Boeung Kak Area
Drainage and Flooding Assessment

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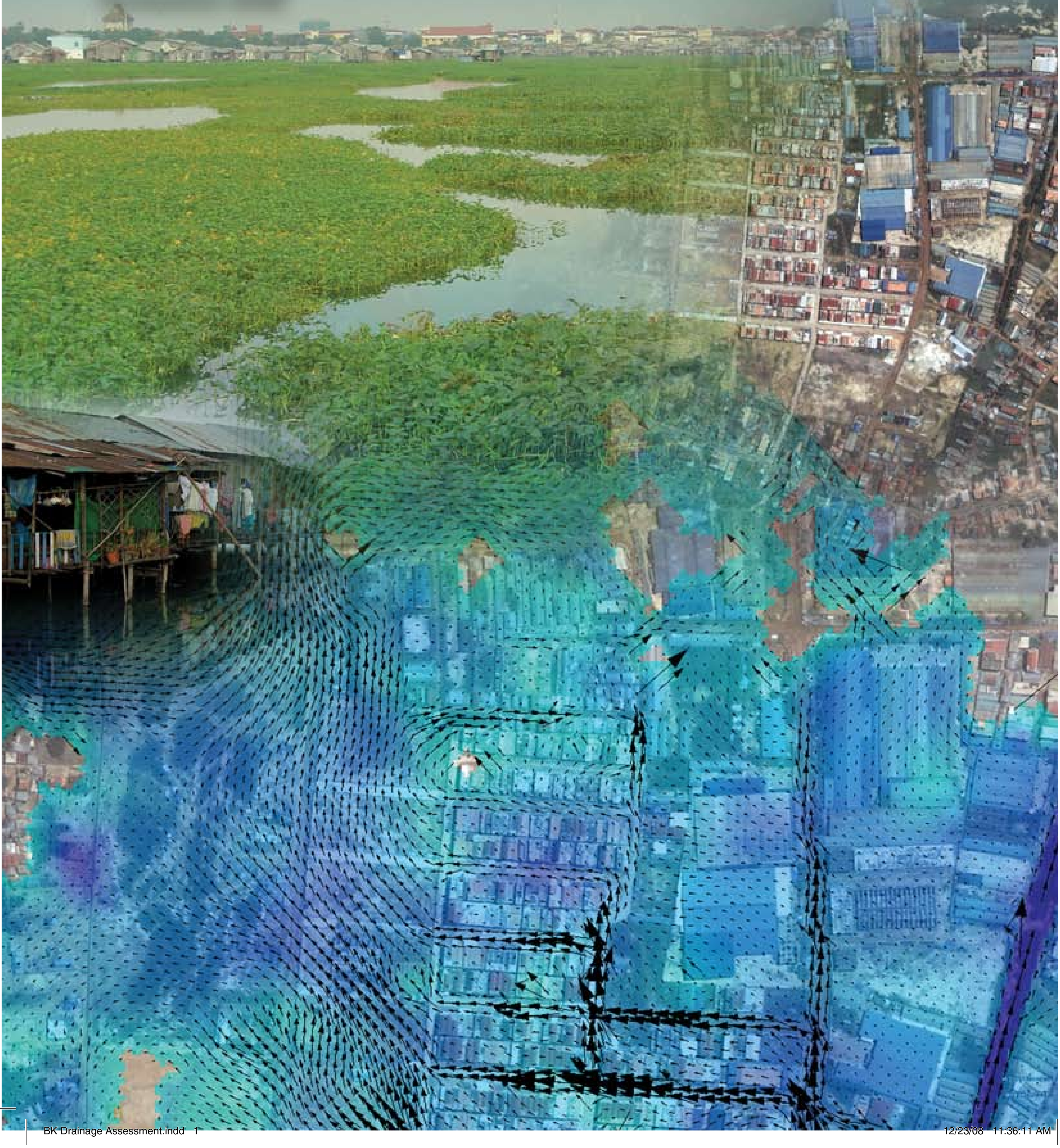
December 2008



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របាយការណ៍សង្ខេប

បឹងកក់ ជាបឹងមួយដែលមានផ្ទៃទំហំ ៩០ ហិកតា ស្ថិតនៅក្នុងខណ្ឌដូនពេញ រាជធានីភ្នំពេញ ។ ក្រុមហ៊ុនអភិវឌ្ឍន៍ឯកជនមួយ មានឈ្មោះ ស៊ូកាគុ អ៊ីន បានជួលបឹងនេះដែលមានទំហំផ្ទៃសរុបរួមទាំងបឹងផង ១៣២ ហិកតា ពីសាលាក្រុងភ្នំពេញ ហើយគ្រោងនឹងបូមដីចាក់បំពេញបឹងរួចអភិវឌ្ឍន៍តំបន់នេះ។ ឯកសារនេះគឺជារបាយការណ៍ស្រាវជ្រាវអំពីសក្តានុពលនៃផលប៉ះពាល់ដោយសារទឹកជំនន់ដែលបណ្តាលមកពីគម្រោងអភិវឌ្ឍន៍តំបន់បឹងកក់នេះ ។

បឹងកក់ គឺជាបឹងបិទជិត នៅដាច់ពីគេ-មានន័យថា ការទទួលទឹក ពុំអាចបានច្រើនលើសពីទំហំនេះ ហើយគ្មានផ្លូវសម្រាប់ទឹកហូរចេញពីបឹងនេះទេ ។ ទឹកភ្លៀងដែលហូរចូលទៅក្នុងបឹងត្រូវដក់ជាប់នៅទីនោះរហូតដល់វារីងហួត ឬ ជ្រាបចេញទៅអស់។ បរិមាណទឹកភ្លៀងដែលហូរចូលបឹងនេះមើលទៅដូចជាព្រឹត្តិការណ៍ព្យុះមួយយ៉ាងធំដោយ ក្នុងខែ មេសា ឆ្នាំ ២០០៨ កន្លងនេះ បរិមាណទឹកភ្លៀងមានទំហំ ដល់ទៅ ៣៦០.០០០ ម៉ែត្រគ្រីគុណ។ សម្រាប់ប្រជាពលរដ្ឋ ដែលរស់នៅតំបន់បឹងកក់ បរិមាណទឹកប៉ុននេះ គេគិតថា មិនធំទេ។

ក្រោយពីមានការចាក់ដីបំពេញ និង អភិវឌ្ឍន៍តំបន់បឹងកក់ ទឹកភ្លៀងនៅក្នុងអភិវឌ្ឍន៍នេះនឹងត្រូវបានគេបង្ហូរចេញទៅភាគខាងជើង ដែលជាតំបន់ទំនាបនៅជិតៗនោះ។ ការទាយទុកអំពីកំពស់ទឹកដែលឡើងខ្ពស់បំផុតនៅពេលមានជំនន់ ដែលអាចកើតឡើងដោយសារគ្មានការកាត់បន្ថយ គឺជាកំពស់ទឹកមួយដែលឡើងខ្ពស់មិនអាចទទួលយកបាន។ ក្រុមហ៊ុន ស៊ូកាគុ អ៊ីន បានចេញផ្សាយនូវរបាយការណ៍វាយតម្លៃផលប៉ះពាល់បរិស្ថាន និង សង្គមកាលក្នុងខែ សីហា ឆ្នាំ ២០០៨ កន្លងទៅនេះ។របាយការណ៍នោះ មានសរសេរតែអំពីផែនការកាត់បន្ថយដែលមានលក្ខណៈស្រពិចស្រពិលមួយប៉ុណ្ណោះ ដូចជា និយាយថា" ជីកប្រឡាយដែលមានផ្ទៃពី ២០-២១ ម៉ែត្រក្រឡា នៅក្នុងតំបន់ "។ ផែនការនេះមើលទៅហាក់ដូចជាមិនបានផ្អែកទៅលើការវាយតម្លៃវិស្វកម្មឱ្យបានត្រឹមត្រូវសោះ។ លើសពីនេះទៀត ក្រុមហ៊ុន ស៊ូកាគុ អ៊ីន មិនបានអនុវត្តនូវកាតព្វរបស់ខ្លួនក្នុងកាត់បន្ថយផលប៉ះពាល់ដោយការអភិវឌ្ឍន៍របស់ខ្លួនថែមទៀត។

ការតភ្ជាប់យ៉ាងស្អិតរមួតរវាងគំរូធារាសាស្ត្រមួយនិង ពីរ ត្រូវបានបង្កើតឡើងសម្រាប់បឹងនិង ខណ្ឌឬស្សីកែវនៅជិតនោះ។ គេបានរៀបចំចេញជា ៤ ឆាក ដូចខាងក្រោម:

- ករណីមានស្រាប់

- ការអភិវឌ្ឍន៍ដំណាក់ដំបូង (ចាក់ដីលុបបឹង - ជាការកាត់បន្ថយមុនការសាងសង់)
- ការអភិវឌ្ឍន៍ដំណាក់ទី ២ (ចាក់ដីលុបបឹង និង ជីកព្រែក ២១ ម៉ែត្រក្រឡាបន្ថែម កាត់ផ្នែកខ្លះនៃតំបន់បឹងកក់ស្របតាមប្រឡាយទៅទិសខាងជើង) និង
- ការអភិវឌ្ឍន៍ដំណាក់ទី ៣ (ចាក់ដីចាក់លុបបឹង ជីកប្រឡាយ ២១ ម៉ែត្រក្រឡាបន្ថែម កាត់ផ្នែកខ្លះនៃតំបន់បឹងកក់ស្របតាមប្រឡាយទៅទិសខាងជើងហើយពង្រីកទំហំផ្លូវទឹកកន្លែងជួបគ្នាជាពីរដង នៅត្រង់កន្លែងណាដែលមានផ្លូវឆ្លងកាត់)។

ដោយបឹងនេះ ជាបឹងបិទជិតដែលអាចទទួលទឹកបន្ថែមបានតិចតួចនោះ តំបន់ដែលគ្រោងអភិវឌ្ឍន៍នោះ គឺជាទំហំធំល្មមដែលបណ្ដាលឱ្យមានទឹកហៀរចេញ។ ទឹកដែលហៀរចេញនេះអាចបណ្ដាលឱ្យមានផលប៉ះពាល់យ៉ាងធ្ងន់ធ្ងរដល់ទ្រព្យសម្បត្តិ និង ជីវិតរបស់មនុស្សដែលនៅក្រោមខ្សែរទឹក។

នៅក្នុងដំណាក់អភិវឌ្ឍន៍ទាំងបីខាងលើ ផលប៉ះពាល់ដោយសារទឹកជំនន់យ៉ាងខ្លាំងបានបង្ហាញឱ្យឃើញក្នុងផ្នែកជាច្រើននៃខណ្ឌឫស្សីកែវ។ គំរូដែលគេបានយកតាម បានបង្ហាញឱ្យឃើញថាប្រព័ន្ធធារាសាស្ត្រនៅផ្នែកក្រោមខ្សែរទឹកនៃតំបន់បឹងកក់ មានភាពស្មុគស្មាញ ហើយតម្រូវឱ្យមានគំរូធារាសាស្ត្រលំអិតមួយ ដើម្បីកំណត់នូវវិធានការណ៍កាត់បន្ថយដ៏សមរម្យមួយ ។ លទ្ធផលនៃការការសិក្សានេះ ក៏បានបង្ហាញឱ្យឃើញផងដែរថា វិធីសាស្ត្ររបស់ក្រុមហ៊ុន ស៊ូកាគុ ក្នុងការជីកប្រឡាយទំហំពី ២០ - ២១ ម៉ែត្រក្រឡា នៅក្នុងតំបន់ គឺជាវិធីសាស្ត្រមិនគ្រប់គ្រាន់ឡើយ។ ប្រសិនបើពុំមានការគ្រោងរៀបចំ និង វិភាគវិធីសាស្ត្រនេះឱ្យបានល្អិតល្អន់ទេ នេះអាចជាការធ្វេសប្រហែសនាំមកនូវផលវិបាក។ ការទទួលខុសត្រូវក្នុងការរៀបចំគម្រោង និង ការងារកាត់បន្ថយជាកាតព្វកិច្ចរបស់ក្រុមហ៊ុន ស៊ូកាគុ អ៊ីន។ ការងារទាំងនេះត្រូវតែអនុវត្តជាផ្នែកមួយនៃការអភិវឌ្ឍន៍មុននឹងចាក់ដីចាក់បំពេញបឹង ដើម្បីទប់ស្កាត់កំណើនគ្រោះថ្នាក់ដល់អាយុជីវិត និង ទ្រព្យសម្បត្តិ។

៧. សេចក្តីសន្និដ្ឋាន និង អនុសាសន៍

៧.២. សេចក្តីសន្និដ្ឋាន

សេចក្តីព្រៀងរបាយការណ៍នេះ បានរៀបចំឡើងដើម្បីវាយតម្លៃផលប៉ះពាល់ដោយសារទឹកជំនន់ដែលអាចកើតឡើងក្រោយពីការចាក់ដីលប់បឹង និង ការអភិវឌ្ឍន៍ជាបន្តបន្ទាប់ទៀតនៅតំបន់បឹងកក់នេះ ។ សេចក្តីសន្និដ្ឋានខាងក្រោម ជាការដកស្រង់ចេញពីការវាយតម្លៃខាងលើនេះ:

- មានការផ្សាភ្ជាប់យ៉ាងជិតដិតនូវគំរូនៃទំហំទឹកជំនន់មួយនិងពីរ ដែលត្រូវបានបង្កើតឡើងនៃតំបន់បឹងកក់ និងតំបន់ភាគខាងជើង ។ គំរូនេះគឺជាការបង្ហាញនូវលក្ខណទឹកជំនន់ និង ការរំដោះទឹកចេញនៃតំបន់ ដែលអាចយកជាការបានព្រមទាំងត្រូវបានប្រើប្រាស់ដើម្បីវាយតម្លៃផលប៉ះពាល់នៃទឹកជំនន់ដែលសង្ឃឹមថានឹងកើតឡើងដោយសារគម្រោងអភិវឌ្ឍន៍។
- ដោយសារតែបឹងនេះជាប្រព័ន្ធបិទជិតដោយមានលទ្ធភាពទទួលទឹកបានតិចតួច នោះតំបន់គម្រោងអភិវឌ្ឍន៍ គឺជាទីតាំងមួយដែលមានទំហំធំល្មមអាចបង្ករបរិមាណទឹកហៀរចេញបាន។ ទឹកដែលហៀរចេញនេះអាចបណ្តាលឱ្យមានផលប៉ះពាល់យ៉ាងខ្លាំងទៅលើទ្រព្យសម្បត្តិ និង គ្រោះថ្នាក់ដល់ជីវិតមនុស្សដែលនៅតំបន់ទាបជាងតំបន់អភិវឌ្ឍន៍នេះ។
- កម្រិតទឹកជំនន់អតិបរមា ត្រូវបានបង្ហាញរួចហើយថា មានការកើនឡើងរហូតដល់ ០.៤ម ដោយសារតែការអភិវឌ្ឍន៍នេះទាំងនៅក្នុងព្រឹត្តិការណ៍ (ARI) ១០ ឆ្នាំ និង ៥០ ឆ្នាំ ។ តំបន់ដែលរងផលប៉ះពាល់ខ្លាំងជាងគេ គឺនៅភាគខាងជើងបឹងកក់ទាំងនៅផ្នែកខាងកើត និងខាងលិចផ្លូវរថភ្លើង ព្រមទាំងតំបន់នានាដែលស្ថិតក្នុងចម្ងាយប្រហែល ១.៥ គម ខាងជើងបឹងកក់។ ការកើនឡើងយ៉ាងខ្លាំងគឺនៅទិសពាយ័ព្យរហូតដល់តំបន់អភិវឌ្ឍន៍ កាំកូស៊ីធី និង បឹងពោងពាយ។
- ការស្តារប្រព័ន្ធរំដោះទឹកចេញដែលលើកឡើងនៅក្នុងរបាយការណ៍វាយតម្លៃផលប៉ះពាល់បរិស្ថាន និង សង្គមរបស់ក្រុមហ៊ុន ស៊ូកាគុ អ៊ីន បង្ហាញថាជាការមិនគ្រប់គ្រាន់ដើម្បីកាត់បន្ថយផលប៉ះពាល់ទឹកជំនន់ដែលបង្ករដោយគម្រោងអភិវឌ្ឍន៍បឹងកក់នេះឡើយ។

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- ➢ លូទឹកដែលត្រូវបានកសាងឡើងដោយសាលាក្រុងភ្នំពេញថ្មីៗនេះដែលតភ្ជាប់តំបន់ទួលគោក ជាមួយ និង ប្រឡាយអូរវែង គឺជាលូទឹកមួយដែលមានទំហំតូចពេក។
- ➢ គួរកត់សំគាល់ថា ការកើនឡើងនេះ មិនត្រឹមតែជម្រៅ និង កម្ពស់ទឹកជំនន់តែប៉ុណ្ណោះទេ ប៉ុន្តែភាពញឹកញាប់នៃទឹកជំនន់ក៏អាចកើនឡើងដែរ។ ក្រោយពីធ្វើការអភិវឌ្ឍន៍ កម្រិតទឹកជំនន់នៅក្នុងរយៈពេលដូចគ្នា ក្រោមលក្ខខណ្ឌដដែល នឹងកើតឡើងញឹកញាប់ជាងមុន។ ទឹកដែលហូរចេញ និង ប្រព័ន្ធរំដោះទឹកដ៏ច្រើនលើសលប់ រួមបញ្ចូលគ្នា នៅក្នុងរាជធានីភ្នំពេញ មានន័យថានៅពេលមានទឹកជំនន់ម្តងៗ នោះទឹកនឹងមានគុណភាពយ៉ាងទាបជាទីបំផុត និង បង្ករឱ្យមានបញ្ហាដល់សុខភាពសាធារណៈ ។
- ➢ គួរកត់សំគាល់ផងដែរថា បរិមាណទឹកហៀរចេញពីគម្រោងអភិវឌ្ឍន៍ ដែលបានធ្វើការប៉ាន់ស្មាន (ទាញចេញពីគំរូធារាសាស្ត្រ) គឺជាការប៉ាន់ស្មានដូចមុនដដែលដោយកំណត់ដង់ស៊ីតេការអភិវឌ្ឍន៍ទាប ។ ប្រសិនបើការអភិវឌ្ឍន៍ស្ថិតក្នុងដង់ស៊ីតេខ្ពស់ ឬ មធ្យម ដូចនេះផលប៉ះពាល់ដែលបង្ហាញខាងលើនឹងអាចធ្ងន់ធ្ងរជាងនេះ។
- ➢ តាមទស្សនៈវិស្វកម្មធារាសាស្ត្រ ការអភិវឌ្ឍន៍តំបន់បឹងកក់ដោយពុំមានគំរូលំអិតដែលគួរចេញពីការយល់ដឹងនៃប្រវត្តិទឹកជំនន់ និង ការរំដោះទឹកឱ្យបានត្រឹមត្រូវ នោះអាចនឹងបង្ករឱ្យមានភាពធ្ងន់ធ្ងរ និង ញឹកញាប់នៃទឹកជំនន់កាន់តែខ្លាំងជាងមុន ព្រមទាំងមានគ្រោះថ្នាក់ដល់សុខភាពសាធារណៈថែមទៀតផង ។

តាមបទដ្ឋានពិភពលោក ការបូមដីលប់ប្រភពទឹកណាមួយ គឺជាប្រការមួយដែលគេមិនត្រូវធ្វើទេ។ គេមិនអាចបន្តពង្រីកទីក្រុងតាមរយៈការកសាងទំនប់ដែលមានចំណុចរួមធំ ចាក់ដីលប់ចន្លោះចំហរដើម្បីពង្រីកទីតាំងសម្រាប់រៀបចំក្រុងឡើយ។ ការពង្រីកបែបនេះតម្រូវឱ្យមានគម្រោងការងារសាធារណៈយ៉ាងធំ និង ចំណាយយ៉ាងច្រើន ហើយការធ្វើបែបនេះក៏នាំឱ្យមានការខូចខាតដល់ប្រព័ន្ធរំដោះទឹកធម្មជាតិដែលមាននៅជុំវិញទីក្រុងសព្វថ្ងៃផង។ ហេតុនេះហើយទើបមានការចាំបាច់ត្រូវរៀបចំវិធីថ្មីវិញដើម្បីពង្រីកទីក្រុងភ្នំពេញ ។ ផែនការថ្មីនេះត្រូវតែគោរពបរិស្ថានធម្មជាតិ ដោយត្រូវទទួលស្គាល់ថាទំហំផ្ទៃទឹកដ៏ធំនោះ មានតួនាទីជាអាងស្តុកមួយយ៉ាងធំ ព្រមទាំងអាចជា មួយផ្នែក ឬ ទាំងមូល ជាទេសភាពទីក្រុងដែលមានការទាក់ទាញនៅពេលអនាគតផង។ (ម៉ូលីវ៉ាន់ ២០០៣) ។

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គេទទួលស្គាល់ថាផ្នែក (BAU) និង សាលាក្រុងភ្នំពេញបានធ្វើការពិចារណាចំពោះការអភិវឌ្ឍន៍ក្រុងនៅពេលអនាគត ដូចដែលបានឃើញនៅក្នុងផែនការគោលរបស់ក្រុង។ នៅខាងជើងភ្នំពេញ ផែនការគោលនេះរួមមាន បណ្តាញប្រឡាយបង្ហូរទឹកចេញដែលមានតភ្ជាប់គ្នាជាមួយបឹងនានា។ ប៉ុន្តែ គេពុំបានឃើញមានការបង្ហាញនូវគំរូធារាសាស្ត្រលំអិតនៃប្រព័ន្ធនេះត្រូវបានធ្វើឡើងសោះ។ ហេតុដូច្នេះហើយ ទើបមិនអាចកំណត់បានថាតើ ប្រព័ន្ធបង្ហូរទឹកដែលនឹងត្រូវកសាងនាពេលអនាគត អាចការពារទ្រព្យសម្បត្តិពីទឹកជំនន់បានដែរឬទេ ។

ជាចុងក្រោយ ផែនការគោលរបស់សាលាក្រុងមិនបានដាក់បញ្ចូលនូវការអភិវឌ្ឍន៍តំបន់បឹងកក់នេះទេ ។ ការបូមដីលប់បឹងកក់ដែលកំពុងដំណើរការនេះ ជាការបង្ហាញឱ្យឃើញថា ពេលដែលសាលាក្រុងធ្វើផែនការគោល ខ្លួនមិនបានតាំងចិត្តឱ្យបានរឹងមាំក្នុងការអភិវឌ្ឍន៍ប្រកបដោយនិរន្តភាពទេ ដែលអាចបង្ហាញថា ភ្នំពេញជាគ្រាប់ គុជ នៃអាស៊ីនោះ។

៧.២. អនុសាសន៍

ផ្អែកលើការវាយតម្លៃទឹកជំនន់ និង ការបង្ហូរទឹកចេញនៅក្នុងតំបន់ដែលបានសិក្សា និងតំបន់គម្រោងអភិវឌ្ឍន៍ យើងអាចលើកឡើងជាអនុសាសសន៍ដូចខាងក្រោម:

➢ ពិចារណាអំពីចំនួនប្រជាពលរដ្ឋដ៏ច្រើនរស់នៅក្នុងទំនាបភាគខាងជើង និងជាតំបន់ដែលធ្លាប់មានទឹកជំនន់ញឹកញាប់រួចមកហើយ គំរូដែលត្រូវយកមកអនុវត្ត ត្រូវតែជាសមាសភាពមួយយ៉ាងសំខាន់នៃដំណើរការរៀបចំផែនការ និងការវាយតម្លៃផលប៉ះពាល់ណាដែលជឿជាក់បាននៃគម្រោងអភិវឌ្ឍន៍ ។ទោះបីជាគម្រោងរៀបចំប្រព័ន្ធទឹកស្អុយ ដូចបានលើកឡើងក្នុងរបាយការណ៍ស្តីពីការវាយតម្លៃផលប៉ះពាល់បរិស្ថាន និង សង្គមក៏ដោយ ក៏ក្រុមវាយតម្លៃទឹកជំនន់ពុំបានទទួលរបាយការណ៍លំអិតណាមួយអំពីបញ្ហានេះដែរ។ ប្រព័ន្ធទឹកស្អុយក៏ទំនងជាពុំបានគិតគូរដល់ផ្លូវសម្រាប់ទឹកជំនន់ហូរចេញដែលគួរជាទីចាប់អារម្មណ៍នៅក្នុងរបាយការណ៍នេះឡើយ។ របាយការណ៍វាយតម្លៃផលប៉ះពាល់បរិស្ថាន និង សង្គមពុំបានដាក់បញ្ចូលនូវផ្លូវទឹកជំនន់ហូរចេញនៅក្នុងការអភិវឌ្ឍន៍ឬឃើញមានការវិភាគក្នុងកម្រិតណាមួយដែលតម្រូវឱ្យមានដើម្បីធ្វើការពង្រីកប្រឡាយដែលជួយកាត់បន្ថយផលប៉ះពាល់ដោយសារការអភិវឌ្ឍន៍នេះឡើយ។

- ដូចគ្នានេះដែរការផ្តល់នូវកម្រិតនៃការជឿជាក់ថាតើប្រព័ន្ធដែលបានស្នើឡើងនឹងដំណើរការបានឬអត់នោះ ដំណើរការគិរួ ហាក់ដូចជារកឃើញតែតំបន់ដែលមានបញ្ហាស្រាប់។ ការរៀបចំគម្រោងនិង ការអនុវត្តហេដ្ឋារចនាសម្ព័ន្ធដើម្បីកាត់បន្ថយទឹកជំនន់នៅក្នុងតំបន់ដែលមានបញ្ហាស្រាប់ សាលាក្រុងត្រូវចាត់ទុកជាការងារអាទិភាពខ្ពស់ជាងការកែលំអរហេដ្ឋារចនាសម្ព័ន្ធដើម្បីជួយសម្រួលការអភិវឌ្ឍន៍ធំៗរបស់ក្រុមហ៊ុនឯកជន។
- ការទទួលខុសត្រូវក្នុងការកែលំអរហេដ្ឋារចនាសម្ព័ន្ធដើម្បីជួយសម្រួលដល់ការអភិវឌ្ឍន៍ឯកជនត្រូវតែជាការទទួលខុសត្រូវរបស់ក្រុមហ៊ុនអភិវឌ្ឍន៍ខ្លួនឯងផ្ទាល់។ ប្រសិនបើក្រុមហ៊ុនចង់អភិវឌ្ឍន៍តំបន់ណាមួយ គេត្រូវតែអនុវត្តរាល់ការងារចាំបាច់ទាំងឡាយដើម្បីធានាយ៉ាងណាកុំឱ្យមានផលប៉ះពាល់អវិជ្ជមានដល់ទ្រព្យសម្បត្តិ និង អាយុជីវិតជុំវិញ ។
- ហាក់ដូចជាខ្វះការពិគ្រោះយោបល់ជាមួយសហគមន៍មូលដ្ឋាន និង គ្មានតម្លាភាពនៅក្នុងដំណើរការនេះ។ សហគមន៍មូលដ្ឋាន ពុំមែនគ្រាន់តែជាភាគីពាក់ព័ន្ធមួយដ៏សំខាន់ប៉ុណ្ណោះទេ ប៉ុន្តែថែមទាំងជាប្រភពព័ត៌មានយ៉ាងសំខាន់អំពីបញ្ហានៅក្នុងមូលដ្ឋាន និង ទឹកជំនន់ទៀតផង។ ព័ត៌មានបែបនេះ គឺមានតម្លៃយ៉ាងខ្លាំងចំពោះការរៀបចំ និង អនុវត្តយុទ្ធសាស្ត្រកាត់បន្ថយទឹកជំនន់។ អនាគតប្រសិនបើមានការវាយតម្លៃអំពីទឹកជំនន់ និង ការបង្ហូរទឹកចេញនៃតំបន់ណាមួយ ត្រូវទាញយកព័ត៌មានពីប្រភពដ៏មានតម្លៃបែបនេះព្រមទាំងផ្តល់តម្លាភាពដល់សហគមន៍ចំពោះបញ្ហាទឹកជំនន់នេះ។
- គម្រោងចាក់ដីលប់បឹងកក់នេះត្រូវពិចារណាឡើងវិញចំពោះបញ្ហាប៉ះពាល់ដែលបង្ករឡើង និង កង្វះភាពស្របគ្នា ជាមួយផែនការគោលរបស់សាលាក្រុង។

EXECUTIVE SUMMARY

Boeung Kak is a 90 hectare lake located within the Doun Penh district in the north of Phnom Penh city. A private developer, Shukaku Inc, has leased an area of 132ha, including the lake, from the Municipality of Phnom Penh and plans to fill and develop the area. This report investigates the potential impact on flooding as a result of the proposed development of the Boeung Kak area (BKA).

Boeung Kak is a closed lake system, meaning that the catchment is not much larger than the lake itself, and there is no outlet for water from the lake. Rainfall onto the lake itself is stored within the lake until it evaporates or infiltrates. The volume of this direct rainfall was estimated for a storm event in April 2008 at 360,000m^3. This event was not noted as particularly large by residents of the lake.

Following filling and development of the BKA, rainfall on the development is expected to be diverted to neighbouring areas downstream to the north. The anticipated increase in peak flood levels and flood frequency that would result without mitigation is considered unacceptable. Shukaku Inc released an Environmental and Social Impact Assessment in August 2008. This ESIA includes only vague plans for mitigation, such as 'dig a canal 20-21m^2 in area'. These plans do not appear to be based on sound engineering assessment. Further, Shukaku Inc disputes their obligation to mitigate the impact of their development.

A dynamically linked one and two-dimensional hydraulic model has been developed for the lake and the neighbouring Russei Kai district. Four scenarios have been modelled:

- Existing Case;
- Development Scenario 1 (filling of the BKA, pre-construction of mitigation);
- Development Scenario 2 (filling of the BKA and excavating 21m^2 of additional cross sectional area along the canals to the north); and
- Development Scenario 3 (filling of the BKA, excavating 21m^2 of additional cross sectional area along the canals to the north and doubling the size of the cross drainage structures at road crossings).

While the lake is a closed system with little catchment contribution beyond the lake itself, the proposed development area is large enough to generate large volumes of runoff. This runoff has potential to cause significant impacts on property and hazard to life downstream.

On all three development scenarios, significant flooding impacts are shown to occur across parts of the Russei Kai district. The modelling undertaken has demonstrated that the hydraulic system downstream of the BKA is complex and requires detailed hydraulic modelling to determine appropriate mitigation measures. The findings of this study have also shown that Shukaku Inc's approach to 'dig a canal 20-21m^2 in area' is insufficient. Without more detailed design and analysis this approach is potentially negligent. The responsibility to design and provide mitigation works falls to Shukaku Inc. These works must be constructed as part of the development prior to filling of the lake to prevent increased risk to life and property.

DISCLAIMER

This report has been compiled by a group of concerned professionals in the field of drainage and flood engineering and is focussed on highlighting potential issues of the proposed Shukaku Inc development of the Boeung Kak area. It is imperative that detailed hydraulic analysis be undertaken as part of the design process. Further, the contributors to this report bear no responsibility for any works that may be undertaken based on any component of this report.

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CONTENTS

1 INTRODUCTION

This report has been prepared by a team of professional drainage and flooding engineers with concerns regarding the environmental impact of the proposed filling and development of the Boeung Kak area (BKA) of Phnom Penh. The company that proposes to develop the area, Shukaku Inc, have released an Environmental and Social Impact Assessment (ESIA) report. This report refers to a drainage design for the proposed development. However, a copy of the drainage design has not been available to the project team that has undertaken the assessment detailed herein. It is unclear from the ESIA whether the drainage design takes account of long term flooding in the BKA and surrounding area. Long term drainage issues are the focus of this report.

Boeung Kak is a 90 hectare lake located within the Doun Penh district in the north of Phnom Penh. Like all of Phnom Penh's lakes, it forms an integral part of Phnom Penh's complex drainage system. Boeung Kak, however, is unique. The contributing catchment covers little more than the area of the lake itself. In addition, there is no gravity outlet from the lake. Thus, the lake functions as a closed system. Rainfall runoff and wastewater generated within the catchment flow into the lake and are stored. This stored water then dissipates through evaporation and infiltration processes. An outlet from the lake is understood to have existed, although it is likely to have become blocked and built upon.

Since Boeung Kak operates as a closed hydrological system, there is no downstream receiving environment for runoff. Boeung Kak, therefore, plays an important role in reducing storm runoff through neighbouring low lying areas.

The filling of Boeung Kak for urban development is likely to disrupt the equilibrium of the hydrological system. Reduction or complete removal of the active storage by lake filling will result in runoff from the BKA being routed further downstream, increasing the amount of runoff through neighbouring catchments. This additional load has the potential to cause stress on the downstream system, and is likely to worsen flooding. In particular, increased flood frequency and peak flood levels are of concern.

As part of this drainage assessment, a dynamically linked one and two-dimensional flood model of Boeung Kak and part of the neighbouring Russei Kai district has been developed. Using the flood model, the flood assessment team has demonstrated the potential for increased flooding as a result of the development of the BKA.

The master plan for the Boeung Kak development does not include details of proposed trunk drainage. Some drawings showing proposed pipelines under Road 70 to the north of Boeung Kak were included in the ESIA, however, little detail was provided on drainage within the development or canal mitigation downstream of the project.

The master plan for trunk drainage throughout the Russei Kai district has been sourced and is an important reference for this assessment. Some assumptions have been made as part of the flood modelling exercise, as discussed in Section 4.2.2. Absolute flood levels may differ on site to those presented here. However, the guiding principles and flow mechanisms are considered valid, and the relative impacts provide a good indication of what is likely to occur due to development of the Boeung Kak lake area.

2 STUDY AREA AND EXISTING DRAINAGE

2.1 Location and Topography

Phonm Penh is located on the south-western floodplain of the Mekong River at the confluence with the Tonle Sap and Tonle Bassac watercourses. The city lies between the Prek Phnov and Prek Thnot watercourses to the north and south of the city respectively. Refer to Figure 2-2 for locality.

The city centre, first established on the high riverbanks, is situated adjacent to the Tonle Sap in the east of the greater Phnom Penh region. The city centre is at an elevation of approximately 10 metres above mean sea level (ASL). The city has since expanded into lower lying areas beyond the river bank. These surrounding low lying areas are primarily used for agriculture, although there are scattered residential and industrial zones. The adjacent low lying land is as low as 4m ASL in the south and 6m ASL in the north.

Boeung Kak is located immediately to the north-west of the city centre of Phnom Penh. Refer to Figure 2-3 for local area plan. The lake covers an approximate area of 90 hectares. Its catchment boundary is formed on the south and west by a raised railway embankment, at an approximate level of 10.0m ASL. To the north is the Road 70 embankment at 10.3m ASL and to the east, the raised bank of the Tonle Sap at up to 11m ASL. The bed of the lake is as low as 2.0m ASL, with the exception of a raised area in the centre.

Boeung Kak is surrounded by residential and light industrial areas. Over the last three decades, the lakeside areas have experienced significant settlement. It is estimated that over 4,000 families currently live on or around the lake (STT, 2008).

2.2 Flooding and Drainage Overview

"*The major environmental constraints on the city of Phnom Penh are flooding and drainage*" (Molyvann, 2003)

Annual floods on the Mekong River typically commence in June and lead to very high water levels. The highest flood on record in Phnom Penh occurred in 1894 with a peak flood level of 11.78m ASL (Molyvann, 2003). Annual maximum and minimum water levels at the Tonle Sap / Mekong River confluence are shown on Figure 2-1, as recorded at the Chaktomouk Station. As can be seen from Figure 2-1, water levels in the rivers rise and fall annually by up to 9 metres, with the annual maximum water level in the Tonle Sap generally between 8 and 10m ASL.

The significant volume of flow in the Mekong River (estimated to be in the order of 40,000m^3/s) backs up into the Tonle Sap, reversing its flow for approximately 110 days of the year. This unique river system has a significant impact on the local hydrology of Phnom Penh.

As the development of Phnom Penh expanded away from the higher river bank, a series of dikes were constructed to prevent floodwaters from the surrounding rivers inundating the low lying land during the monsoon season. Drainage to prevent flooding from local rainfall (average annual rainfall of 1,376mm) within the dikes was necessary. In the 1960s, Phnom Penh developed a '*system of water drainage which included a network of pipes to drain both rain water and used household water.*

In addition, existing "prek" (canals) and "beng" [termed "boeung" in this report] *(ponds) were included in this drainage system*' (Molyvann 2003).

Phnom Penh's catchments and basic drainage schematic are shown on Figure 2-4. The piped drainage / sewer network is most extensive in the centre and south of the city, with areas to the north of Boeung Kak relying primarily on prek and boeung drainage systems. Preks were also constructed to allow floodwaters to bring nutrient-rich silt to the agricultural areas surrounding the city. The operation of preks is well controlled through invert levels or sluiceways.

During the monsoon season, when river levels are higher than the ground level of much of Phnom Penh, pump stations are used to pump the city runoff across the dikes from the boeungs and preks into the rivers. In some parts, runoff is collected and stored until river levels have dropped and it can be released by gravity through sluiceways.

Regional flooding and local drainage therefore present a serious risk to the entire Phnom Penh region.

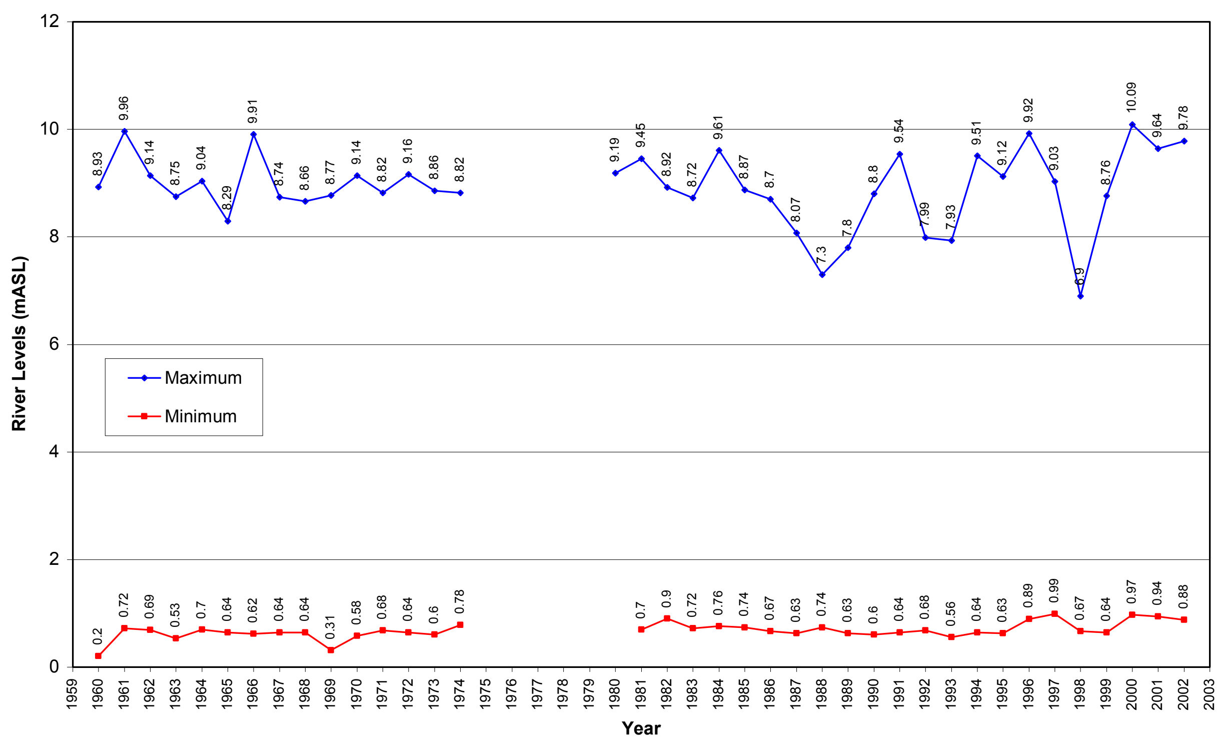


Figure 2-1 Recorded Water Levels at Chaktomouk Station (source JICA)

2.3 Drainage of Phnom Penh

2.3.1 General

The drainage of Phnom Penh can be categorised into southern and northern zones as follows:

- Southern Zone - draining into the Prek Thnot and Tonle Bassac watercourses; and
- Northern Zone – draining into the Prek Phnov and Tonle Sap watercourses.

The city catchment plan is shown on Figure 2-4 with the two zones divided by the Boulevard Confederation de la Russie / Pochentong Road and National Road 4 (NR4). The BKA lies within the Northern Zone. Details of the Southern Zone have, therefore, been omitted from this report.

2.3.2 Northern Drainage Zone

The 108km^2 northern drainage zone can be further sub-divided into four main catchments as listed in Table 2-1 and shown on Figure 2-4.

Table 2-1 Northern Zone Catchments

Watershed	Area (km^2)
City North	5.9
Northeast Area	38.9
Northwest Area	51.1
Pochentong West	12.1
Total North Zone	**108.0**

The Pochentong West catchment is predominantly agricultural. The minimal runoff from this catchment flows across the railway line to the north and into the Northwest Area catchment.

Similarly, the Northwest Area catchment is predominantly agricultural. Runoff from this catchment generally flows to the east across Hanoi Road into the Northeast Area. The elevation of the Northwest Area is typically higher than the low lying land in the Northeast Area. Numerous sluiceways beneath Hanoi Road are un-maintained and in poor operational condition. There is also an abandoned pump station in the north along Hanoi Road (shown on Figure 2-4 as the 'Khmuonb Rd' pump station).

The City North catchment can be further split into the Boeung Kak and north Tuol Kork catchments. As described in the previous sections, Boeung Kak catchment is a closed hydrological system and does not drain into any receiving catchment. The northern part of the Tuol Kork district (north of Boulevard Confederation de la Russie) discharges into the Northeast Area via three small pump stations.

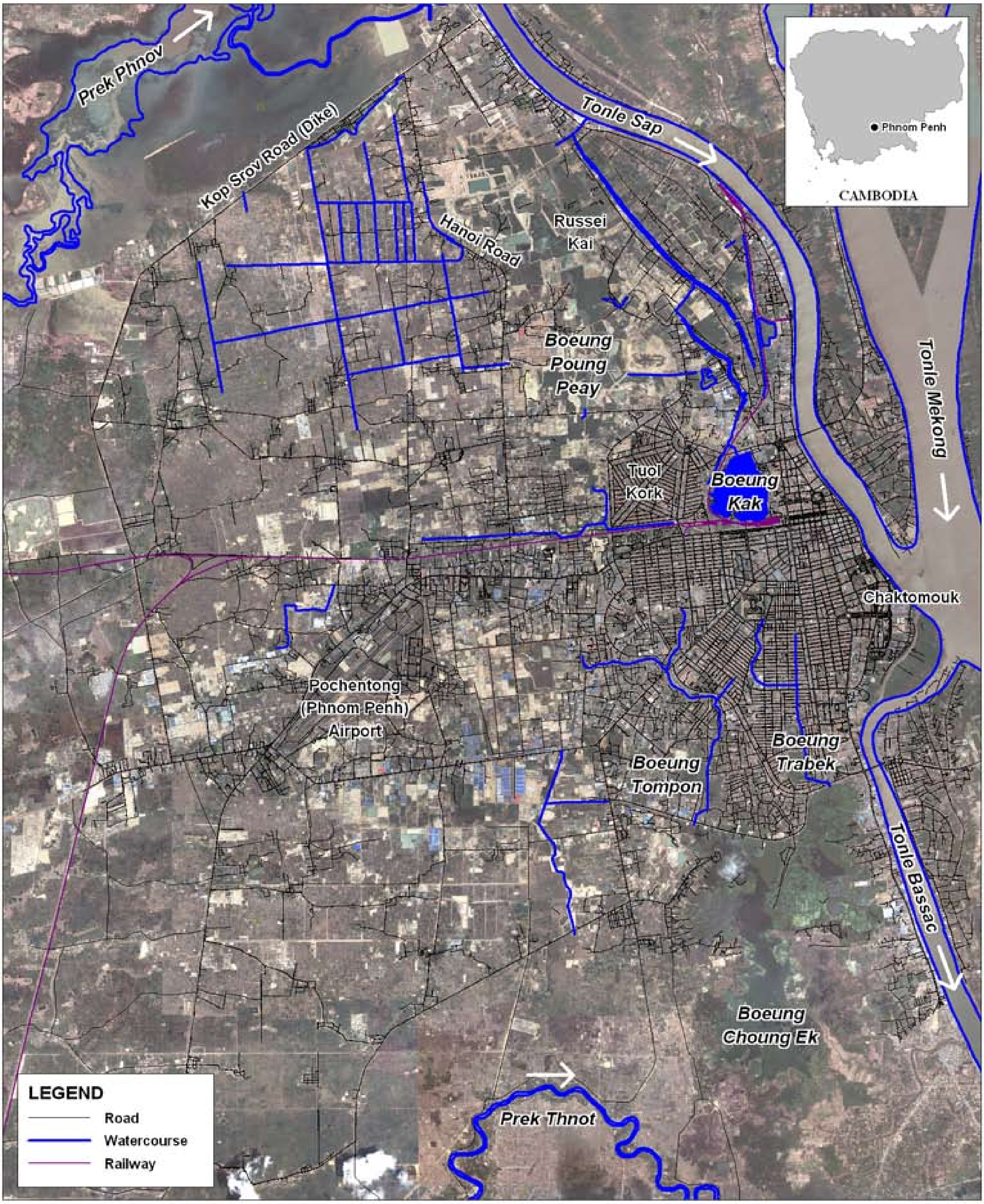
With the exception of the Boeung Kak area, runoff from the entire northern zone flows into the Northeast Area. It is understood that a drainage sluiceway beneath Road 70 used to drain Boeung Kak. This sluiceway is no longer in operation, possibly due to blockage and having been built over.

All runoff to the Northeast Area is stored in the low lying swamp area known as Boeung Poung Peay until it is pumped or released into the Tonle Sap at Svay Pak. The Svay Pak drainage sluiceway and pump station are at the northern end of the Oveng Canal.

2.4 Drainage Infrastructure Maintenance

The drainage system of Phnom Penh was generally well maintained until civil war in the early 1970's. Since this time, the drainage infrastructure of Phnom Penh has largely fallen into disrepair. Many of the piped systems are blocked and many of the original preks have been filled or buildings have constructed on top of them.

JICA (1999) reported that most of the city's drainage infrastructure is blocked by up to 80%. Blockages are typically caused by encroaching settlements and high volumes of solid waste. These blockages are placing additional stress on the current under-capacity drainage network and are, therefore, one of the leading causes of flooding within the city centre.



Drawing Title:

Locality Plan

Drawing No.

Figure 2-2

Drawing is based on base information supplied by the client, 2008.
Background image referenced by the project team from image extracted from Google Earth.
The project team endeavours to ensure that the information provided in this map is correct at the time of publication. The project team does not warrant, guarrantee or make representations regarding the currency, correctness and accuracy of the information contained in this map.

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Approx. Scale

Boeung Kak Area Drainage Assessment

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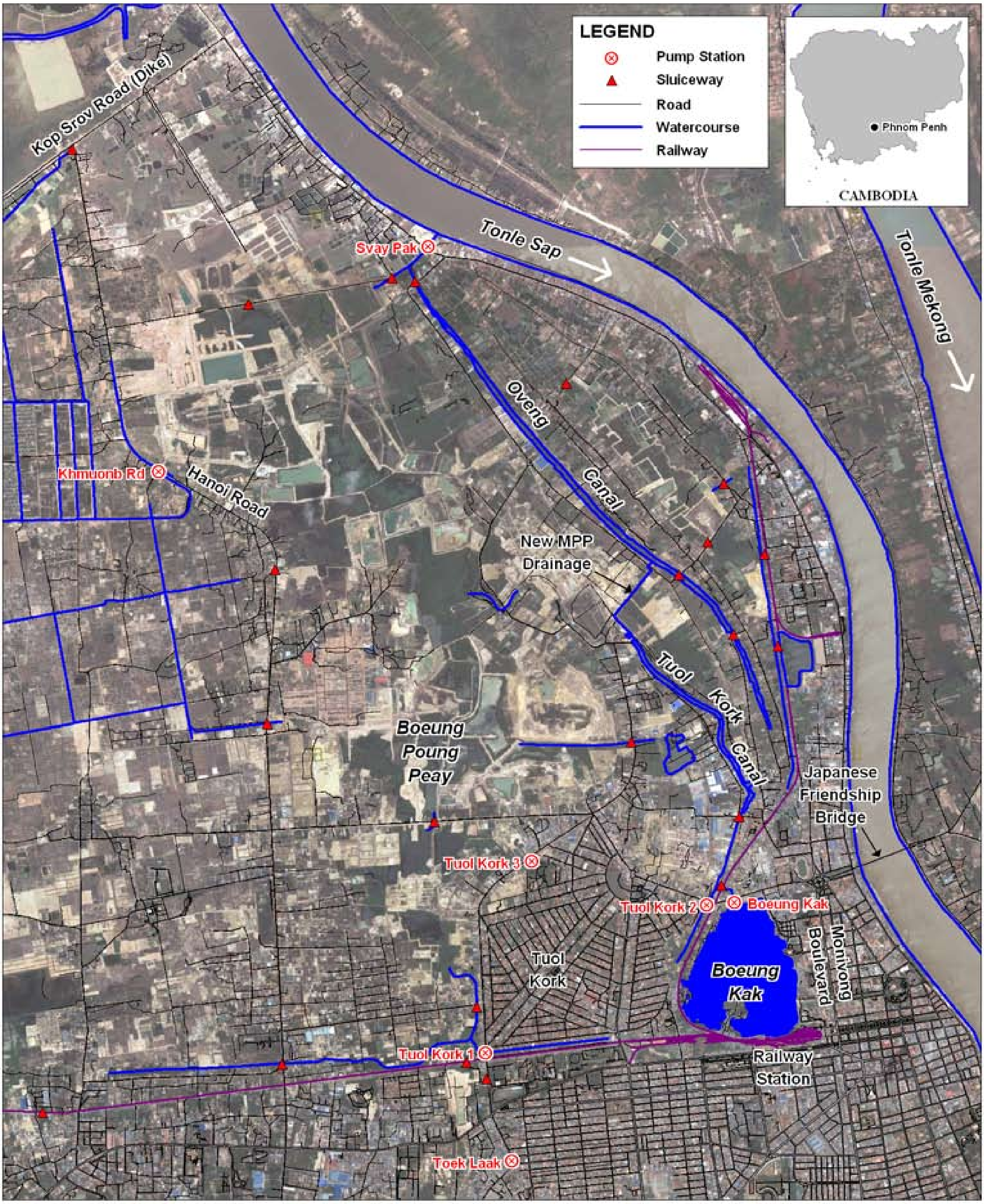

Drawing Title:

Local Area Plan

Drawing No.

Figure 2-3

Drawing is based on base information supplied by the client, 2008.
Background image referenced by the project team from image extracted from Google Earth.
The project team endeavours to ensure that the information provided in this map is correct at the time of publication. The project team does not warrant, guarrantee or make representations regarding the currency, correctness and accuracy of the information contained in this map.

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Boeung Kak Area Drainage Assessment

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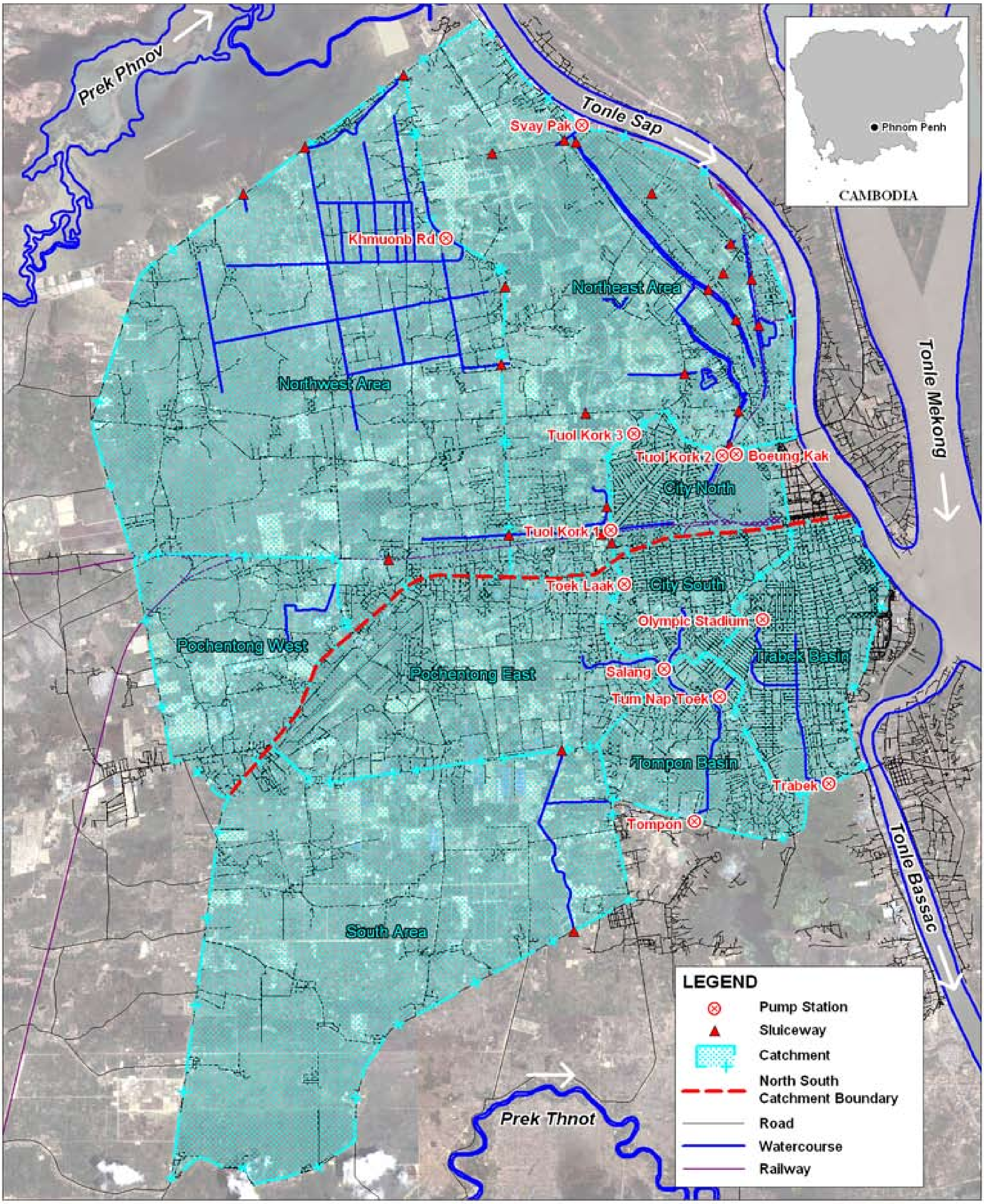

Drawing Title:

Phnom Penh General Catchment Plan

Drawing No.

Figure 2-4

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Boeung Kak Area Drainage Assessment

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3 PHNOM PENH DRAINAGE MASTERPLAN

In October 2007, the Bureau des Affaires Urbaines (BAU) and the Municipality of Phnom Penh (MPP) released the 'Livre Blanc du Developpement et de l'Amenagement de Phnom Penh'. This document contains considerable detail regarding all aspects of the future development and town planning of Phnom Penh. Included in the document is a masterplan which shows the proposed trunk drainage scheme for Phnom Penh, as shown in Appendix A.

As part of Phnom Penh's rapid urban development, two 'satellite' cities are currently under construction in the northeast area. These are the Grand Phnom Penh and Camko City developments. Although exact details of the masterplans for both developments were unavailable to this study, sufficient information was found on community information signs for each development. Refer to Photos 1 and 2 in Appendix B.

With respect to trunk drainage, the information on these community signs for both developments is generally consistent with the masterplan produced by BAU and MPP. A schematic representation of the proposed trunk drainage for the northeast area is shown on Figure 3-1.

The BAU/MPP drainage masterplan for Phnom Penh appears to recognise the requirement for additional trunk drainage infrastructure in the northeast area. An additional pump station is currently being constructed along the Kop Srov outer ring dike. The proposed pump station will be connected to Boeung Poung Peay via a large canal of 50m width. This canal is referred to as the 'Grand Canal du Nord'. Refer to Appendix A for a schematic layout of the Grand Canal du Nord. This canal will also be connected to the Oveng Canal near the Svay Pak drainage sluiceway and pump station.

As part of the BAU/MPP masterplan, the proposed drainage canals and Boeung Poung Peay will be connected to the irrigation canals of the northwest area. These canals are shown to cross the Hanoi Road in the same location as the existing abandoned pump station and existing sluiceways. It is expected that the existing canals will be cleared of the material currently causing their blockage.

To the south, an interesting feature of the BAU/MPP masterplan is the connection of the Tuol Kork canal to Boeung Poung Peay, in addition to the existing connection to the Oveng Canal. A canal is also shown as an outlet from Boeung Kak to the Tuol Kork canal. Importantly, there is no indication or consideration in the Masterplan that Boeung Kak will be filled for development.

At the time of writing, there was sufficient evidence to suggest that the implementation of the BAU/MPP masterplan is underway. Such evidence includes:

- Construction of the 'Grand Canal du Nord' is underway. Refer to Photo 3 in Appendix B.
- Construction of the canal at the entrance to Grand Phnom Penh is complete. Refer to Photo 4 in Appendix B.
- Excavation of the deep lake (Boeung Poung Peay) to the northwest of Camko City is currently underway. This excavation is the source of the fill for the development. Refer to Photo 5 in Appendix B.

Unlike the drainage augmentation of the Boeung Saleng and Boeung Trabek basins in the south of Phnom Penh, MPP have advised that no detailed modelling has been undertaken to determine the potential impact of subject development or for the design the drainage systems. It is unclear whether the developers of Grand Phnom Penh or Camko City have undertaken any modelling to assess the potential impact of development or inform channel design requirements.

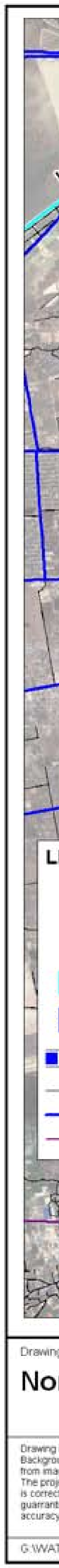
In 1999, JICA released the 'Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh'. In this document, eight projects were proposed to upgrade the city's drainage and flood protection infrastructure. Since release of the report, most of these projects have been implemented. The focus of that study and subsequent projects was in the southern drainage zone, with the exception of the following works in the northeast area:

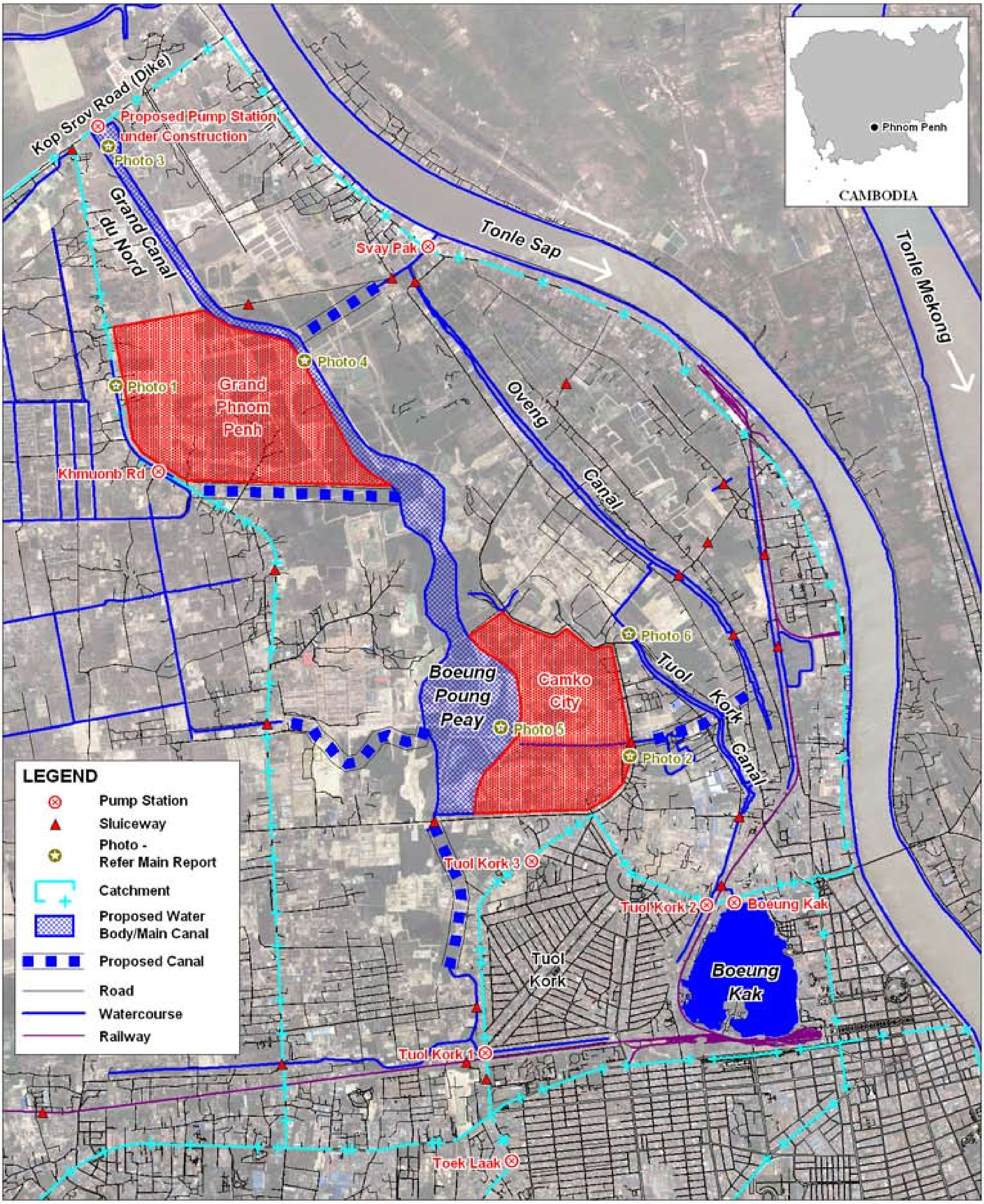
- Upgrade of the Svay Pak sluiceway;
- Reinforcement of the Kop Srov dike; and
- Construction of the Poung Peay Drainage Main.

JICA assessed whether construction of a pump station at Svay Pak would be feasible. Their study concluded that the operating costs would be economically unviable. However, as part of the sluiceway upgrade project, a pump station has been constructed and is currently operated by MPP.

During that study, a two-dimensional hydraulic flood model was developed for the greater Phnom Penh region. The model was based on a 200m square grid. However, due to the complex network of drainage canals, sluiceways and topography, this model resolution is considered to be too coarse for the detailed modelling and design of drainage infrastructure.

The MPP have also commenced construction of a culvert and canal connecting the Tuol Kork Canal to the Oveng Canal. Refer to Figure 3-1 for location and Photo 6 in Appendix B. This linkage is likely to ease flooding immediately to the north of the BKA.





Drawing Title:

Northeast Area Drainage Masterplan

Drawing No.

Figure 3-1

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Boeung Kak Area Drainage Assessment

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4 STUDY METHODOLOGY

4.1 General Approach

Best practice in any flooding and drainage assessment includes quantification of inflows using hydrological modelling and subsequent quantification of depths and velocities using hydraulic modelling. This study has adopted this approach using state-of-the-art modelling techniques applied to available data as described below.

4.2 Hydrological Modelling

4.2.1 Design Rainfall Event Selection

Hydrological modelling is the process of estimating the likely quantity and rate of runoff in a catchment from a given rainfall event. Estimates of runoff can be for either historical storm events, or design rainfall. Historical event analysis is commonly used for model calibration prior to design rainfall typically being used for the design of infrastructure.

Design events such as the 100 year average recurrence interval (ARI) event are an estimate of the rainfall that could be statistically expected to occur once every 100 years. Across the world, the 100 year ARI event is commonly used as a flood damage prevention requirement (ARR87). More frequent events such as the 5 year or 10 year ARI are more commonly used for the sizing of sub-surface drainage infrastructure and to prevent nuisance flooding.

In this report, infrastructure used for flood prevention is described as ‘trunk drainage’ infrastructure. This includes overland flowpaths, large collector pipes, canals, pump stations and basins. Minimising the hazard to people and damage to property and infrastructure and minimising hazard to people are major factors in this process.

The MPP have adopted the following design rainfall events:

- 2 year ARI for the design of secondary drainage infrastructure such as the city’s sub-surface drainage network;
- 5 year ARI for the design of primary drainage infrastructure such as trunk drainage canals; and
- 10 year ARI for the design of infrastructure vital to the protection of the city, such as dikes and pump stations.

Use of the 5 year and 10 year ARI events for the design of trunk drainage is considered inadequate. Given the considerable expense that is required for construction of trunk drainage infrastructure, it seems more appropriate to ensure flooding occurs less frequently than every five or ten years. This is especially valid for the flood prone northern area, where flooding poses a significant public health risk.

Therefore, for this assessment, the 10 year and 50 year ARI events have been assessed. The 10 year ARI is to identify deficiencies in the current drainage infrastructure which is supposed to cater for that event and 50 year ARI is used to assess more serious flooding risks. It should be noted that, as part of a detailed environmental impact assessment for the Boeung Kak development, provision for events larger than this is strongly recommended.

Hydrologic modelling of the entire catchment is undertaken at a scale appropriate for the study. Hydrology results are then input to the hydraulic model, which calculates flood levels, extents, velocities and flow rates.

4.2.2 Hydrological Modelling Methodology

Three types of hydrological inflow boundaries have been applied to the 1D/2D flood model as follows:

- Constant flow rate from the Tuol Kork II pump station;
- Hydrograph inflow from the proposed Boeung Kak development; and
- Rainfall applied directly to the two dimensional (2D) hydraulic model grid.

Inflows from the Tuol Kork catchment have been applied to the hydraulic model based upon the maximum pumping rate of the Tuol Kork II pump station. This has been assessed as 4,200m^3/hr (DPWT Sewage Works 2007)

The estimated runoff hydrograph from the BKA has been calculated using WBNM software. WBNM is a runoff routing program widely used within Australia. Chapter 5 provides further detail on this approach.

Rainfall occurring over the hydraulic model area has been applied directly to the model grid surface. This feature is a powerful feature of the TUFLOW hydraulic modelling software package detailed below.

4.3 Hydraulic Modelling

4.3.1 General Arrangement

Hydraulic modelling has been undertaken using the TUFLOW hydrodynamic flood modelling software. TUFLOW is a dynamically linked one and two-dimensional modelling package which is used widely across Australia, the United States, continental Europe and the United Kingdom.

TUFLOW enables one-dimensional (1D) representation of channels and structures, such as culverts, to be dynamically nested within a broader two-dimensional (2D) grid of the surrounding areas. The 2D grid allows localised topographical features, such as road embankments, to be suitably represented. Surface roughness is also represented in the 2D domain. Refer to www.tuflow.com for further details.

A 10m square grid cell size has been selected for this model. The grid size has been selected to enable all influential topographic features to be represented, whilst keeping simulation run times to a manageable duration.

The extents and layout of the hydraulic model are shown on Figure 4-1. Canals and associated culverts have been represented as 1D components. This includes the Tuol Kork and Oveng Canals.

Where culverts are located beneath road crossings, 1D culvert structures have been modelled, with 1D weirs used to simulate the flow of water across the road embankments.

A static water level boundary has been used for Boeung Poung Peay, setting the water level at 6.8m ASL. This level was used by JICA (1999) as an initial water level under flood conditions. As a conservative approach, a static water level equal to 6.1m ASL has been applied to the downstream boundary on the Oveng Canal.

Land use and corresponding surface roughness has been determined from aerial photography and verified during site inspections.

4.3.2 Hydraulic Model Assumptions

As with any modelling exercise, various assumptions have been made. The assumptions typically relate to topography, land use and hydraulic controls, such as drainage structures. Two site inspections have been undertaken by the drainage assessment team; in May 2008 and August 2008. The site inspections were necessary to verify some of the assumptions inherent in the modelling process. The timing of the site visits was particularly relevant, allowing the team to view the study area under different seasonal conditions.

Key assumptions are detailed below:

- *Cross-section of Trunk Drainage Canals:* Due to inundation, detailed survey of the trunk drainage canal cross sections was not possible. However, measurements were taken where possible. As with most drainage systems, the hydraulic behaviour is largely dictated by the hydraulic losses across structures and is less dominated by the conveyance capacity of the open channels. Hence, the effect of these assumptions is not considered to have a significant bearing on the overall conclusions drawn.
- *Cross-Drainage structures*: Due to inundation, detailed survey of the hydraulic structures along the trunk drainage canals was not possible. However, measurements were taken where possible. As discussed above, the hydraulic behaviour is largely dictated by the hydraulic losses across such structures. However, in this system with such a flat gradient, the hydraulic structures are likely to be operating in outlet control for the majority of the flood events. Hence, assumptions regarding the inverts of the hydraulic structures become less relevant under this flow regime and the effect of these assumptions is not considered to have a significant bearing on the overall conclusions drawn.
- *Blockage*: For the purpose of this impact assessment, no blockage factors have been applied to the canals or cross drainage structures. At the time of both site inspections, it was recorded that most canals and cross drainage structures were significantly blocked. However, this impact assessment assumes that the canals and structures have been cleared of blockages.
- *Downstream Water Level:* The downstream water level in Boeung Poung Peay has been set at 6.8m ASL (JICA, 1999).
- *Pumping Rates:* The Tuol Kork II pump station has been assumed to have two pumps, each operating at 2,100m^3/hr.

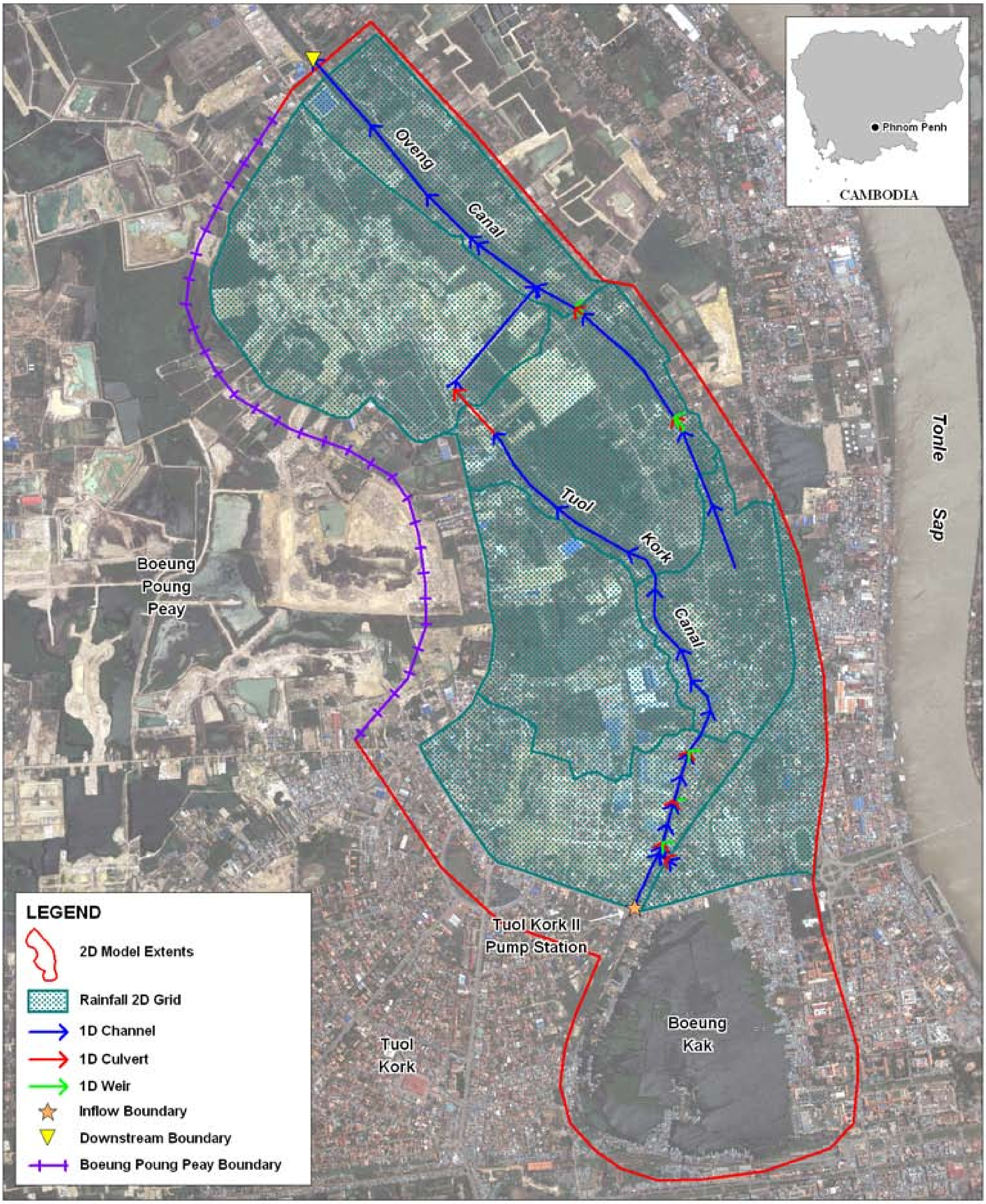
Although these assumptions have the potential to affect the results of the modelling, it is important to note that the focus of the modelling exercise is the relative impacts caused by the development of

Boeung Kak. As the assumptions used in the existing case have also been applied to the developed case model, the relative impact is expected to be a good estimate of that which would actually occur.

4.3.3 Scenarios

The following two scenarios have been modelled for this assessment:

- Existing Case– this scenario assumes no discharge from the BKA. The Tuol Kork II pump station is assumed to be running at full capacity.
- Development Scenario 1 – this scenario includes the discharge from a fully urbanised development in the BKA, however, works to upgrade the trunk drainage system to convey the additional flow resulting from the development are assumed not yet constructed. This is in line with Table 8-1 of the ESIA, which states that upgrade of the canal system will occur after development of the Boeung Kak area. There will therefore be a period of increased likelihood of higher peak flood levels. Drainage within the development is not represented. It is assumed that all flows generated from the BKA catchment enter the Tuol Kork Canal immediately to the north of Road 70. The same flow rate from Tuol Kork II pump station is applied as per the existing case (i.e. full capacity).
- Development Scenario 2 – this scenario includes the discharge from a fully urbanised development in the BKA. It also includes widening of the trunk drainage canals downstream of the proposed development as can be best interpreted from the ESIA. The ESIA states that the options for mitigation are to “dig a canal with 20-21m² in diameter based on each canal. On the other hand, the idea of broadening the Bak Touk canal up to 12 m wide and O'Veng (the long lake) up to 45 meter wide”. Importantly, this scenario assumes removal of the new culverts constructed by MPP connecting the Tuol Kork and Oveng Canals.
- Developnment Scenario 3 – this scenario is similar to Development Scenario 2, although includes a 100% enlargement of all cross drainage infrastructure along the Tuol Kork and Oveng Canals. This scenario has been modeled to highlight the hydraulic importance of the cross drainage structures.



Drawing Title:

Hydraulic Model Layout

Drawing No.

Figure 4-1

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Boeung Kak Area Drainage Assessment

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5 HYDROLOGICAL ANALYSIS

5.1 Historical and Design Rainfall

Daily rainfall records were obtained from the Pochentong Meteorological Station, near the Phnom Penh Airport, for the period between 1981 and 2008. The station is approximately 7km from Boeung Kak. Short duration storms, typical of the monsoon period, are generally caused by localised convective storm cells. It is, therefore, possible that short duration storm events recorded at Pochentong, may not have occurred at Boeung Kak at a similar intensity. However, since Phnom Penh is relatively flat, little orographic variation to the rainfall patterns can be expected. Therefore, the rainfall recorded at Pochentong can be considered a representative average of rainfall at Boeung Kak.

As part of the 'Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh' (JICA 1999), CTI Engineering analysed the historical rainfall records from the Pochentong Meteorological Station between 1981 and 1997. Four different rainfall intensity duration relationships were assessed for the 2, 5, 10, 30 and 50 year average recurrence interval events. The Horner type relationship was adopted for that study.

A further study, undertaken by a Norwegian consultant COWI, produced similar rainfall intensities as those presented by JICA. To derive standard design rainfall intensities, MPP considered both studies, and adopted a relationship that provided intensities within the range of those presented by JICA and COWI.

Design rainfall intensities adopted by MPP for smaller events, and those presented by JICA for larger events, are presented in Table 5-1.

Table 5-1 Design Rainfall Intensities

Duration	5 year ARI *		10 year ARI *		50 year ARI **		100 year ARI **	
	Intensity (mm/hr)	Total (mm)	Intensity (mm/hr)	Total (mm)	Intensity (mm/hr)	Total (mm)	Intensity (mm/hr)	Total (mm)
30 min	88.3	44.2	100.3	50.2	147.6	73.8	166.0	83.0
1 hour	59.4	59.4	69.2	69.2	102.2	102.2	120.0	120.0
3 hour	26.0	78.0	31.1	93.3	38.2	114.7	45.9	137.6
6 hour	14.2	85.2	17.1	102.6	23.2	139.0	27.8	166.8
12 hour	7.50	90.0	9.07	108.8	11.3	135.3	13.5	162.4
24 hour	3.89	93.4	4.71	113.0	6.83	164.0	7.30	175.2

* as adopted by MPP
** as presented by JICA, 1999

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5.2 Temporal Pattern

For this assessment, the temporal pattern adopted by MPP has been used. The pattern is representative of a monsoonal storm event with the main rainfall burst occurring at the start of the rainfall period. The temporal pattern is shown on Figure 5-1.

The same pattern has been adopted for all duration and recurrence interval events.

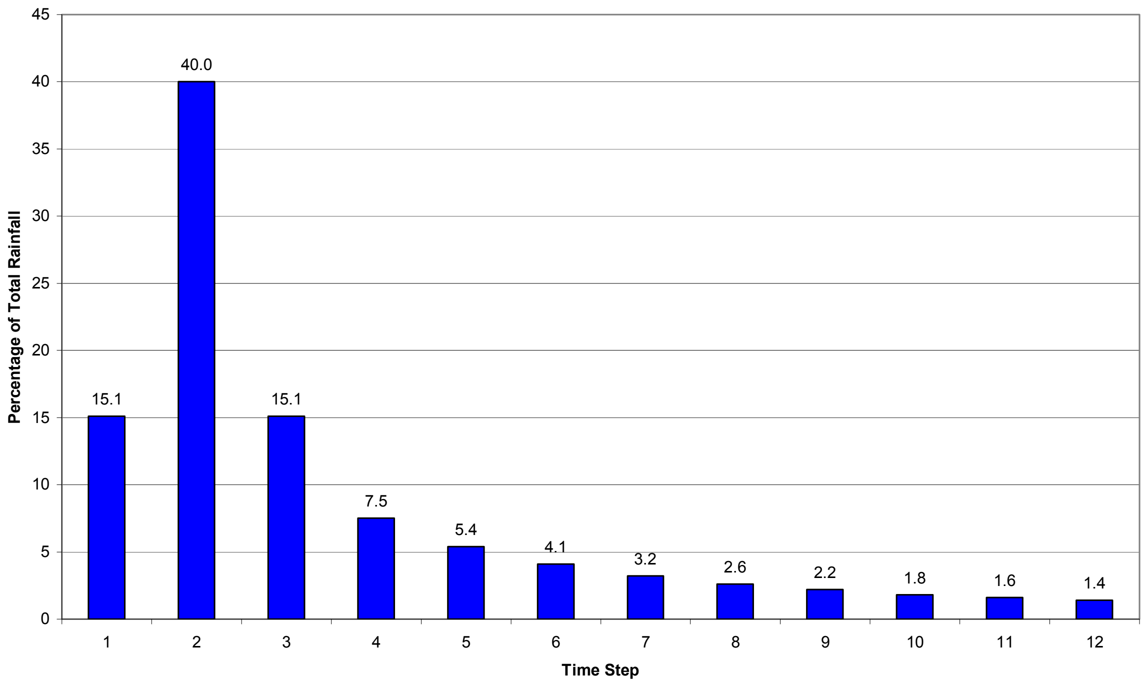


Figure 5-1 Adopted Temporal Pattern

5.3 WBNM Model Parameters

Losses for the WBNM model were set as 20mm initial loss and 2.5mm/hr continuing loss. The proposed development has been assumed to be 60% impervious as per typical low density residential development. This is considered conservative for this impact assessment. Reduction of the initial loss and increase in the impervious fraction will cause an increase in runoff and will subsequently exacerbate flooding downstream.

A catchment lag parameter equal to 1.6 was used as recommended in the WBNM User Guide (2007).

5.4 Modelling Results

Hydrological modelling was undertaken for all event durations listed in Table 5-1 ranging from 30 minutes to 24 hours. The duration that resulted in the largest flow rate within the BKA was found to be 1 hour. Given the proportion of the 1D/2D hydraulic model area in comparison to the BKA and analysis presented by JICA, a critical duration of 3 to 6 hours in the urban areas downstream of the BKA can be expected.

6 HYDRAULIC ANALYSIS

6.1 Critical Event Modelling

As discussed in Section 5, hydrographs were estimated for input into the hydraulic model. Although the highest flow rate from the BKA was found to result from the 1 hour event, the critical duration event is that which results in the highest flood levels. For the entire study area, a critical duration of 3 to 6 hours is expected. Therefore, the 1 hour, 3 hour and 6 hour duration events were simulated in the hydraulic model to determine the critical duration event.

This process considers both short, high intensity storm bursts causing high peak flow rates, as well as longer duration events which ultimately result in a greater volume of rainfall.

Analysis of the results indicates that a combination of the 1 hour and 3 hour events leads to peak flood levels across different parts of the study area. Therefore, the results of the two duration events have been combined to form envelopes of peak flood levels and depths.

6.2 Existing Case Modelling Results

Existing case peak flood depths for the 10 year ARI event are presented on Figure 6-1 and represent the maximum depths expected during the 1 hour and 3 hour duration events. These values do not occur in all places at one particular time during the flood. Rather, they are the peak value at any time during the flood at each 10m grid cell.

Similarly, existing case peak flood depths for the 50 year ARI event are presented on Figure 6-2. Again, these figures represent the maximum depth expected during the 1 hour and 3 hour duration events.

Across the area to the west of the Tuol Kork Canal, peak flood depths typically range between 0.1m and 0.8m for the 10 year ARI event and 0.2m and 1.0m for the 50 year ARI event. To the north of Road 70, peak flood depths typically range between 0.1m and 0.6m during both events. This area is prone to flooding from local rainfall and flows backing up beneath the railway from the Tuol Kork Canal (2 x 1.0m diameter pipes). These results are consistent with reports of past flooding events in this area from residents and shop owners, as well as flood marks on walls, buildings and fences.

To the southwest of the Oveng Canal, flood depths are generally shallower, between 0.1m and 0.2m during both events. It should be noted that flooding in this northern area is likely to be influenced by backwater effects in the Oveng Canal. Thus, the assumed water levels will have an impact upon predicted flooding. For a more detailed study of the flooding in this northern area, modelling should be undertaken to include the Svay Pak pump station and connecting canals.

6.3 Impact Assessment Results

As expected, the hydraulic modelling predicts that the proposed development will increase the rate and volume of runoff entering the drainage system north of Road 70. The simple reason for this increase is due to the loss of important flood storage capacity currently in Boeung Kak. Although the lake does not store floodwater from external areas, rainfall on the lake itself can generate more than

360,000m^3 of water over two days, as evidenced by rainfall in April 2008. Without the lake flood storage, the runoff from the proposed development will be un-attenuated and flow directly into an area with currently poor drainage infrastructure to the north.

Development Scenario 1 peak flood depths and impacts for the 10 year ARI event are presented on Figure 6-3 and Figure 6-4 respectively. These figures represent the maximum depth and increase in peak flood levels/depths expected during the 1 hour and 3 hour duration events.

Development Scenario 1 peak flood depths and impacts for the 50 year ARI event are presented on Figure 6-5 and Figure 6-6 respectively. Again, these figures represent the maximum depth and increase in peak flood levels/depths expected during the 1 hour and 3 hour duration events.

Peak flood levels are shown to increase as a result of the development by up to 0.4m in both the 10 year and 50 year ARI events. The areas of greatest impact are immediately to the north of BKA on both the east and west sides of the railway embankment, and approximately 1.5km to the north of BKA. Significant increases are expected to the northwest as far as the proposed development site of Camko City and Boeung Poung Peay.

It should be recognised that not only will flood levels increase, but the frequency of flooding will also increase. Although events smaller than the 10 year ARI have not been analysed, it can be inferred from the impact in the 10 year ARI that higher flood levels in smaller events would also occur. Thus, for example, flood levels that occur once every two years on average under existing conditions, may occur every year following development of the BKA.

It is interesting to note that flood impacts do not extend further north than the new culvert constructed by MPP connecting the Tuol Kork and Oveng Canals. The peak flow rate in the culvert is approximately 2m^3/s in any event. This indicates that the culverts are significantly undersized, thus are creating a constriction to flows. It should also be noted that the many road crossings along the Tuol Kork and Oveng Canals have insufficient cross drainage capacity. This point is particularly valid along the Tuol Kork Canal where floodwater breaks out of the canal at the road crossings. During the site inspections, some local shop owners described how this occurred during the 2007 floods. Flood marks on buildings provide clear evidence of this. These culverts should be enlarged to increase their capacity.

Development Scenario 1 flood depths and velocity vectors are shown on Figure 6-7 and Figure 6-8 for the 10 year and 50 year ARI 3 hour duration event. The depths and velocity vectors shown are at 2 hours simulation time. As can be seen from these two figures, there is significant inundation of the residential and industrial areas to the north of 70, even in a 10 year ARI event.

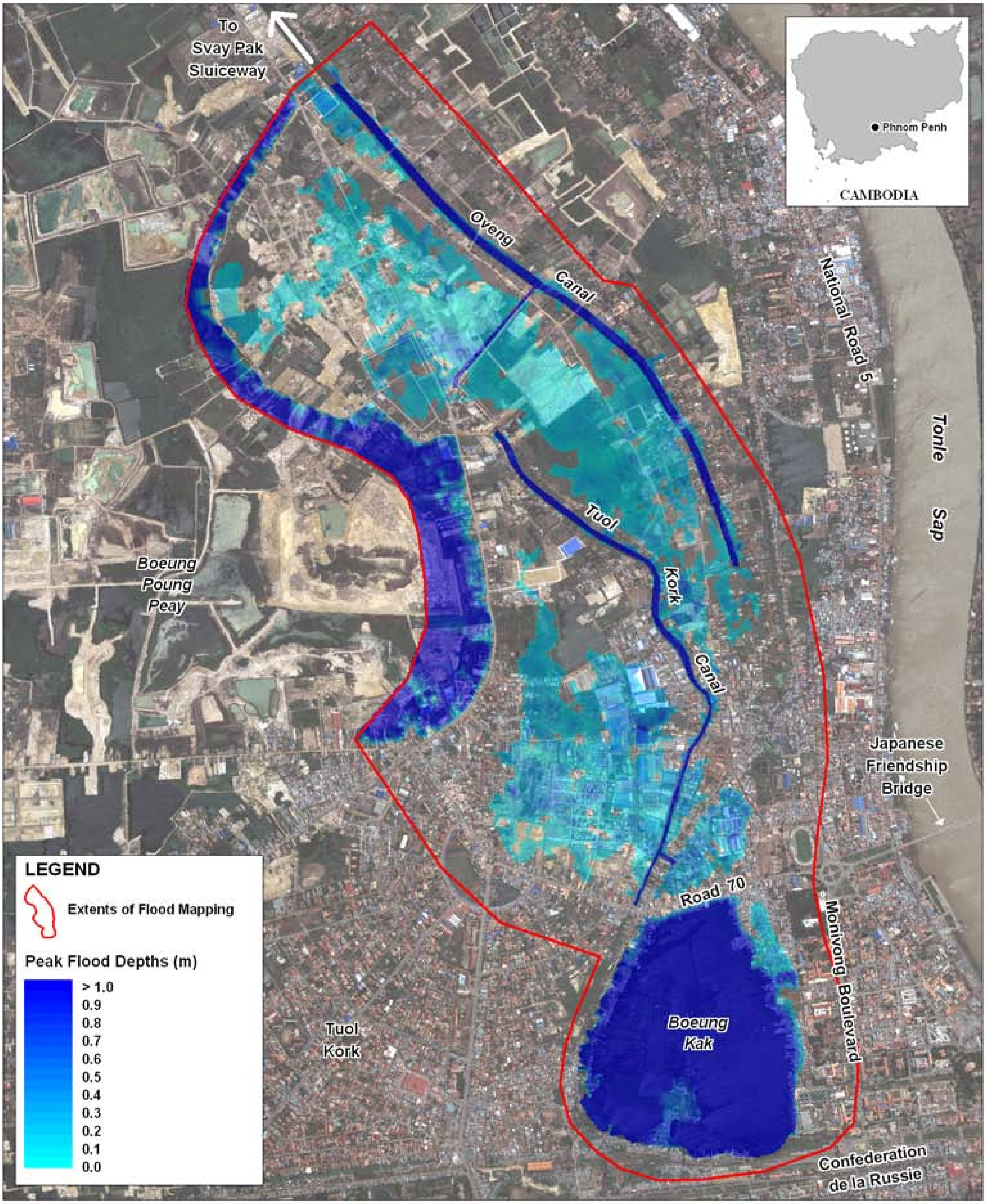
In also needs to be noted that the estimated runoff rates from the proposed development (derived from the hydrological model) are conservative estimates assuming low density development. If the development is medium or high density, then the impacts presented above will be worse.

Refer to Appendix C and Appendix D for snapshots of flood depth animations for the 10 year and 50 year ARI events.

The results of Development Scenarios 2 and 3 are presented on Figure 6-9 and Figure 6-10. These two figures show that increasing the capacity of the Tuol Kork and Oveng Canals is likely to reduce the flooding impacts caused by the development of BKA. Comparison between Figure 6-9 and

Figure 6-10 also highlights the importance of the cross drainage structures along both canals. The modelling shows that simply doubling the size of the structures is not sufficient, and flood levels and frequency of inundation still occurs under Development Scenario 3. More detailed hydraulic investigation is required in this area.

It is also important to note how removal of the culverts, recently constructed by MPP, connecting the Tuol Kork and Oveng Canals will reduce the impact of flooding upstream. This highlights the earlier statement that these culverts are significantly undersized.



Drawing Title:

10 Year ARI Existing Case Peak Flood Depths

Drawing No.

Figure 6-1

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Boeung Kak Area Drainage Assessment

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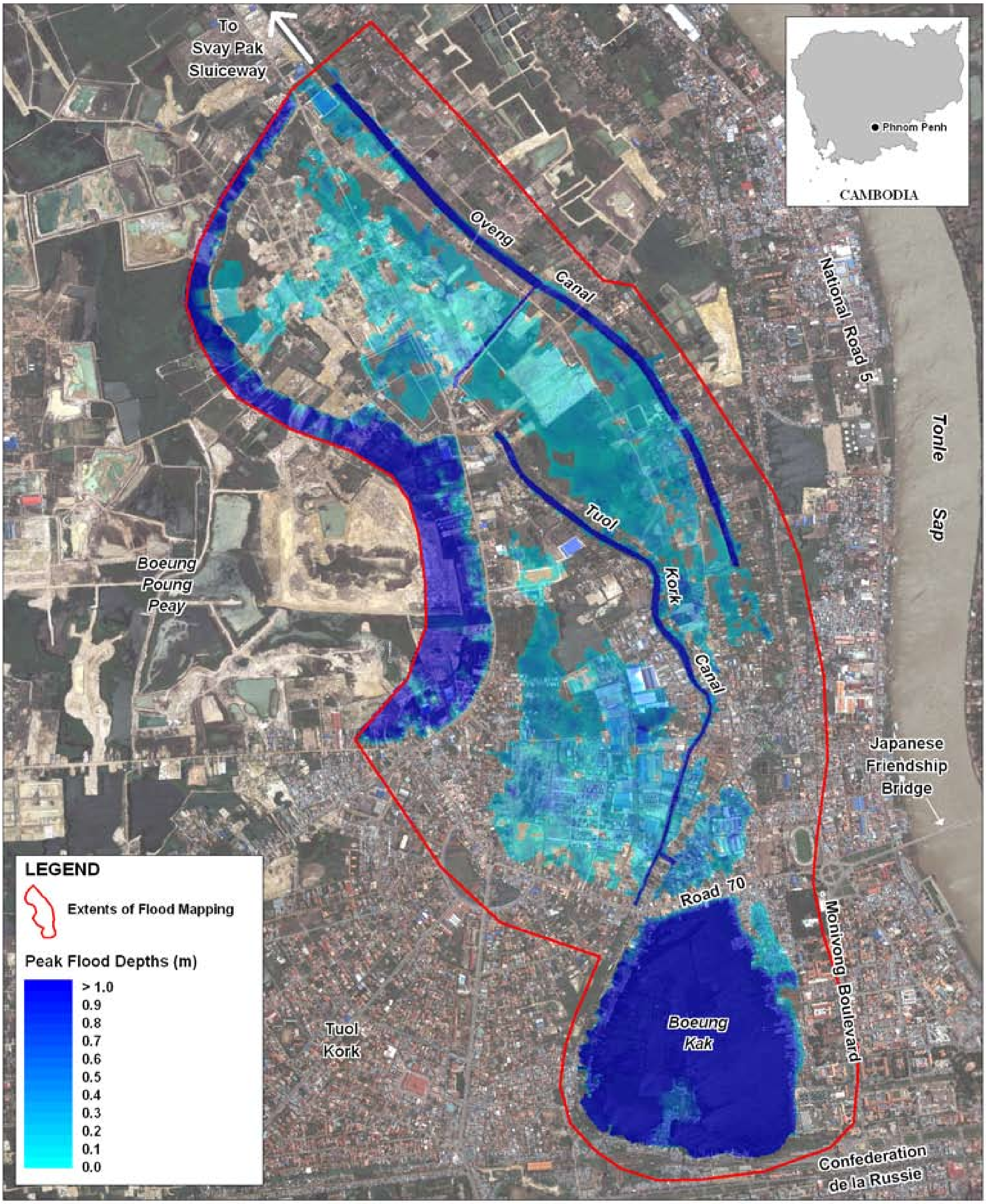

Drawing Title:

50 Year ARI Existing Case Peak Flood Depths

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Figure 6-2

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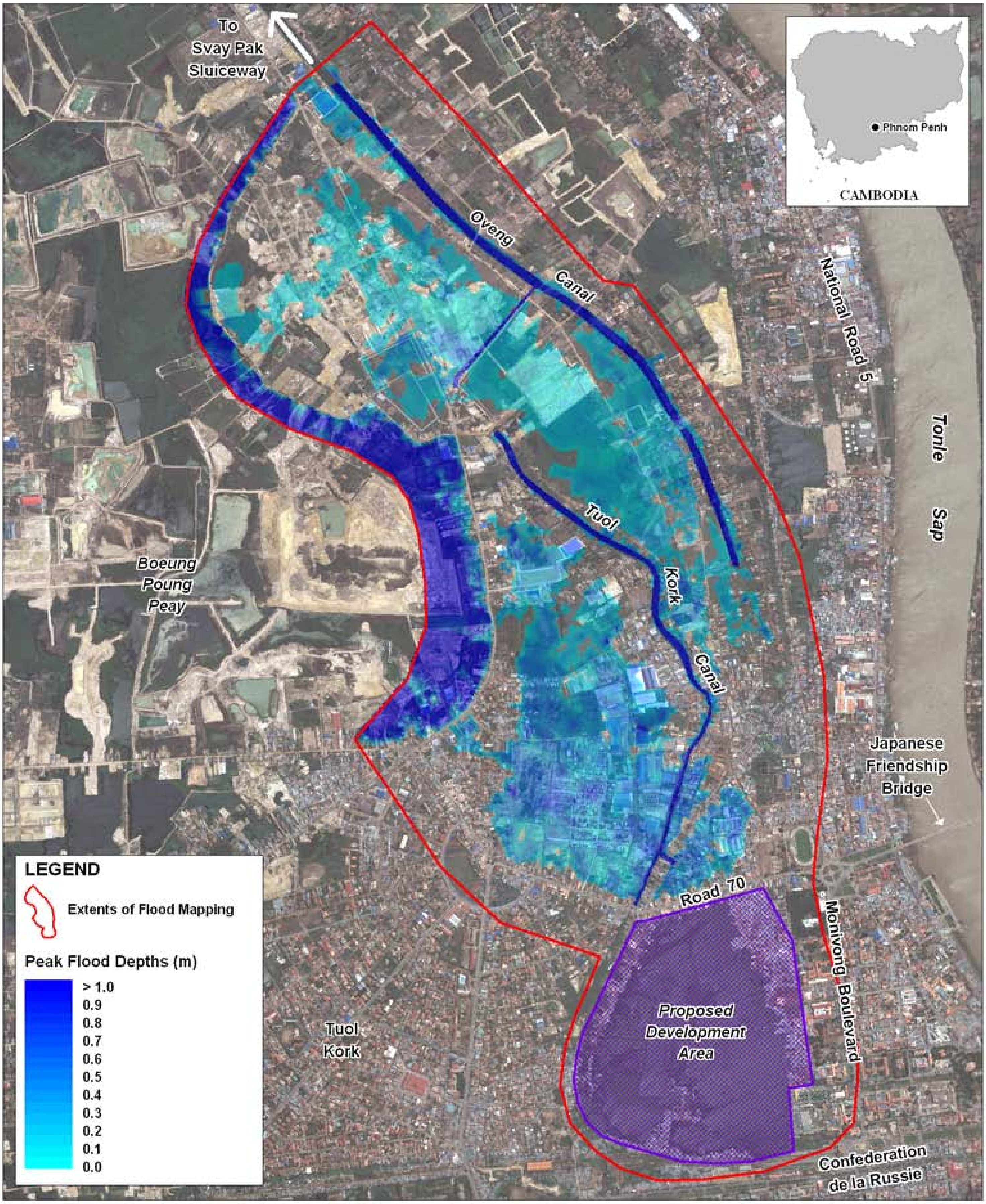

Drawing Title:

10 Year ARI Development Scenario 1 Peak Flood Depths

Drawing No.

Figure 6-3

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Boeung Kak Area Drainage Assessment

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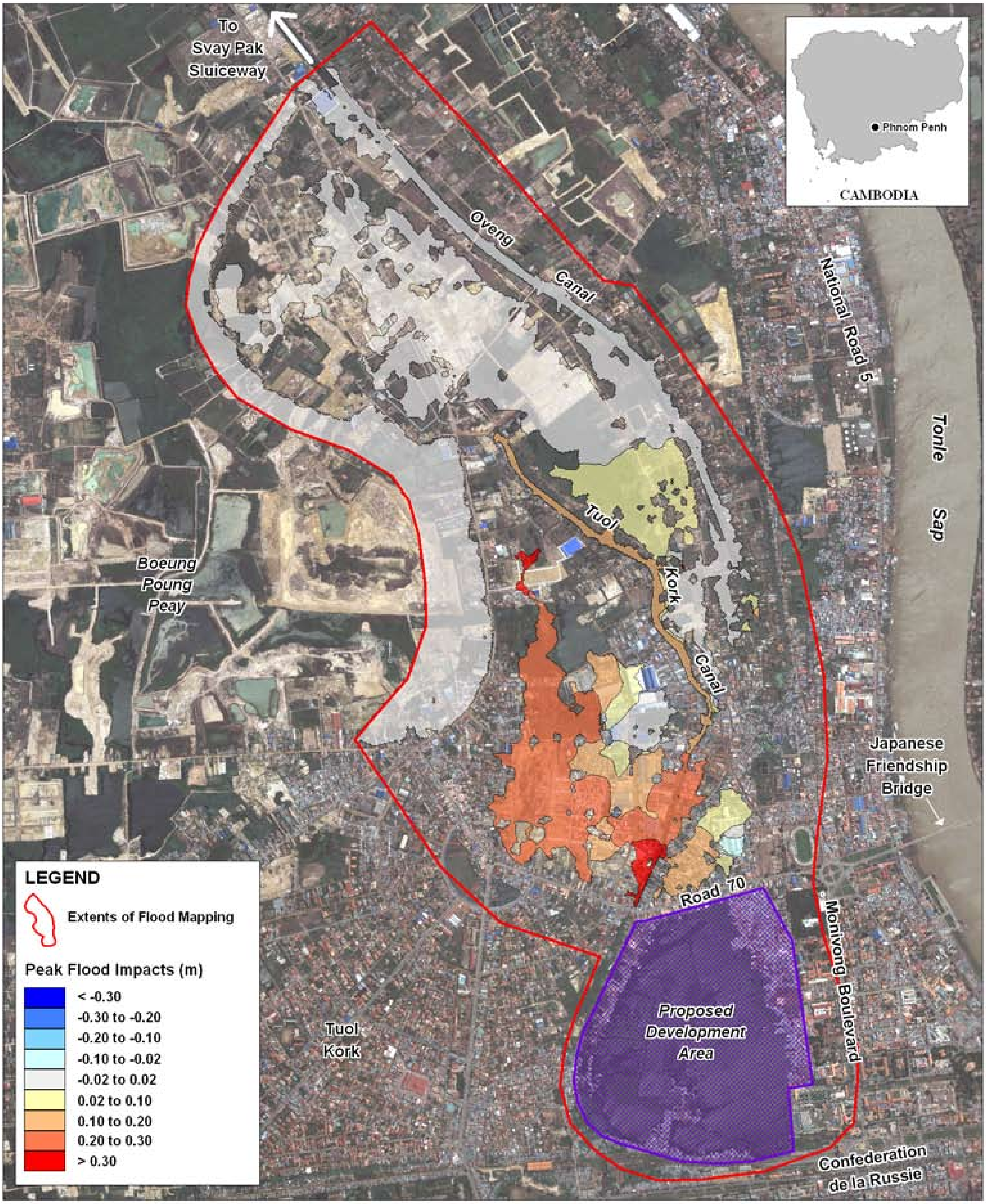

Drawing Title:

10 Year ARI Development Scenario 1 Peak Flood Impacts

Drawing No.

Figure 6-4

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Boeung Kak Area Drainage Assessment

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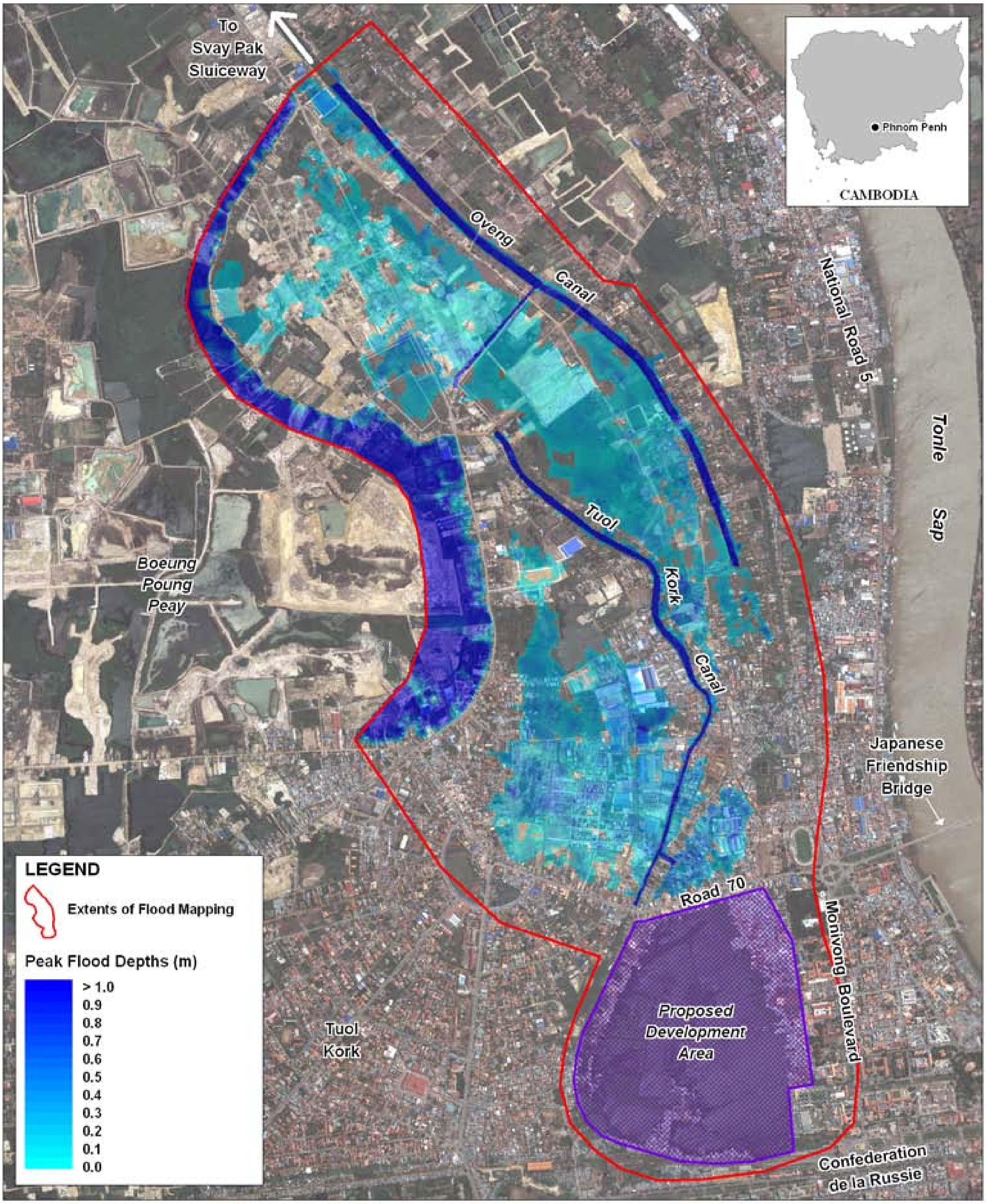

Drawing Title:

50 Year ARI Development Scenario 1 Peak Flood Depths

Drawing No.

Figure 6-5

Boeung Kak Area Drainage Assessment

Drawing is based on base information supplied by the client, 2008.
Background image referenced by the project team from image extracted from Google Earth.
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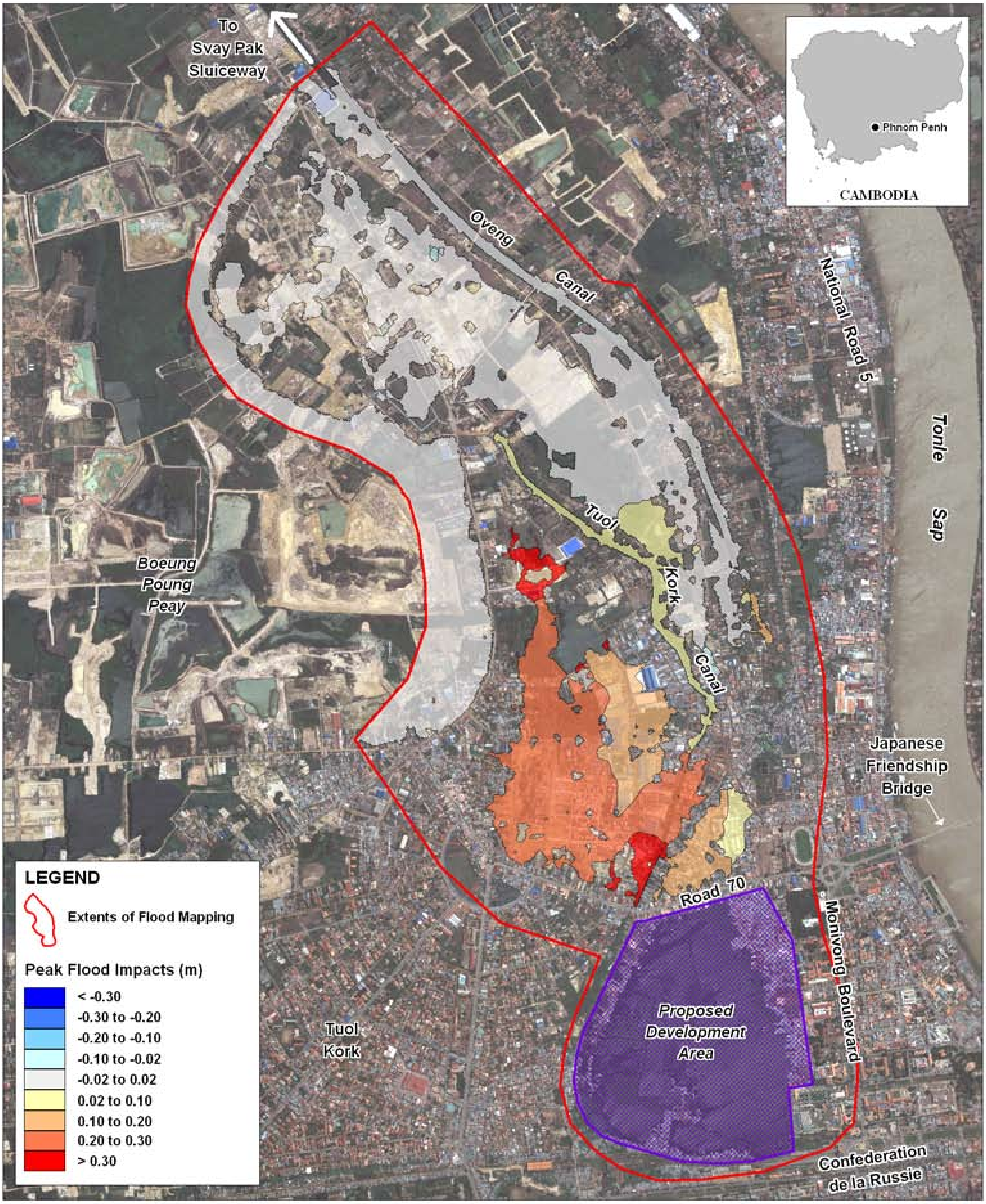

Drawing Title:

50 Year ARI Development Scenario 1 Peak Flood Impacts

Drawing No.

Figure 6-6

Drawing is based on base information supplied by the client, 2008
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guarrantee or make representations regarding the currency, correctness and
accuracy of the information contained in this map.

N

0 0.5 1km

Approx. Scale

Boeung Kak Area Drainage Assessment

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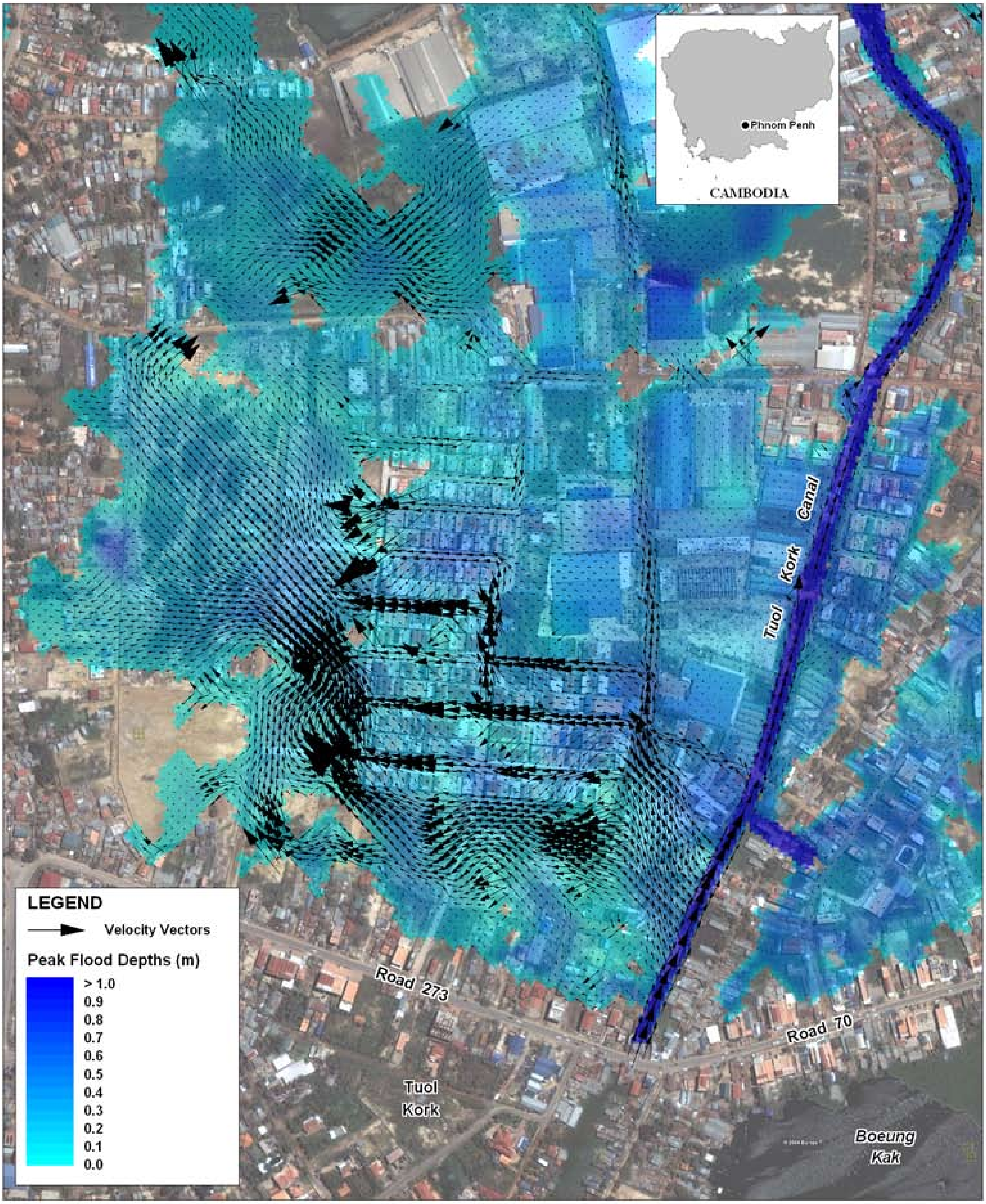

Drawing Title:

10 Year ARI 3 Hour Event Developed Case Velocity Vectors Simulation Time = 2.0 Hours

Drawing No.

Figure 6-7

Drawing is based on base information supplied by the client, 2008.
Background image referenced by the project team from image extracted from Google Earth.
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N

0 100 200m
Approx. Scale

Boeung Kak Area Drainage Assessment

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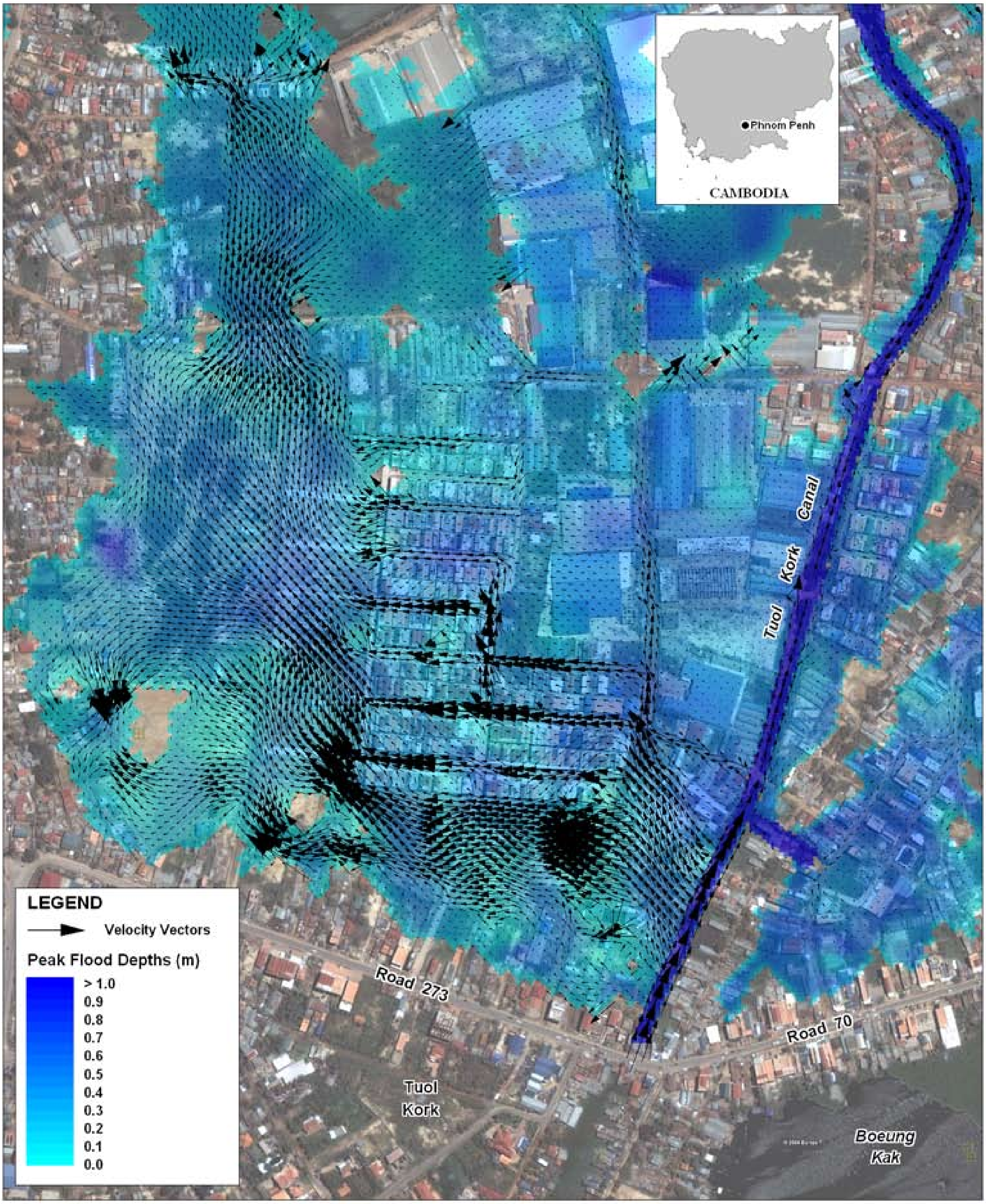

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50 Year ARI 3 Hour Event Developed Case Velocity Vectors Simulation Time = 2.0 Hours

Drawing No.

Figure 6-8

Drawing is based on base information supplied by the client, 2008.
Background image referenced by the project team
from image extracted from Google Earth.
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N

0 100 200m
Approx. Scale

Boeung Kak Area Drainage Assessment

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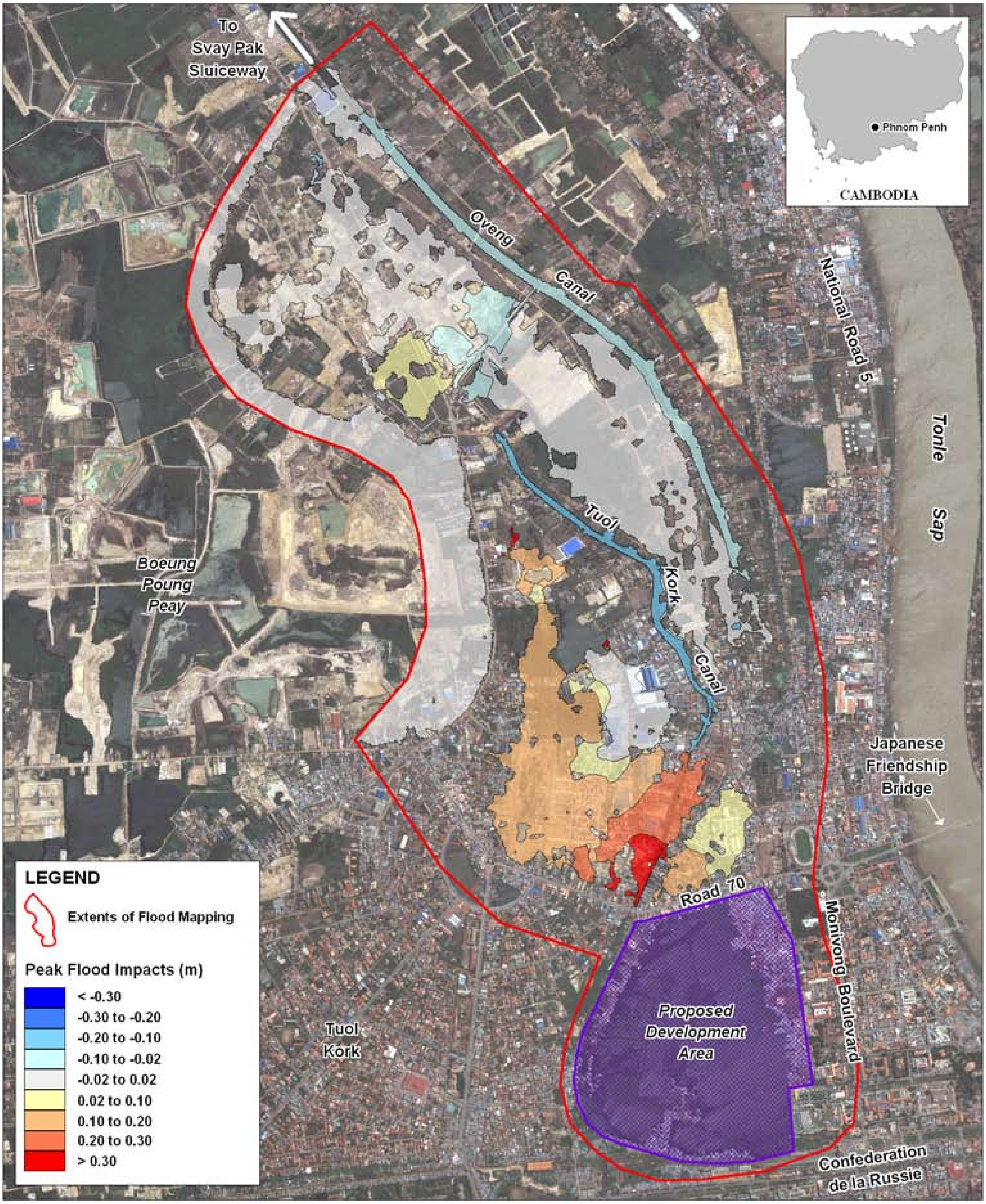

Drawing Title:

50 Year ARI Development Scenario 2 Peak Flood Impacts

Drawing No.

Figure 6-9

Drawing is based on base information supplied by the client, 2008.
Background image referenced by the project team
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N

0 0.5 1km

Approx. Scale

Boeung Kak Area Drainage Assessment

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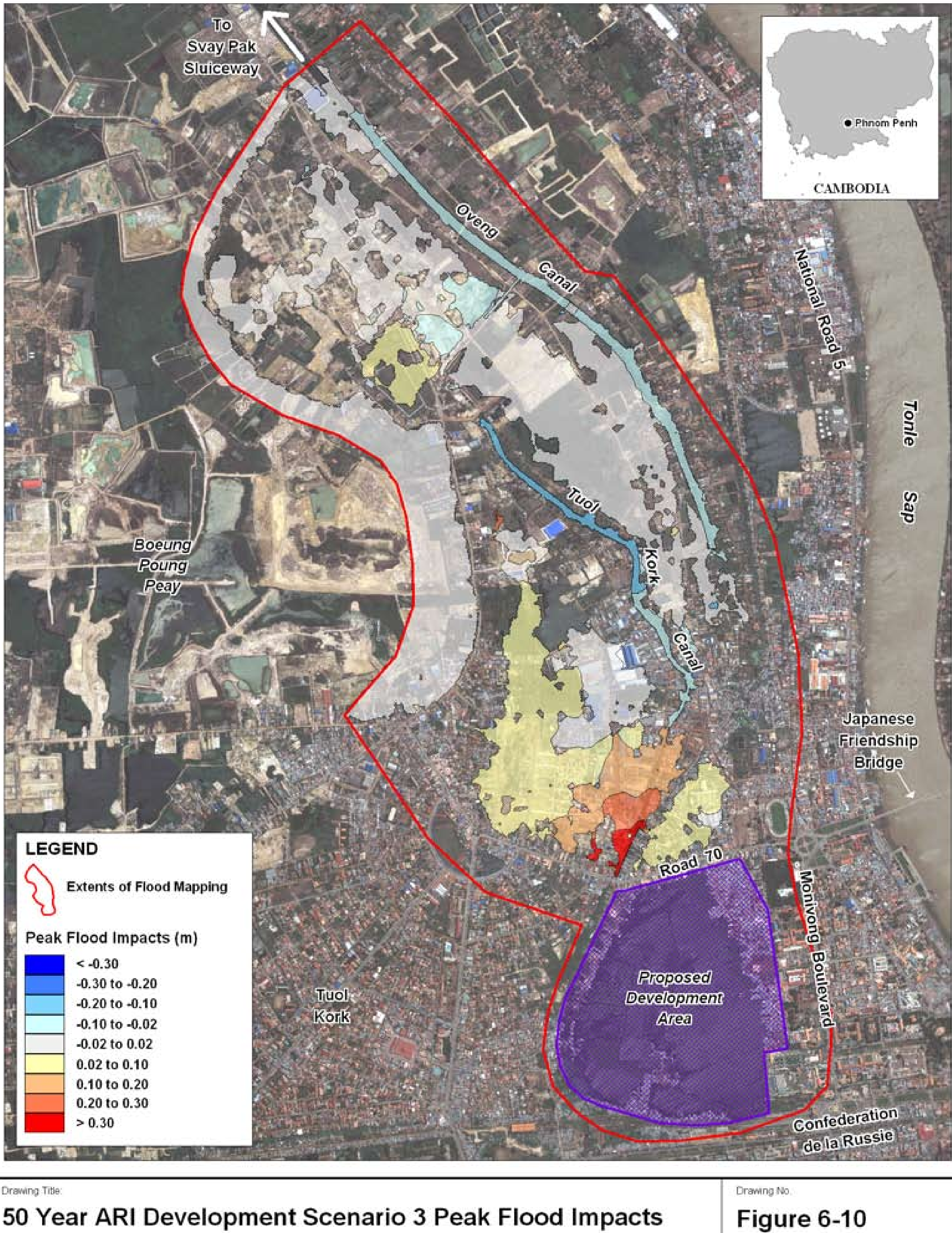

Drawing Title:

50 Year ARI Development Scenario 3 Peak Flood Impacts

Drawing No.

Figure 6-10

Drawing is based on base information supplied by the client, 2008.
Background image referenced by the project team from image extracted from Google Earth.
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N

0 0.5 1km
Approx. Scale

Boeung Kak Area Drainage Assessment

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7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

This draft report has been prepared to determine the impact on flooding that may be expected following the filling and subsequent development of the Boeung Kak Area (BKA). The following conclusions can be drawn from this assessment:

- A dynamically linked one-dimensional/two-dimensional hydrodynamic flood model has been developed of the BKA and the area to the north. The model is a valid representation of the flooding and drainage behaviour of the area and has been used to assess the expected impacts on flooding due to the proposed development.
- While the lake is a closed system with little catchment contribution beyond the lake itself, the proposed development area is large enough to generate large volumes of runoff. This runoff has potential to cause significant impacts on property and hazard to life downstream.
- Peak flood levels are shown to increase as a result of the development by up to 0.4m in both the 10 year and 50 year ARI events. The areas of greatest impact are immediately to the north of BKA on both the east and west sides of the railway embankment, and approximately 1.5km to the north of BKA. Significant increases are expected to the northwest as far as the proposed development site of Camko City and Boeung Poung Peay.
- The drainage improvements proposed in Shukaku Inc's ESIA are shown to be insufficient to alleviate flooding impacts due to the development of BKA.
- The culverts recently constructed by MPP connecting the Tuol Kork and Oveng Canals are significantly undersized.
- It should be recognised that not only will flood depths and levels increase, but the frequency of flooding will also increase. Flood levels for a given return period under existing conditions will occur more frequently following development. The combined effluent and stormwater drainage system in Phnom Penh means that any flooding will have serious water quality and public health implications.
- In also needs to be noted that the estimated runoff rates from the proposed development (derived from the hydrological model) are conservative estimates assuming low density development. If the development is medium or high density, then the impacts presented above will be worse.
- From a hydraulic engineering perspective, development of the BKA without detailed modelling that draws on knowledge of historical flooding and appropriate mitigation is likely to significantly increase flood severity and frequency, and the risk to public health.

By global standards, the filling of any waterbody is not a recommended practice. "*It is not possible to continue expanding the city through the building of ever larger concentric dykes, filling in the interceding space to provide new areas for urbanisation. Such a method of expansion requires too massive and costly public works projects, and will also destroy the natural drainage systems remaining around the city today. It is therefore necessary to develop a new approach to the expansion of Phnom Penh. This new plan must respect the natural environment while recognising* *that large areas of water, serving as storage reservoirs, will be an integral and attractive part of the future urban landscape."* (Molyvann, 2003).

It is acknowledged that the BAU and MPP have given consideration to the future development of Phnom Penh, as evidenced within the city masterplan. In the north of Phnom Penh, this masterplan includes a network of drainage canals interconnected with the lakes. However, there is no evidence to suggest that detailed hydraulic modelling of such a system has been undertaken. It, therefore, cannot be determined if any future constructed drainage elements will be effective in protecting property from flooding.

Finally, the BAU/MPP masterplan does not include development of the BKA. The filling of Boeung Kak that is underway demonstrates that, while the MPP may have developed a masterplan, it is not committed to working towards sustainable development that will showcase Phnom Penh as the 'Pearl of Asia'.

7.2 Recommendations

Based on the flooding and drainage assessment of the study area and the proposed development, the following recommendations are made:

- Considering the large population of people living within the low lying areas of the north, and the existing high frequency of flooding, modelling should be a critical component of the planning process and any credible impact assessment of the proposed development. While a sewage design is refered to in the ESIA, no details were available to this flooding assessment team. The sewage system is also unlikely to include allowance for stormwater/floodwater conveyance as forms the focus of this report. The ESIA does not include reference to any stormwater/floodwater conveyance within the development, or evidence of the level of analysis required to ensure any canal upgrades will mitigate the impact of the development.
- As well as providing a degree of confidence that the proposed system will work, the modelling process is likely to identify existing problematic areas. Design and implementation of infrastructure for flood mitigation in existing problematic areas should be a higher priority to the MPP than upgrading infrastructure to accommodate large private developments.
- The responsibility for upgrading existing infrastructure to accommodate private development should be the responsibility of the developer. If they wish to develop an area, they should undertake all works necessary to ensure there is no negative impact to surrounding property and life.
- There appears to be a lack of community consultation and transparency in the process. Not only is the community one of the most important stakeholders, it is a vital source of information on local issues such as flooding. Such information is invaluable during the design and implementation of flood mitigation strategies. It is recommended that any future assessment of flooding and drainage of the area draw upon this valuable resource and provide transparency to the community regarding this important issue of flooding.
- The proposed filling of Boeung Kak should be reconsidered in light of the impacts it will create and the lack of consistency with the BAU/MPP masterplan.

8 REFERENCES

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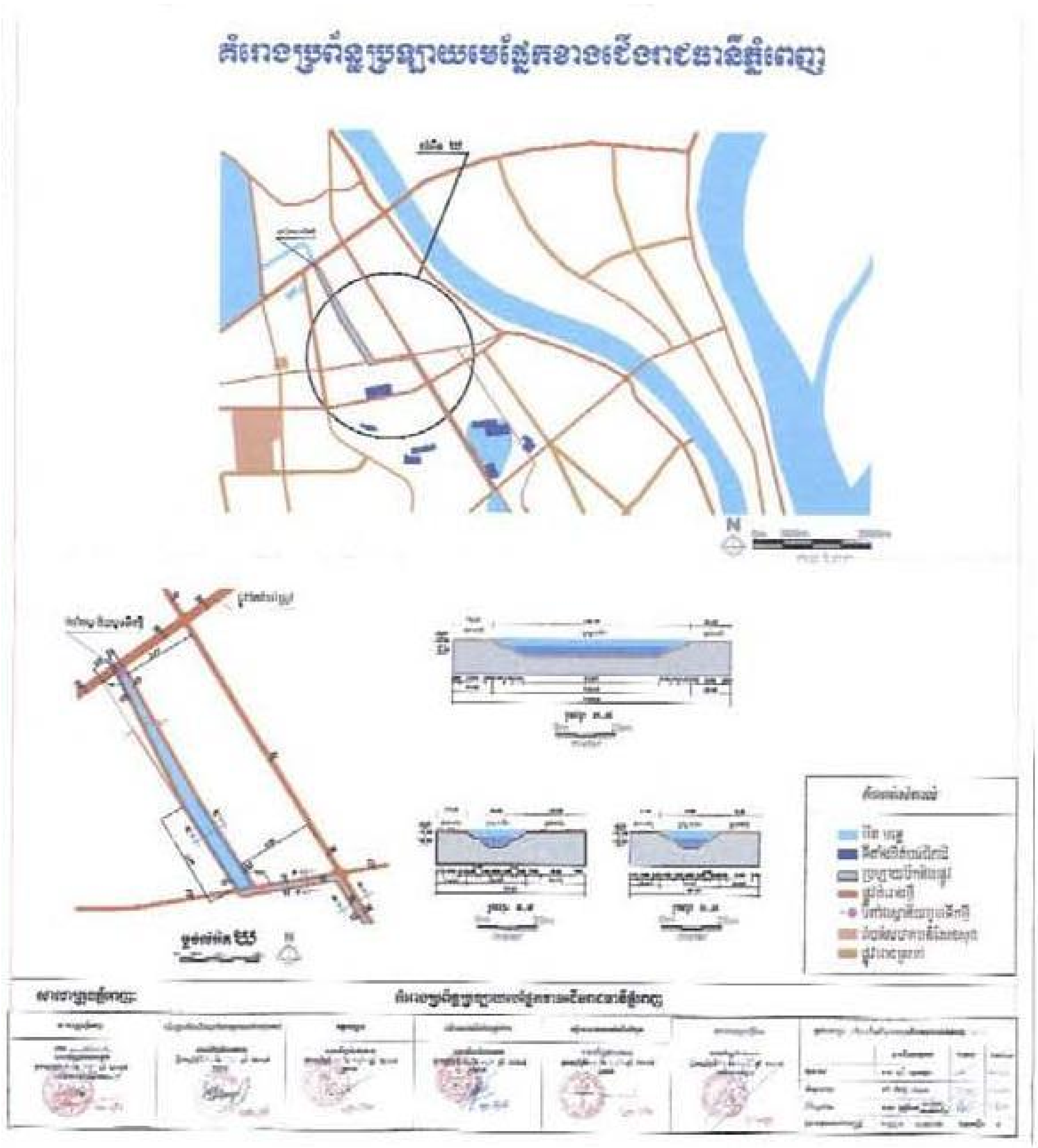
APPENDIX A: PHNOM PENH BAU/MPP MASTERPLAN



Grand Canal du Nord – Schematic Layout

APPENDIX B: PHOTOGRAPH

Photo 1: Grand Phnom Penh Development Project Information Sign

Photo 2: Camko City Development Project Information Sign

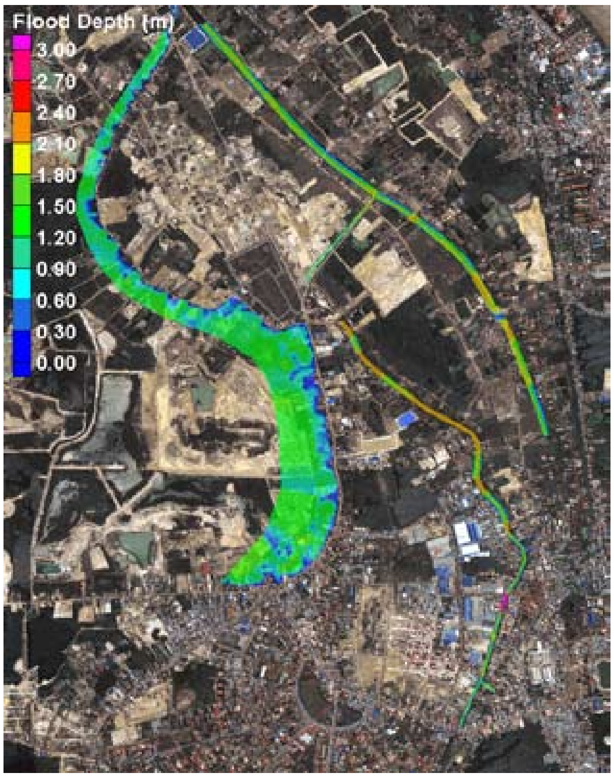
Photo 3: Construction of the Grand Canal du Nord

Photo 4: Canal Adjacent to Grand Phnom Penh

Photo 5: Excavation of Boeung Poung Peay

Photo 6: Construction of Tuol Kork Canal to Oveng Canal Drainage Link

APPENDIX C: FLOOD ANIMATIONS – 10 YR 3 HR FLOOD DEPTH



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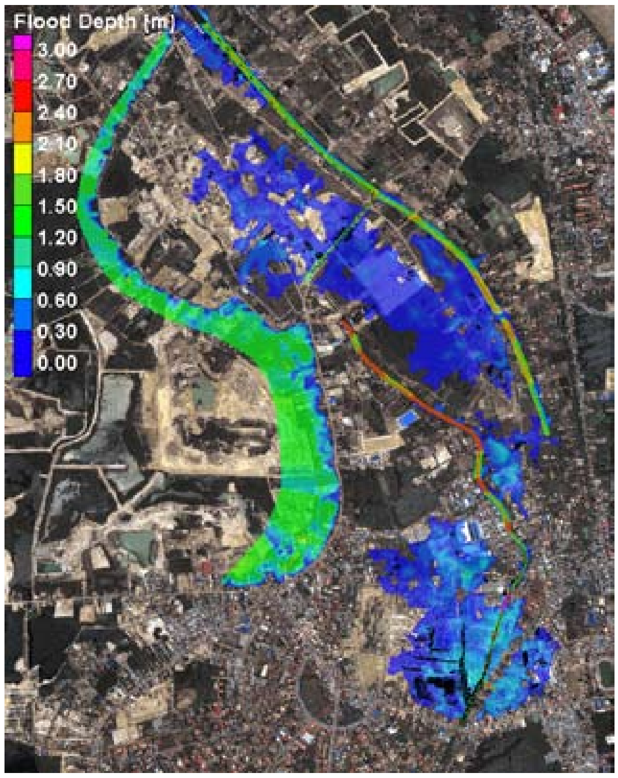

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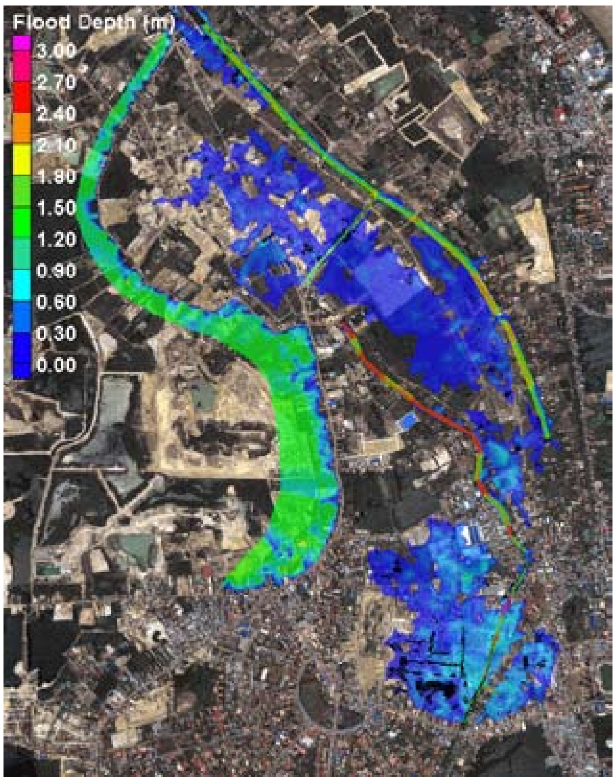

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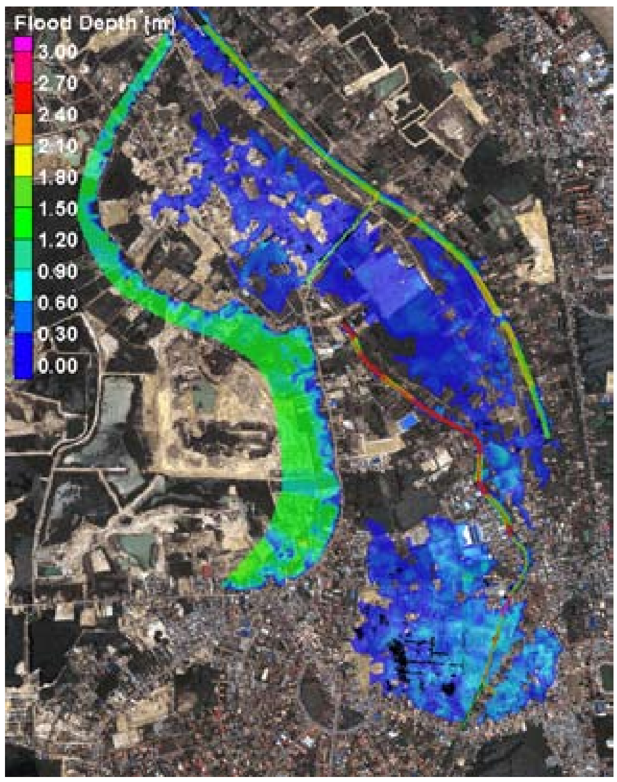

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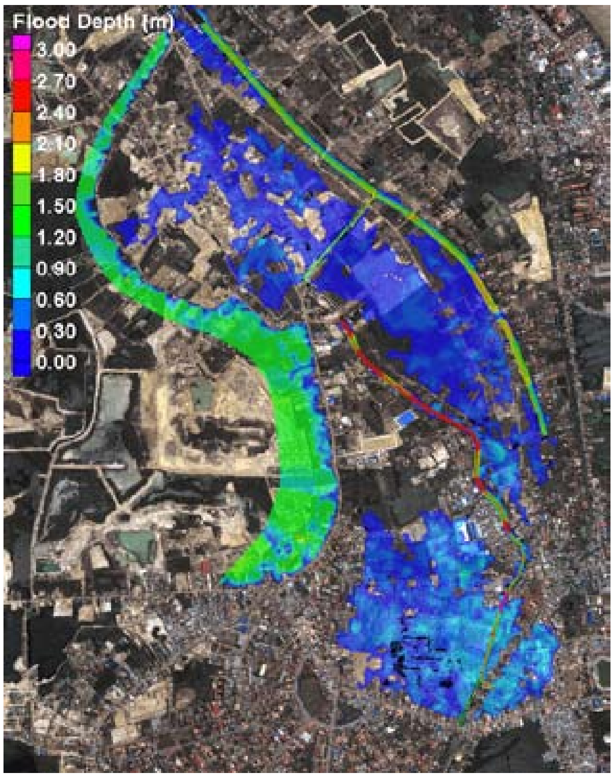

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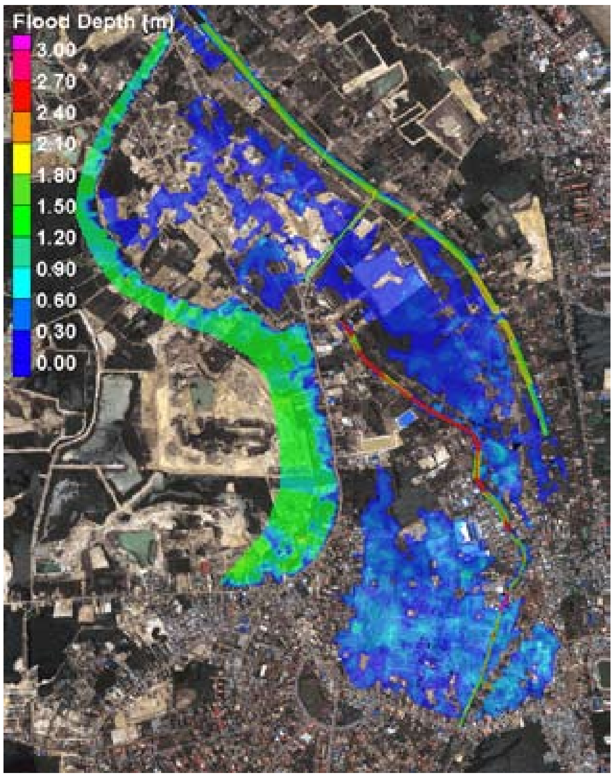

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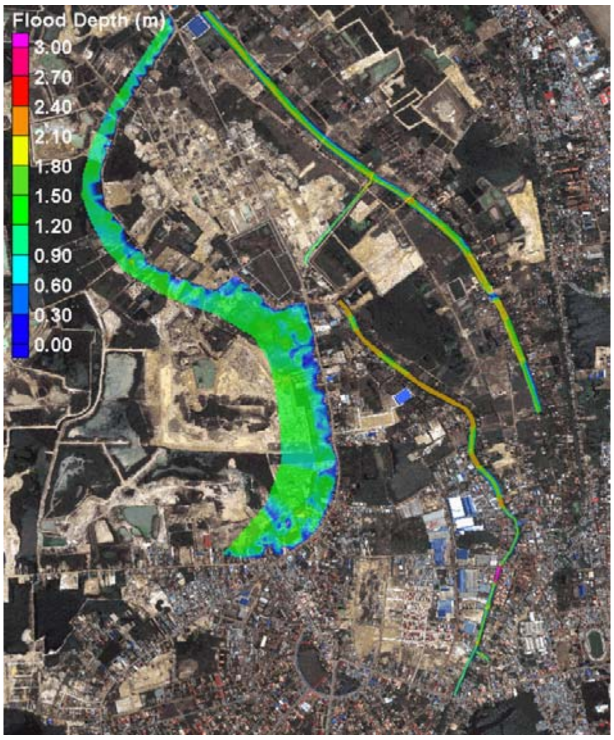
APPENDIX D: FLOOD ANIMATIONS – 50 YR 3 HR FLOOD DEPTH



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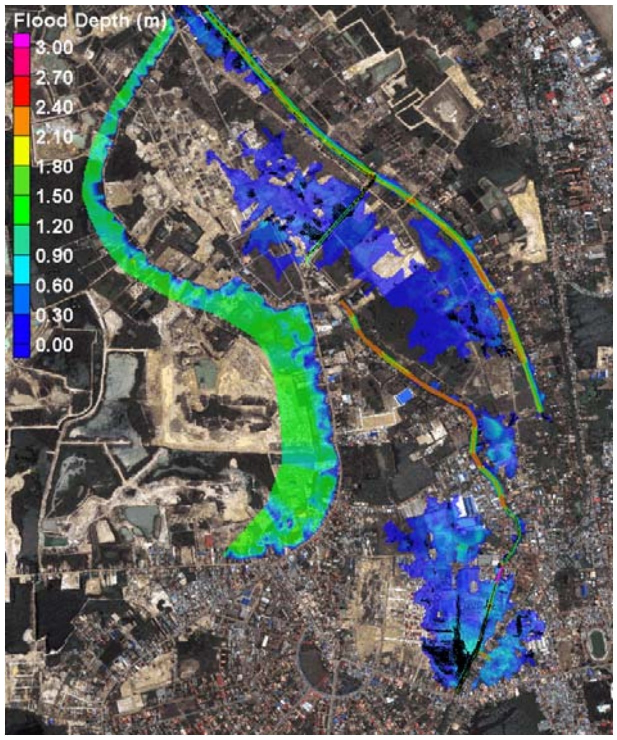

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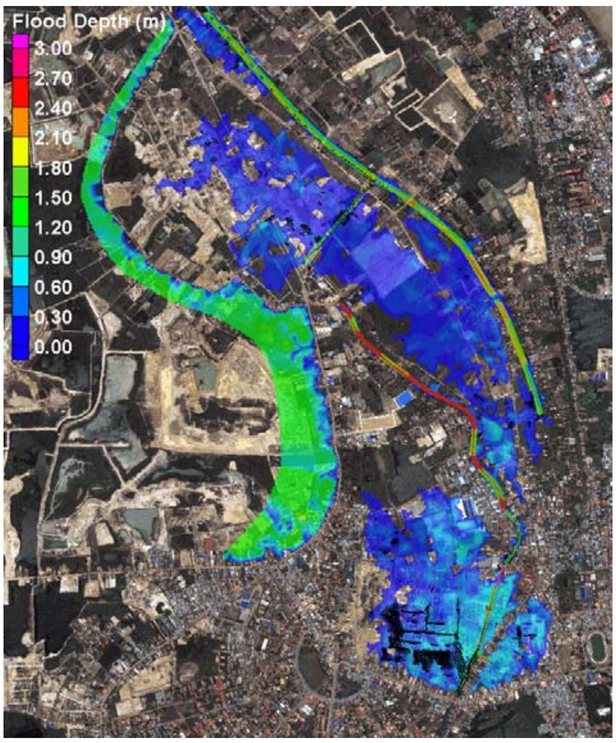

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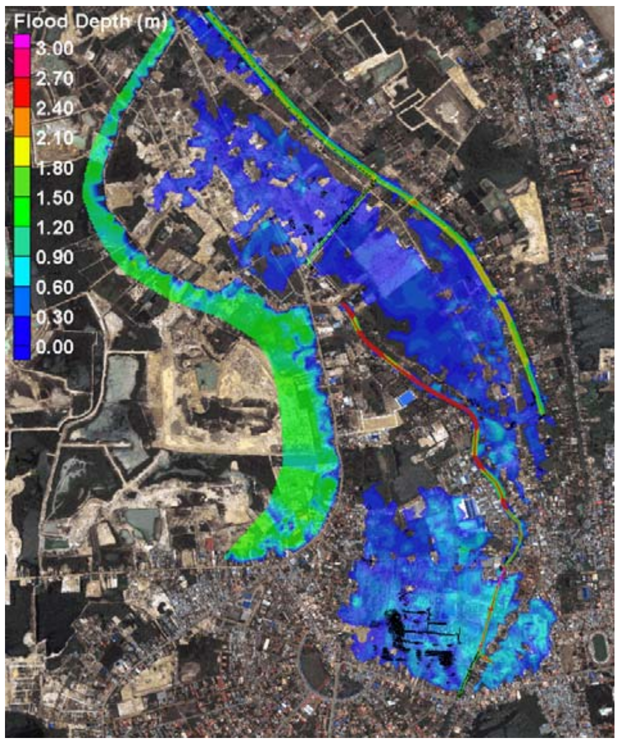

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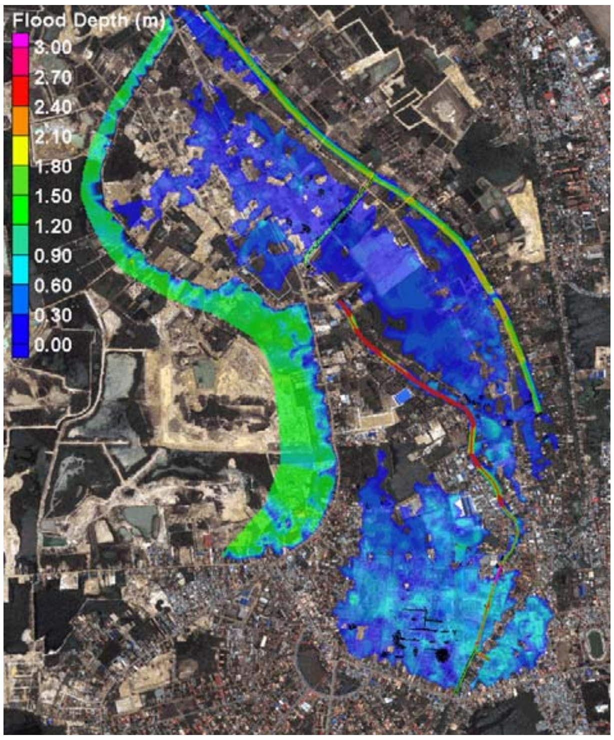

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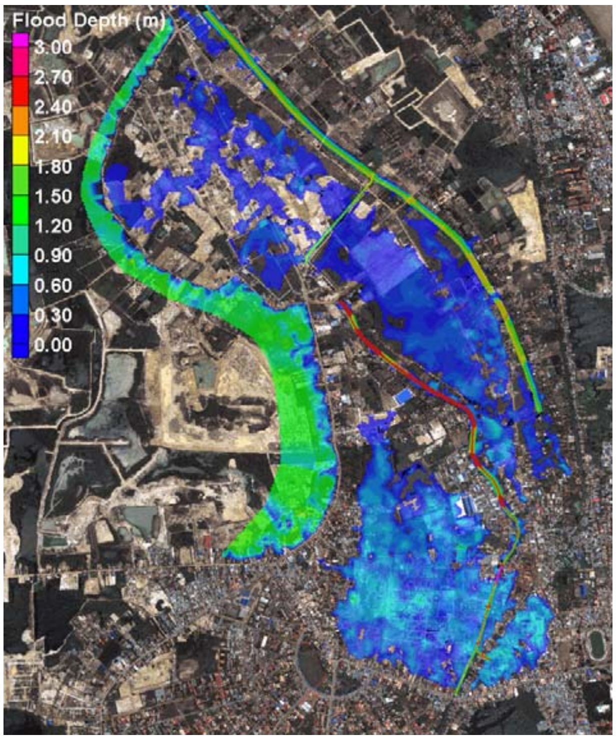

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