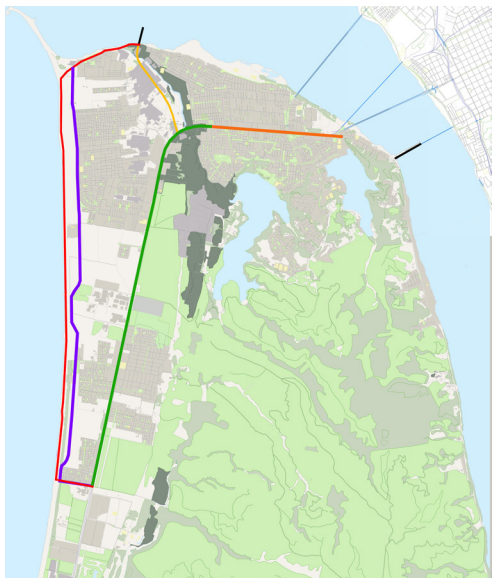
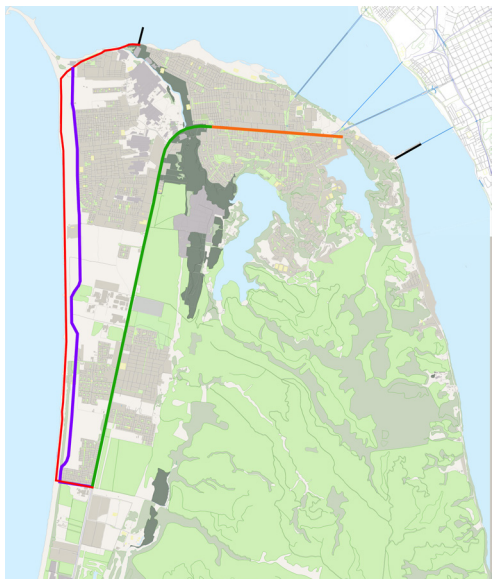
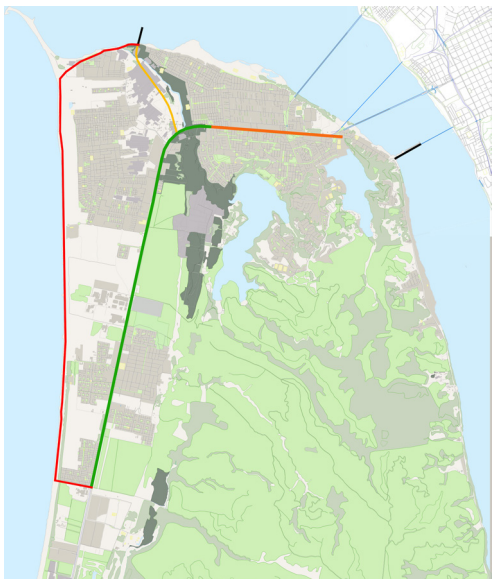
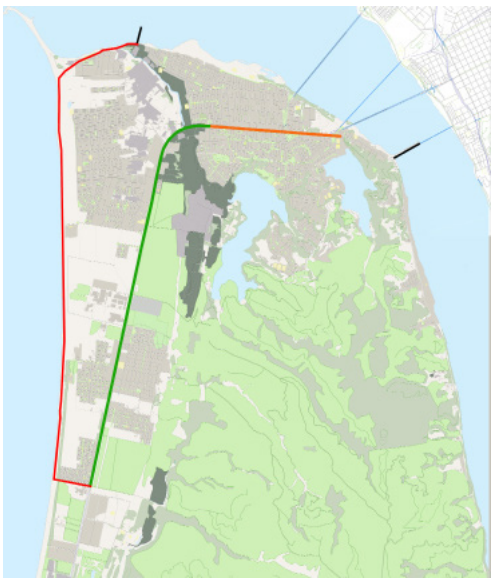
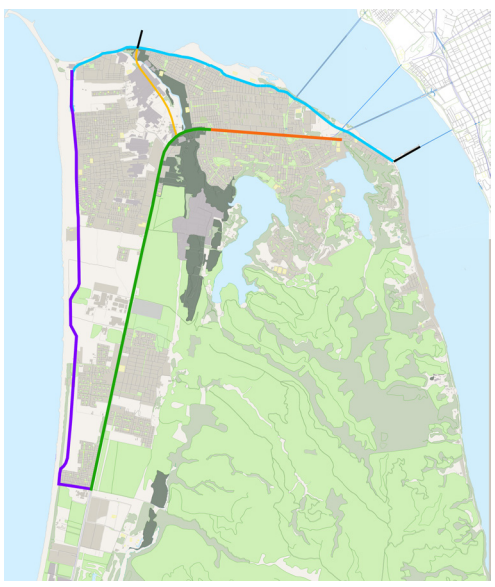
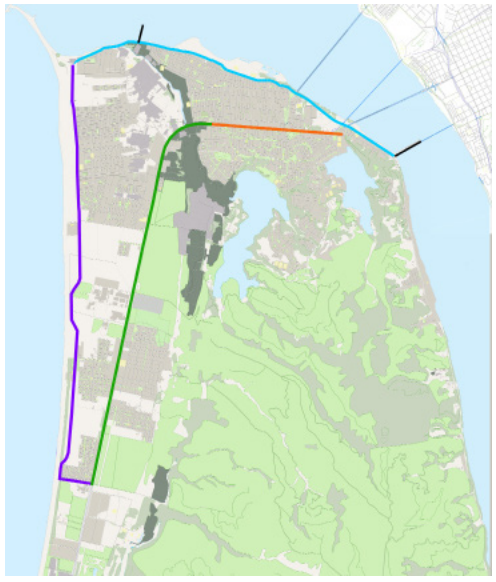
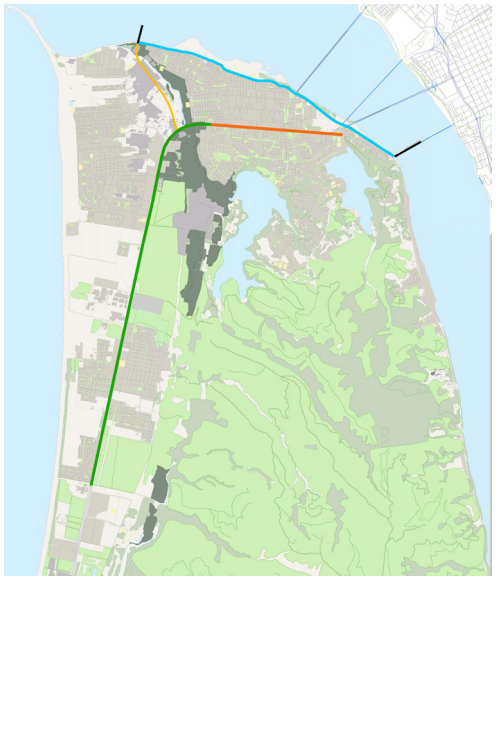
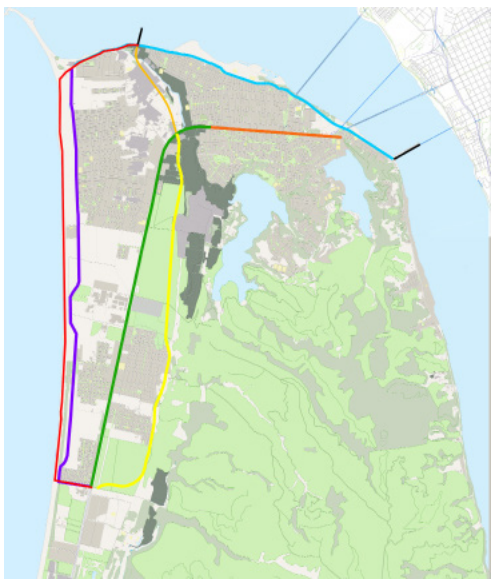
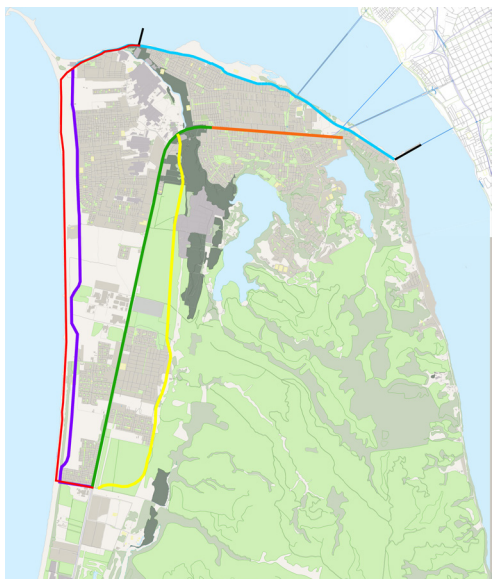
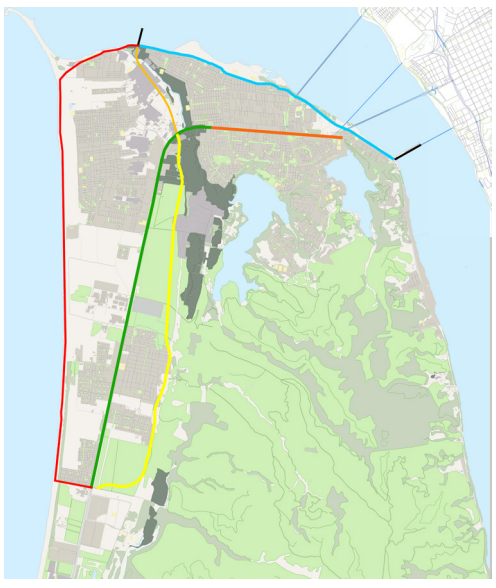
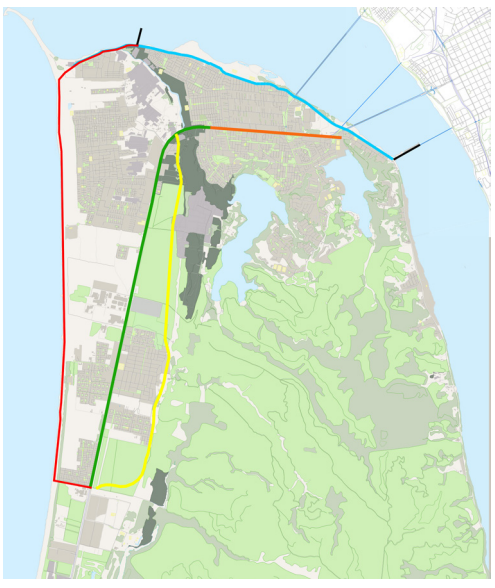
Appendix

I-A

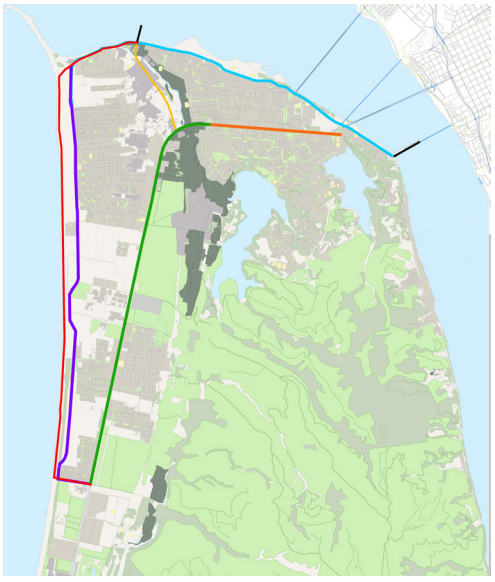
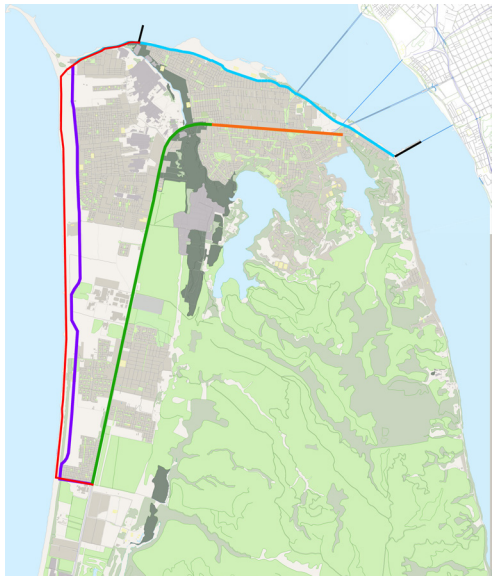
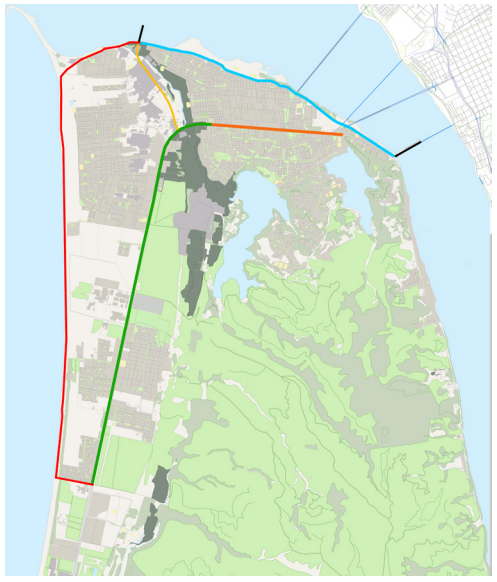
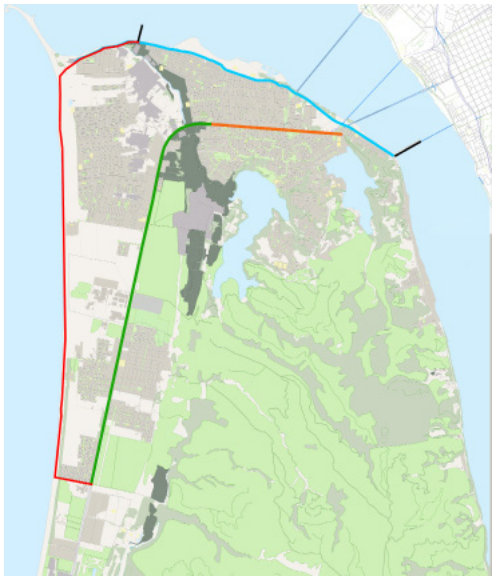
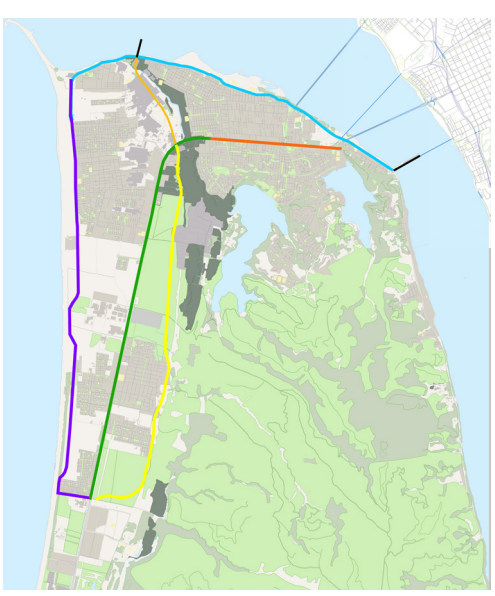
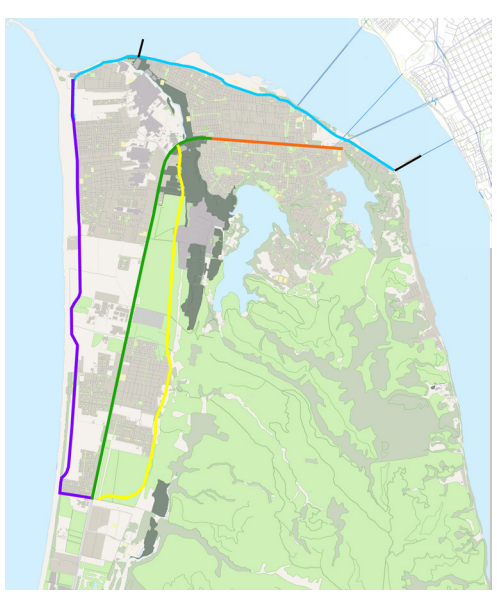
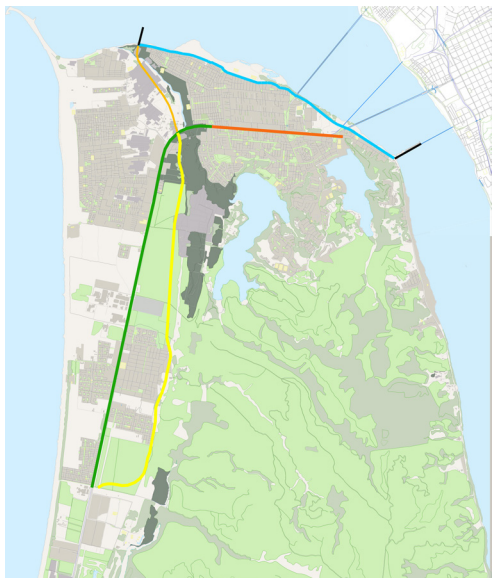
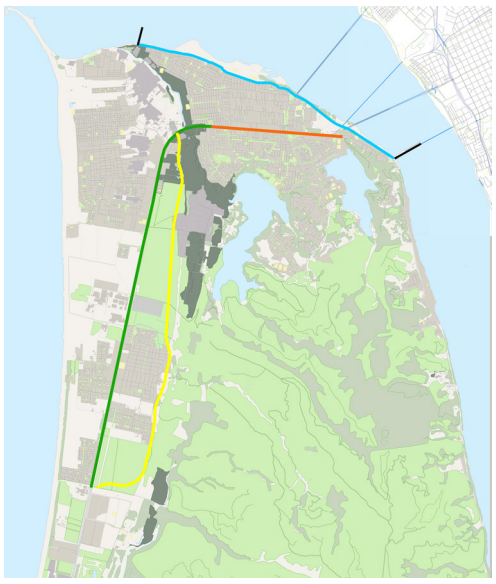
Step by step decision making process for eliminating variants

Step 1: 30 Variants [1/2]

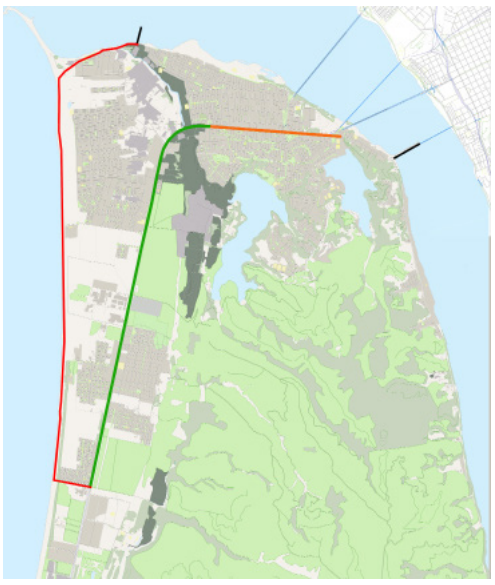








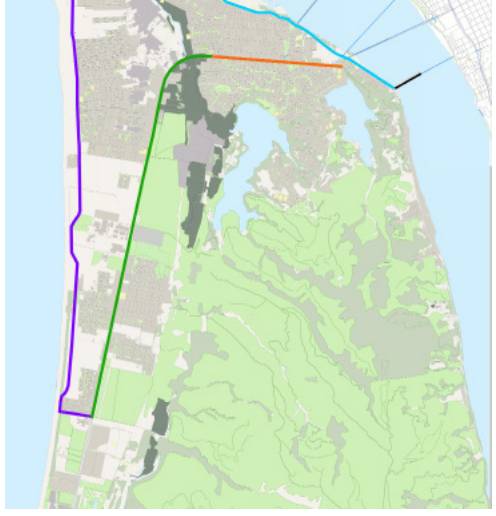
Step 1: 30 Variants [2/2]

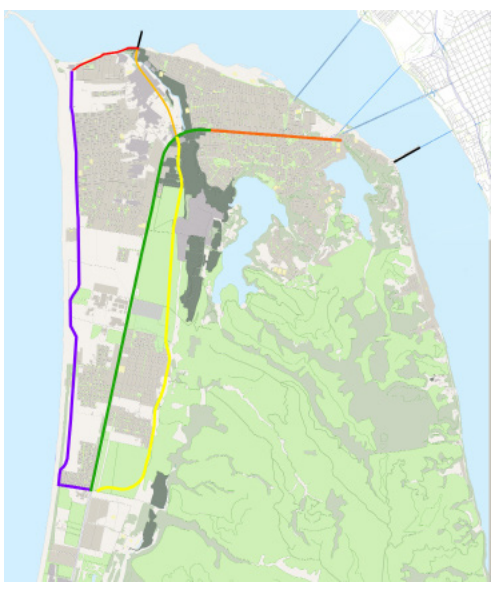









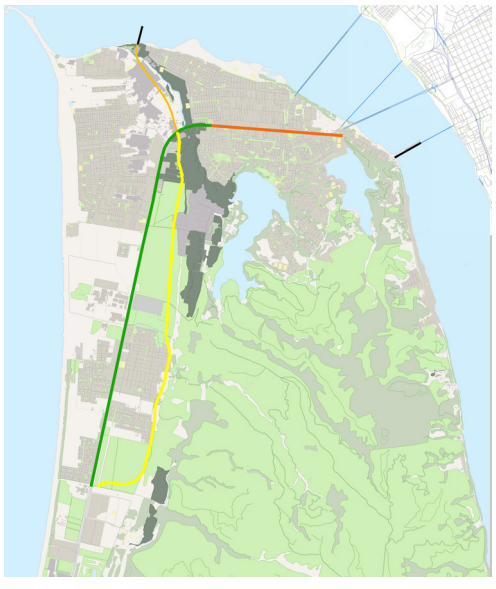
Step 2: 11 Remaining variants [1/2]

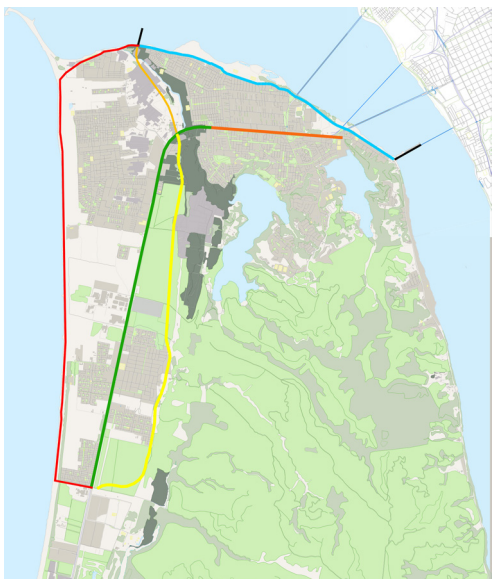


XX





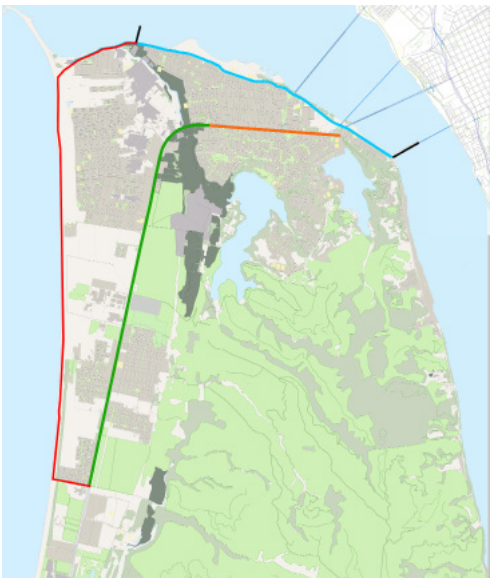
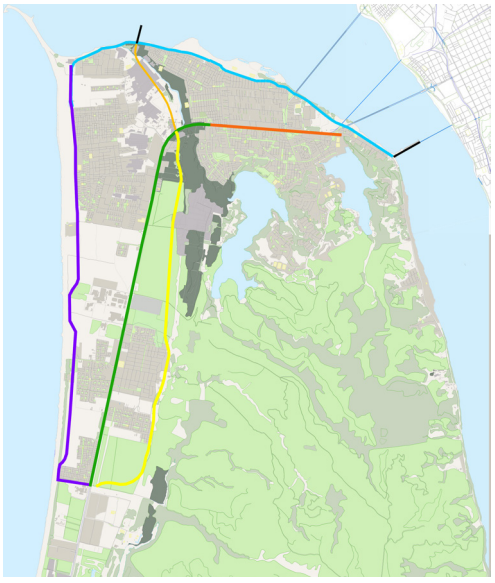


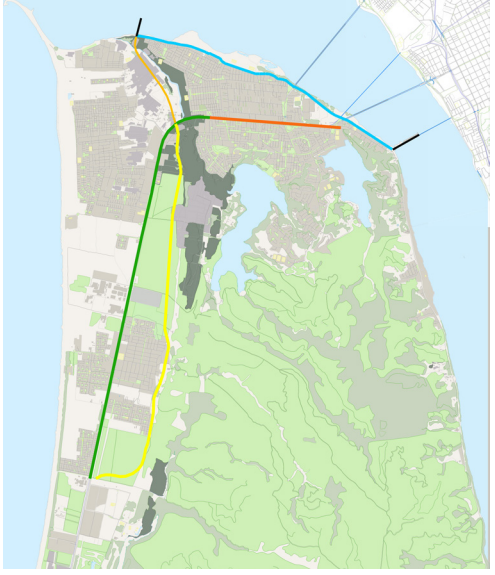


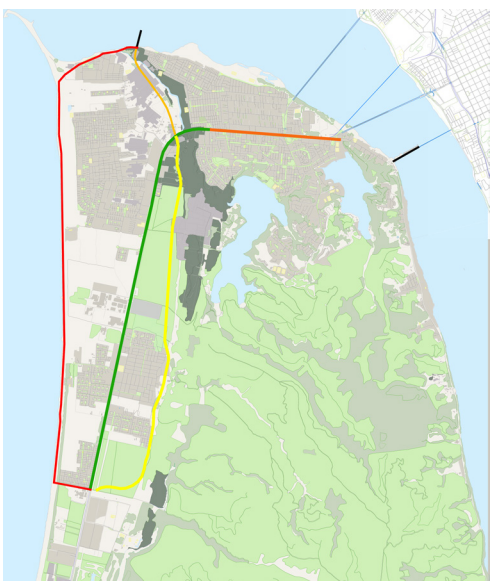
IV

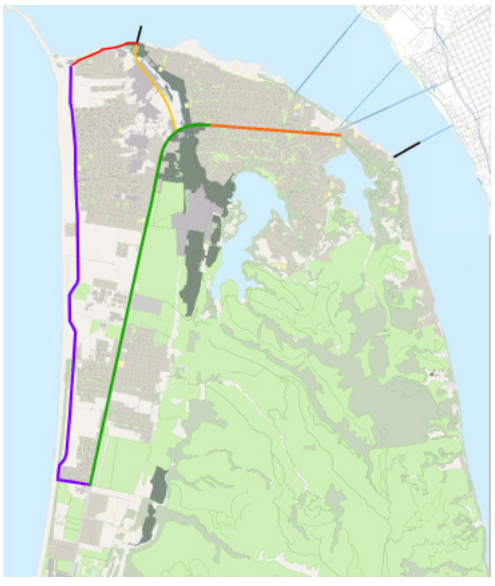
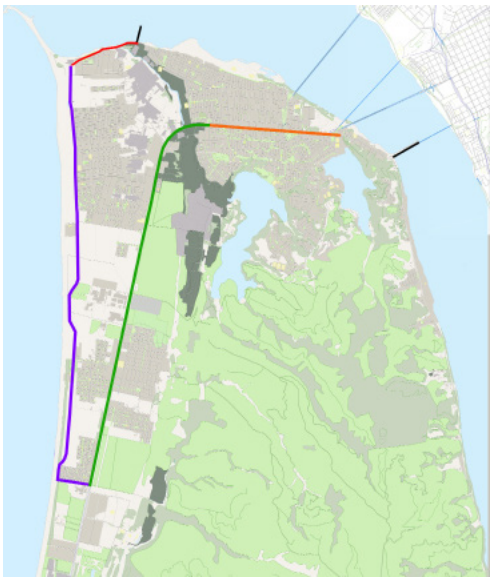
Step 2: 11 Remaining variants [2/2]

XVII

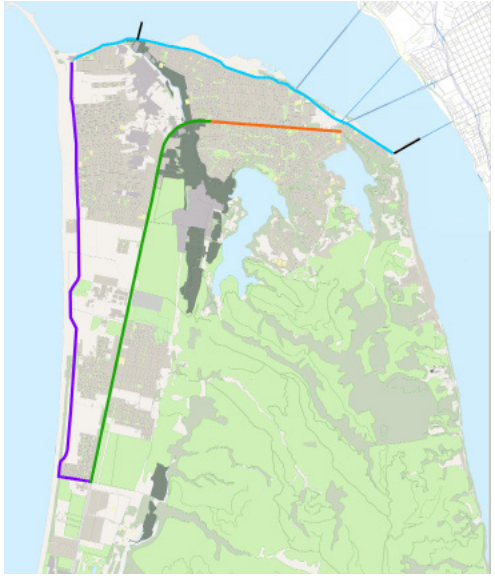



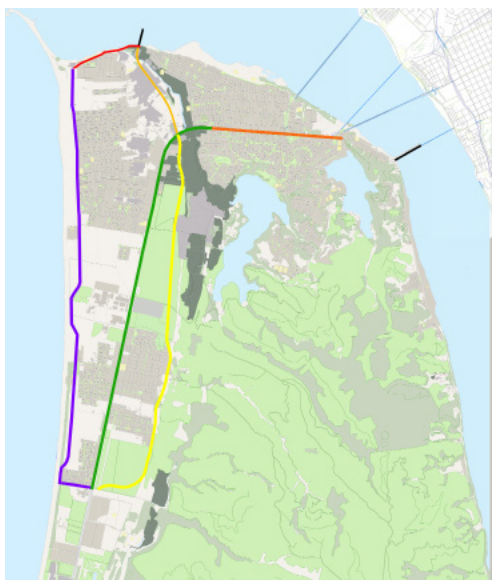




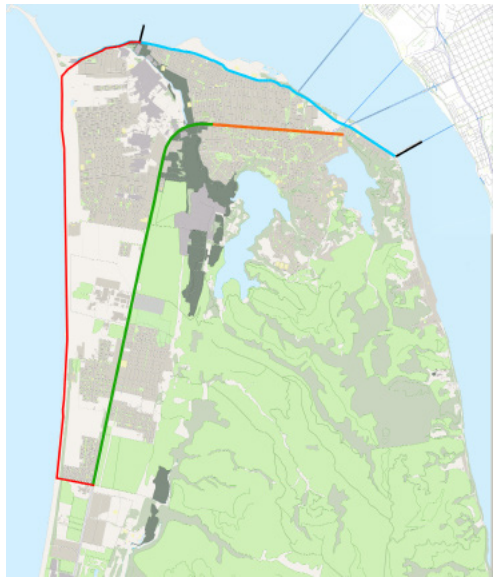



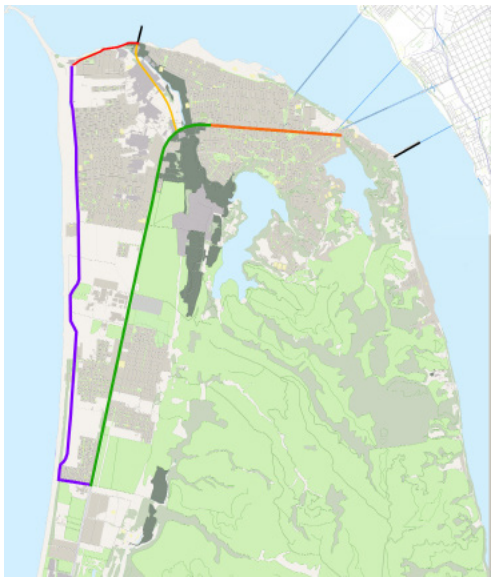
Step 3: Five final variants [1/2]





Step 3: Five final variants [2/2]





II-A

Discharges in Los Batros

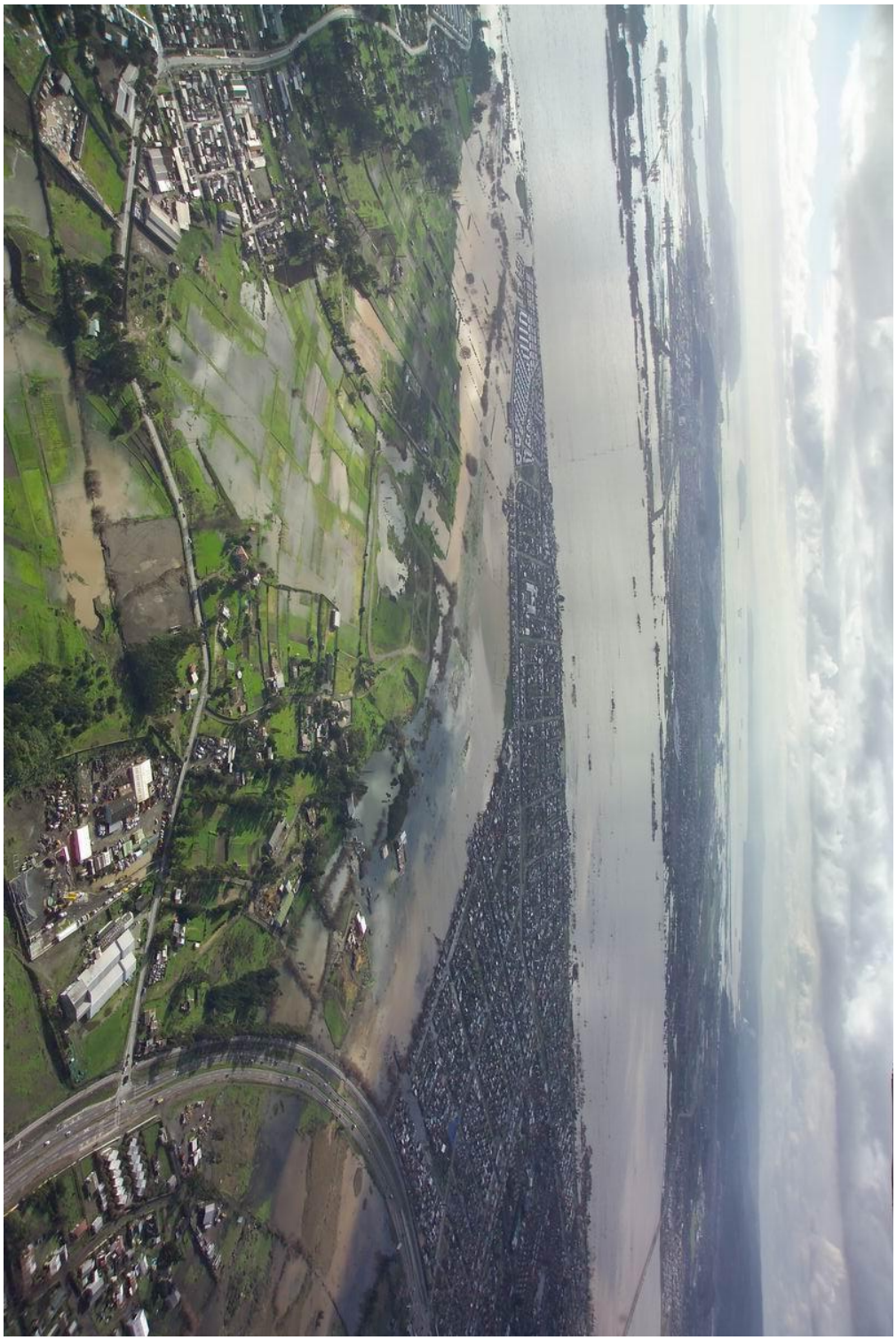
In the following table, from (Baecheler, Romero Bravo, & Alcayaga Saldias, 2007), the discharges for return periods of 2, 5, 10, 25, 50 and 100 years are shown. For this study only T=2 and T=100 are used. The first column is the distance from the Estero mouth to the cross-section with the specific discharges. The cross-section numbers are given in the second column.

Km	Sección	Caudal según Periodo de Retorno (m^3/s)					
		2	5	10	25	50	100
4276	Secc 01	7,139	9,534	11,170	13,677	15,990	18,460
4176	Secc 02	3,570	4,650	5,400	6,340	9,120	10,050
3775	Secc 06	1,680	2,179	2,549	2,979	4,079	4,499
3275	Secc 11	0,425	0,555	0,640	0,755	1,090	1,205
3175	Secc 12	1,345	1,624	1,849	2,074	2,749	3,004
3074	Secc 13	0,150	0,198	0,228	0,270	0,390	0,430
2974	Secc 14	0,150	0,198	0,228	0,270	0,390	0,430
2467	Secc 19	2,370	2,890	3,280	3,750	4,969	5,429
2434	Secc 20	0,090	0,110	0,130	0,150	0,220	0,240
2339	Secc 23	0,150	0,198	0,228	0,270	0,390	0,430
2256	Secc 24	0,680	0,890	1,030	1,210	1,610	1,780
2078	Secc 26	0,150	0,198	0,228	0,270	0,390	0,430
2004	Secc 27	0,420	0,550	0,630	0,740	0,990	1,090
1759	Secc 31	1,295	1,705	1,965	2,315	3,215	3,455
1614	Secc 34	0,270	0,350	0,410	0,480	0,640	0,710
1464	Secc 35	0,725	0,955	1,105	1,295	1,855	1,955
1310	Secc 36	0,580	0,750	0,870	1,020	1,460	1,610
917	Secc 38	2,590	3,380	3,940	4,620	6,270	6,920
671	Secc 40	0,170	0,220	0,255	0,300	0,430	0,475
391	Secc 41	0,170	0,220	0,255	0,300	0,430	0,475
4	Secc 43	0,350	0,460	0,530	0,610	0,890	0,990
Total		**24,468**	**31,812**	**36,918**	**43,694**	**57,568**	**64,067**

II-B

Inundation map and aerial photo of Los Batros for 2006 flood

Inundation map as model result for the calibration of the Los Batros model for the 2006 flood.



Aerial photograph of a flooded Los Batros taken in July 2006, looking to the North.

II-C

Inundation map Biobío and Los Batros for T = 100 (Scenario II)

Detail of the inundation map for T=100 years

Including Costanera Sur and Ruta Humedal

Legend

Area inundated for the T=100 years event

Road on embankment

Road on piles

50 0 50 100 150 200 m

Legend

Area inundated for the T=100 years event

Road on embankment

Road on piles

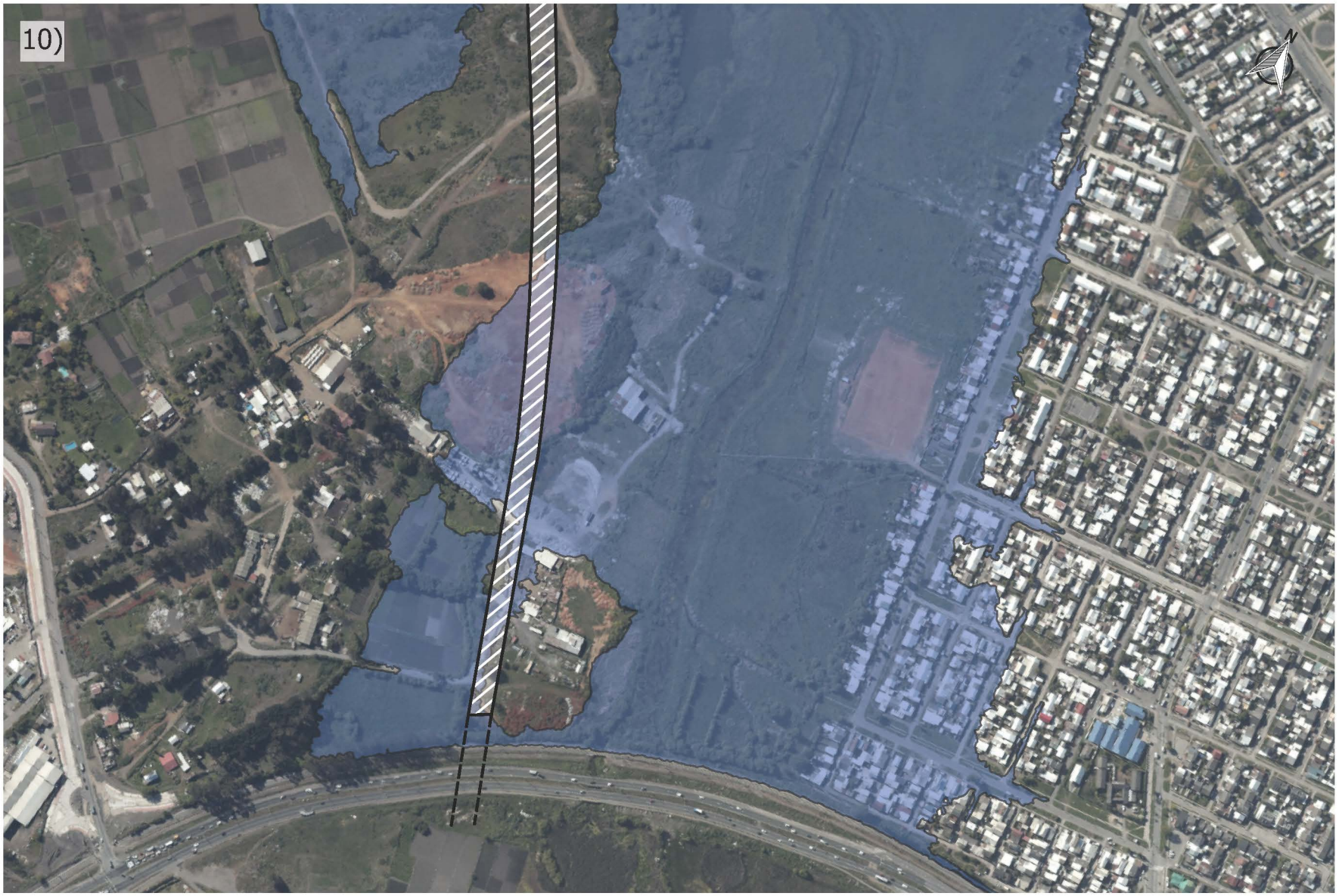
50 0 50 100 150 200 m


4)
5)
Legend
Area inundated for the T=100 years event
Road on embankment
Road on piles
50 0 50 100 150 200 m


6)
7)
Legend
Area inundated for the T=100 years event
Road on embankment
Road on piles
50 0 50 100 150 200 m


8)
Legend
Area inundated for the T=100 years event
Road on embankment
Road on piles
50 0 50 100 150 200 m


9)
Legend
Area inundated for the T=100 years event
Road on embankment
Road on piles
50 0 50 100 150 200 m



Legend

Area inundated for the T=100 years event

Road on embankment

Road on piles

50 0 50 100 150 200 m

III-A

Damage pictures Coquimbo

Below several pictures can be found that show the impact of the tsunami in Coquimbo.

Scour at the beach side of the road

Difference with and without grass → less scour around the palm tree.

Big parts of the road broke off, slabs of asphalt as well and were deposited at another spot.

At the location of a very small river, even more damage to the road could be found; bike path, pedestrian lane and revetment are completely gone.

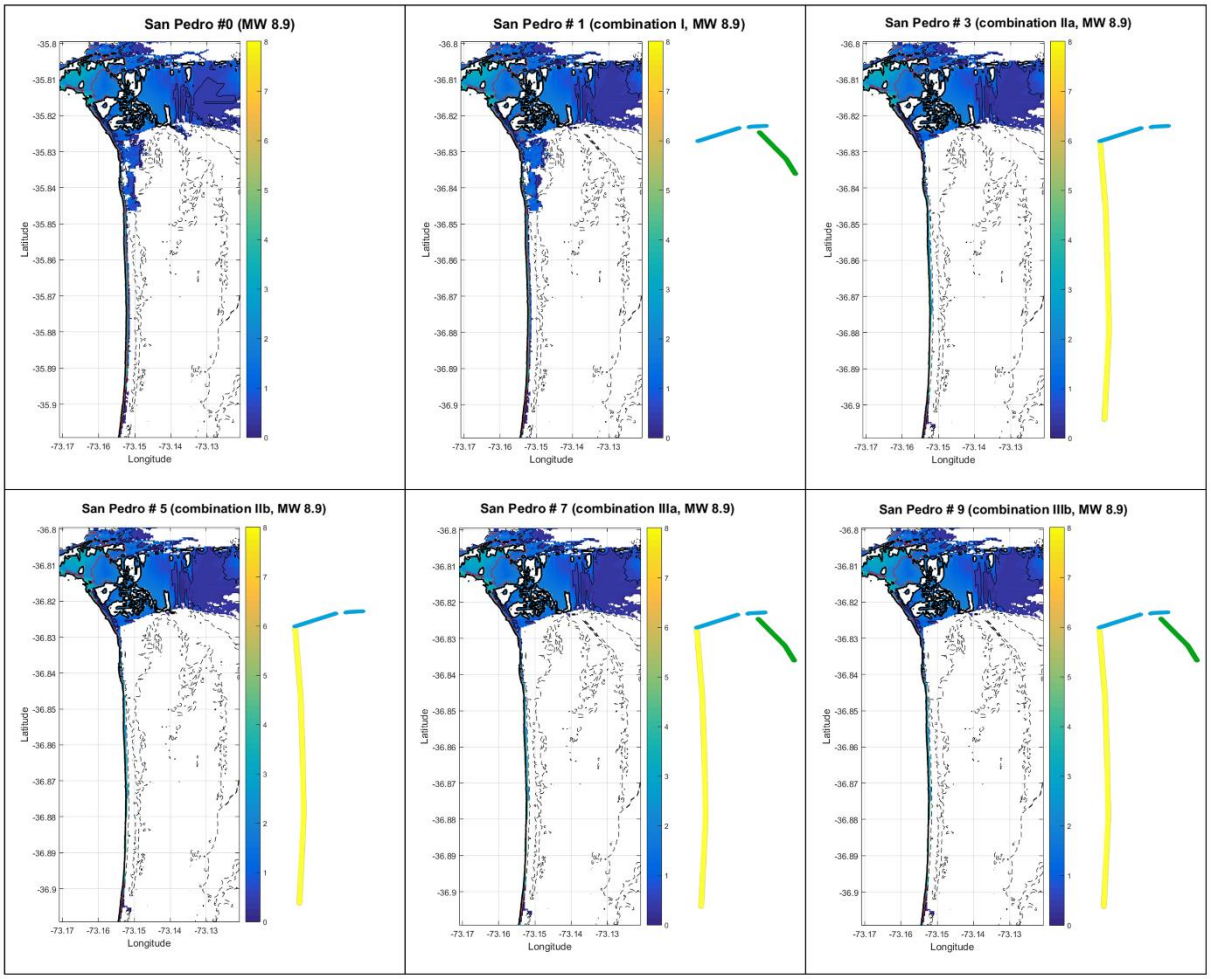
Perfect example of scour around a “pile”. Palm tree dragged out to sea


Only entrance structure remained, trucks pushed together and railroad tracks were bend.


In the city of Coquimbo: homes destroyed.

III-B

Results MW 8.9



III-C

Matlab script example for changing the bathymetry

```
%% coordinates to points example

% starting grid
C0_d = [73.24 37.02];
%% coast
Cc0 = [73.1526 36.9047];
Cc1 = [73.1513 36.8750];
Cc2 = [73.1528 36.8426];
Cc3 = [73.1536 36.8272];

pc0 = round((C0_d-Cc0)*3600 +1);
pc1 = round((C0_d-Cc1)*3600 +1);
pc2 = round((C0_d-Cc2)*3600 +1);
pc3 = round((C0_d-Cc3)*3600 +1);


%% changing bathymetry in grid
clc
clear all
close all

load grid_d2.dat;

display('combination 1 = river + wetland, combination 2 = river + coastal,
combination 3 is river+coastal+wetland')
y = input('which combination, 1,2 or 3? y= ')

    A = grid_d2;
    Coordinates_to_points_d2;
    Y = 37.02:-(1/3600):36.775;
    X = 73.24:-(1/3600):73.1;
    if y == 1;
        riverside_grid_d2;
        A = A_new;
        Wetland_grid_d2;
        Mw = mw1+mw2;
        Mr = mr1+mr3;
%         plot_grid;
        hold on; contour(X,Y,Mw,'k');
        hold on; contour(X,Y,Mr,'k');
        hold off
        set(gca,'Ydir','reverse')
        set(gca,'Xdir','reverse')
        xlabel('Coordinates W')
        ylabel('Coordinates Z')
        ylabel(colorbar,'[m]')
    elseif y == 2;
        riverside_grid_d2;
        A = A_new;
        coastalroad_grid_d2;
        Mc = mc1+mc2+mc0;
        Mr = mr1+mr3;
%         plot_grid;
```

```
        hold on; contour(X,Y,Mc,'k');
        hold on; contour(X,Y,Mr,'k');
        hold off
        set(gca,'Ydir','reverse')
        set(gca,'Xdir','reverse')
        xlabel('Coordinates W')
        ylabel('Coordinates Z')
        ylabel(colorbar,'[m]')
    elseif y == 3;
        riverside_grid_d2;
        A = A_new;
        coastalroad_grid_d2;
        A = A_new;
        Wetland_grid_d2;
        Mw = mw1+mw2;
        Mc = mc1+mc2+mc0;
        Mr = mr1+mr3;
%         plot_grid;
        hold on; contour(X,Y,Mw,'k');
        hold on; contour(X,Y,Mc,'k');
        hold on; contour(X,Y,Mr,'k');
        hold off
        set(gca,'Ydir','reverse')
        set(gca,'Xdir','reverse')
        xlabel('Coordinates W')
        ylabel('Coordinates Z')
        ylabel(colorbar,'[m]')
    end

%% Line coastal elevation (River and Wetland follow same idea)
clc

B = size(A);

mc0 = zeros(B);
mc1 = zeros(B);
mc2 = zeros(B);
nc0 = ones(B);
nc1 = ones(B);
nc2 = ones(B);

% height at points
hc0 = 6.5;
hc1 = 6.5;
hc2 = 6.5;
hc3 = 6.5;

%% line formulas
%line 0
y0 = pc0(2):(pc1(2)-1);
x0_a = round((y0 - pc0(2)) * (pc1(1)-1 - pc0(1)) / (pc1(2)-1 - pc0(2)) +
pc0(1));
x0_b = x0_a -1;
%line 1
y1 = pc1(2):(pc2(2)-1);
```

```
x1_a = round((y1 - pc1(2)) * (pc2(1)+1 - pc1(1)) / (pc2(2)+1 - pc1(2)) +
pc1(1));
x1_b = x1_a -1;
%line 2
y2 = pc2(2):pc3(2);
x2_a = round((y2 - pc2(2)) * (pc3(1) - pc2(1)) / (pc3(2) - pc2(2)) + pc2(1));
x2_b = x2_a -1;
%% steps for changing value for specific points.
%line 0
aac1 = sub2ind(size(A), y0, x0_a);
aac2 = sub2ind(size(A), y0, x0_b);
%line 1
ac1 = sub2ind(size(A), y1, x1_a);
ac2 = sub2ind(size(A), y1, x1_b);
%line 2
bc1 = sub2ind(size(A), y2, x2_a);
bc2 = sub2ind(size(A), y2, x2_b);
%% zeros matrix with road height
%line 0
tc0 = linspace(hc0,hc1,length(aac1));

for i=1:length(aac1)
    mc0(aac1(i))=tc0(i);
    mc0(aac2(i))=tc0(i);
end
%line 1
tc1 = linspace(hc1,hc2,length(ac1));

for i=1:length(ac1)
    mc1(ac1(i))=tc1(i);
    mc1(ac2(i))=tc1(i);
end
%line 2
tc2 = linspace(hc2,hc3,length(bc1));

for i=1:length(bc1)
    mc2(bc1(i))=tc2(i);
    mc2(bc2(i))=tc2(i);
end

%% ones matrix with zeros line
nc0(aac1)=0; nc0(aac2)=0;
nc1(ac1)=0; nc1(ac2)=0;
nc2(bc1)=0; nc2(bc2)=0;

%% create final data
P = A.*nc0.*nc1.*nc2;

A_new = P + mc0 + mc1 + mc2;
```

IV-A

Survey

Encuesta

Estimados Estudiantes:

Nosotros, al igual que ustedes, somos estudiantes de Ingeniería Civil y necesitamos su ayuda para nuestra investigación sobre los problemas de congestión de San Pedro de la Paz. Esta encuesta nos dará una idea más clara sobre lo que las personas de San Pedro creen es más importante respecto a problemas de infraestructura. Al hacer esto, podemos incluir las opiniones de ustedes (locales) en nuestras propuestas y así mejorar nuestra investigación.

Es muy simple.
En cada pregunta se proponen dos criterios que son importantes para el análisis de los diseños de infraestructura de transporte (una breve explicación de cada uno es dada más abajo para que entiendas mejor a qué se refieren).
Para cada caso, debes elegir cuál de las dos opciones es más importante o si son ambas igualmente importantes.

Estos son los criterios:

Costos: Los gastos en que incurres al viajar de A hasta B. Piensa en gasolina y peajes, en el caso de vehículo particular y tarifa para transporte público.

Tiempo: El tiempo que te toma ir desde A hasta B en tu auto o transporte público considerando todas las posibles demoras en el trayecto.

Impacto Ambiental: El impacto que un camino puede tener en la flora y fauna del lugar y en la posible inundación del lugar.

Impacto Social: El impacto que tiene el camino en los habitantes del sector. Piensa en: ruido, contaminación, bloquea la vista o interrumpe las rutas de evacuación.

Seguridad: Si es que el camino te ofrece seguridad para manejar en el y si cruzas posibles áreas inseguras.

Co-beneficios: Un beneficio extra que se puede obtener de la construcción del camino. Esto significa que este proyecto resuelve otro problema además del problema de infraestructura. Por ejemplo, un camino que también puede funcionar como una barrera para impedir inundación.

Confiabilidad: Si es que siempre puedes confiar en la disponibilidad del camino sin que ocurran demoras inesperadas.

Comodidad: En el caso de vehículos particulares, este criterio se refiere a si puedes manejar por este camino de manera cómoda. Esto significa, por ejemplo, que no tienes tantas intersecciones semaforizadas o obstaculización de camiones, existe buena señalización, etc. En el caso de transporte público y ciclistas se refiere a la disponibilidad y buen diseño de paraderos y ciclovías, respectivamente.

1.	☐	Tiempo	☐	Costos	☐	Igualmente Importante
2.	☐	Co-beneficios	☐	Impacto social	☐	Igualmente Importante
3.	☐	Seguridad	☐	Confiabilidad	☐	Igualmente Importante
4.	☐	Impacto ambiental	☐	Comodidad	☐	Igualmente Importante
5.	☐	Costos	☐	Seguridad	☐	Igualmente Importante
6.	☐	Impacto social	☐	Tiempo	☐	Igualmente Importante
7.	☐	Confiabilidad	☐	Co-beneficios	☐	Igualmente Importante
8.	☐	Impacto social	☐	Impacto ambiental	☐	Igualmente Importante
9.	☐	Costos	☐	Confiabilidad	☐	Igualmente Importante
10.	☐	Tiempo	☐	Seguridad	☐	Igualmente Importante
11.	☐	Co-beneficios	☐	Impacto ambiental	☐	Igualmente Importante
12.	☐	Comodidad	☐	Impacto social	☐	Igualmente Importante
13.	☐	Seguridad	☐	Comodidad	☐	Igualmente Importante
14.	☐	Impacto ambiental	☐	Costos	☐	Igualmente Importante

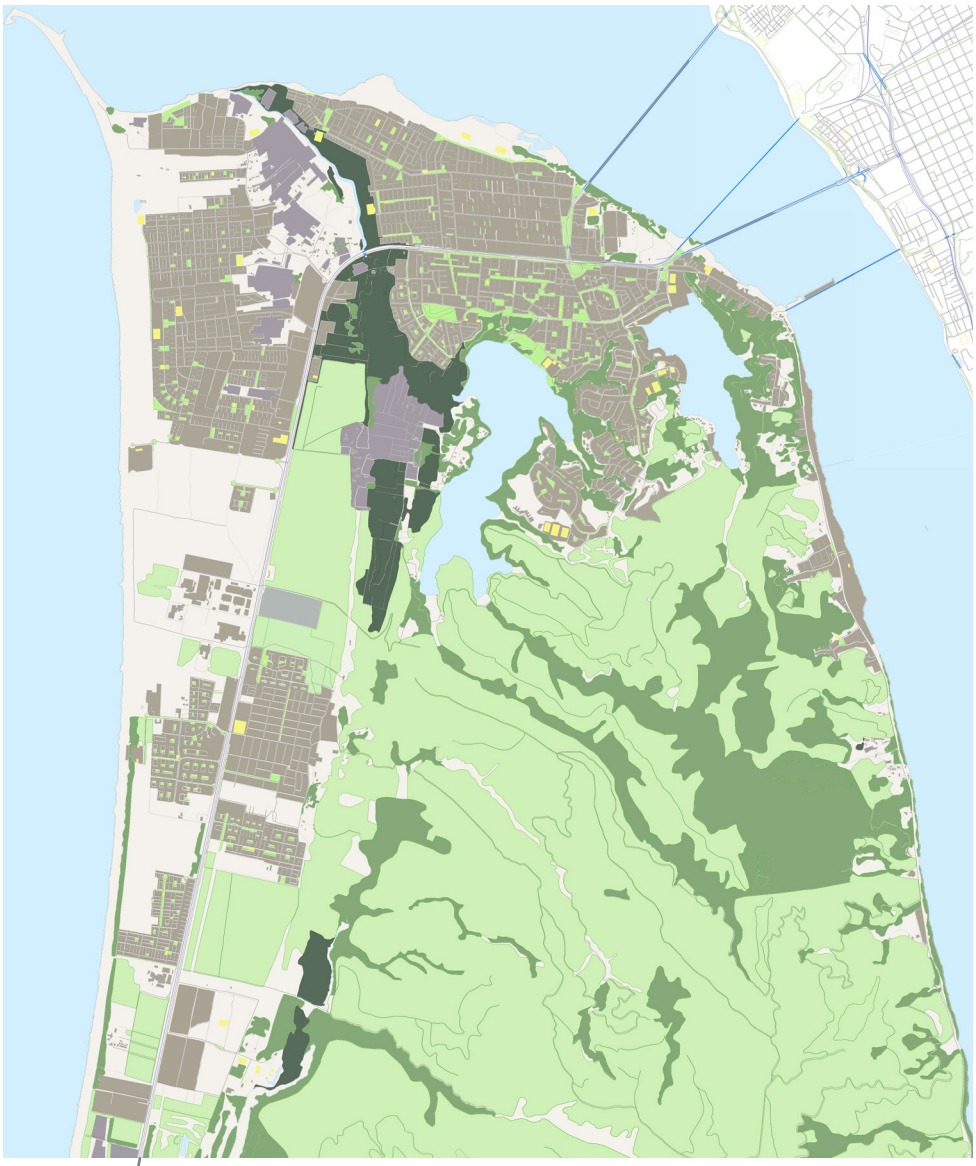
15.	☐	Tiempo	☐	Confiabilidad	☐ Igualmente Importante
16.	☐	Costos	☐	Impacto social	☐ Igualmente Importante
17.	☐	Comodidad	☐	Co-beneficios	☐ Igualmente Importante
18.	☐	Seguridad	☐	Impacto ambiental	☐ Igualmente Importante
19.	☐	Co-beneficios	☐	Tiempo	☐ Igualmente Importante
20.	☐	Confiabilidad	☐	Impacto social	☐ Igualmente Importante
21.	☐	Costos	☐	Co-beneficios	☐ Igualmente Importante
22.	☐	Tiempo	☐	Comodidad	☐ Igualmente Importante
23.	☐	Seguridad	☐	Impacto social	☐ Igualmente Importante
24.	☐	Comodidad	☐	Confiabilidad	☐ Igualmente Importante
25.	☐	Tiempo	☐	Impacto ambiental	☐ Igualmente Importante
26.	☐	Co-beneficios	☐	Seguridad	☐ Igualmente Importante
27.	☐	Comodidad	☐	Costos	☐ Igualmente Importante
28.	☐	Confiabilidad	☐	Impacto ambiental	☐ Igualmente Importante

En qué basó sus respuestas a las preguntas anteriores, viajar en bus (transporte público) o manejar un auto?

☐ Auto ☐ Bus

Para mejorar los resultados de esta encuesta nos gustaría saber dónde vive. Si usted es de San Pedro de la Paz, por favor utilice el mapa más abajo para indicar en qué barrio (sector) vive con una cruz. Si vive más al sur marque la opción correcta debajo del mapa.

Muchas gracias por su ayuda!



☐ Coronel

☐ Lota

☐ Localidades al sur de Lota

Table IV - A 1: Survey results

Pairwise Combination	*First criterion more important*	*Second criterion more important*	*Equally important*
Time vs. Costs	12	0	20
Co-benefit vs. Social impact	13	11	8
Environmental impact vs. Comfort	9	11	11
Costs vs. Safety	4	16	12
Social impact vs. Time	2	19	10
Social impact vs. Environmental impact	9	9	14
Time vs. Safety	6	7	18
Co-benefits vs. Environmental impact	7	17	7
Comfort vs. Social impact	14	9	8
Safety vs. Comfort	18	3	10
Environmental impact vs. Costs	10	13	8
Costs vs. Social impact	14	8	9
Comfort vs. Co-benefits	15	6	10
Safety vs. Environmental impact	14	4	13
Co-benefits vs. Time	0	22	9
Costs vs. Co-benefits	17	4	10
Time vs. Comfort	16	1	14
Safety vs. Social impact	18	3	9
Time vs. Environmental impact	16	3	12
Co-benefits vs. Safety	1	23	7
Comfort vs. Costs	8	12	11

Table IV - B1: Absolute scores solution level

Absolute score *(1-5)*	Accessibility time	Travel time	Fuel & Operational costs	Toll fee	Ecological impact	River hydrodynamics	Tsunami inundation	Evacuation routes	Zone disturbance	Complexity	Signposting	Speeding	Area	Drivability	Bike lanes	Bus stops	Surroundings	Co-benefits	**Totaal**
Pedro Aguirre Cerda	1	2	1	5	5	3	3	1	2	2	2	5	5	1	5	5	4	1	53
Ruta 160	4	5	5	5	1	3	3	4	3	3	2	1	5	5	4	5	3	5	66
Costanera Sur	2	4	5	5	1	3	1	5	3	3	2	1	5	5	3	1	5	1	55
Ruta Pie de Monte	4	5	5	1	1	3	3	1	3	3	2	1	5	5	4	1	4	1	52
Costanera Mar	2	3	3	5	4	3	3	5	3	3	2	1	1	3	3	1	1	5	51
Ruta Costa	3	5	5	5	4	3	5	5	1	5	5	1	3	5	3	1	5	5	69
Ruta Humedal	5	5	5	1	1	1	3	5	5	5	5	1	5	5	4	1	4	1	62

Main Criteria	Sub criteria	1	2	3	4	5
Time	***Accesibility time***	Limited amount of access points dominated by traffic lights and stop signs.	Limited amount of acces points with traffic lights.	Limited amount of access points. No traffic lights but with stop signs.	Multiple access points. No traffic lights and with stop signs.	Multiple access points. No traffic lights and no stop signs.
	Travel time	Multiple traffic lights. Pedestrian crossings. Bus stops.	Multiple traffic lights. Pedestrian crossings. No bus stops.	Limited amount of traffic lights. No pedestrian crossings. Bus stops.	No traffic lights. No Pedestrian crossings. Bus stops.	No traffic lights. No pedestrian crossings. No bus stops.
Costs	***Fuel & Operational costs***	≥10 potential stops.	≤7 potential stops.	≤4 potential stops.	≤1 potential stops.	No potential stops.
	Toll	Toll fee. (Private roads)				No toll fee. (Public roads)
Safety	***Complexity***	Complex crossings. Railway on streetlevel. Stop signs and traffic lights. Mixed transportation modes.	Complex crossings. Railway on streetlevel. Stop signs and traffic lights. Exclusive bus lanes. Trucks on the road.	Simple crossings. Railway not on streetlevel. No bicylcle and pedestrian crossings. Continuous traffic flow. Mixed transportation modes.	Simple crossings. Railway not on streetlevel. Bicylcle and pedestrian crossings. Continuous traffic flow. Mixed transportation modes.	Simple crossings. Railway not on streetlevel. Bicylcle and pedestrian crossings. No trucks. Continuous traffic flow. Exclusive bus lanes
	Signposting	No signs.	Signs at the major crossing. Information presented to late.	Signs at the major crossings. Information presented in time.	Signs everywhere. Information not presented in time.	Signs everywhere. Information presented in time.
	Speeding	Long distance between potential stops.		Medium distance between potential stops.		Short distance between potential stops.
	Area	Dangerous areas .		Mixed areas.		Safe areas.
Comfort	***Drivability***	Limited amount of traffic lights. Pedestrian crossings. Mixed transportation modes.	Limited amount of traffic lights. Pedestrian crossings. Exclusive bus lanes.	Limited amount of traffic lights. No Pedestrian crossings. Mixed transportation modes.	No traffic lights. Continuous flow. Mixed transportation modes.	No traffic lights.Continuous flow. Exclusive Bus lanes. No Trucks.
	Bike lanes	No bike lanes.	Interfered bike lanes.	Continuous bike lane. No crossing possibilities.Limited exit/access possibilites.	Continuous bike lane. Crossing possibilities. Multiple exit/acces possibilities.	Continuous bike lane. Crossing possibilities.Connction to current bike lane network.
	Bus stops	No bus stops.		Limited amount of bus stops.		Multiple bus stops.
	Surrounding	Unattractive surrounding.	Crowded city surrounding.	Residential surrounding.	Natural /Resdential surrounding.	Natural surrounding.
Environmental impact	***Ecological impact***	Major disturbane flora and fauna in wetlands.	Forms barrier for the local fauna.	Intersects natural forest.	Intersects wastelands.	Intersects urban areas.
	River hydrodynamics	Negative influence on flooding.		No influence on flooding.		Protection agains flooding.
	Tsunami inundation	Negative impact on tsunami inundation.		No impact on tsunami inundation.		Protection against inundation
Social impact	***Evacuation routes***	Road forms a barrier. High traffic density. Crossings not improved.	Road forms a barrier. Decreasing traffic intensity.Crossings not improved.	Road forms a barrier. High density. Crossings improved.	Road forms a barrier. Decreasing density. Crossings improved.	No impact on the evacuation routes.
	Zone disturbance	Road crosses high income areas.	Road crosses medium-high income.	Road crosses low-medium income areas.	Road crosses low income areas.	Road does not cross any urban areas
Co-benefits		Provides no co-benefits.				Provides co-benefits.