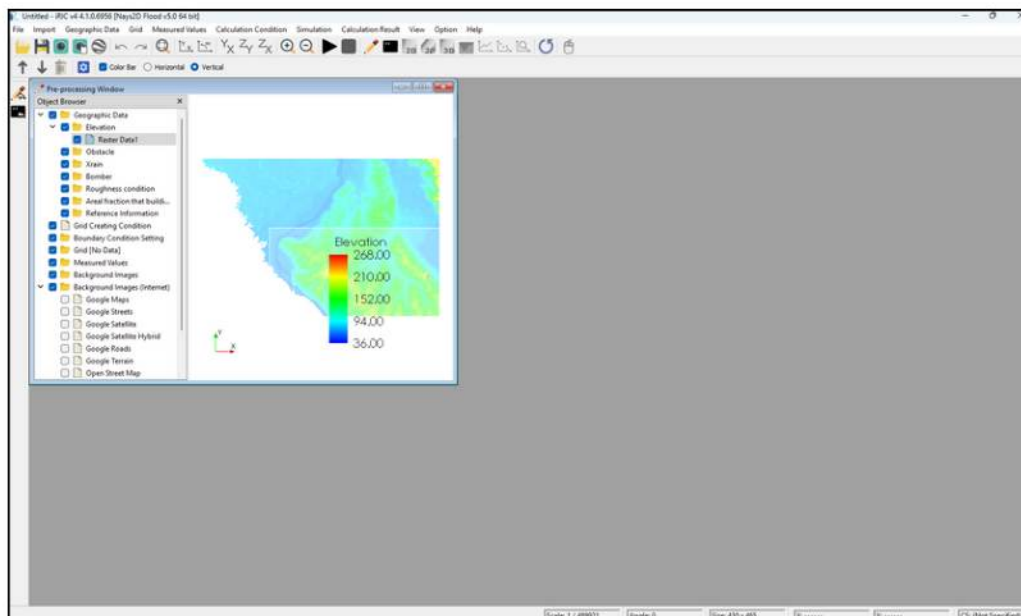
- Se selecciona el archivo DEM_PY_Training01.tif, una vez abierto se pulsa OK a la ventana emergente que aparecerá.



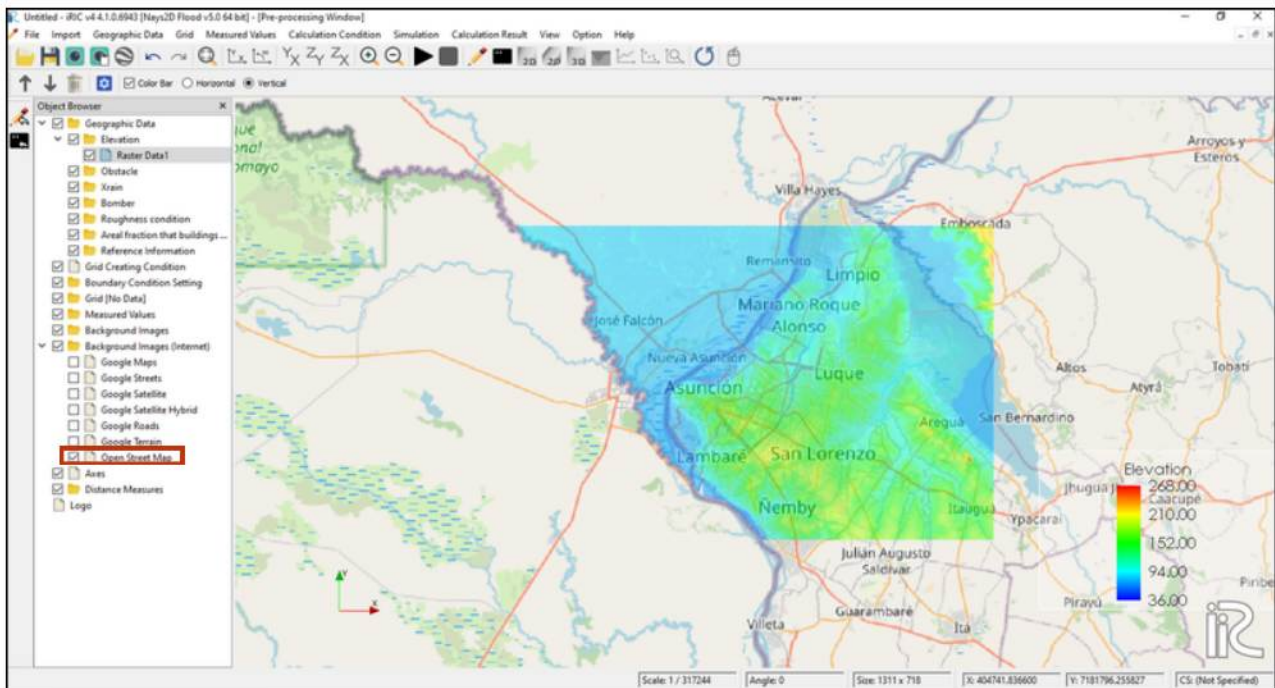
- Se especifica el sistema de coordenadas a “EPSG:32721: WGS 84 zone 21S”.



- Dependiendo de la capacidad de la computadora y del tamaño del DEM, puede tardar algunos momentos en importar los datos. El mismo se visualizará de la siguiente manera:



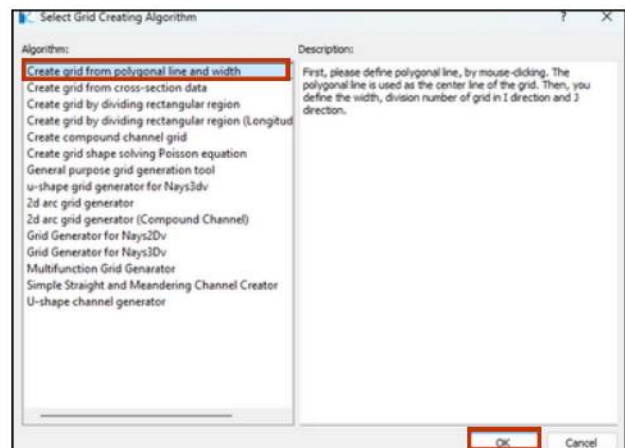
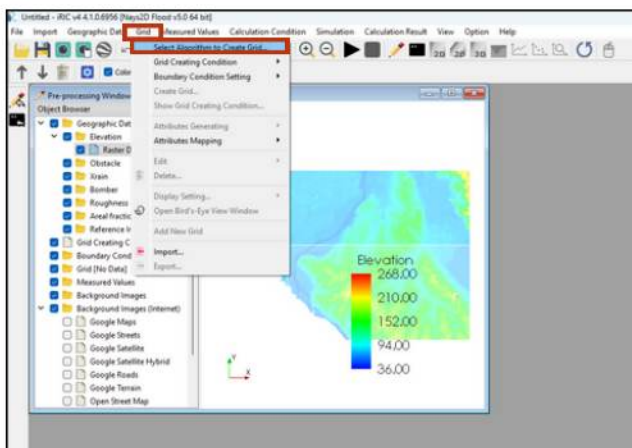
- Primero, se activa el mapa base de **"OpenStreetMap"** o en su defecto **"Google Maps"**, ya que servirá como referencia para definir con precisión los puntos de "Upstream" y "Downstream" en la simulación.



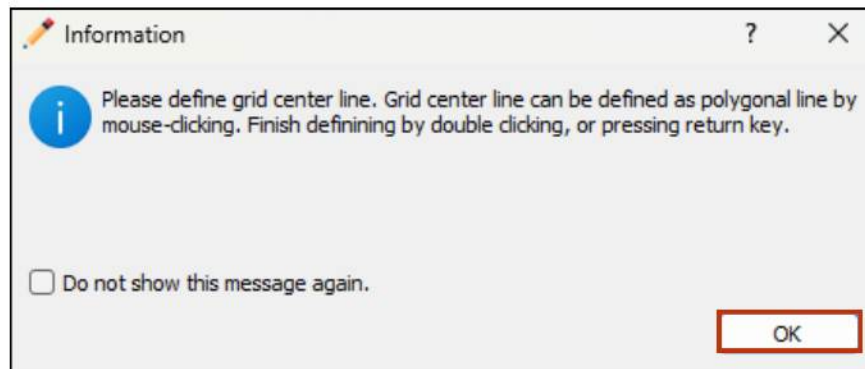
8.1.4. Creación de cuadrícula de cálculo

8.1.4.1. Creación de Grilla

- Desde el panel de control, se selecciona el elemento **"Grid"**, que hace referencia a las cuadrículas de cálculo. Se elige **"Select algorithm to Create Grid"** para seleccionar el algoritmo adecuado para crear una malla o cuadrícula.
- Se abrirá una ventana emergente para seleccionar el tipo de algoritmo para la creación de las cuadrículas, el cual se elegirá **"Create grid from polygonal line and width"** que permitirá establecer el **"Upstream/Downstream"** para la simulación.



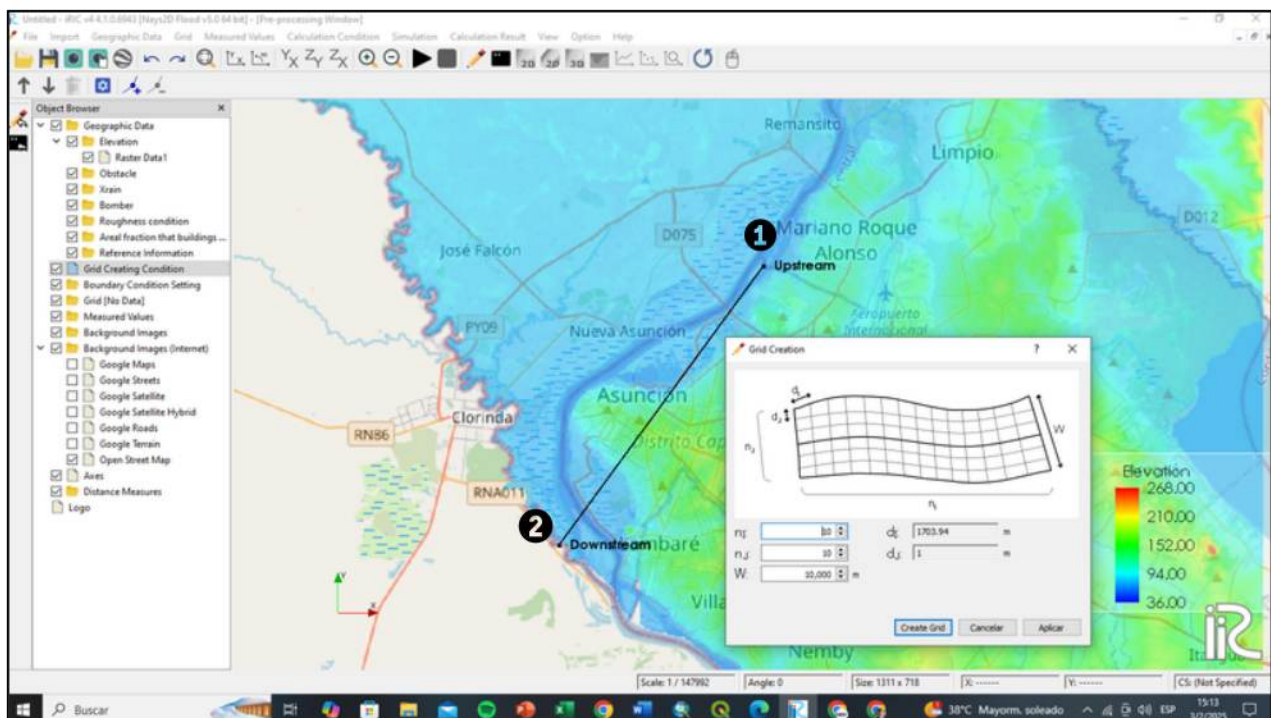
- Aparecerá una ventana emergente con instrucciones sobre cómo definir la línea central de la malla como una línea poligonal, utilizando clics del mouse. Para finalizar la definición, se debe hacer doble clic o presionar la tecla Enter. Se hace clic en **"OK"** para continuar.



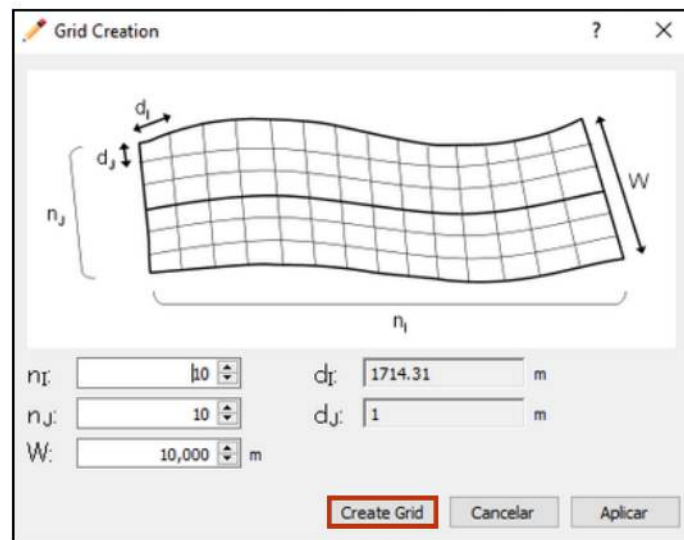
- Es importante mencionar que el área de trabajo puede ampliarse maximizando la ventana de Pre-procesamiento, lo que facilita una mejor visualización y manipulación de los datos.



- Para definir el punto de inicio, se indica con un solo clic en la ubicación correspondiente al (1) "Upstream". Luego, para establecer el (2) "Downstream", realiza un doble clic en el punto final. Si se desea alejar o acercar el maps se debe presionar Control mientras se mueve la rueda del mouse. Esta selección se realiza para señalar el inicio y final del flujo de agua que se desea simular con el software.



- Una vez establecido los puntos, se desplegará la ventana emergente de “Grid Creation” para establecer los valores de ancho y largo de las cuadrículas, donde:
 - n_l (Número de Celdas Longitudinales): introduce el número deseado de celdas en la dirección longitudinal. Un mayor número de celdas aumentará la precisión pero también el tiempo de cálculo.
 - n_j (Número de Celdas Transversales): introduce el número deseado de celdas en la dirección transversal.
 - d_l (Distancia Longitudinal de la Celda): especifica la longitud de cada celda en la dirección longitudinal.
 - d_j (Distancia Transversal de la Celda): especifica el ancho de cada celda en la dirección transversal.
 - W : es el ancho de las celdas en la dirección transversal (eje J).

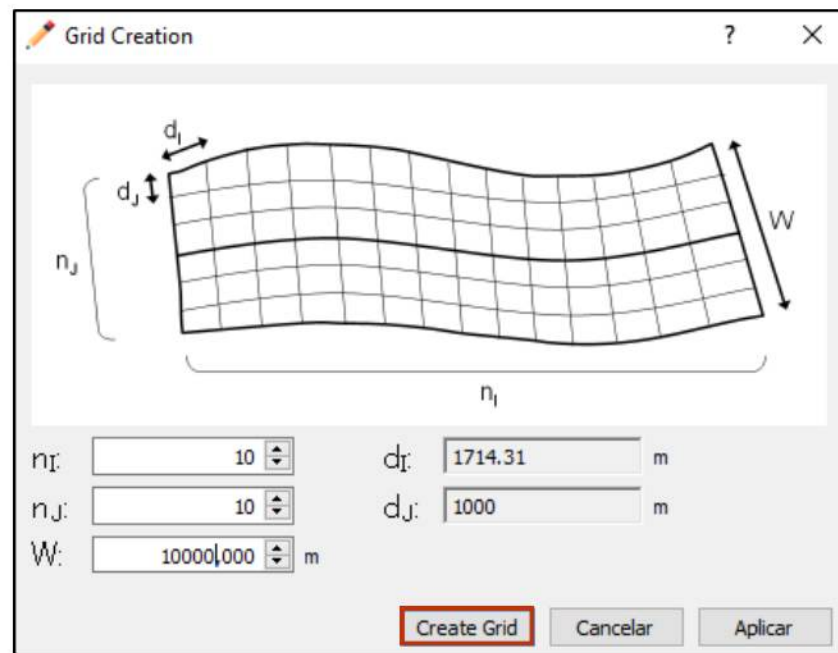


- Para la práctica, se analizan las distintas resoluciones de creación de la malla, las cuales pueden ajustarse según las necesidades del operador. En cada caso, se observa que, a medida que se incrementa la resolución de la cuadrícula, también aumenta la cantidad de celdas dentro del área definida.

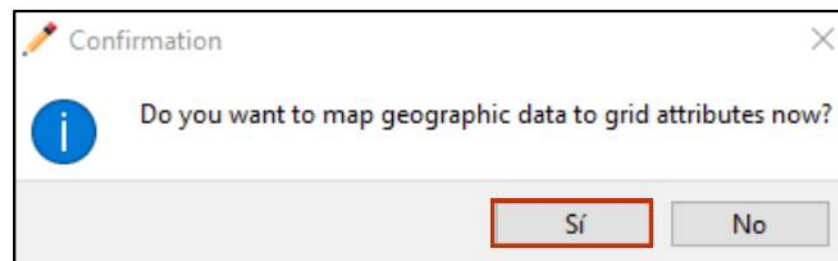
8.1.4.2. Configuración de datos para simulaciones de inundaciones por cuenca y precipitación

- En esta sección, se presentarán tres ejemplos de resolución de grilla para simulaciones de inundaciones considerando diferentes configuraciones. Cada caso mostrará cómo varía la precisión del modelo según la densidad de la grilla establecida por el operador. A medida que se incrementa la resolución, el número de celdas dentro del área de estudio aumenta, permitiendo una mayor precisión en la representación del flujo de agua y la topografía del terreno.

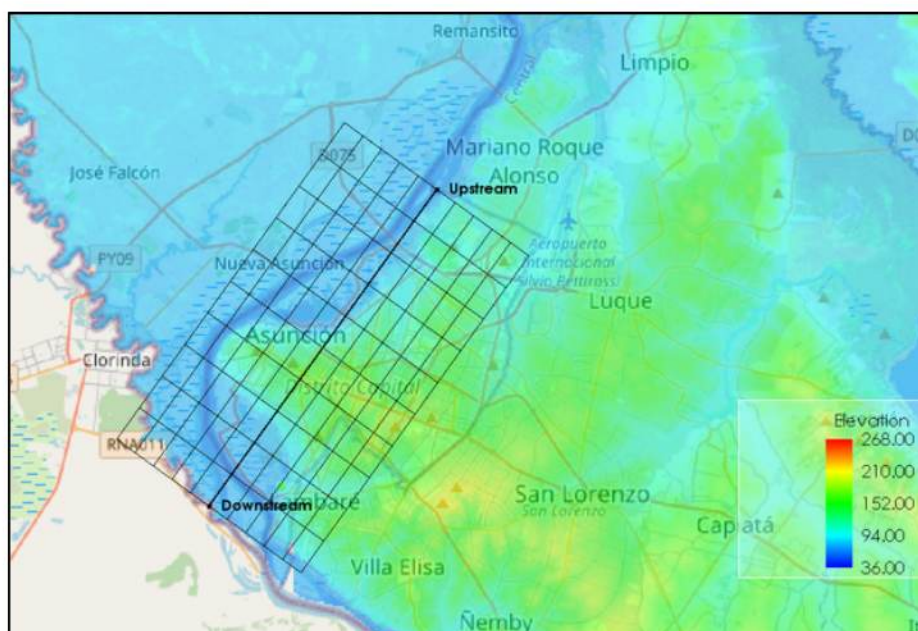
- Caso 1
 - Configuración de la grilla y valor de ancho y largo de las cuadrículas.



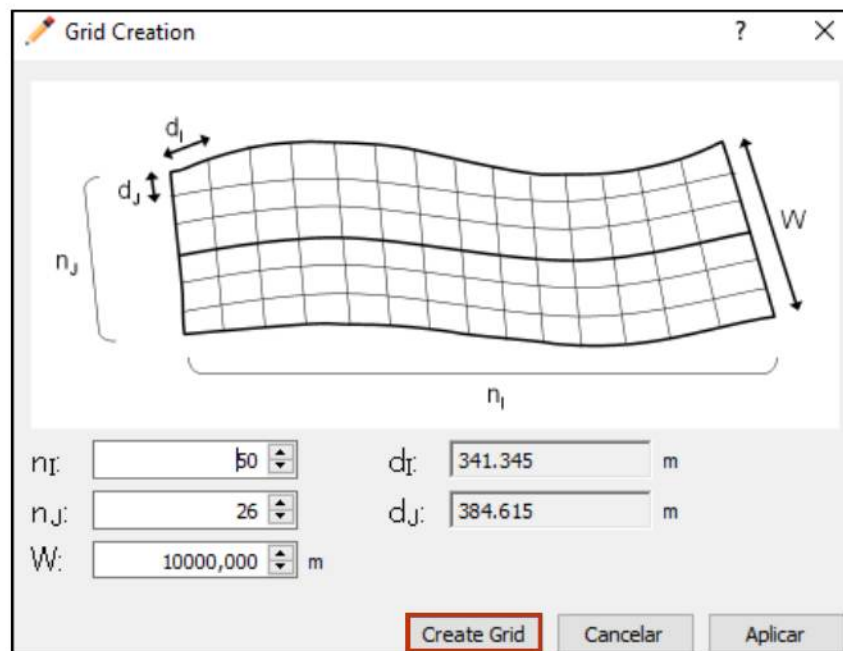
- "Sí" para la asignación de atributos.



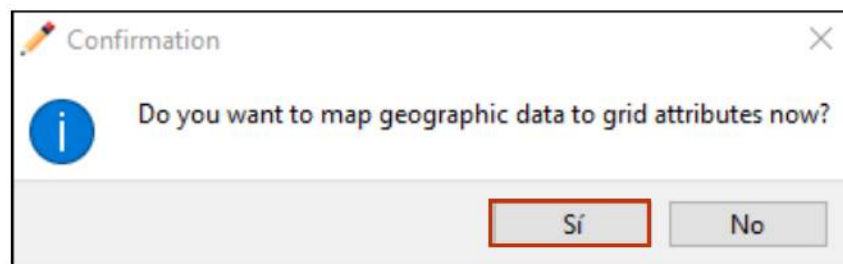
- Se observan la resolución de la grilla que varía según la configuración del operador.



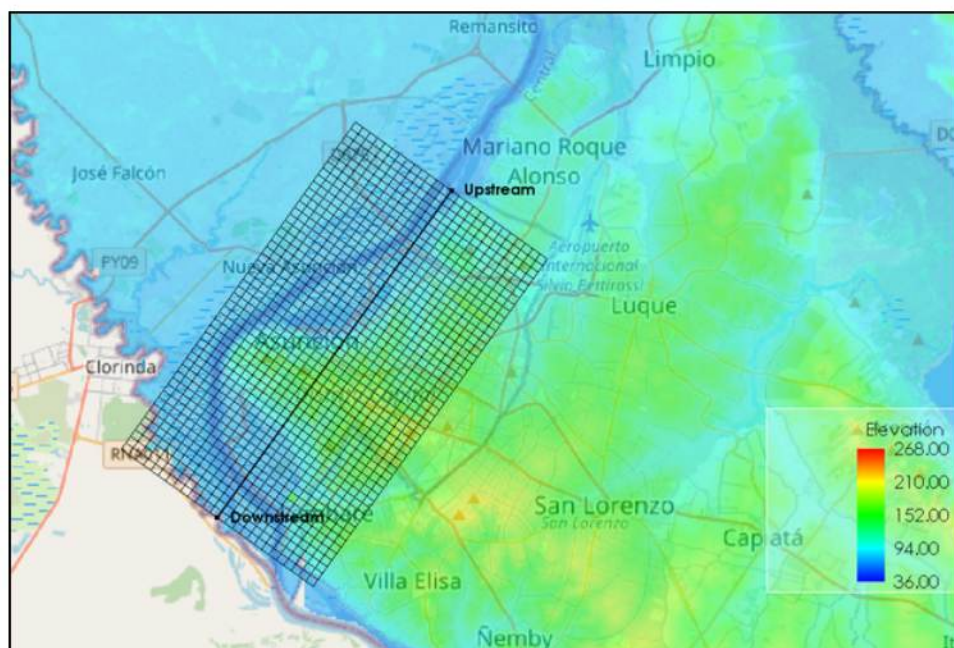
- Caso 2
 - Configuración de la grilla y los valor de ancho y largo de las cuadrículas.



- “Si” para la asignación de atributos.

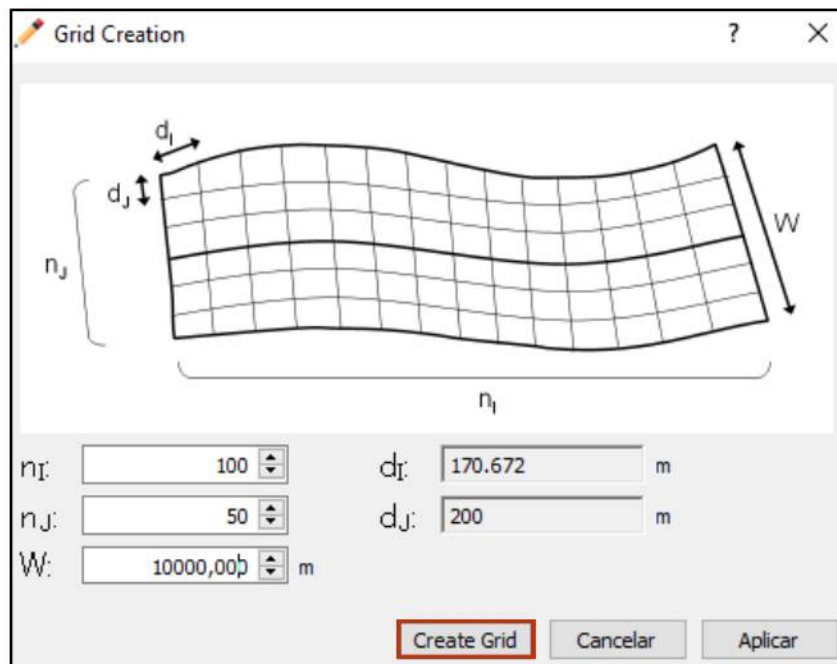


- Se observan la resolución de la grilla que varía según la configuración del operador.

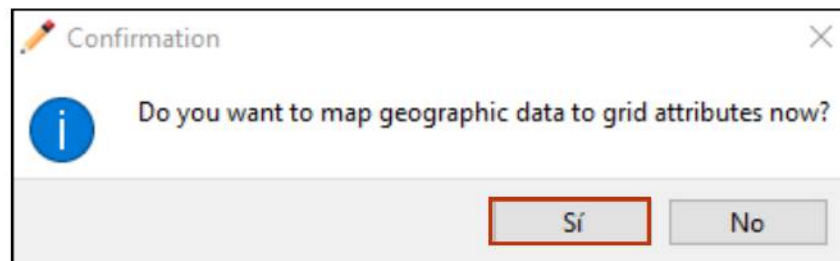


- Caso 3

- Configuración de la grilla y los valor de ancho y largo de las cuadrículas.



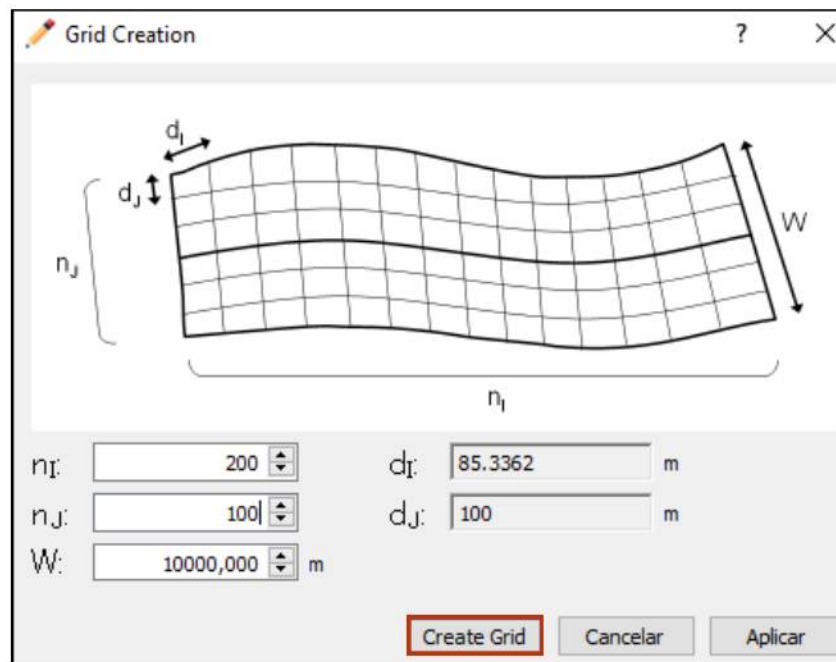
- “Sí” para la asignación de atributos.



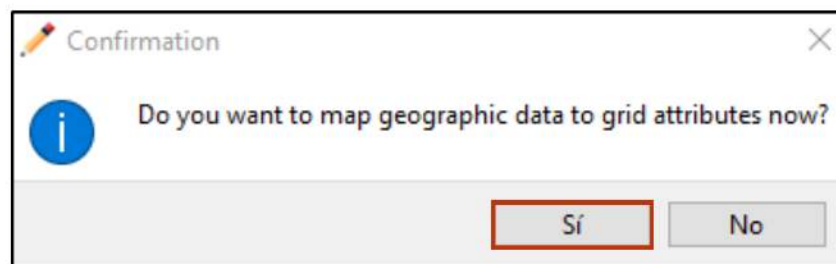
- Se observan la resolución de la grilla que varía según la configuración del operador.



- Caso 4
 - Configuración de la grilla y establecemos los valor de ancho y largo de las cuadrículas.



- “Sí” para la asignación de atributos.



- Se observan la resolución de la grilla que varía según la configuración del operador.



8.1.5. El Hidrograma

Representa la variación temporal del caudal o nivel del agua, se obtiene a partir de mediciones de campo o mediante modelos hidrológicos de escorrentía. En el caso del Río Paraguay, su extensa cuenca fluvial hace que el cálculo de la escorrentía en puntos específicos sea un desafío, debido a la complejidad de los procesos hidrológicos que intervienen en su dinámica.

En este entrenamiento, se emplea un hidrograma modelo elaborado por el equipo de CTI Engineering International, con el objetivo de facilitar el aprendizaje.

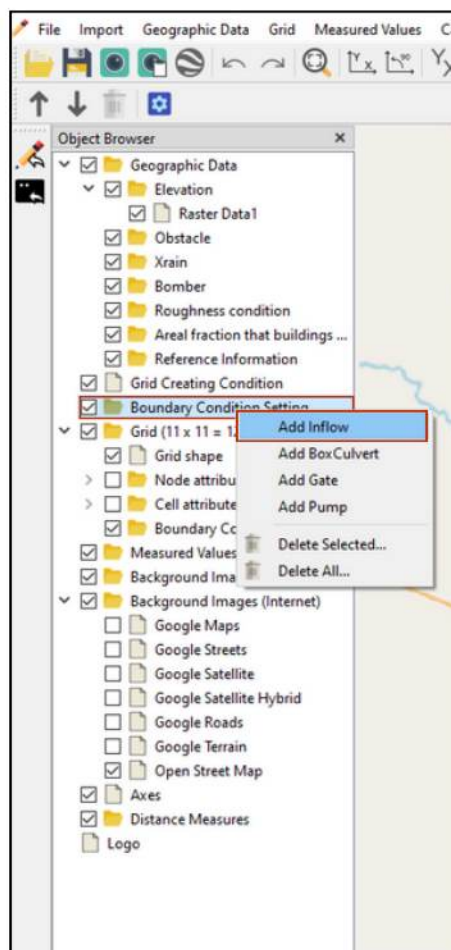
8.1.5.1. Obtención de los datos

- Para la obtención de los datos que se utilizarán se obtienen en el siguiente link: <https://drive.google.com/drive/folders/15wO8vHjFoM-VzUOI8FNyp1ETP5o6tv?usp=sharing>
- El archivo debe estar en formato CSV.

8.1.5.2. Iniciar configuración del Caudal

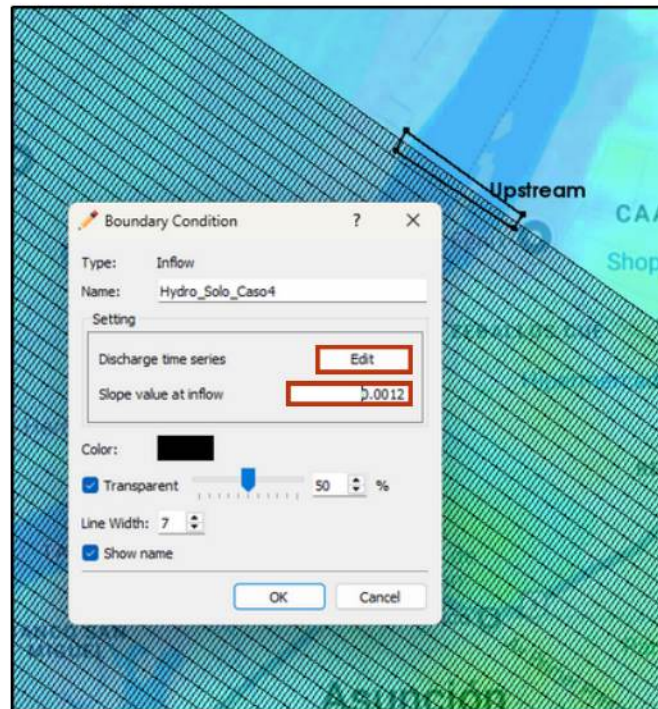
Para la simulación se utilizará la grilla del Caso 4.

- Para incorporar los datos de entrada en el modelo, diríjase al panel de contenido del área de trabajo. Luego, se selecciona la opción **“Boundary Condition Setting”** con el clic derecho o secundario y selecciona **“Add Inflow”** para añadir el caudal de entrada a la simulación.



- Una vez creado **"New Inflow"**, este aparecerá en la tabla de contenidos. Para definirlo, nos dirigimos al área de trabajo y selecciona, mediante clics, los vértices que delimitarán el área de ingreso del flujo del río. Para finalizar el trazado, se realiza un doble clic.

Es importante que la mitad del trazado quede dentro de los cuadros de la malla y la otra mitad fuera, asegurando una correcta representación del flujo. Luego de definir el área, aparecerá una ventana emergente donde se configuran las condiciones de límite **"Boundary Condition"**, tal como se muestra en la siguiente imagen:



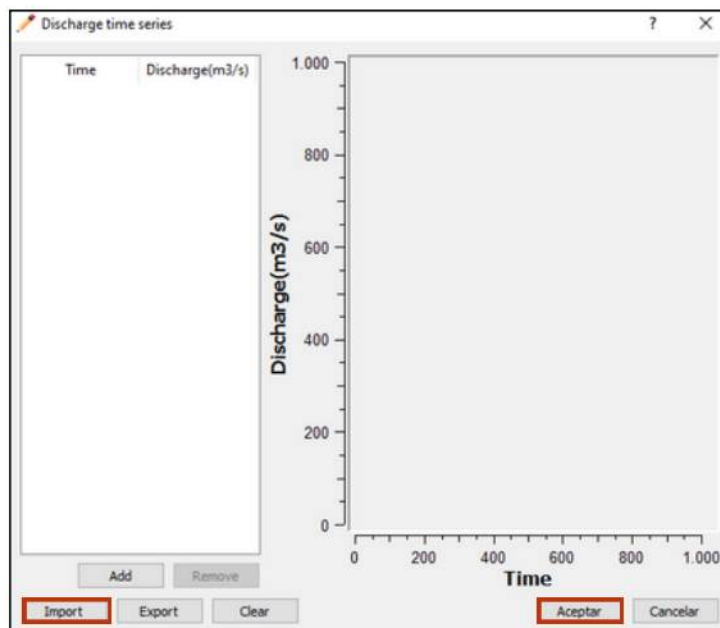
- En la ventana emergente se le asigna el nombre, en este caso se le asignó el nombre Hydro_Solo_Caso4, es solo ya que no se le agregó obstáculos. Seguidamente, cambiamos el valor del ítem **"Slope value at inflow"** a 0.0012, luego nos dirigimos a el Botón de **"Edit"**.

Es importante aclarar que el valor de "Slope value at inflow" de 0.0012, fue proveído por el equipo de CTI Engineering International luego que fuera estimado la pendiente del lecho del río.

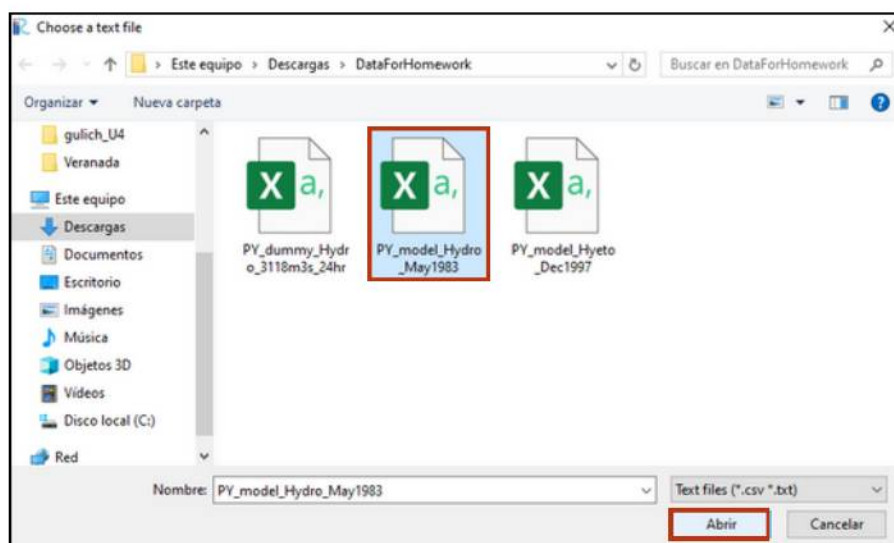
- A la siguiente ventana emergente le damos "Aceptar".



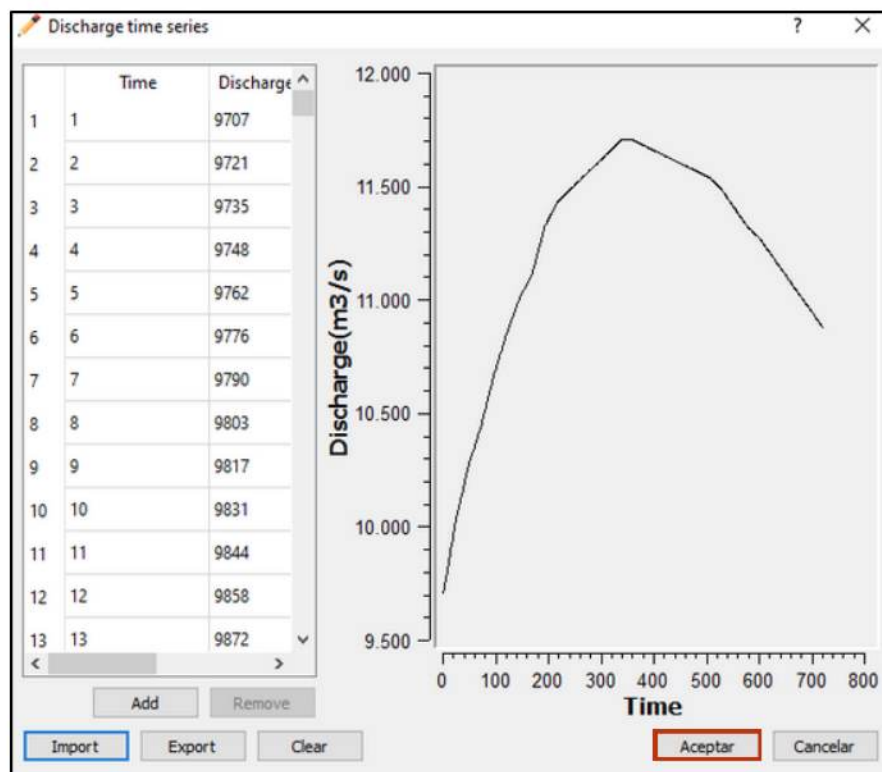
- Seguidamente, se abrirá otra ventana **"Discharge Time Series"**, donde se deben ingresar los valores de caudal en función del tiempo. Para ello, se pueden agregar datos manualmente con el botón **"Add"**, pero en este caso se importa un archivo con valores predefinidos mediante **"Import"**, los datos se pueden limpiar la lista con **"Clear"**. En el gráfico de la derecha, se visualizará la serie temporal del caudal una vez que se hayan ingresado los datos. Finalmente, se confirma la configuración presionando **"Aceptar"**.



- Se selecciona el archivo con extensión .csv, utilizando los datos previamente descargados y proporcionados por la JICA **"PY_model_Hydro_May1983"**.



- Se muestra la siguiente visualización. Para continuar, clic en **"Aceptar"** lleva a la ventana anterior y finaliza la configuración con el botón **"OK"**.

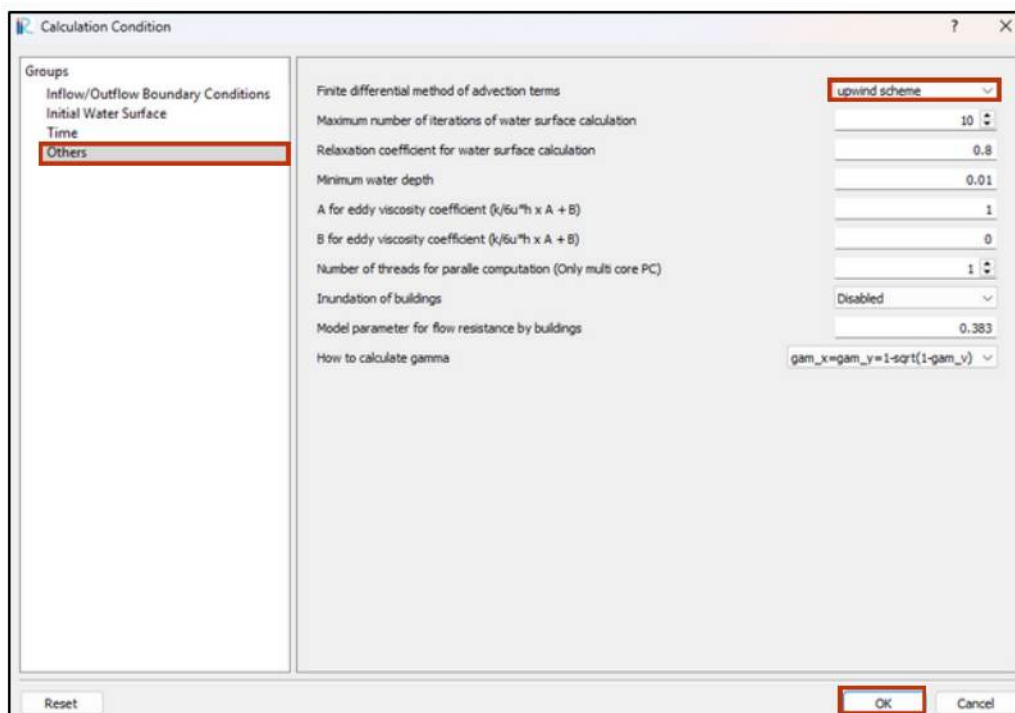
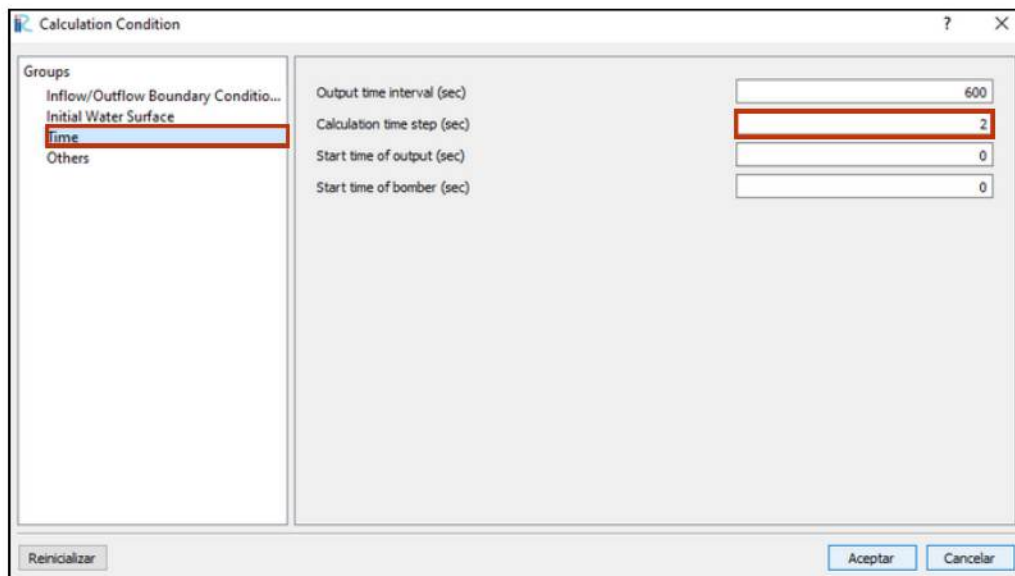


8.1.5.3. Condiciones de Cálculo

- En el Menú de herramientas acceder a "Calculation Condition".



- En la siguiente ventana, se modifica según lo indicado en las imágenes a continuación:



Se modificó la unidad de tiempo de descarga de segundos a horas. Se definió un paso de tiempo (time step) de simulación de 2 segundos.

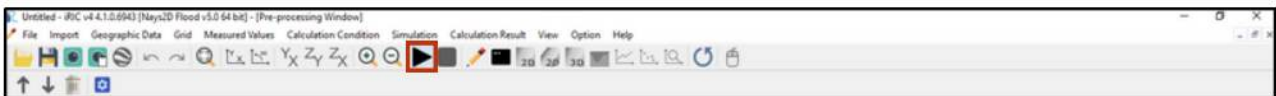
En la sección **"Finite Differential Method of Advection Terms"**, donde el modelo emplea un esquema de diferencias finitas para aproximar los términos de advección en las ecuaciones diferenciales del flujo, se seleccionó el **"Upwind Scheme"** (esquema a favor del viento o de flujo ascendente). Este método numérico mejora la estabilidad de la simulación al considerar la dirección del flujo en el cálculo de los valores de cada punto de la malla. Su uso es especialmente útil para evitar oscilaciones no físicas y es ampliamente empleado en modelos hidrodinámicos y de transporte de contaminantes.

Se recomienda utilizar una resolución más alta para obtener resultados más detallados, aunque esto puede aumentar el tiempo de cálculo.

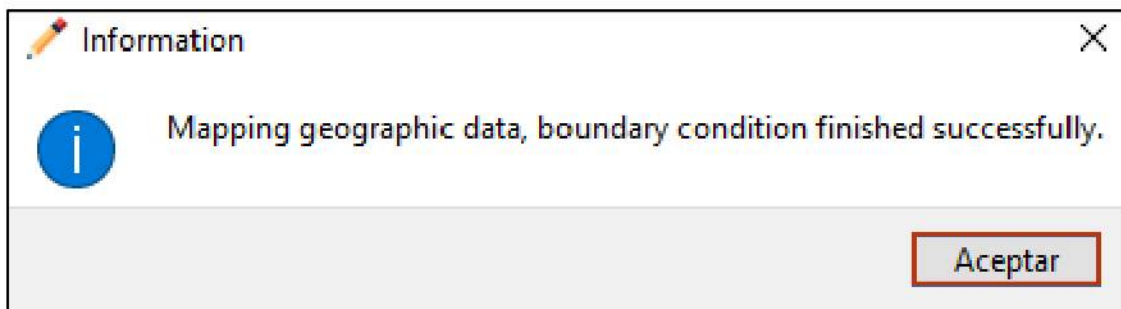
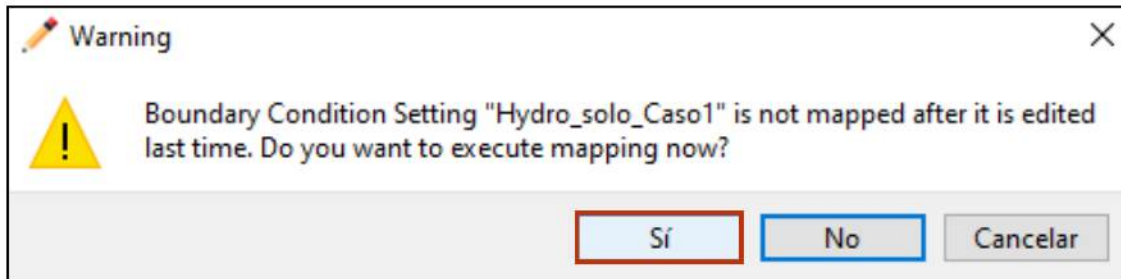
El resto de la configuración se mantiene en su estado predeterminado.

8.1.5.4. Correr la simulación

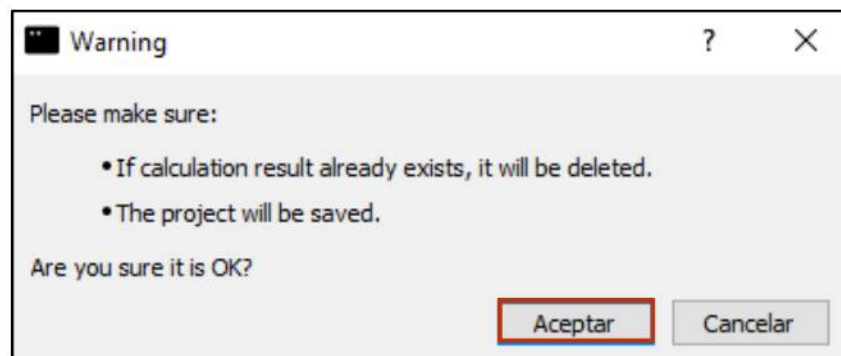
- Nos dirigimos a la barra de herramientas principal a damos clic en “Run” 



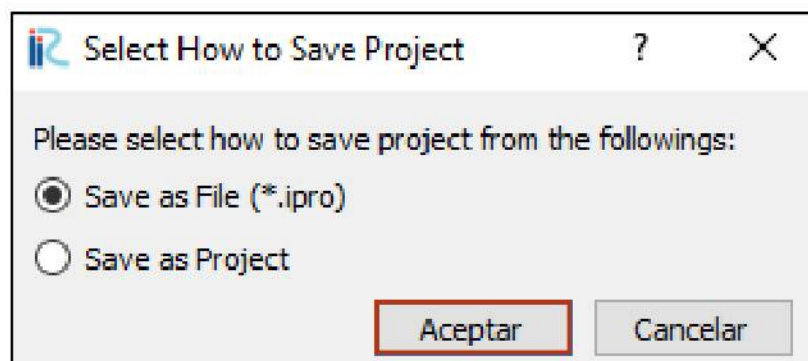
- Continuamos con “SI” y luego “Aceptar”.



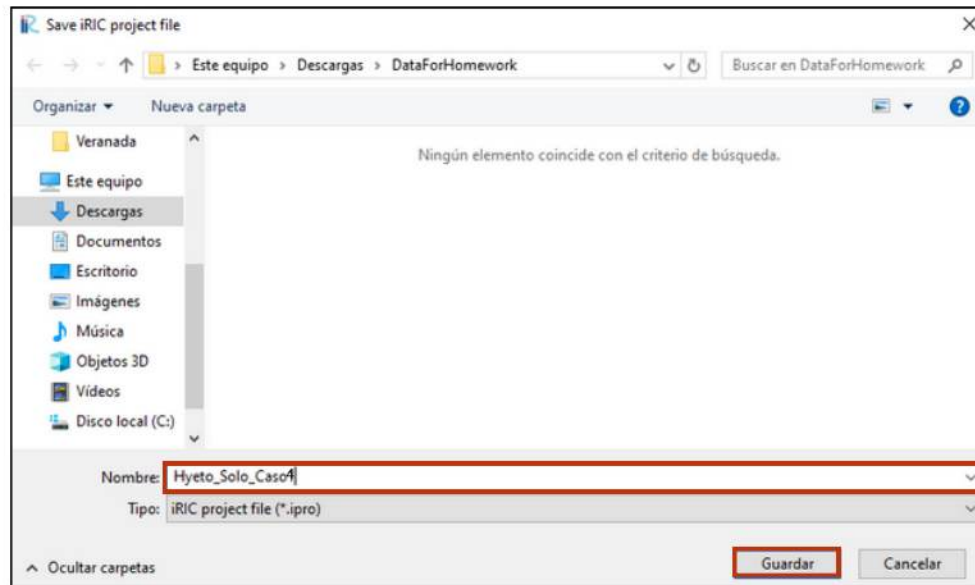
- En la barra de herramientas clic en “Run” .
- “Aceptar” para continuar.



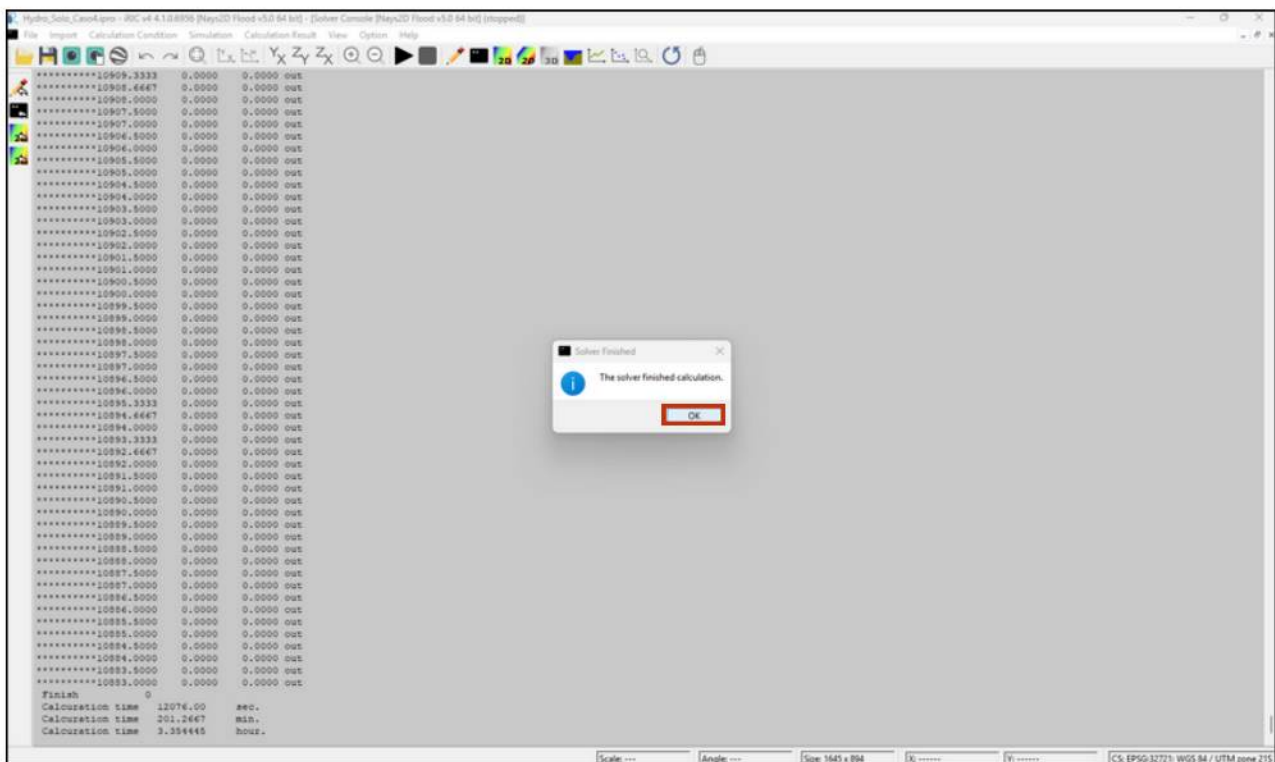
- “Aceptar para continuar” con la primera opción para guardar el proyecto.



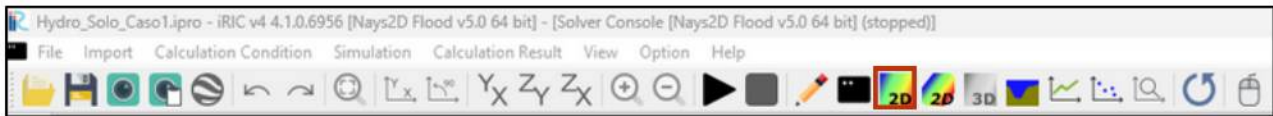
- Se se asigna un nombre al proyecto y el directorio donde será guardado.



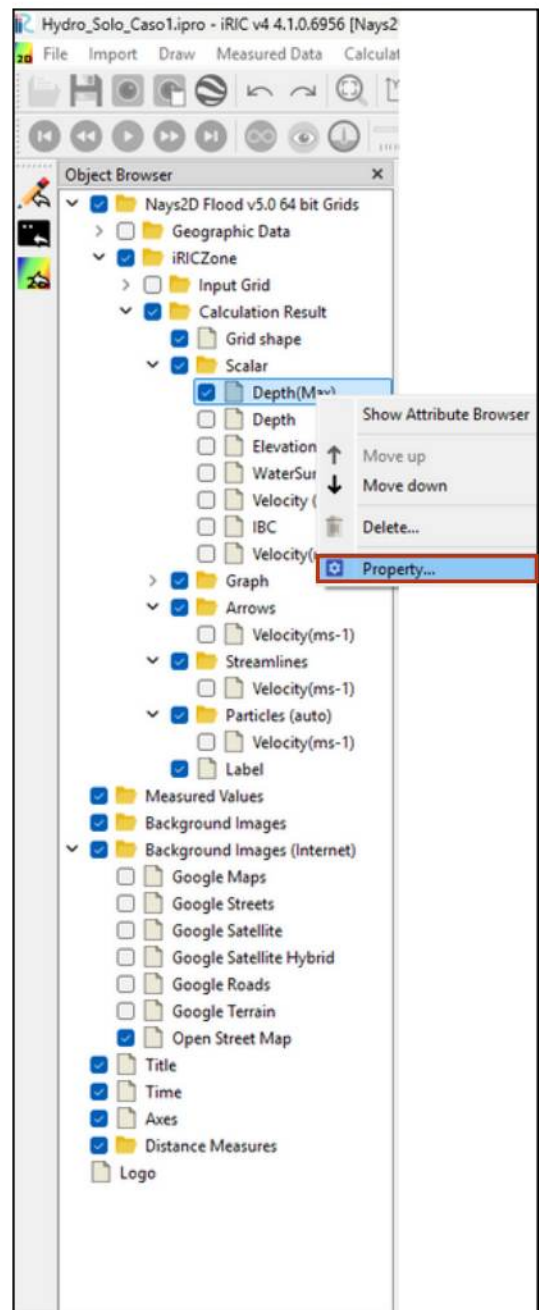
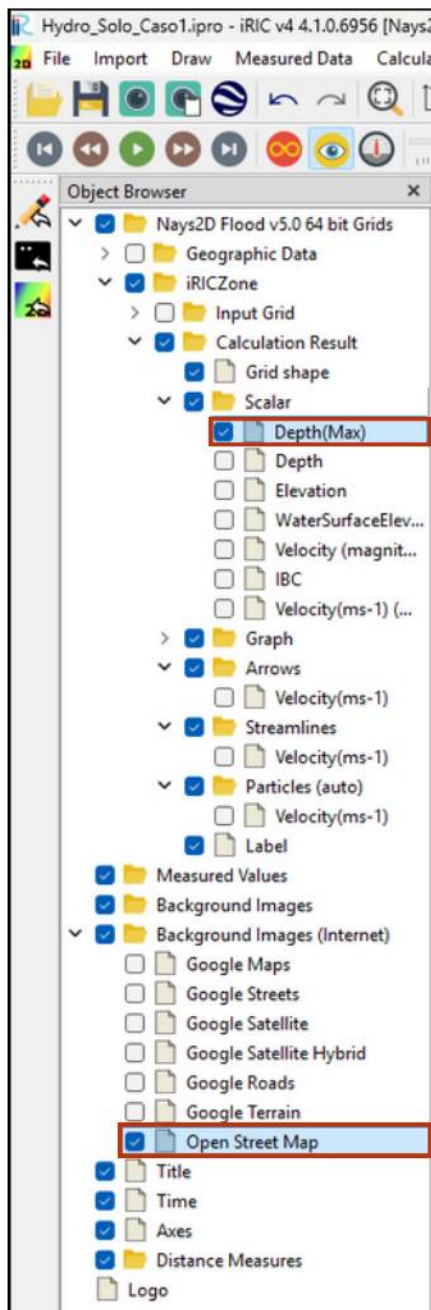
- Una vez finalizado el cálculo de las condiciones, confirmar la configuración seleccionando "OK".



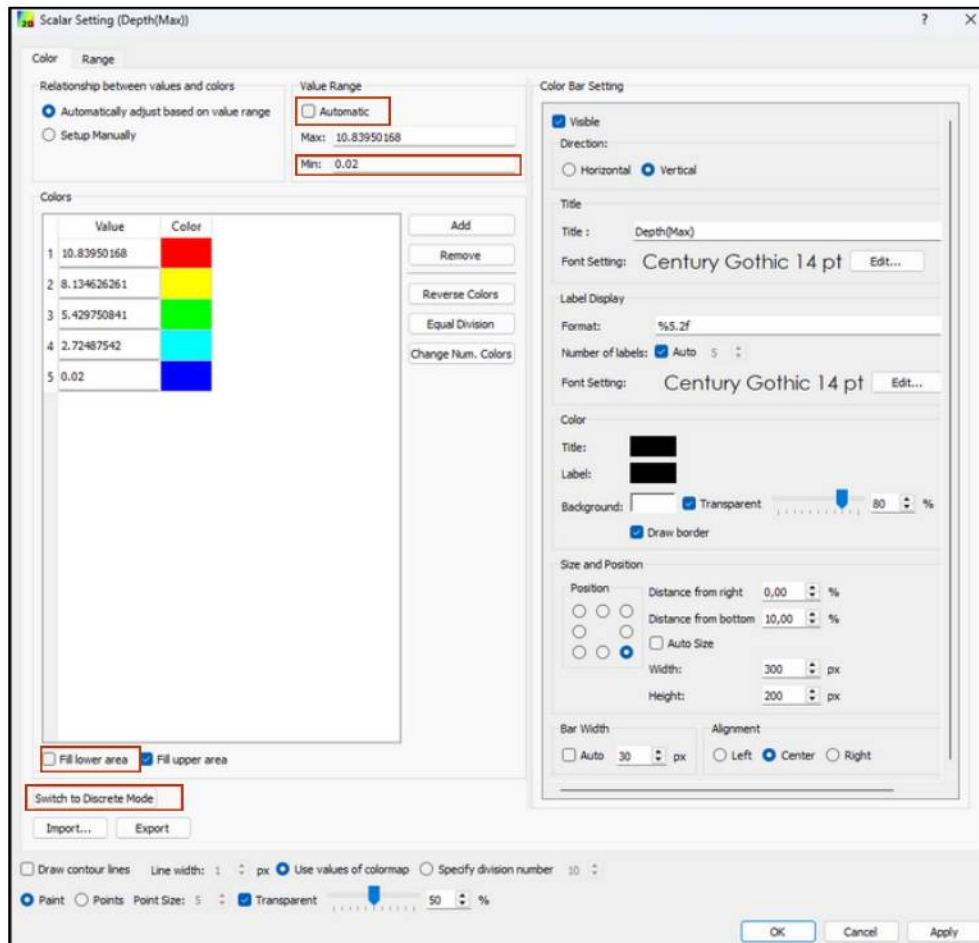
- En barra de herramientas principal clic en la primera opción de visualización en 2D.



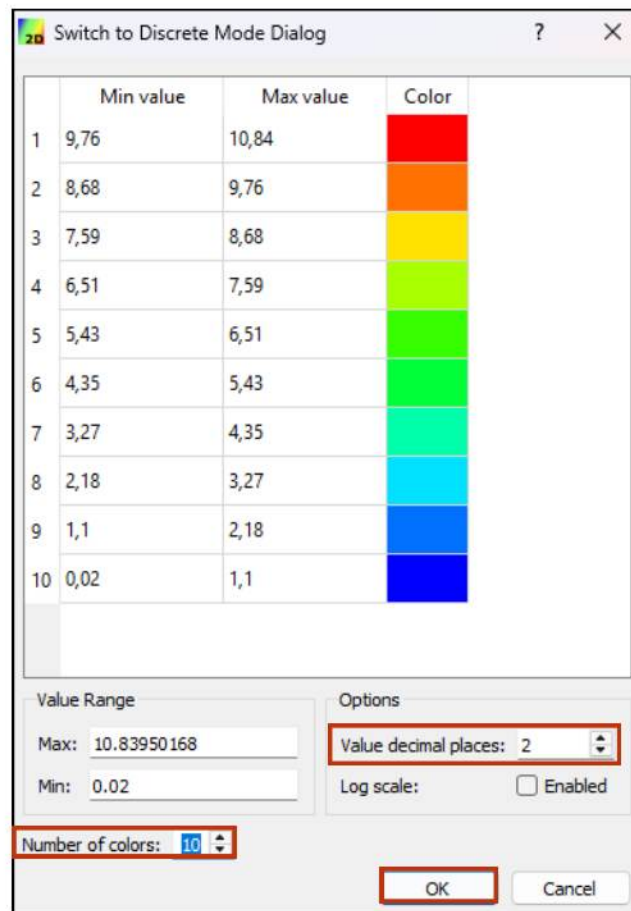
- Activar nuevamente el mapa base “**Open Street Map**” en Background Images (Internet) y la capa “**Depth (Max)**” en iRICZone > Calculation Result, ambas ubicadas en la tabla de contenidos.
- Realizar las configuraciones finales para la visualización, a través de “**Depth (MAX)**” haciendo clic derecho, Property.



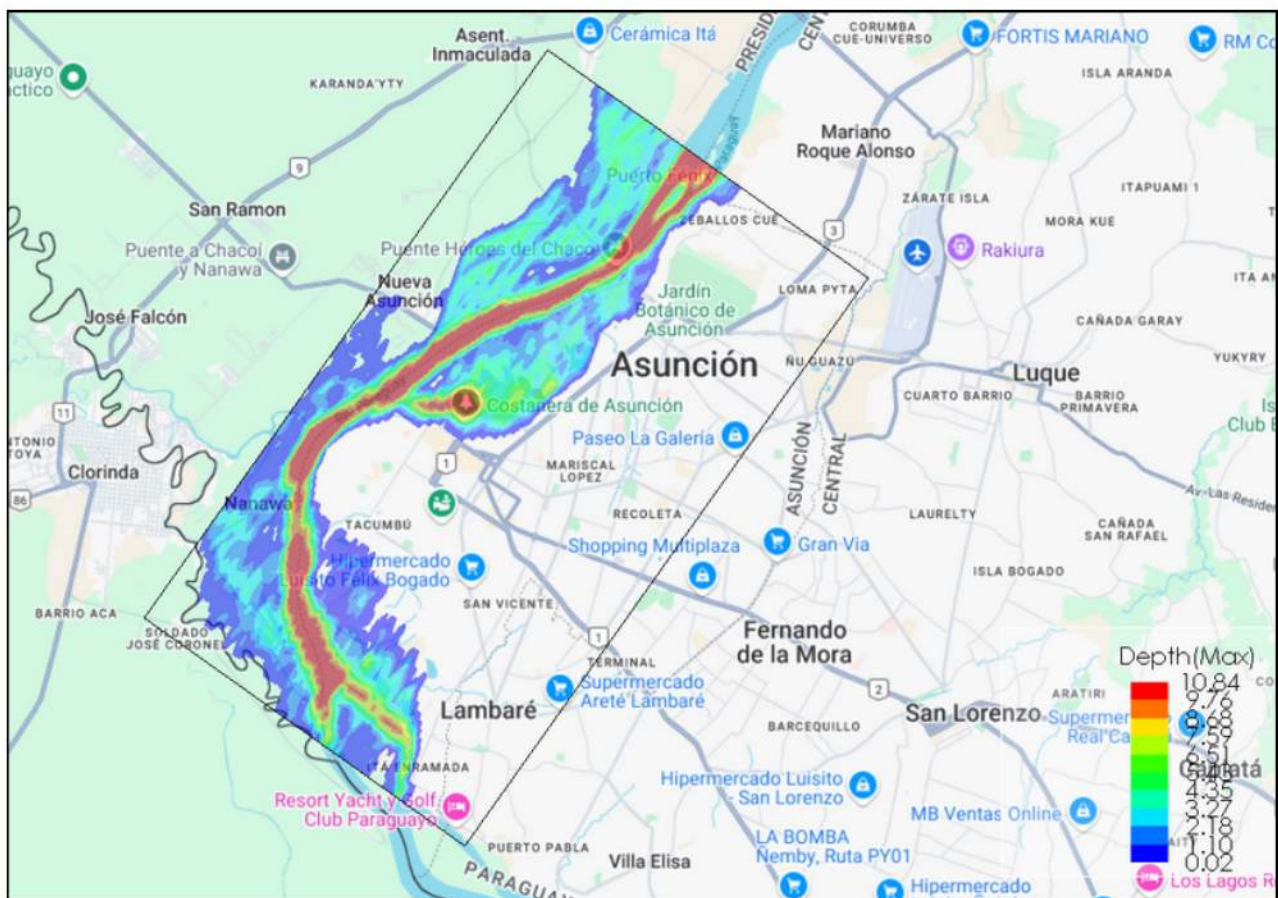
- Seguidamente, se abre una ventana emergente donde se realiza las siguientes configuraciones:
 - Desmarcar “Automatic” en Value Range.
 - Modificar el valor “Min” en Value Range a 0.02.
 - Desmarcar “Fill Lower Area”.
 - Ingresar a “Switch to Discrete Mode”.



- En la ventana emergente de “Switch to Discrete Mode”, se realiza las siguientes modificaciones:
 - Ajustar “Value decimal places” a 2.
 - Asignar el valor 10 en “Number of colors”.
 - Confirmar los cambios presionando OK y luego nuevamente OK.



- La simulación se visualiza de la siguiente manera:

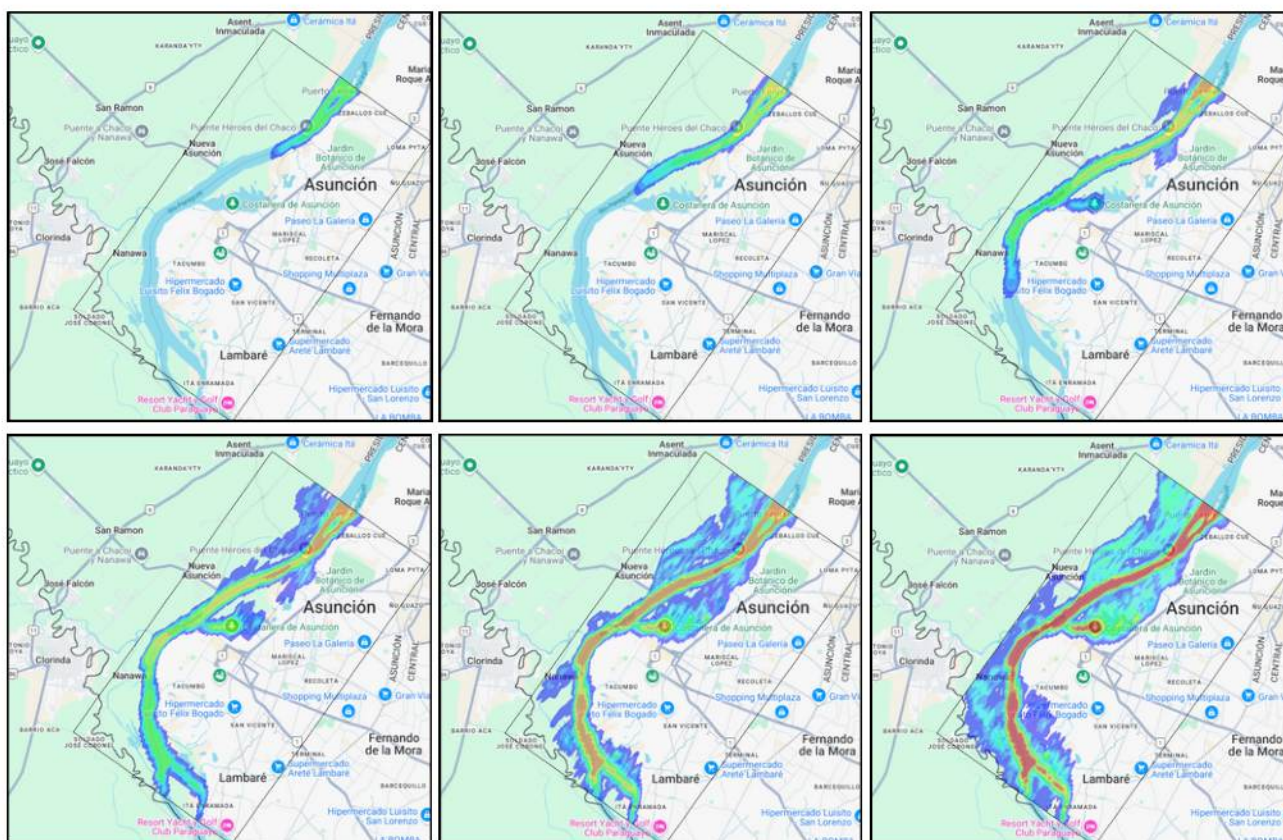


Esta imagen muestra la superposición de un modelo de simulación de inundación sobre una parte de Asunción y el río Paraguay. La malla representa diferentes profundidades de agua mediante una escala de colores, donde el rojo oscuro indica las mayores profundidades (hasta 10.84 m), seguido por tonos naranja y amarillo para niveles intermedios (6-9 m). Las zonas en verde y azul corresponden a áreas con menor acumulación de agua (menos de 3 m), mientras que los tonos morado y celeste sugieren áreas sin inundación o con escasa acumulación. Se observa que la mayor concentración de agua se encuentra en la zona central del modelo, lo que indica posibles áreas bajas y propensas a inundaciones. La simulación sigue el cauce del río Paraguay, lo que sugiere que representa un evento de crecida del río en esta región.

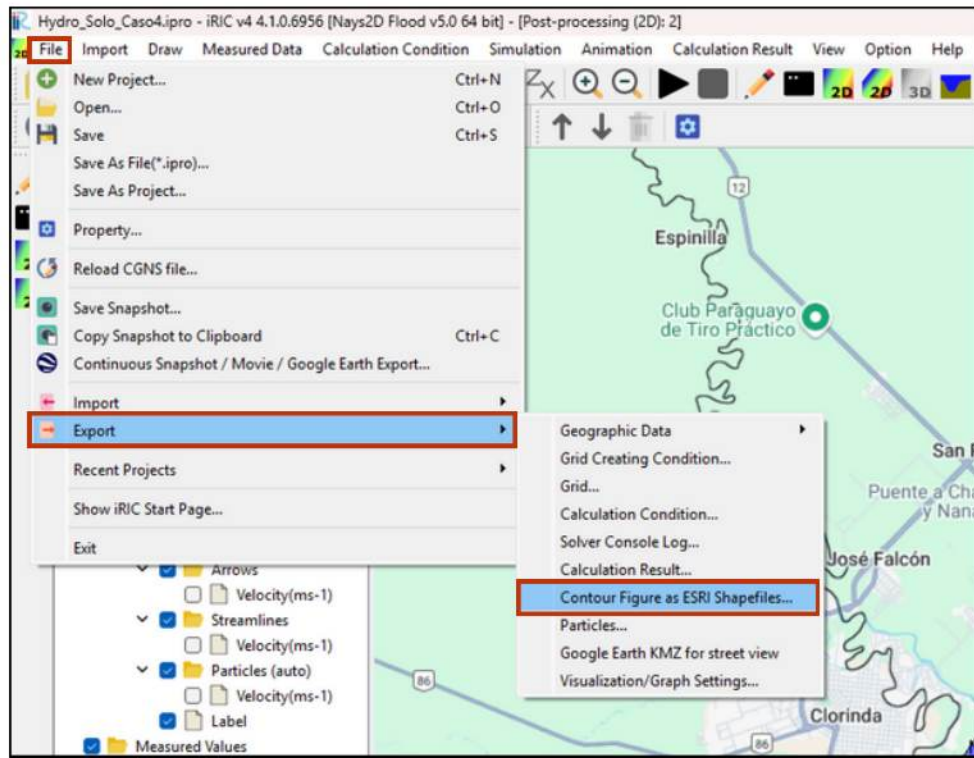
- Para visualizar el curso de la inundación en la simulación, primero se accede a la barra de herramientas de operaciones, luego se ajusta el temporizador a 0 y, finalmente clic en **"Play"** para iniciar la simulación.



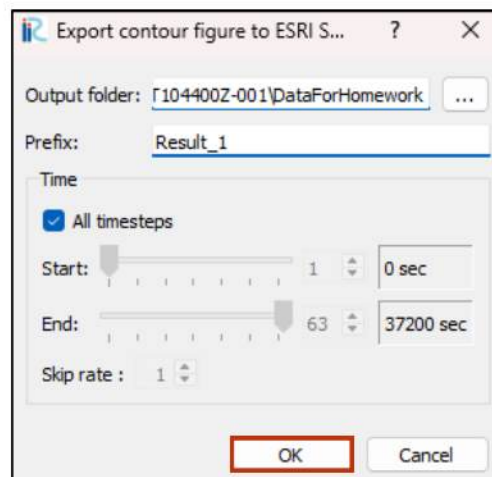
- De esta manera, se puede observar la evolución de la inundación a lo largo del tiempo en la simulación.



- Según los resultados y las comparaciones obtenidas, se deben realizar ajustes en las condiciones de entrada, la malla o el modelo para mejorar la precisión de la simulación, si es necesario.
- Para representar la simulación en un mapa, se exporta en formato Shape (.shp) y se descarga el archivo correspondiente.



- Se define la carpeta de destino y el nombre al archivo, dejando el resto de los datos con los valores predeterminados. Luego, en la carpeta de descarga, se selecciona el último archivo .shp para proceder con el procesamiento del mapa en ArcGIS.



8.1.6. El Hietograma

Representa la variación temporal de la intensidad de la precipitación en una determinada área y periodo de tiempo. Se obtiene a partir de datos de estaciones pluviométricas o modelos hidrológicos que simulan la distribución de la lluvia. En el caso del río Paraguay, el análisis del hietograma es fundamental para comprender los eventos de precipitación que contribuyen a la escorrentía y, en consecuencia, a la dinámica de caudales del río. Dada la variabilidad climática y la extensión de su cuenca, la estimación precisa de la lluvia es un reto clave en la modelización hidrológica.

En este entrenamiento, se emplea un hietograma modelo elaborado por el equipo de CTI y consultores de JICA, con el objetivo de facilitar el aprendizaje y la familiarización con Nays2D_Flood.

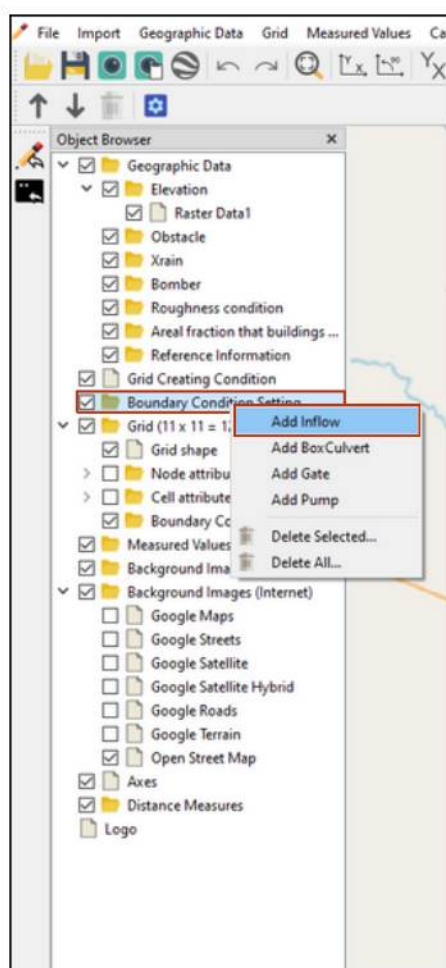
8.1.6.1. Obtención de datos

Para la obtención de los datos que se utilizarán se obtienen en el siguiente link: https://drive.google.com/drive/folders/15wO8vHjFoM-VzUOI18FNyp1ETP5o6tvt?usp=drive_link. El archivo debe estar en formato CSV.

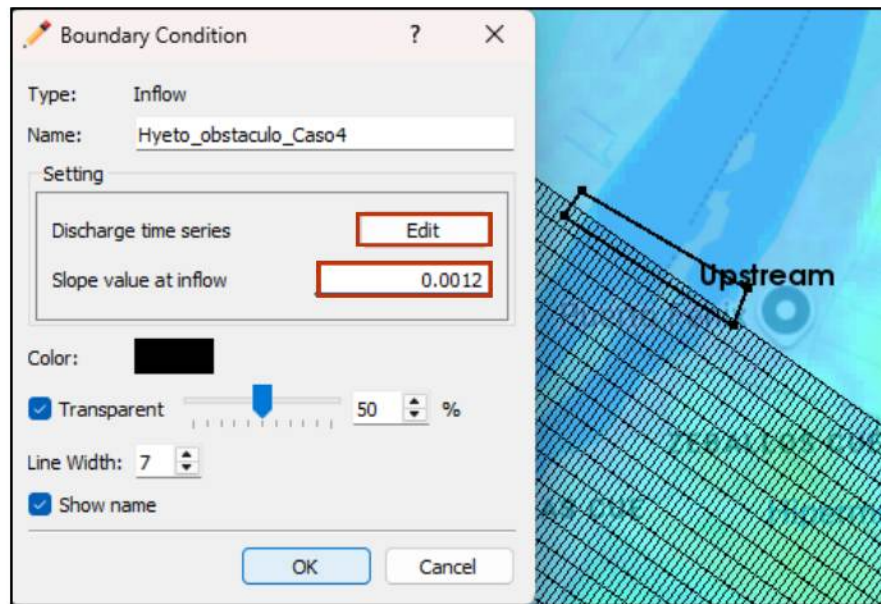
- Para la simulación se utilizará la grilla del Caso 4 nuevamente. Iniciando con un proyecto nuevo.

8.1.6.2. Configuración del Caudal

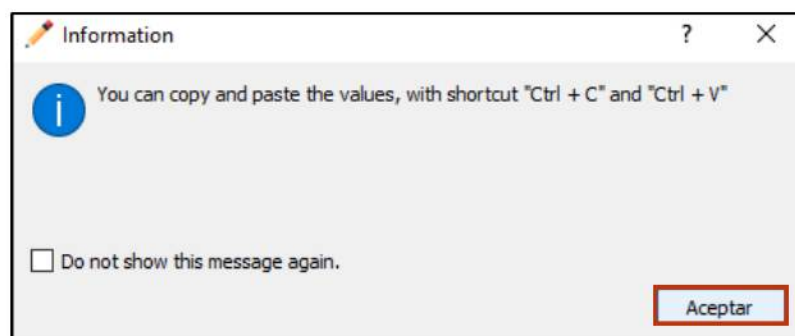
Para incorporar los datos de entrada en el modelo, dirígete al panel de contenido del área de trabajo. Luego, selecciona la opción **“Boundary Condition Setting”** con el clic derecho o secundario y selecciona **“Add Inflow”** para añadir el caudal de entrada a la simulación.



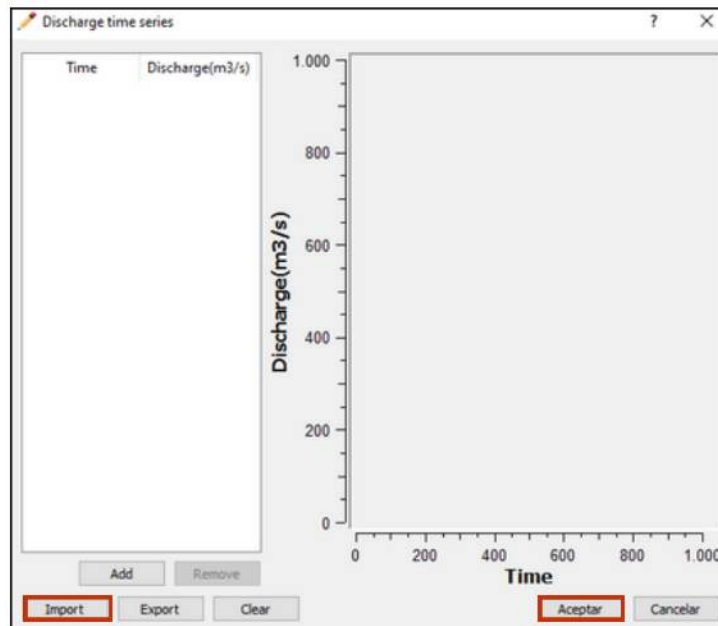
- Una vez creado **"New Inflow"**, este aparecerá en la tabla de contenidos. Para definirlo, en el área de trabajo selecciona mediante clics, los vértices que delimitarán el área de ingreso del flujo del río. Para finalizar el trazado se utiliza un doble clic. Es importante que la mitad del trazado quede dentro de los cuadros de la malla y la otra mitad fuera, asegurando una correcta representación del flujo. Luego de definir el área, aparecerá una ventana emergente donde se configuran las condiciones de límite **"Boundary Condition"**, tal como se muestra en la siguiente imagen:



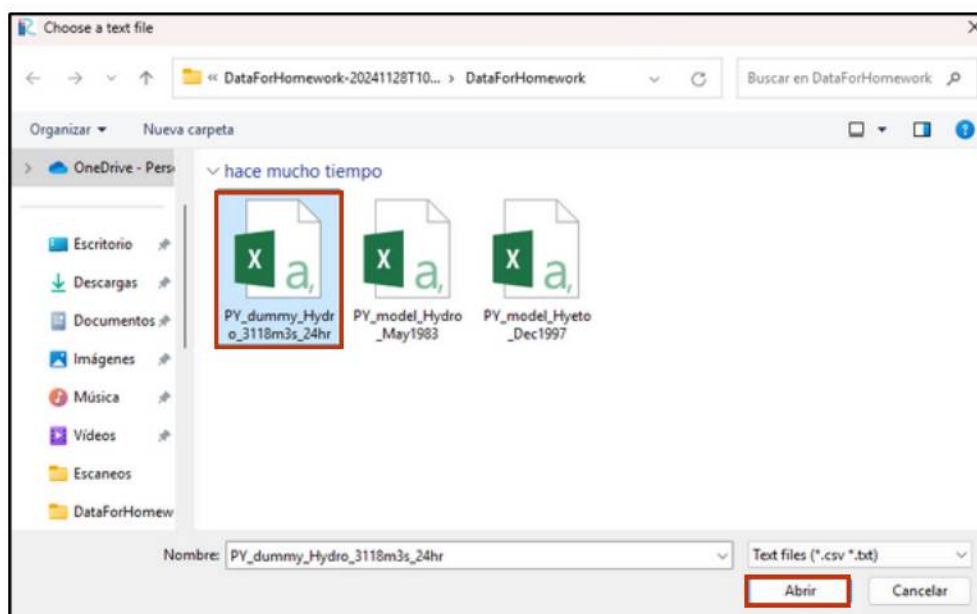
- En la ventana emergente se le asigna un nombre, en este caso se le asignó el nombre Hyeto_obstaculo_Caso4, obstáculo hace referencia a que la simulación tiene obstáculos. Seguidamente, cambiamos el valor del ítem **"Slope value at inflow"** a 0.0012, luego se ingresa en el Botón de **"Edit"**.
- A la siguiente ventana emergente le damos "Aceptar".



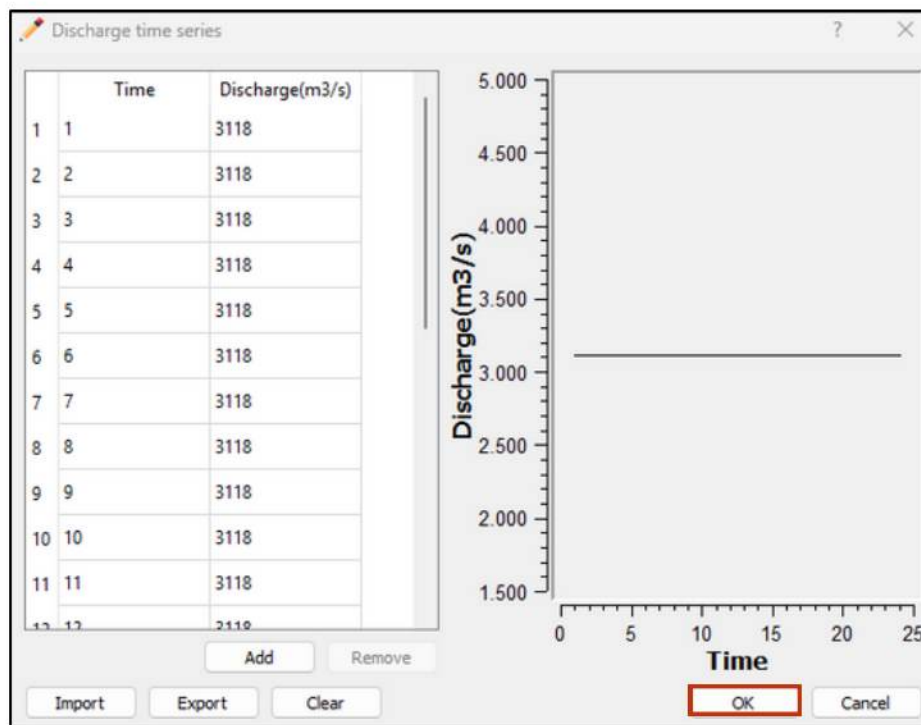
- Seguidamente, se abrirá otra ventana **"Discharge Time Series"**, donde se deben ingresar los valores de caudal en función del tiempo. Para ello, se pueden agregar datos manualmente con el botón **"Add"**, pero en este caso se importa un archivo con valores predefinidos mediante **"Import"**, los datos se pueden limpiar la lista con **"Clear"**. En el gráfico de la derecha, se visualizará la serie temporal del caudal una vez que se hayan ingresado los datos. Finalmente, se confirma la configuración presionando **"Aceptar"**.



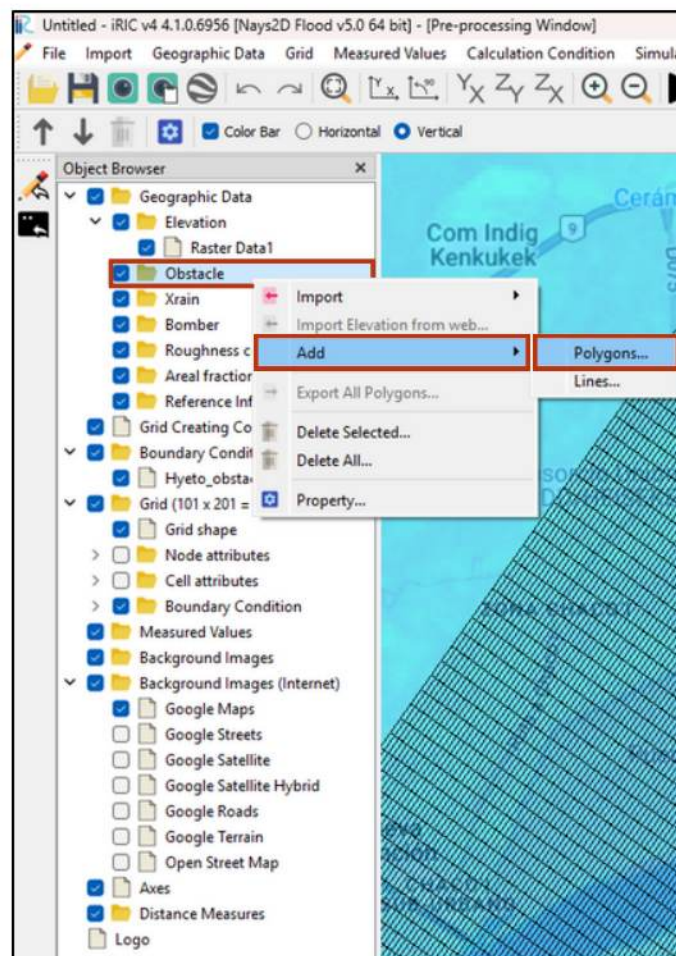
- Se selecciona el archivo con extensión .csv, utilizando los datos previamente descargados y proporcionados por la JICA **"PY_dummy_Hydro_3118m3a24hr"**.



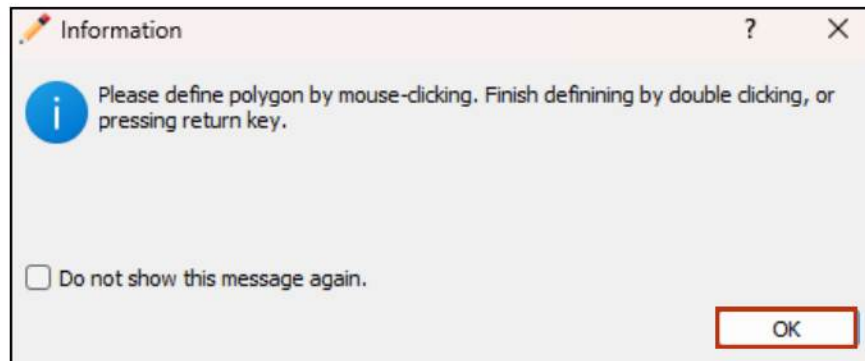
- Se muestra la siguiente visualización. Para continuar, clic en **"Aceptar"** que lleva a la ventana anterior y se finaliza la configuración con el botón **"OK"**.



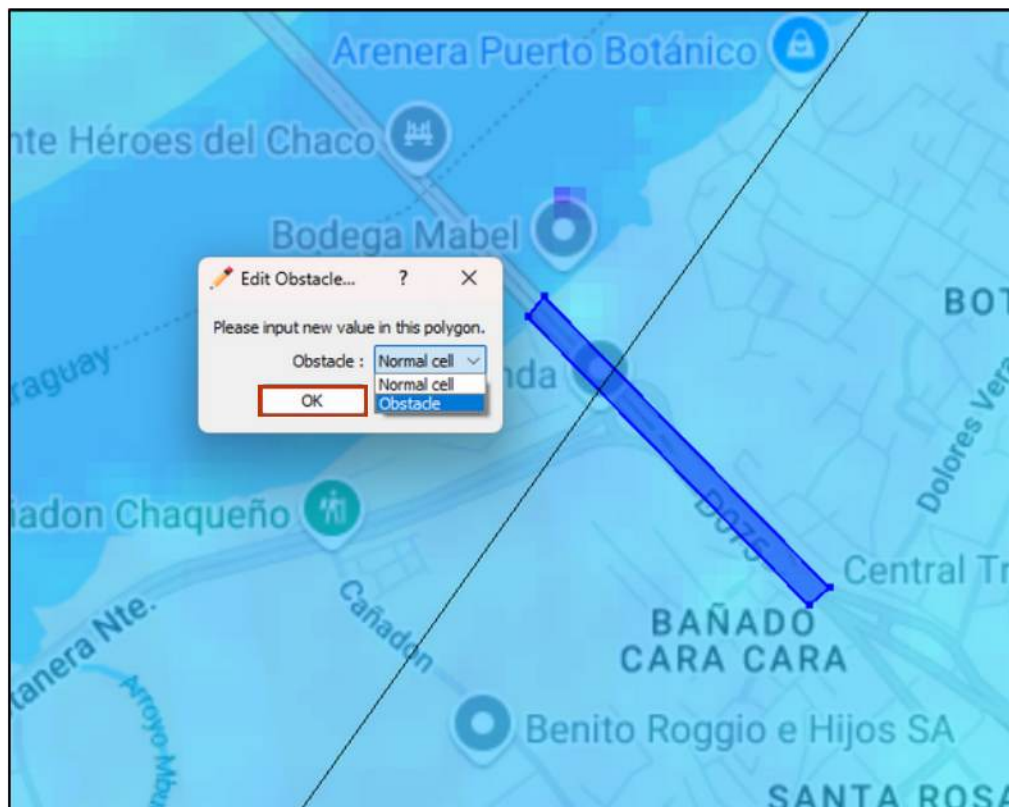
- Dentro de la barra de contenido, se le agrega los obstáculos, cabe mencionar que esto también puede ser agregado al hidrograma.
- Para agregar el obstáculo, clic derecho a Obstacle>Add>Polygon.



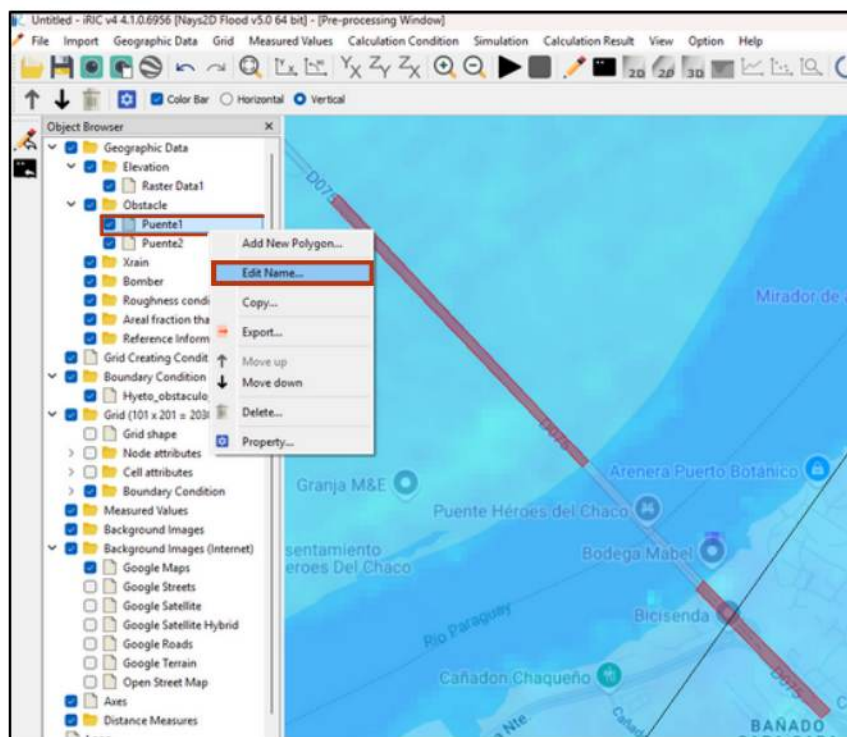
- Se abrirá la siguiente ventana emergente, "Ok" para continuar.



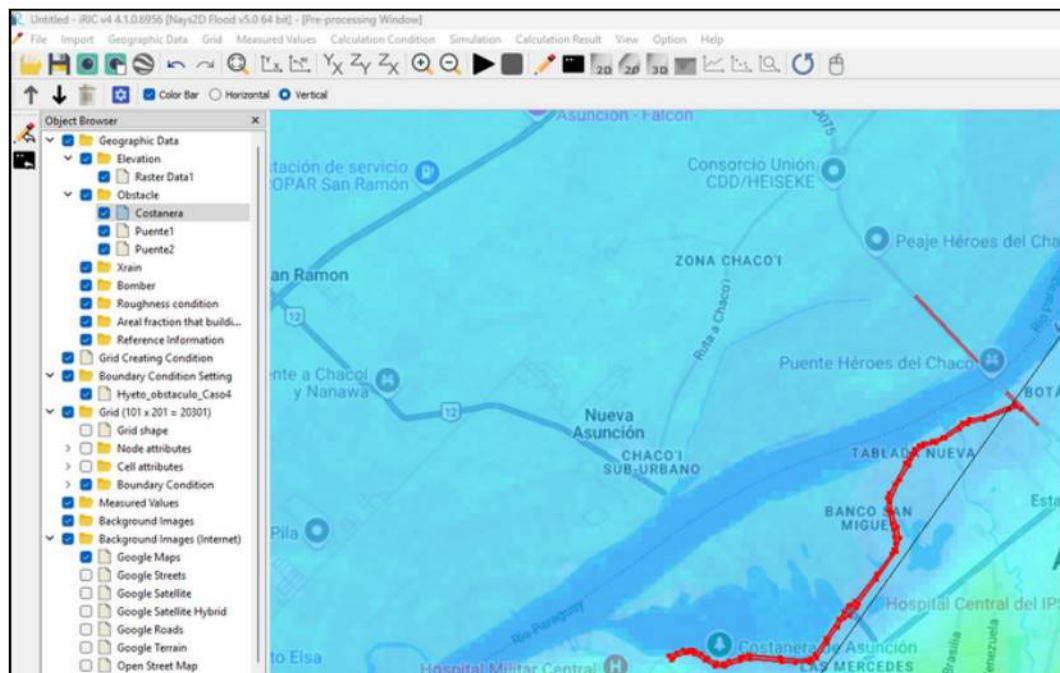
- Para mejorar la visualización de la zona, se desactiva la grilla del área de simulación desde el panel de contenido, lo que permite un trazado más preciso. Para comenzar el dibujo, se hace clic en el punto de inicio del obstáculo y se continúa definiendo los vértices con cada clic. Es importante mencionar que se pueden crear tantos puntos como sea necesario para definir el obstáculo con precisión. Se finaliza con un doble clic en el punto de término. A continuación, aparece una ventana emergente donde se selecciona la opción **"Obstacle"** y se confirma con **"Ok"**. En este caso, se está diagramando una sección del Puente Héroes del Chaco, que se encuentra sobre tierra en ambos extremos del río.



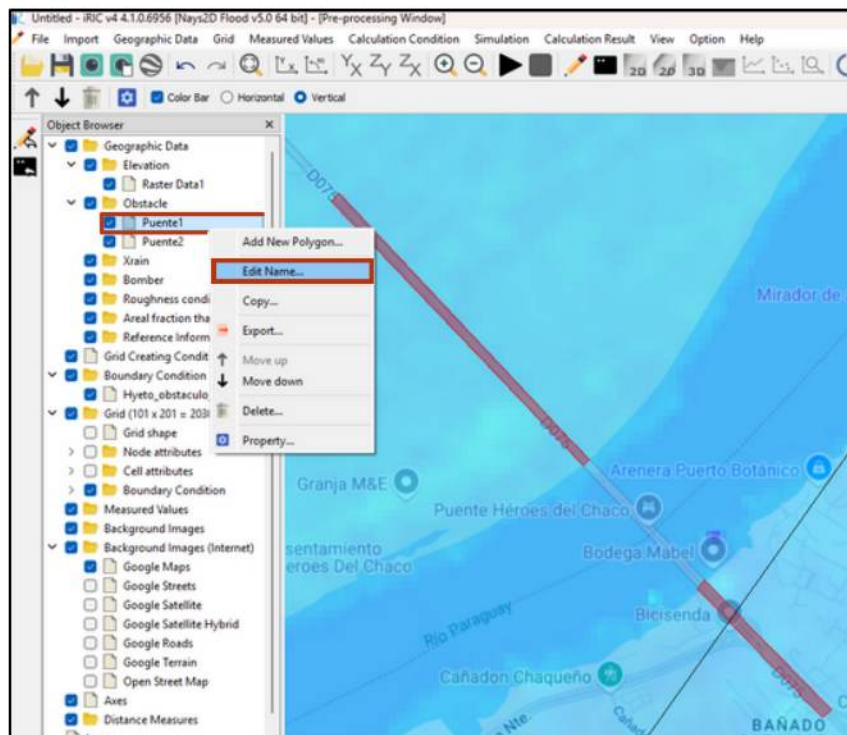
- Se edita el nombre de los obstáculos para una mejor organización del proyecto, haciendo clic derecho sobre el mismo y luego seleccionando **"Edit Name"**.



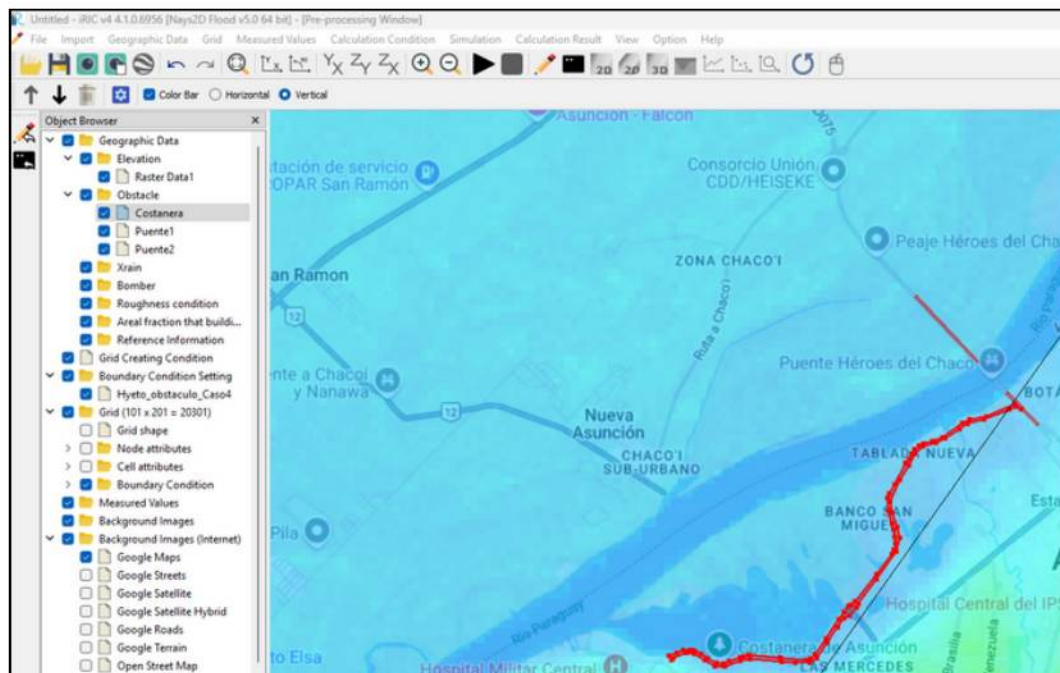
- De la misma manera, se genera el obstáculo correspondiente a la Avenida Costanera, definiendo sus vértices con clics sucesivos desde el punto de inicio hasta el final. Se pueden agregar tantos puntos como sea necesario para asegurar un trazado preciso. Una vez finalizado, se confirma la selección siguiendo el mismo procedimiento utilizado para el **Puente Héroes del Chaco**.



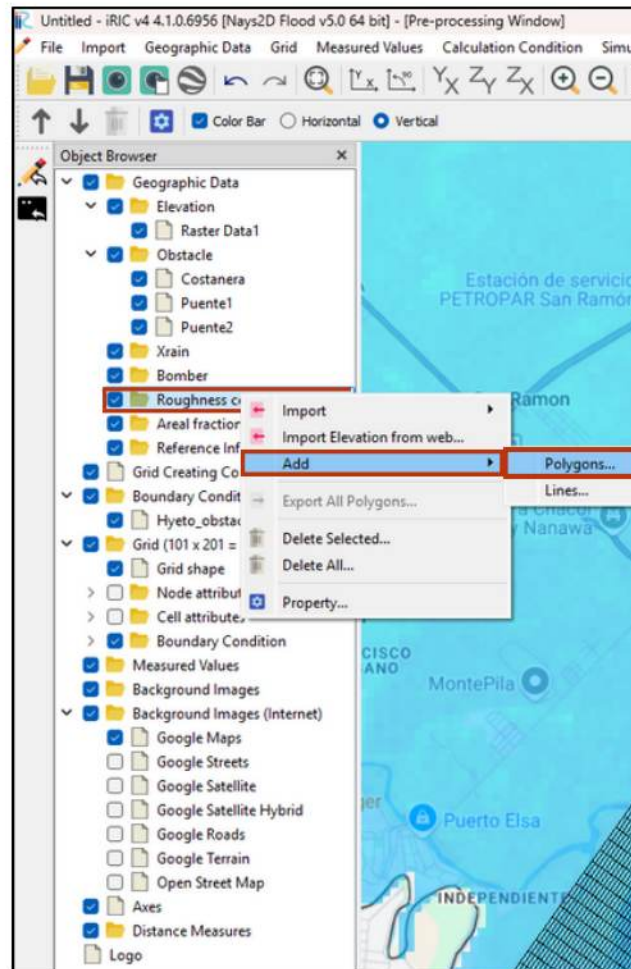
- Se edita el nombre de los obstáculos para mejor organización del proyecto, haciendo clic derecho sobre el mismo y luego Edit Name.



- De la misma manera, se genera el obstáculo correspondiente a la Avenida Costanera, definiendo sus vértices con clics sucesivos desde el punto de inicio hasta el final. Se pueden agregar tantos puntos como sea necesario para asegurar un trazado preciso. Una vez finalizado, se confirma la selección siguiendo el mismo procedimiento utilizado para el Puenete Héroes del Chaco.

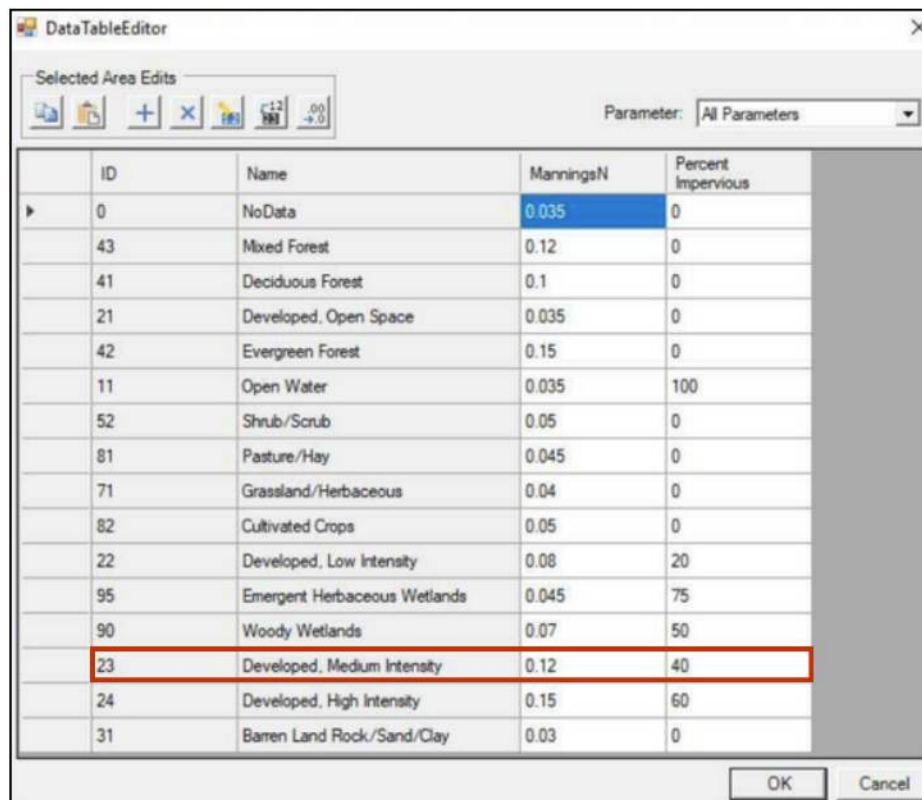


- Además, creamos un polígono para definir la condición de rugosidad, seleccionando la zona urbana dentro de la malla de simulación. Esto permite representar con mayor precisión las características del terreno y su influencia en el flujo del agua.
- Clic derecho en Roughness Condition > Add > Polygons, y en la ventana emergente que aparece, se continua con "Ok" para confirmar la acción.



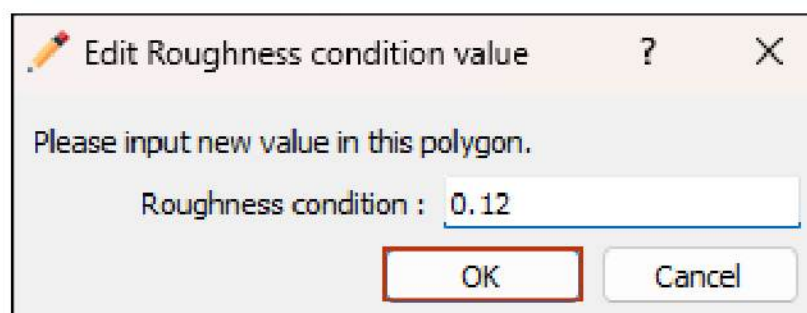
- Seguidamente, se comienza a dibujar el polígono haciendo clic en los puntos que definirán sus vértices. Es importante mencionar que se pueden agregar tantos puntos como sea necesario para delimitar con precisión la zona urbana dentro de la grilla.

- Se asigna el valor del coeficiente de rugosidad (Manning's n) de acuerdo con la tabla mostrada. En este caso, se selecciona la categoría **"Developed, Medium Intensity"** con un valor de **0.12**, ya que representa áreas urbanizadas de intensidad media, lo que se ajusta a la infraestructura de la zona urbana dentro de la simulación. Además, este valor considera un **40% de superficie impermeable**, reflejando la presencia de edificaciones y pavimento en la ciudad.



ID	Name	ManningsN	Percent Impervious
0	NoData	0.035	0
43	Mixed Forest	0.12	0
41	Deciduous Forest	0.1	0
21	Developed, Open Space	0.035	0
42	Evergreen Forest	0.15	0
11	Open Water	0.035	100
52	Shrub/Scrub	0.05	0
81	Pasture/Hay	0.045	0
71	Grassland/Herbaceous	0.04	0
82	Cultivated Crops	0.05	0
22	Developed, Low Intensity	0.08	20
95	Emergent Herbaceous Wetlands	0.045	75
90	Woody Wetlands	0.07	50
23	Developed, Medium Intensity	0.12	40
24	Developed, High Intensity	0.15	60
31	Barren Land Rock/Sand/Clay	0.03	0

Source: HEC-RAS 2D User's Manual <https://rashms.com/wp-content/uploads/2021/06/HEC-RAS-2D-Mannual-Mannings-n.pdf>



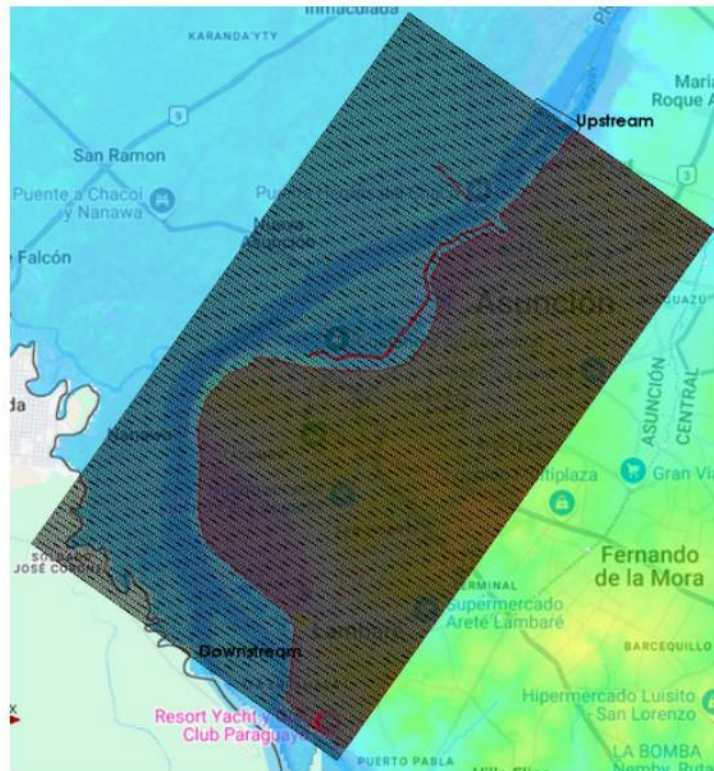
Edit Roughness condition value ? X

Please input new value in this polygon.

Roughness condition :

OK Cancel

- La imagen se visualiza con los elementos incorporados, incluyendo los obstáculos de la **Avenida Costanera**, el **Puente Héroes del Chaco** y la **Rugosidad de la Zona Urbana**. Estos elementos permiten representar con mayor precisión las condiciones del terreno en la simulación, considerando las infraestructuras existentes y su impacto en el flujo del agua.

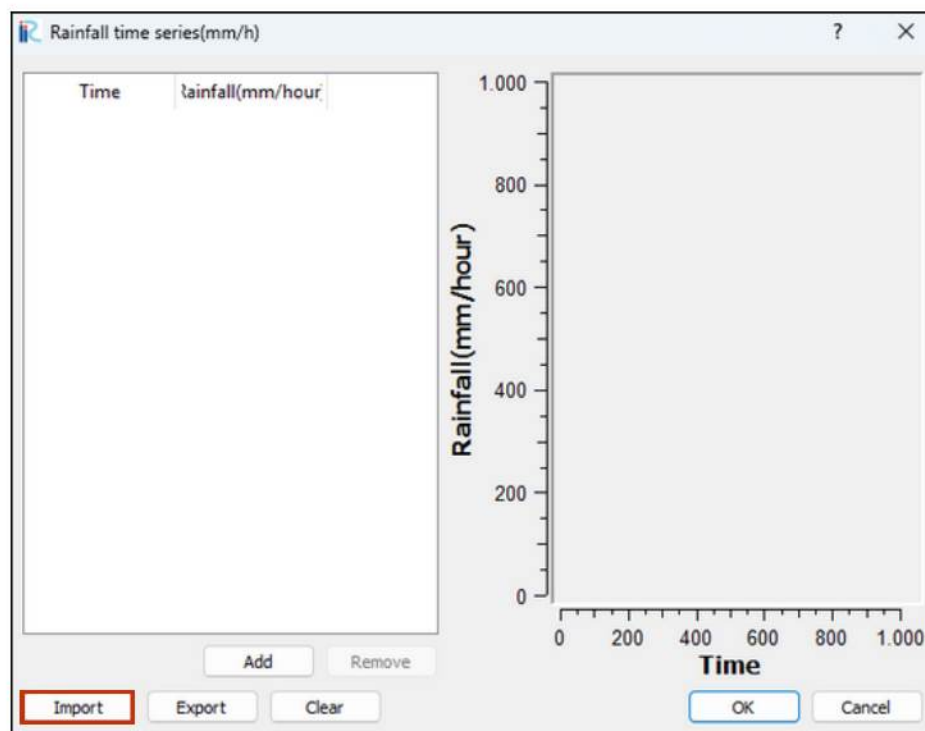
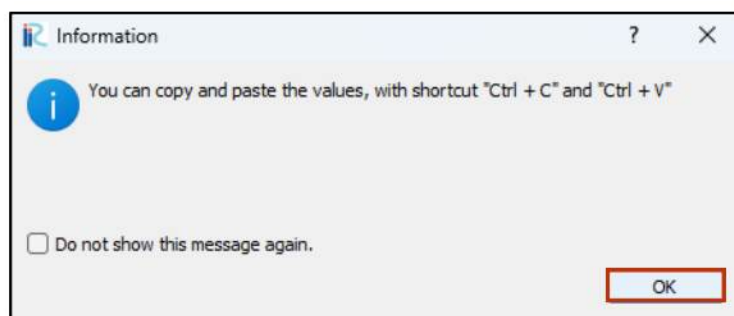
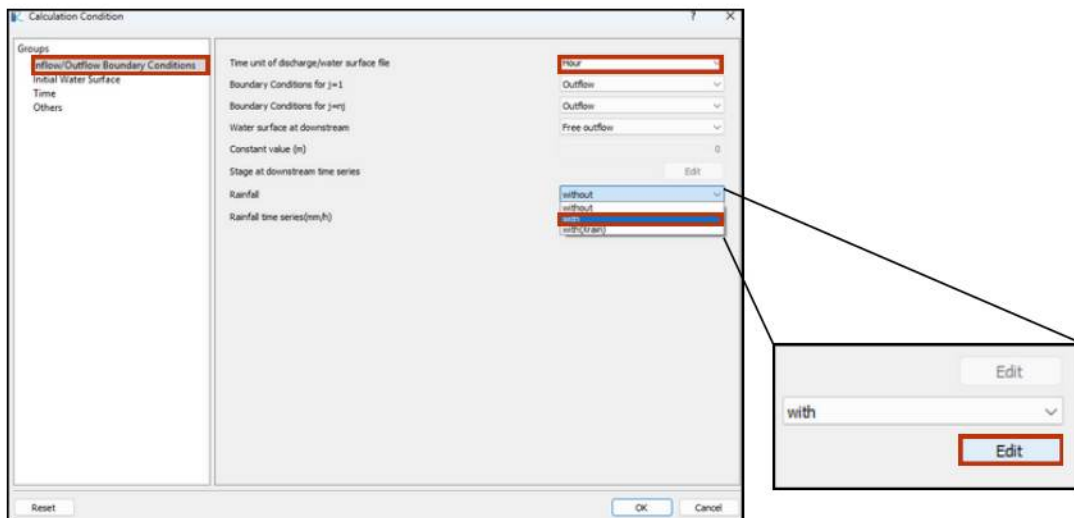


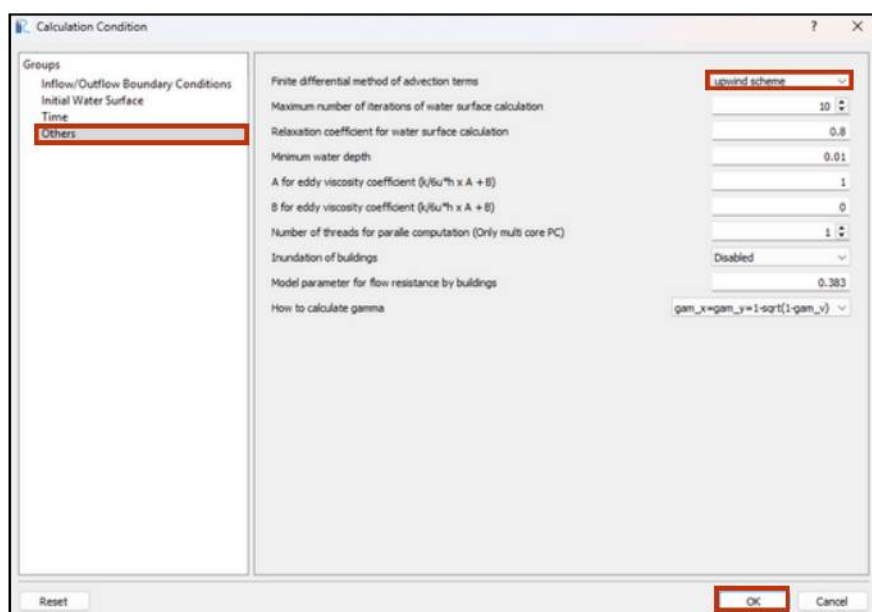
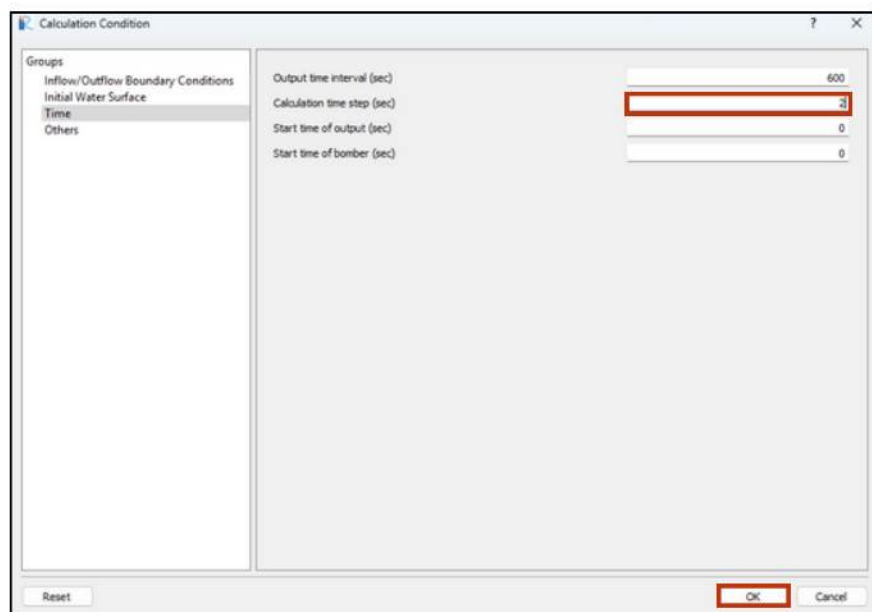
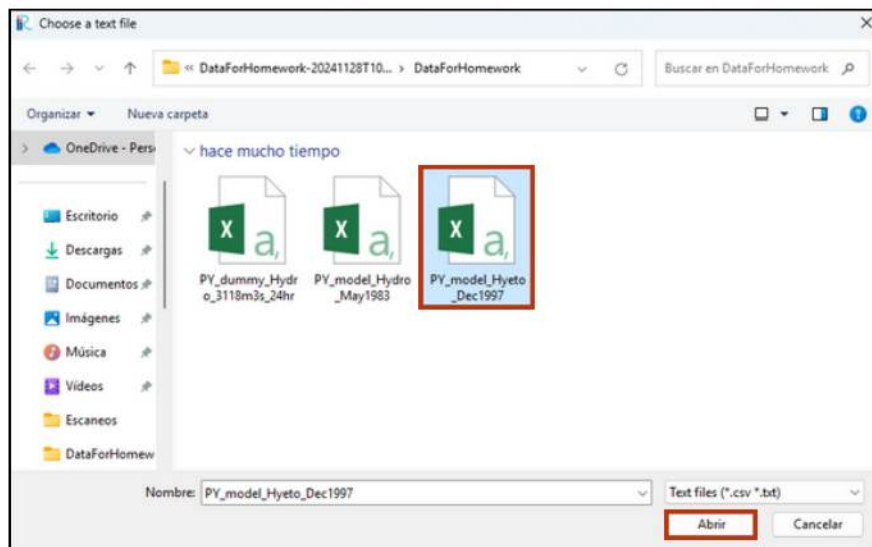
8.1.6.3. Correr la Simulación

- Se accede al Menú de herramientas y se selecciona **"Calculation Condition"**.

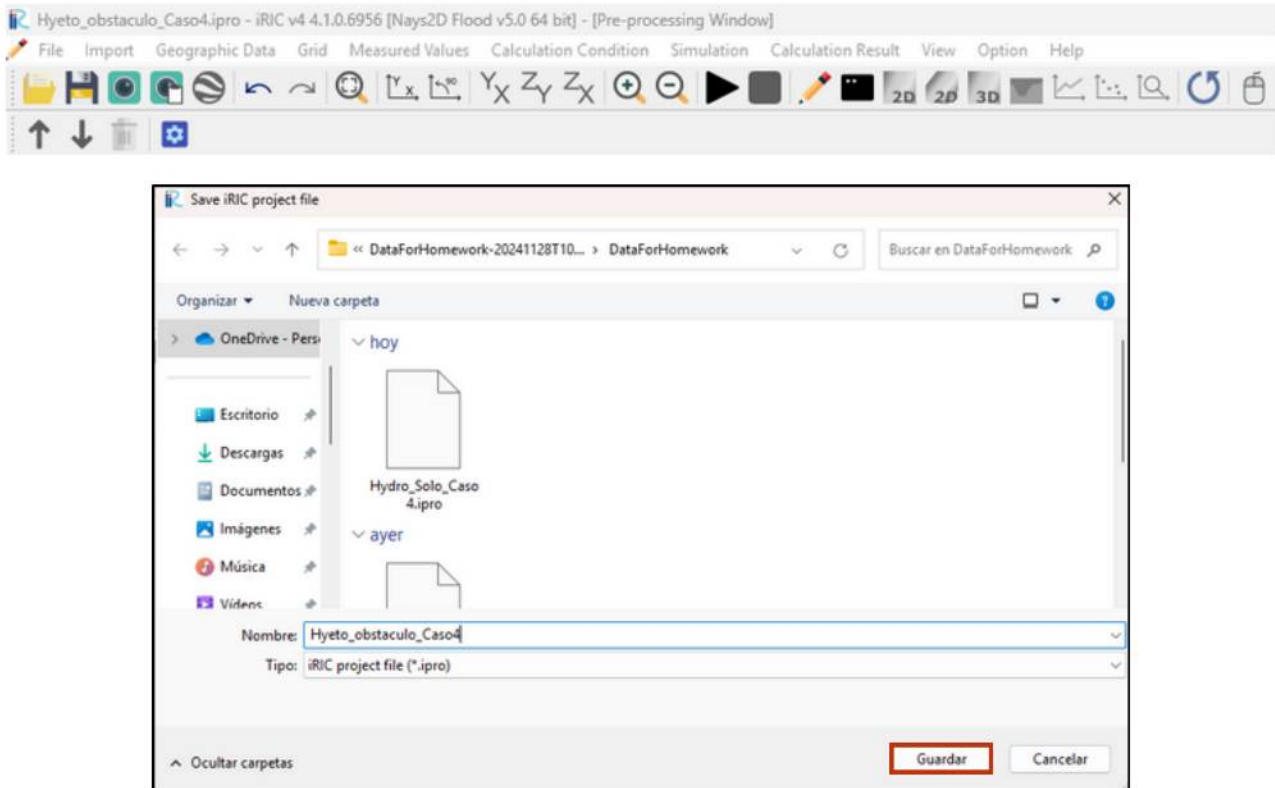


- En la siguiente ventana, se realizan las modificaciones según lo indicado en las imágenes siguientes.



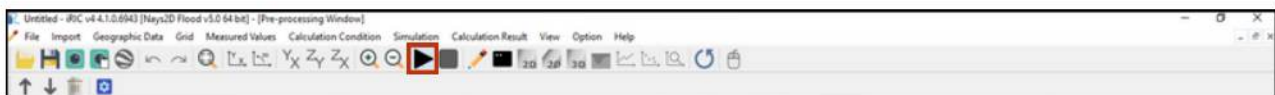


- Se guarda el proyecto para poder ejecutar la animación.

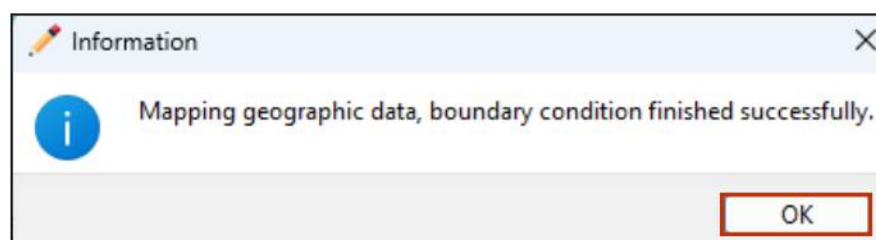
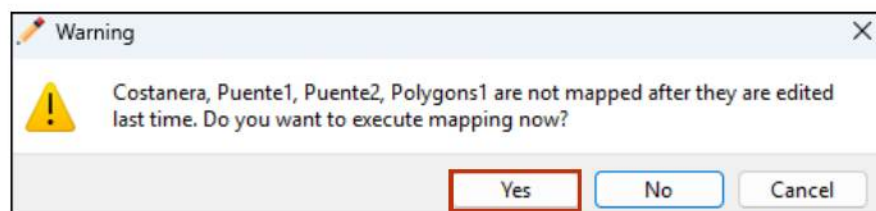


8.1.6.4. Ejecución de la simulación

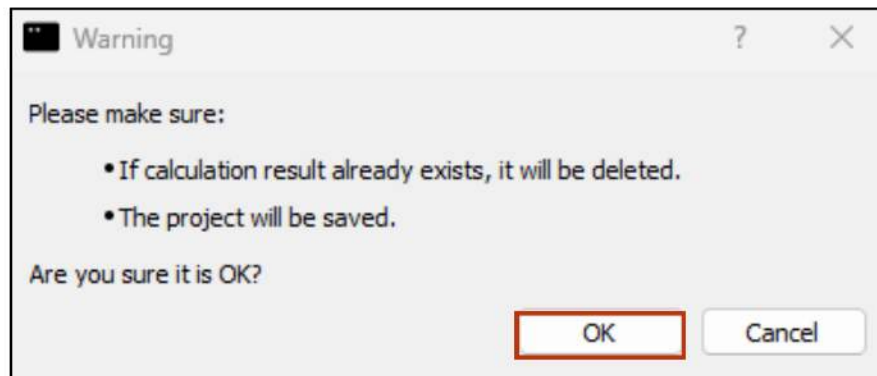
- En la barra de herramientas principal se hace clic en “Run” .



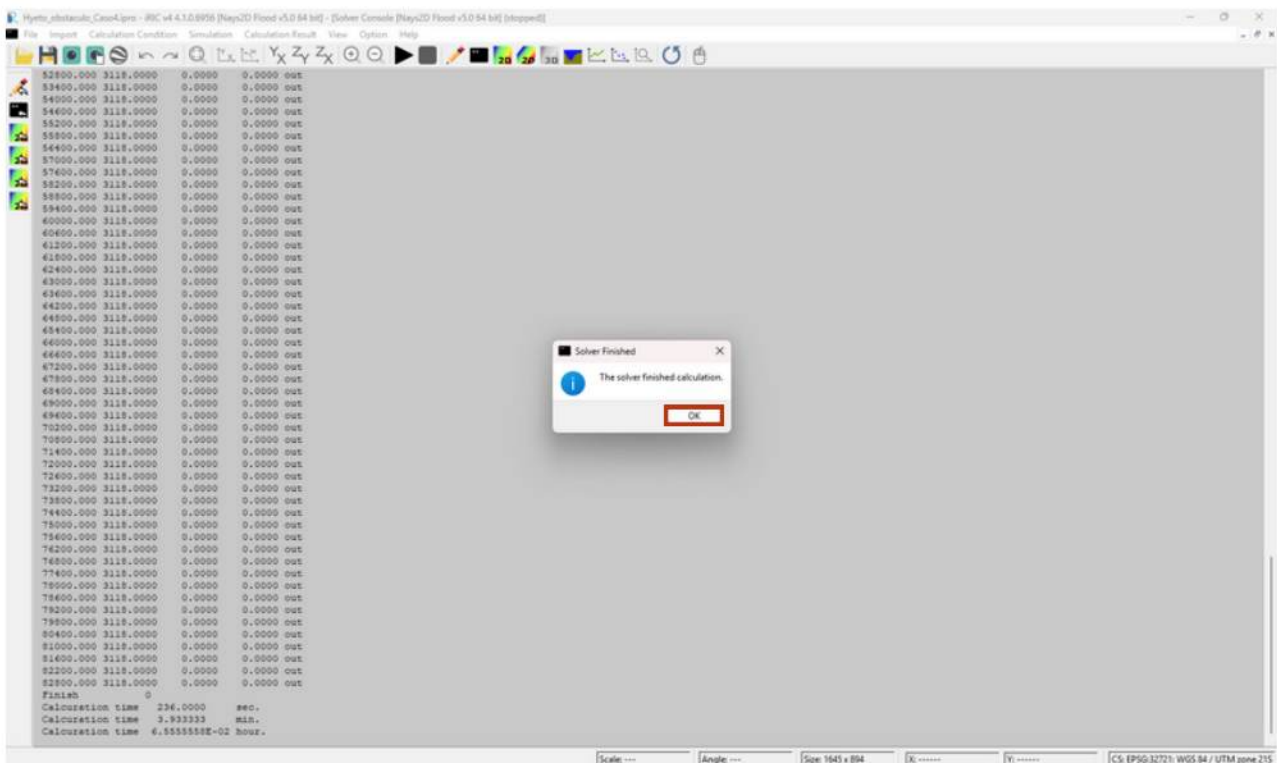
- En el caso de guardar actualizaciones aparecerán ventanas como esta, donde se le da clic en “Yes”.



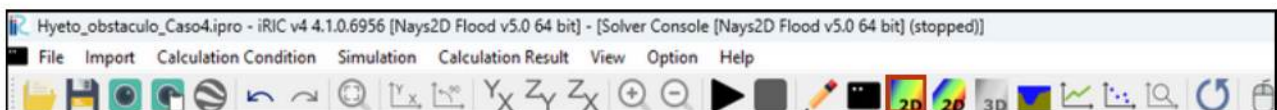
- Nuevamente se hace clic en “Run” . A continuación con “Ok”.



- Se aguarda a que termine de ejecutar la simulación y luego clic en “Ok” para finalizar.

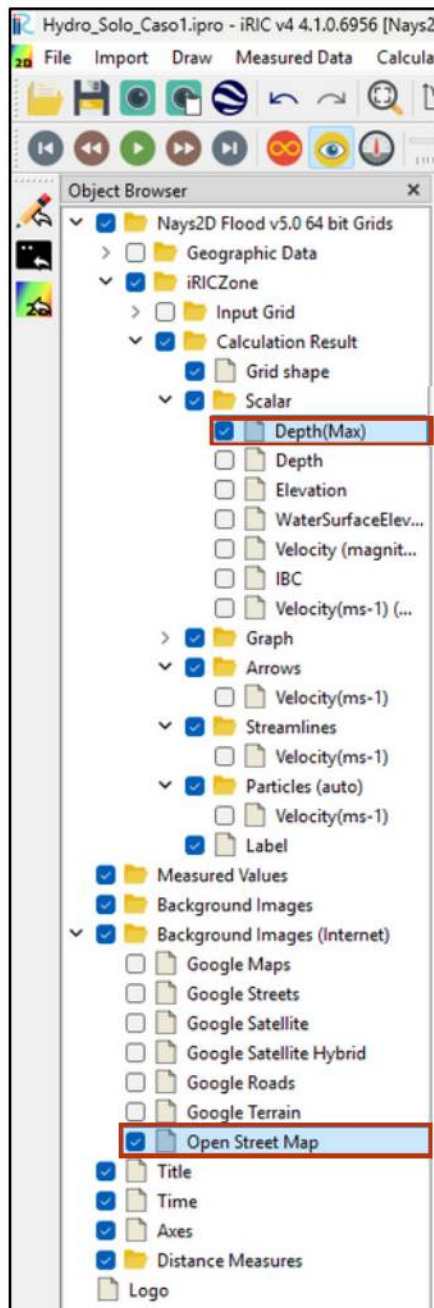


- Se abre la vista de Pos-Procesamiento en 2D.

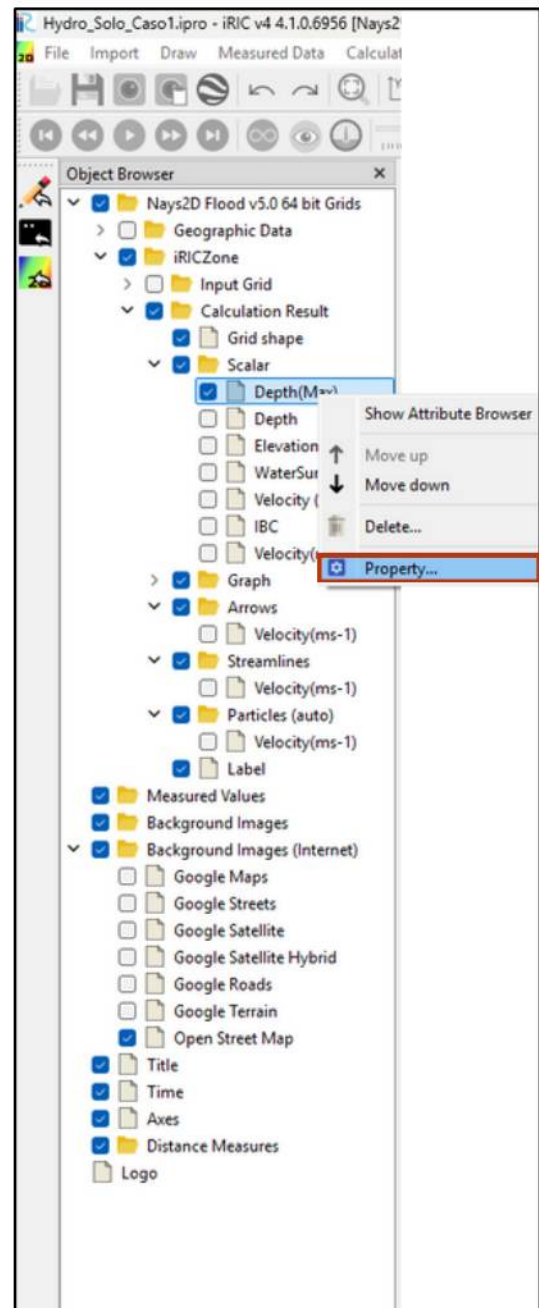


- Hay que asegurarse que activado el mapa base y Depth(MAX) en el panel de contenidos para poder visualizar la simulación.

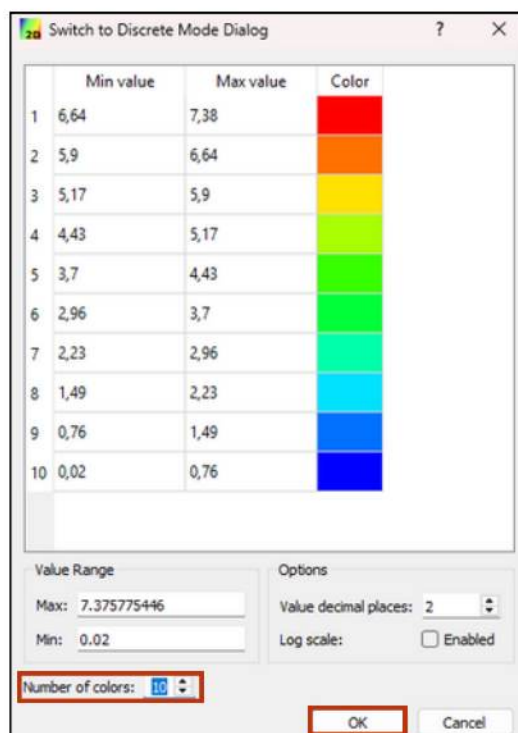
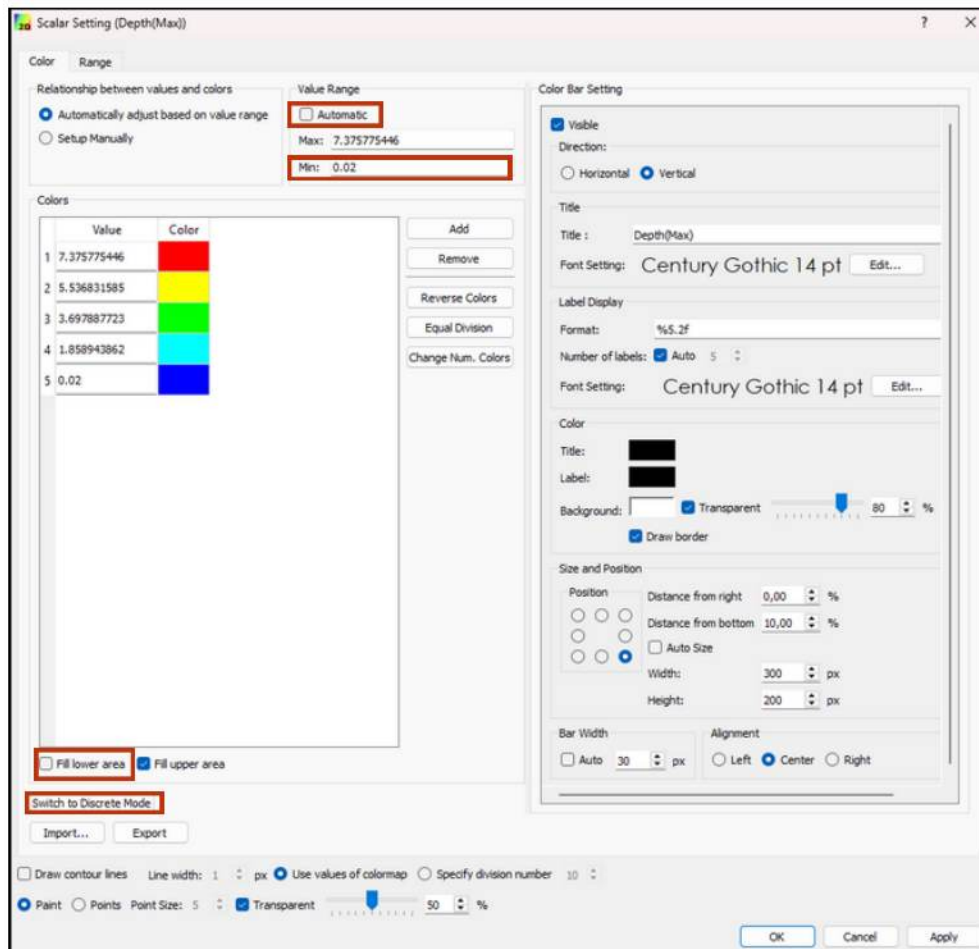
- Se activa nuevamente el mapa base Open Street Map en Background Images (Internet) y Depth(Max) en iRICZone> Calculation Result que se encuentran en la table de contenidos.



- Se realiza configuraciones finales para la visualización, a través de Depth (MAX) haciendo clic derecho, Property.

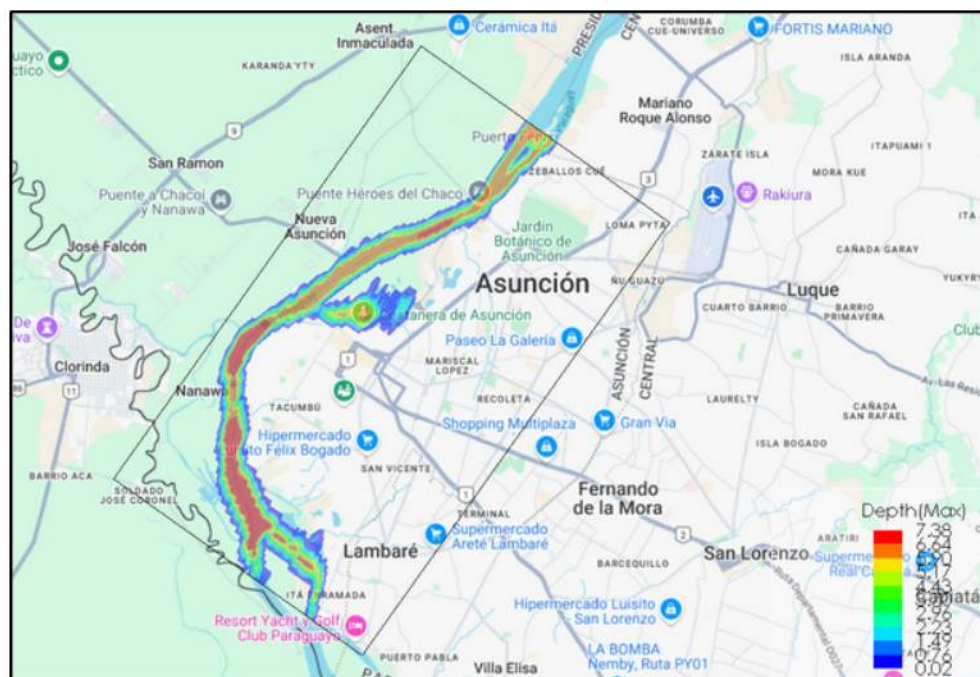


- Seguidamente se abre una pantalla emergente para realizar las siguientes configuraciones:
 - Modificar “Min” en “Value Range” a 0.02.
 - Desembarcar “Fill Lower area”.
 - Ingresar a “Swich to Discrete Mode”.



- En la ventana emergente de “Swich to Discrete Mode”, realizar:
 - Modificar “Value decimal places” a 2.
 - En “Number of colors” asignarle 10.
 - Confirmar los cambios con OK y nuevamente OK.

La imagen de la simulación se ve de la siguiente manera:



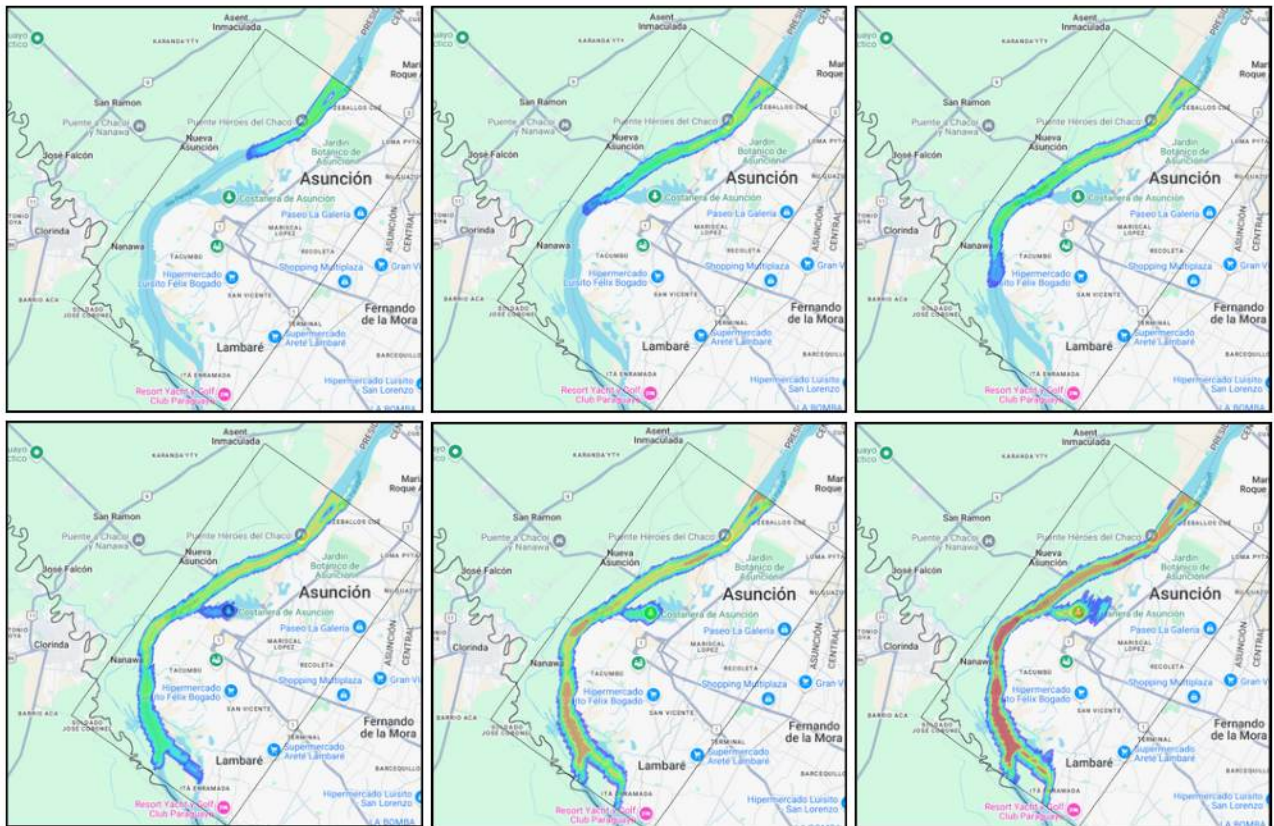
La imagen muestra un modelo de simulación de inundaciones aplicado a Asunción y el río Paraguay, con una superposición de datos sobre un mapa base. La escala de colores en la parte inferior derecha representa la profundidad del agua, donde los tonos rojos y naranjas indican las mayores acumulaciones, superando los 7 metros, mientras que las áreas en verde y azul reflejan niveles más bajos, entre 1 y 4 metros. Los tonos celeste y morado corresponden a zonas con poca o ninguna inundación.

El modelo sigue el cauce del río Paraguay, destacando la influencia de infraestructuras como la Avenida Costanera y el Puente Héroes del Chaco en la distribución del flujo de agua. Esta simulación es clave para el análisis de riesgos y la planificación de medidas de mitigación en áreas vulnerables a inundaciones.

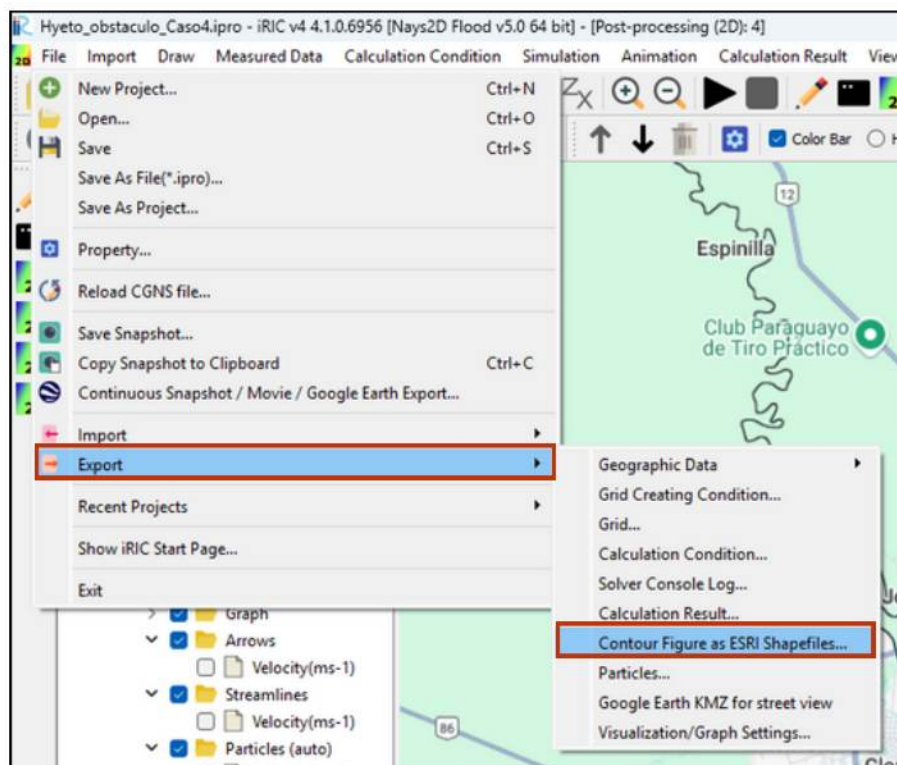
- Para visualizar el desarrollo de la inundación en la simulación, se accede a la barra de herramientas de operaciones, se ajusta el temporizador a 0 y luego "Play" para iniciar la reproducción del modelo.



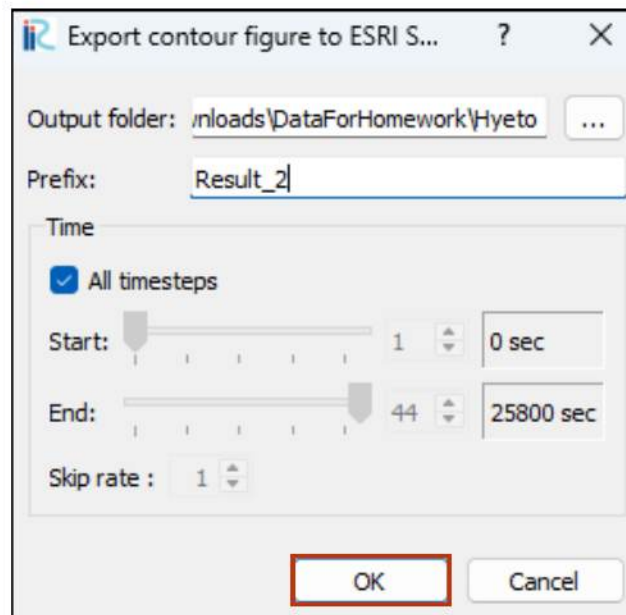
- De esta forma, se puede observar la evolución de la inundación a lo largo del tiempo dentro de la simulación, permitiendo analizar su comportamiento en diferentes momentos del proceso.



Según los resultados y las comparaciones, realizar ajustes en las condiciones de entrada, la malla o el modelo para mejorar la precisión de la simulación, si es necesario. Para representar la simulación en un mapa, se descarga en formato Shape (.shp).



Se define la carpeta de destino y un nombre al archivo, manteniendo los demás parámetros con los valores predeterminados. Luego, desde la carpeta de descarga, se selecciona el último archivo .shp para su procesamiento en ArcGIS.



8.2. Análisis Geoespacial del Modelo Hidráulico en ArcGIS Pro

En esta sección se presenta un paso a paso del procedimiento geoespacial que permite procesar y visualizar, en el software ArcGIS Pro, los resultados obtenidos en iRIC/Nays2D_Flood. Este análisis facilita la interpretación de la dinámica de la inundación en la zona de estudio y la generación de productos cartográficos que sirven como base para la toma de decisiones en gestión del riesgo y planificación territorial.

1. Exportación de resultados desde iRIC: se definen las carpetas de destino y se selecciona el archivo de salida en formato shapefile (.shp), el cual contiene la información sobre la profundidad del agua calculada en la simulación.
2. Carga y procesamiento en ArcGIS Pro: el shapefile generado se incorpora en el entorno SIG, aplicando simbología adecuada y escalas de color que permitan una representación clara y precisa de los valores de profundidad.
3. Generación de mapas temáticos: se elaboran mapas que muestran la distribución espacial de la inundación y la variación de la profundidad del agua. Estos productos pueden integrarse con otras capas geográficas, como redes viales, infraestructura crítica o áreas urbanas, para evaluar los impactos potenciales.
4. Identificación de áreas de riesgo: a partir del cruce de información, se delimitan las zonas más vulnerables a la inundación, lo que contribuye a la planificación urbana, la mitigación de desastres y la gestión sostenible del territorio.

Todas las figuras presentadas en esta sección fueron elaboradas en el software ArcGIS Pro, asegurando la coherencia entre los procedimientos descritos y los resultados cartográficos obtenidos.

Para el análisis espacial se utilizó el software de procesamiento ArcGIS Pro, aunque también es posible realizarlo mediante otros programas de acceso gratuito.

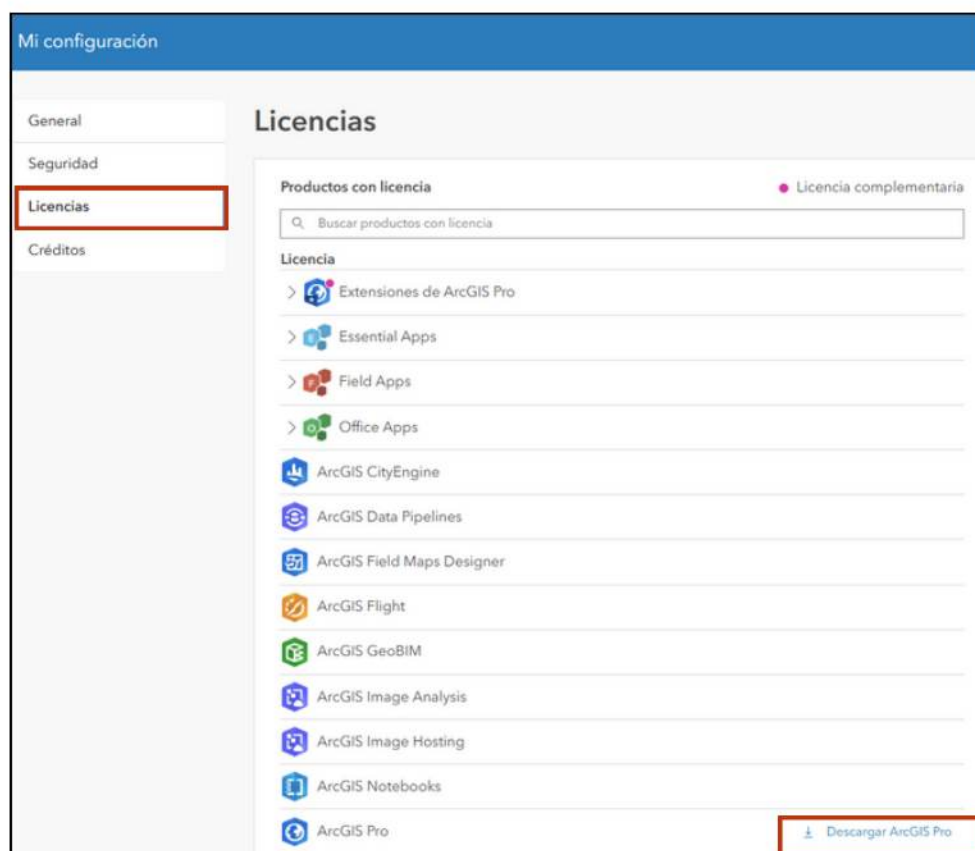
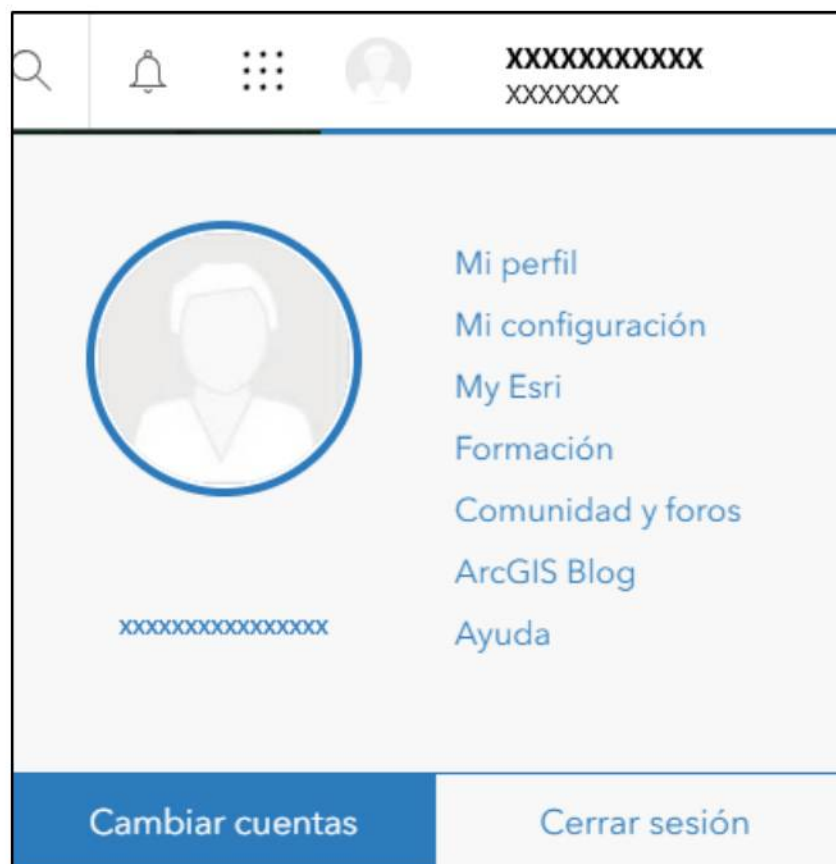
Para el acceso, ingresamos a la página oficial de ArcGis, mediante el siguiente enlace:
<https://www.arcgis.com/index.html>

Inicio sesión con una cuenta obtenida previamente.

8.2.1. Descarga del programa ArcGIS Pro

The image shows the ArcGIS login page. At the top, it says 'Iniciar sesión' next to the Esri logo. The main form is titled 'Inicio de sesión de ArcGIS'. It contains a username field with 'XXXXXXXX' and a password field with masked characters. Below the password field is a checkbox labeled 'No cerrar sesión'. A blue button labeled 'Iniciar sesión' is positioned below the checkbox. Underneath the button are two links: '¿Has olvidado el nombre de usuario?' and '¿Olvidaste la contraseña?'. Below these links is a dropdown menu labeled 'La URL de su organización de ArcGIS'. At the bottom of the form, there are four social media icons (GitHub, Facebook, Google, and YouTube) and a link '¿No tiene cuenta? Crear una cuenta'. A 'Privacidad' link is located at the very bottom right of the form.

Para realizar la descarga, el usuario debe ingresar a su perfil y dirigirse a la sección "Mi Configuración". Desde allí, podrá acceder a las opciones disponibles para la descarga del archivo requerido.



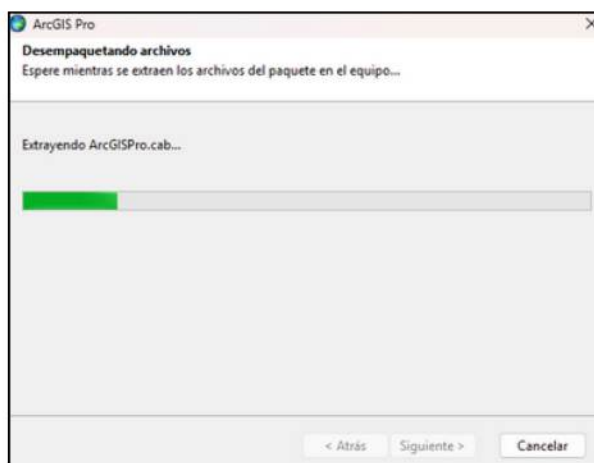
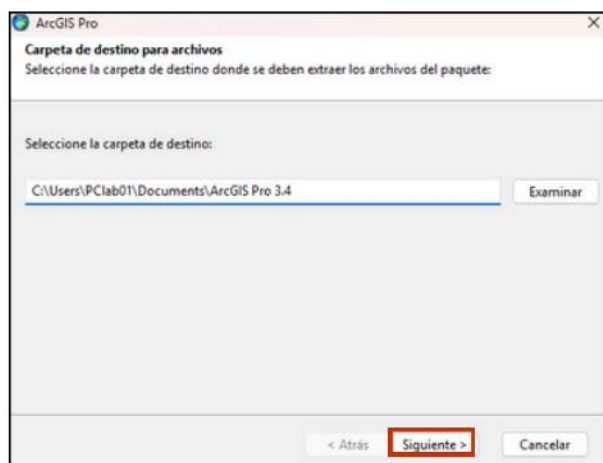
Se inicia la descarga.



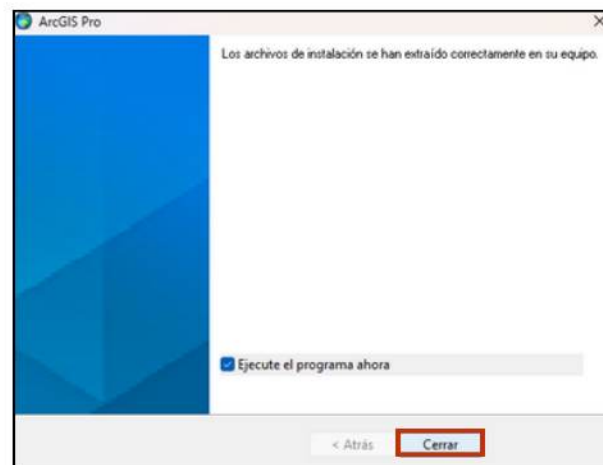
Se espera a que termine la descarga.



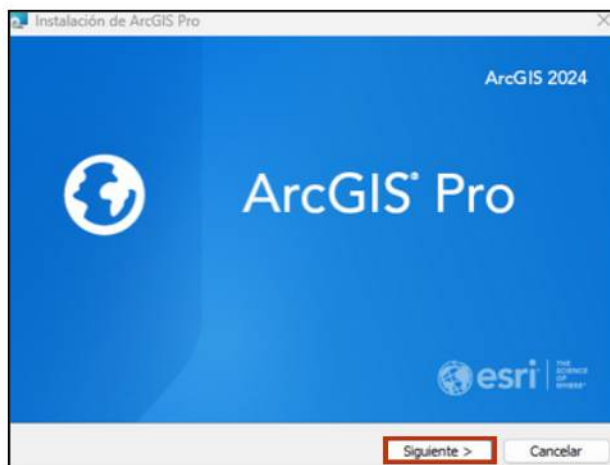
Una vez finalizada la descarga, se ejecuta el archivo para su instalación. Al ejecutarlo, se define la carpeta que contendrá el programa.



Se selecciona "Cerrar" para ejecutar el programa, asegurándose de que la opción "Ejecute el programa ahora" esté marcada.



"Siguiente" para continuar con la instalación.



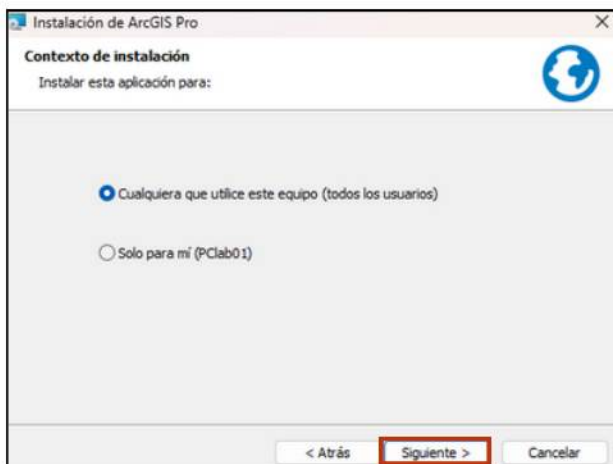
Nuevamente siguiente.



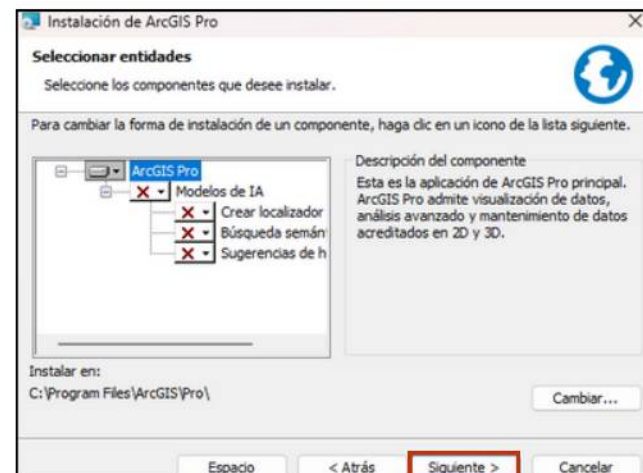
Se aceptan los términos del contrato y se procede haciendo clic en el botón "Siguiente".



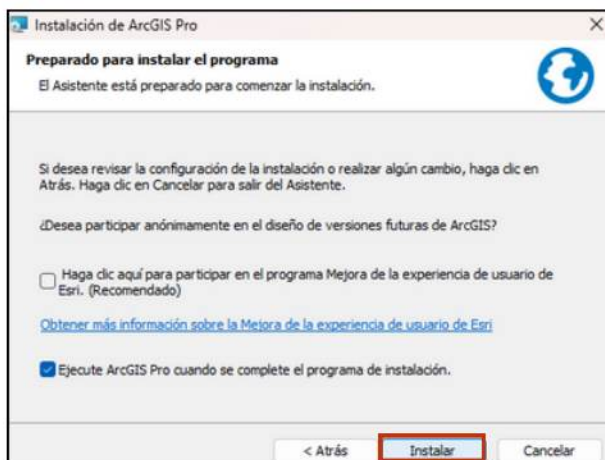
Se selecciona la preferencia de usuarios y luego se hace clic en "Siguiente".



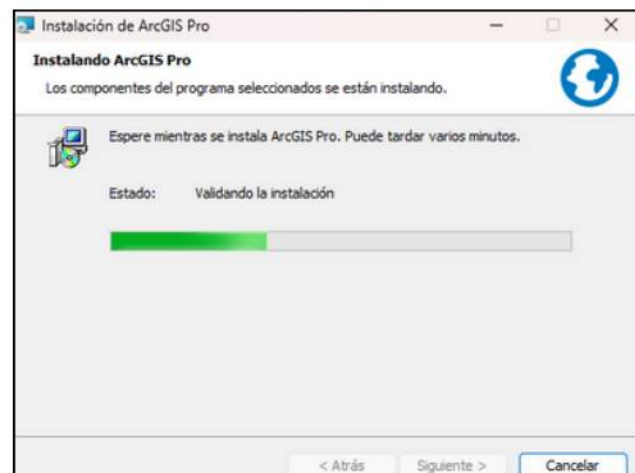
Nuevamente siguiente.



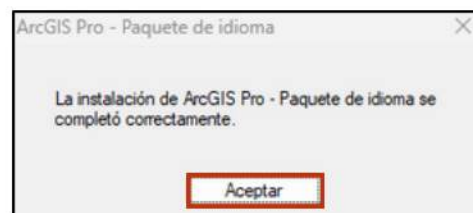
Se prosigue con la instalación haciendo clic en "Instalar".



Se espera a que termine el proceso de instalación.



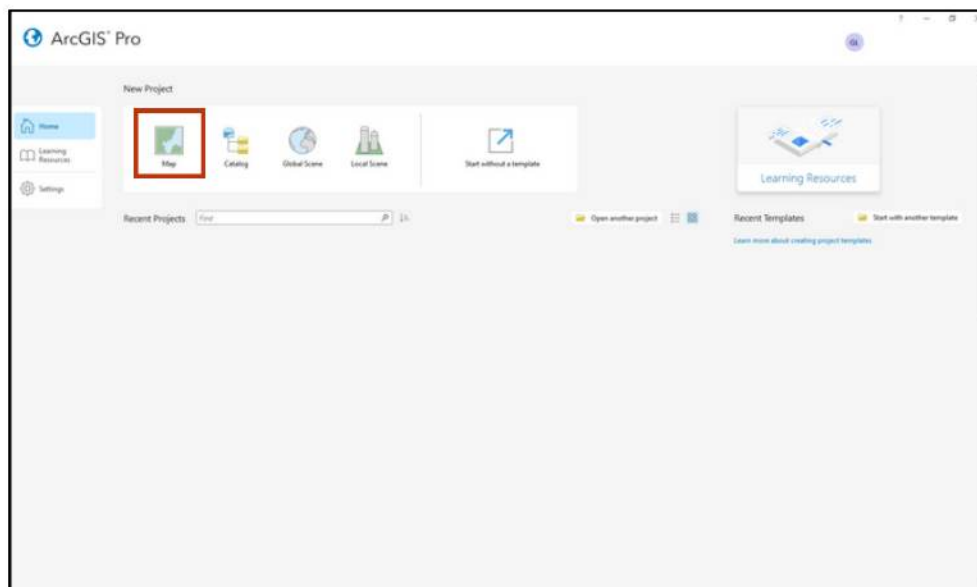
Se finaliza la instalación.



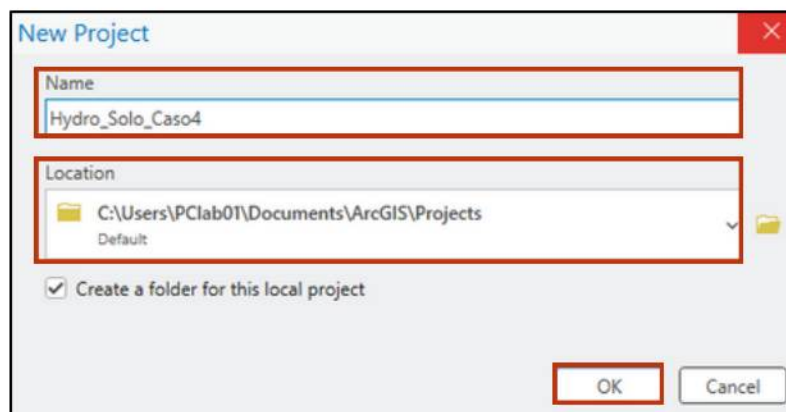
8.2.2. Creación del Proyecto

8.2.2.1. Iniciar proyecto

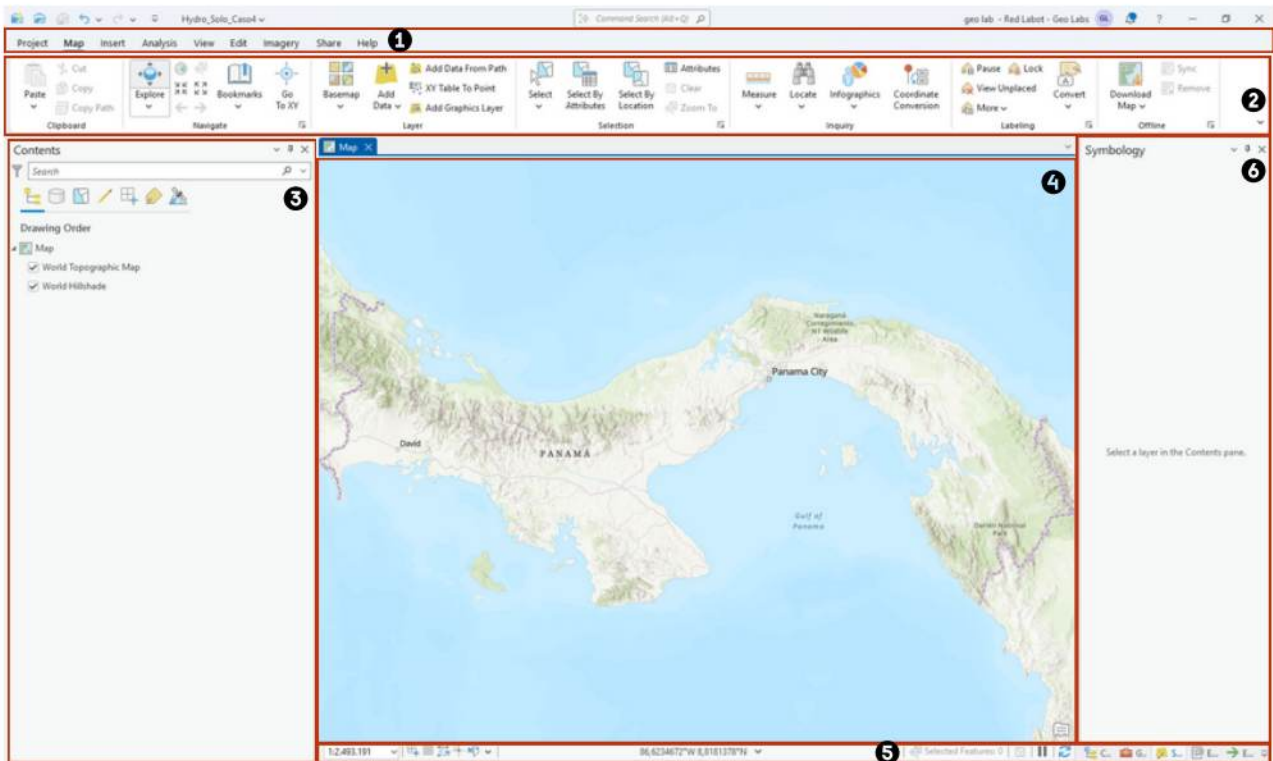
- En la primera pantalla del programa ArcGIS, se inicia el proyecto desde "MAP".



- Se define la carpeta donde se guardará el proyecto, así como el nombre del mismo.



- Ventana Principal de ArcGIS Pro.

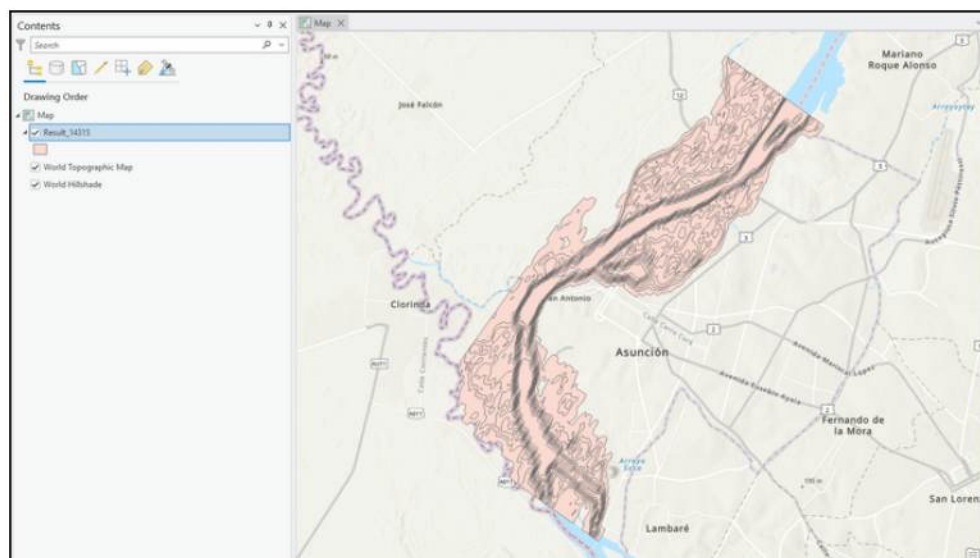


- 1- Barra de Menú.
- 2- Barra de Herramientas Estándar.
- 3- Tabla de Contenidos.
- 4- Ventana de Visualización del Mapa.
- 5- Barra de Estado.
- 6- Área de apertura de Paneles y herramienta importantes.

8.2.3. Configuración de Visualización

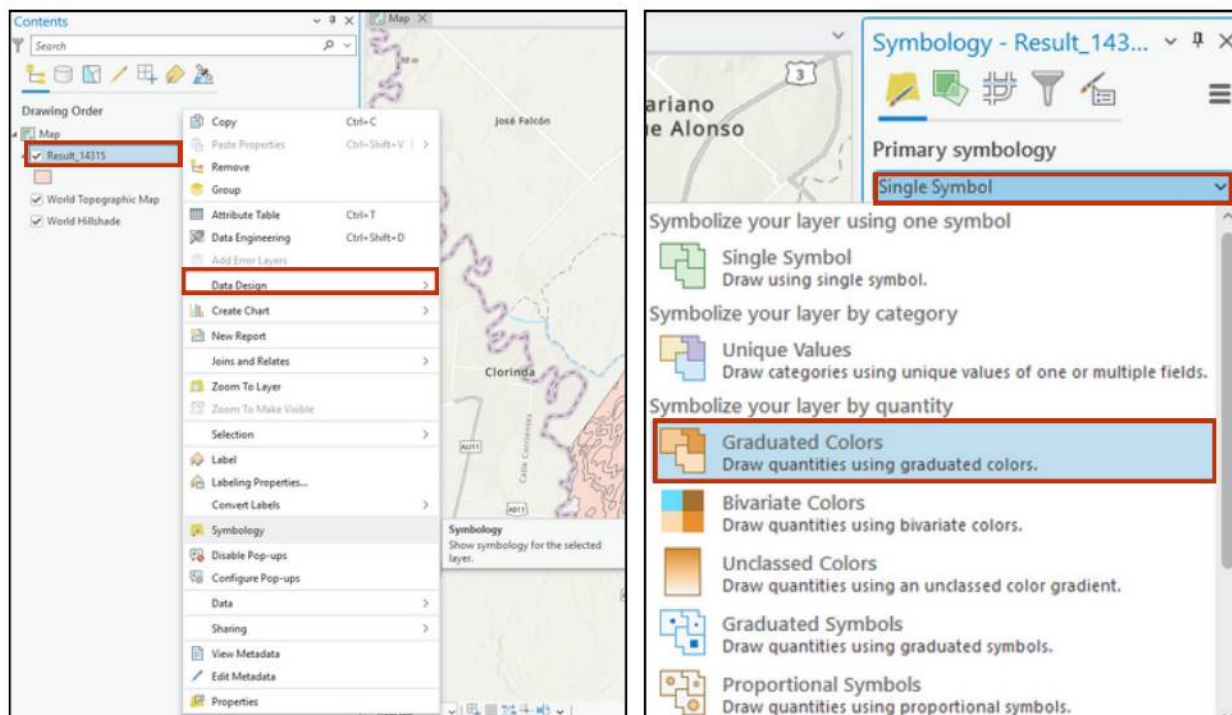
8.2.3.1. Carga del archivo

Nos dirigimos a la carpeta donde descargamos el .shp de iRIC y arrastramos hacia nuestro proyecto, específicamente a la tabla de contenidos encima de "MAP"

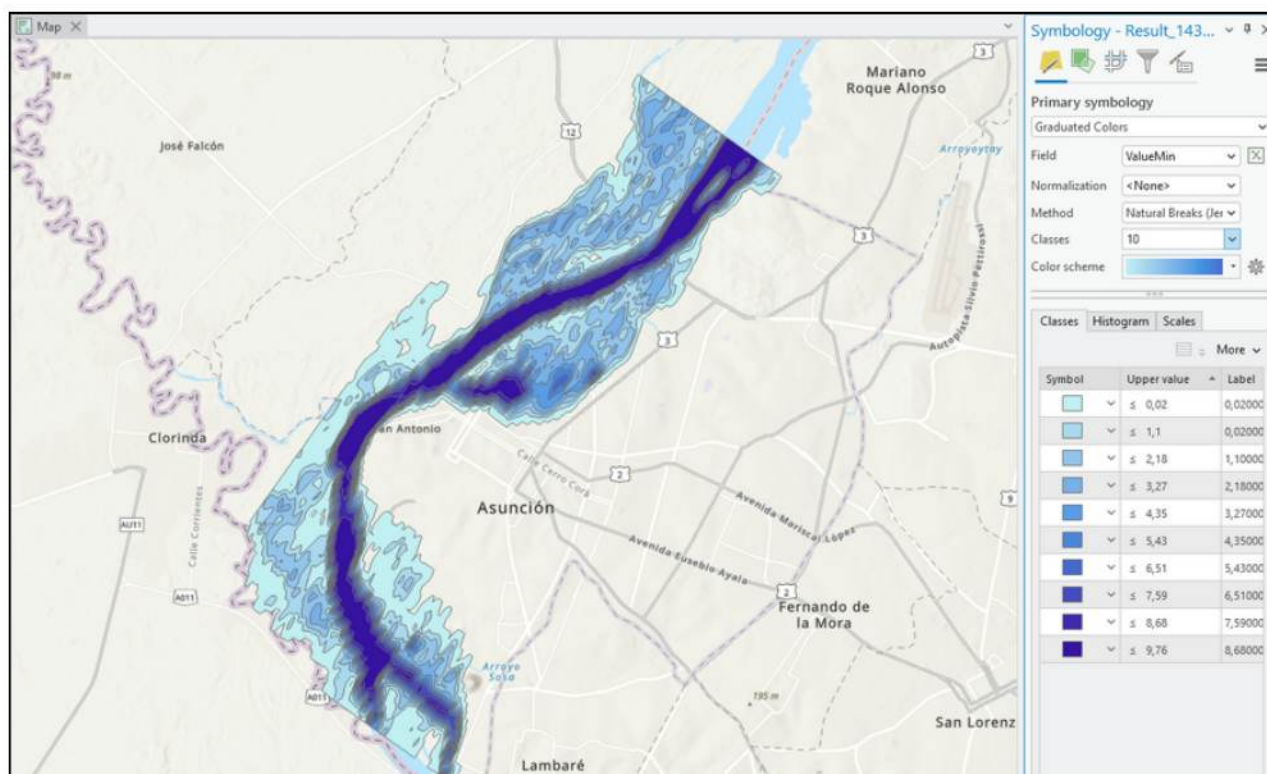


8.2.3.2. Cambio de simbología

Modificamos la simbología haciendo clic derecho y seleccionando "Symbology". Luego, en la opción "Single Symbol", elegimos "Graduated Colors", lo que permite asignar una escala de colores graduados acorde a los valores del archivo, facilitando su interpretación visual. dando clic derecho y "Symbology".

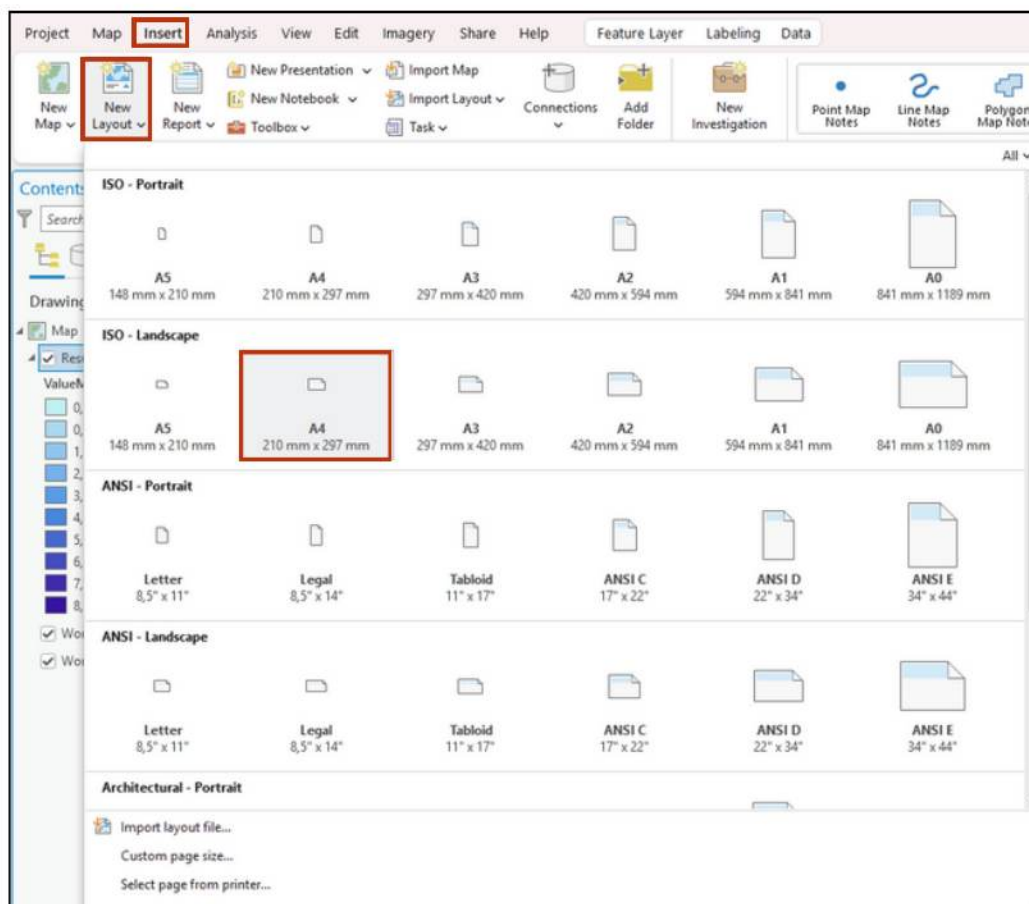


Se ajusta el número de clases a 10, manteniéndolo consistente con la escala utilizada en iRIC. Además, según la preferencia del usuario, es posible modificar el "**Color Scheme**" para mejorar la visualización de los datos.

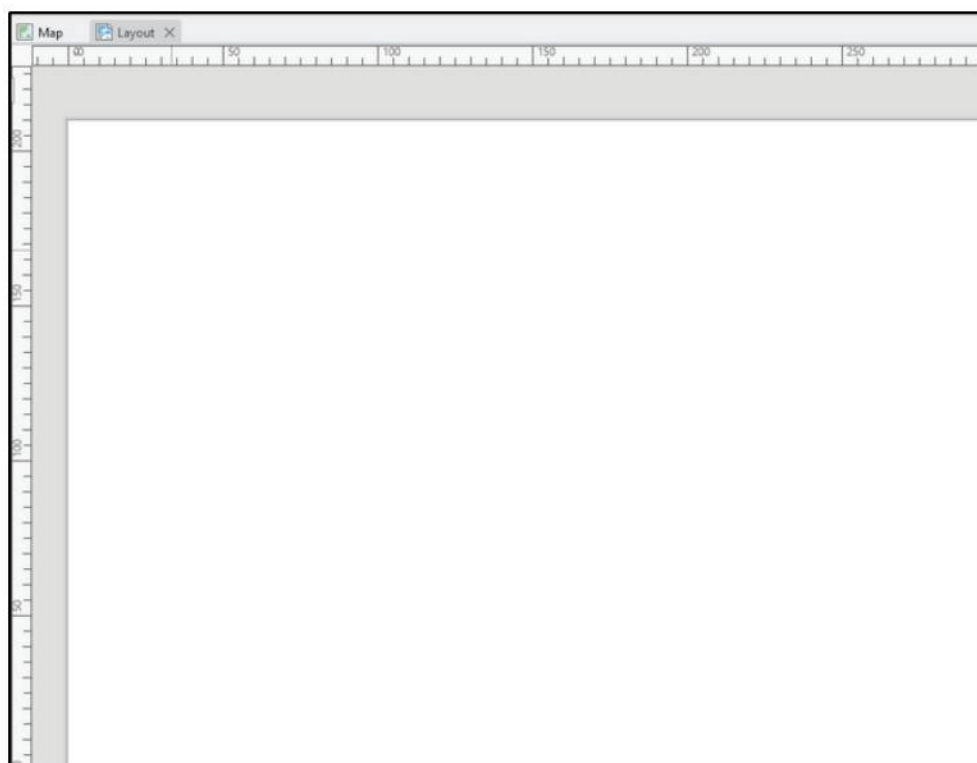


8.2.4. Diseño y configuración del Mapa Final

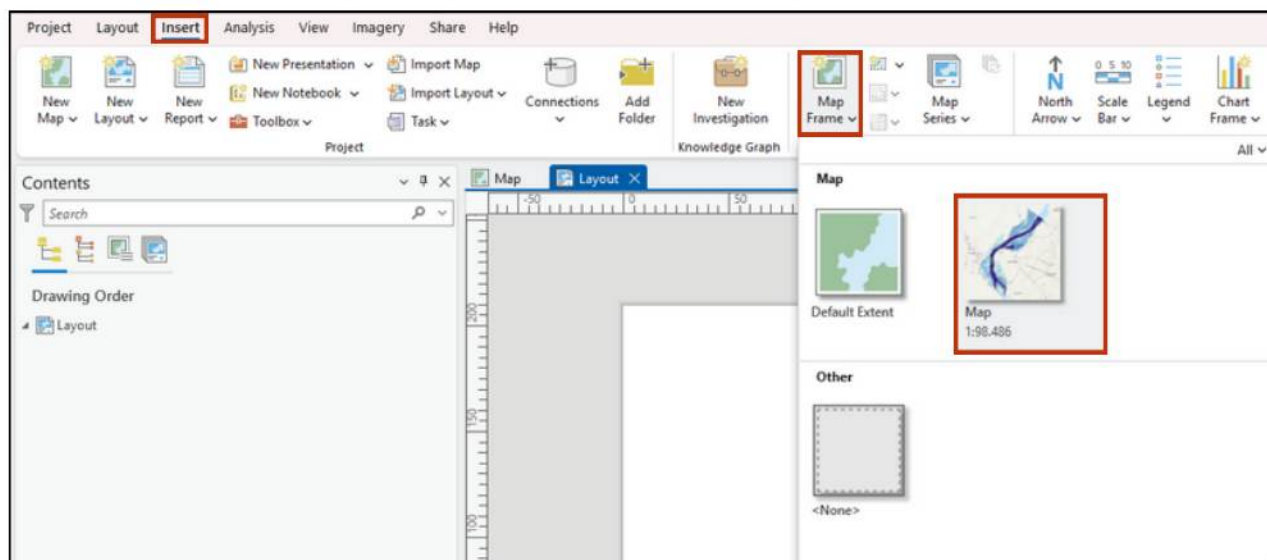
8.2.4.1. Creación del Layout desde la barra de Menús en la pestaña "Insert".



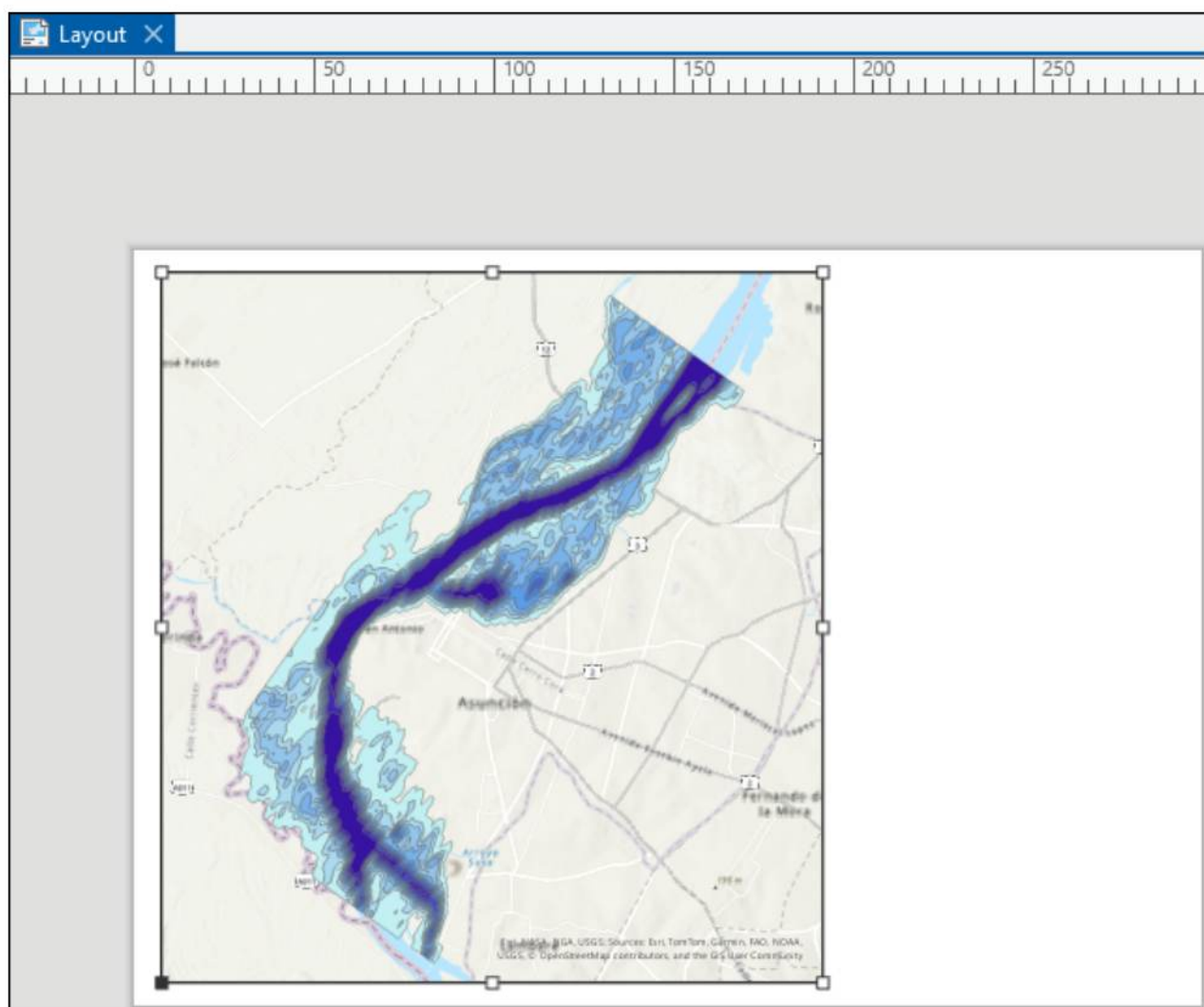
Se abrirá una nueva pestaña con el nombre "Layout" en la ventana de visualización del mapa.



8.2.4.2. Inserción del mapa configurado desde Insert > Map Frame



Definimos el área donde se visualizará el mapa haciendo clic, arrastrando para ajustar el tamaño y soltando para finalizar la inserción.



9. REFERENCIAS

Avila, J. (2022). Procedimiento para la determinación y realización de Hietograma. Universida Santo Tomás -Tunja. <https://repository.usta.edu.co/bitstream/handle/11634/47499/2022avilajuan.pdf>

Aliaga, B. (2016). Los mapas de riesgo. Publicaciones Didácticas. https://core.ac.uk/outputs/235859122/?utm_source=pdf&utm_medium=banner&utm_campaign=pdf-decoration-v1

Arana, I. (2014). Orientaciones para la zonificación del riesgo climático. HELVETAS Swiss Intercooperation. <https://cebem.org/wp-content/uploads/2014/12/3-15-orientacionesh1.pdf>

Chuvieco, E. (1995). Fundamentos de Teledetección Espacial (2ª ed.). Ediciones Rialp, S.A. <http://cursosihlla.bdh.org.ar/Sist.%20Cart.%20y%20Teledet./Bibliografia/FUNDAMENTOS-DE-TELEDETECCION-EMILIO-CHUVIECO.pdf>

Chuvieco, E. (2008). Teledetección Ambiental (3ª ed.). SlideShare. <https://es.slideshare.net/slideshow/teledeteccion-ambiental-lista/12971570>

de San Antonio, J. Fernández, C. Fernández, S. (2004). Caracterización de Amenazas Geológicas en la Ladera Sur - Occidental del Volcán Chaparrastique. Geologos del Mundo. <https://www.xeologosdelmundu.org/wp-content/uploads/2015/01/Volcan-Chaparrastique-2005.pdf>

Environmental Systems Research Institute, Inc. (2022). Educando con SIG. <https://community.esri.com/ccqpr47374/attachments/ccqpr47374/educando-con-sigtkb-board/14/6/Flujos%20de%20trabajo%20ArcGIS%20Pro.pdf>

Environmental Systems Research Institute, Inc. (2025). Imágenes de satélite. <https://support.esri.com/es-es/gis-dictionary/satellite-imagery>.

Ferrando, A; Francisco, J. (2003). En torno a los desastres “naturales”: Tipología, conceptos y reflexiones. <https://www.redalyc.org/pdf/258/25804703.pdf>

Goodchild, M. Haining, R. (2005). SIG y análisis espacial de datos: perspectivas convergentes. Investigaciones Regionales, núm. 6, 175-201. <https://www.redalyc.org/pdf/289/28900609.pdf>

Hezer, H. Rodriguez, C. Celis, A, Bartolomé, M. Caputo, G. (2002). Convivir con el riesgo o la gestión del riesgo. <https://es.scribd.com/document/581600433/Convivir-con-el-riesgo>

Intergovernmental Panel on Climate Change (IPCC). (2009). Glosario. En Planton, S. (ed.) https://www.ipcc.ch/site/assets/uploads/2018/08/WGI_AR5_glossary_ES.pdf

Ihobe. (2022). Inundación Pluvial Asociada a eventos extremos de precipitación en escenarios de Cambio Climático en Euskadi. https://adaptecca.es/sites/default/files/documentos/inplu_es_170123_2_1.pdf

International Centre for Water Hazard and Risk Management under the auspices of UNESCO (ICHARM). sf. RRI model. https://www.pwri.go.jp/icharm/research/rri/rri_top.html?form=MGOAV3

International River Interface Cooperative (iRIC). (sf.). About iRIC. <https://i-ric.org/en/about/>

Ormeño, S. (2006). Teledetección Fundamental. Escuela Técnica Superior de Ingenieros en Topografía, Geodesia y Cartografía. Departamento de Ingeniería Topográfica y Cartografía. Universidad Politécnica de Madrid. <https://oa.upm.es/82765/1/FundamentosTeledeteccion.pdf>

Renda, E. (2017). Manual para la elaboración de mapas de riesgos. PNUD. https://www.argentina.gob.ar/sites/default/files/manual_para_la_elaboracion_de_mapas_de_riesgo.pdf

Raffino, E. (2021). Peligro. Enciclopedia Concepto. <https://concepto.de/peligro/>.

Subramanya, K. (2013). Engineering Hydrology (4^a ed.). McGraw Hill. <http://103.203.175.90:81/fdScript/RootOfEBooks/E%20Book%20Collection%202021/CED/Hydrology%20By%20K.%20SUBRAMANYA.pdf>

United Nations International Strategy for Disaster Reduction (UNISDR). (2009). Terminología sobre Reducción del Riesgo de Desastres. https://www.unisdr.org/files/7817_UNISDRTerminologySpanish.pdf

United Nations. (sf.). Aplicación de datos del mes: Inundaciones Fluviales. <https://www.un-spider.org/es/links-and-resources/data-sources/daotm-river-floods>

U.S. Army Corps of Engineers. (2016). HEC-RAS river analysis system: 2D modeling user's manual (Version 5.0). Hydrologic Engineering Center. <https://www.hec.usace.army.mil/software/hec-ras>

Van Humboldt, A. (2006). Los sistemas de información geográfica. *Geoenseñanza*. 11(1). <https://www.redalyc.org/pdf/360/36012424010.pdf>

MANUAL METODOLÓGICO DE **MANEJO DE DESASTRES**